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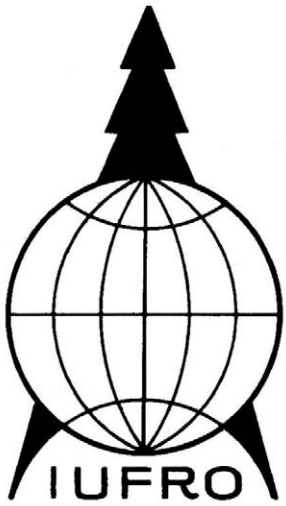
Fourth Workshop of the IUFRO Working Party 7.03.10

Methodology of Forest Insect and Disease Survey in Central Europe

Prague, Czech Republic, September 17–20, 2001



PROCEEDINGS

IUFRO WP 7.03.10 - METHODOLOGY OF FOREST INSECT AND DISEASE SURVEY IN CENTRAL EUROPE
CZECHIA, PRUHONICE, PRAHA, SEPTEMBER 17-20, 2001

Proceedings

Editors: MILOŠ KNÍŽEK, BEAT FORSTER and WOJCIECH GRODZKI

Participants of the Fourth Workshop of the IUFRO Working Party 7.03.10 – Methodology of Forest Insect and Disease Survey in Central Europe, September 17–20, 2001, Praha, Czechia

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Preface

This book of proceedings is the result of the Fourth Workshop of the IUFRO Working Party 7.03.10 *Methodology of Forest Insect and Disease Survey in Central Europe*, held in Prague, Czechia, September 17–20, 2001.

The plenary session of the workshop was divided in the following four roundtables:
1. Recording and evaluating of forest injurious factors using databases and GIS techniques.
2. Monitoring of forest insects and diseases.
3. Flow and exchange of information about epidemic occurrence of insects and diseases in Europe.
4. New pests and diseases, diagnostics, expert and information sources.

Within the roundtables, expert discussions took place and topic related oral contributions were presented. In addition, other forest protection themes were presented during the poster session.

From the workshop results a design of future collaboration on four chosen survey tasks: spruce bark beetles, pine bark beetles, nun moth and oak decline. Different monitoring methods in particular countries would be adapted to reach the possibility of comparison of the results from data collecting and advisory services. Fifty-eight people from 21 countries joined the workshop, presenting 16 oral contributions and 38 posters.

An excursion to the Bohemian Switzerland National Park was the opportunity to visit the stands of Eastern white pine (*Pinus strobus*), an introduced tree species; we learned about its ongoing long term eradication and the problems with diseases and bark beetles, also in neighbouring pine and spruce stands. The participants had the chance to enjoy the beauty of the park's nature. Its geomorphologic scenery is unique in the territory.

A second excursion to the Šumava National Park guided us into Norway spruce stands (*Picea abies*) on the border with Bavaria (Bavarian Forest National Park), where different control strategies against bark beetles were discussed.

The idea and the goals of the working party *Methodology of Forest Insect and Disease Survey in Central Europe* were first designed in 1997, at a preliminary meeting held in Czechia. The main aim is the exchange of information concerning forest pest survey, methods of advisory service and corresponding techniques in particular countries within Central Europe, mainly in the territory with similar forest conditions. The program of the working party has developed during the following workshops under IUFRO patronage (Poland – 1998, Switzerland – 1999 and Romania – 2000).

Acknowledgements

We want to thank very much to the people of the Bohemian Switzerland National Park, namely Ing. MILOŠ TRÝZNA and from Šumava National Park, namely Ing. MILOŠ JŮHA, whom were responsible for our splendid excursions. In addition we would like to thank the members of the staff led by Ing. MILOŠ KNÍŽEK, the chief organizer, from the Department of Forest Protection of Forest and Game Management Research Institute in Prague, for their help with organization of this successful meeting. Many thanks also go to Prague Information Service for guiding us through the history of Prague. Special thanks goes to the crew of the Congress Centre Průhonice who was responsible for the perfect workshop infrastructure and the delicious meals.

Editors

Good morning everybody,

it is my pleasure to welcome you on behalf of the Forestry Department of the Ministry of Agriculture on this workshop organized by IUFRO WP 7.03.10 Methodology of Forest Insect and Disease Survey in Central Europe *in collaboration with the FGMRI Jiloviště-Strnady.*

I am glad to see here so many people, 80 or 90, if I remember well what was written on the list of participants, from 21 countries. I thing that it is a considerable improvement. I suppose that there are also people in this room who participated in the meeting, saying Number Zero, which was held nearly 5 years ago close to the town of Písek in the South Bohemia and since that time, as it seems to me, this group grow strong.

Of course, in between the IUFRO WP was created and many other things happened. The fact that co-organization is provided by FGMRI means that our Forestry Research Institute survived, in spite of many problems, nearly to the cutting age.

In fact your workshop is held in the year in which we try to celebrate, or at least commemorate, 80 years of creation of organized forestry research in the new Czechoslovakia of that time. And I would like to underline that on the very beginning it was just Department or Institute of Forest Protection which was the first one among others organized later.

Unfortunately, or fortunately if you want, your job, forest protection seems to be a subject which is considered, at least in this country, as very necessary – and I believe that it will be true also from the financial point of view.

And this is one of the reasons why we need a lot of information and that I am glad that such meetings, in which the people can exchange their views and statements, are organized. It is of course important also from other points of view.

Going back to the participation – I am not sure if anybody from US succeeded to come because of that horrible event from Tuesday, September 11th. If yes, it is O.K. It seems that everything is step by step going normally. But I am afraid that never it will the same as before... I am informed that last week a lot of our forestry colleagues were trapped on airports, e.g. in Denver, Colorado where the national forestry meetings were scheduled. But in spite of the fact that we are very saddened by it, as written in one letter I received just yesterday: We have to move on as we cannot terrorist win.

So you have to move as well and not to waste your time I would like to wish you a fruitful meeting, a lot of new experiences and partnerships – I am afraid to wish you a good weather for tomorrow excursion as the forecast is not very promising – and, last but not the least, a pleasant stay in our country. Good luck under the IUFRO umbrella.

Dr. Karel Vančura
FGMRI/Forestry Development Department and IUFRO Board

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The use of GIS and databases in the evidence and forecast of forest insects – requests and possibilities

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ABSTRACT: The paper contains some ideas concerning the perspectives of the use of databases and GIS based techniques for the evidence and forecast of forest insects. Some examples of such approach in research and forestry, both in local and regional scale, are presented. The proposition of a common, Central European database and digital map, discussed during the roundtable session of the meeting, are summarised, including the first work description draft.

The general progress in the technology reflexes in the modification of methods applicable for natural phenomena survey and scientific research. Among the newly introduced techniques very important role play computer-based facilities enabling relatively fast and easy gathering and visualisation of the data concerning the natural processes in spatial and temporal scale. One of the tools appreciated as very useful for such kind of scientific activity is the Geographic Information System (GIS) – the infotechnologically based system for the visualisation and analysis of spatially distributed phenomena in course of time.

The GIS is not a completely new tool – the use of such technology is well known in many areas of activity, e.g. in spatial ecology and climatology (BORYSŁAWSKI, ŻYSZKOWSKI 1995), but also in forest management (RĄCZKA et al. 2001), management of the nature protection areas (FAJFR, DRDA 1995; FEDOROWICZ-JACKOWSKI et al. 1995). Furthermore, the data concerning the occurrence of forest insects, diseases, damage, are collected and organised mostly electronically, using the same – the most widespread – data formats and even software. Thus, it is the time to think about the aggregation and common analysis of such kind of data in European dimension. It seems the best way to do it is to start with the use of these newly developed tools, such as electronic databases and GIS – the easiest way of data joining and exchange. The general aim of this paper is to demonstrate the examples of such approach in local scale, and to give some ideas about possible common activity in this field within our IUFRO Working Party.

LOCAL SCALE – RESEARCH

The GIS and related databases is an excellent tool for the scientific research dealing with the natural phenomena such as insect occurrence and insect-caused damage. This method has been used for the analysis of bark beetle occurrence in some European areas. In Šumava National Park (Czech Republic) the spatial analysis of the mortality of Norway spruce stands due to bark beetle infestations was done using remote sensing and GIS tools (ZEMEK et al. 1999). In Beskidy Mts. (Poland) the effects of the spruce forest decline caused by bark beetles, in relation to the regional orography, was also analysed using GIS (TROLL 1995). Such analysis has been done in the areas affected by the biggest forest decline in Poland – in Western Sudeten, where full usefulness of such approach was demonstrated for the spatial analysis, very time-consuming or even impossible by the use of the other, more traditional methods (ZAWIŁA-NIEDŹWIECKI 1994).

For 3 years, the GIS supported spatial analysis of the bark beetle outbreak in the area of two national parks in Tatra Mts. localised on the border between Poland and Slovakia, is carried out under the UE funded project *Integrated risk assessment and new pest management technology in ecosystems affected by forest decline and bark beetle outbreaks (TATRY)* (JAKUŠ 1999). The work is then done in following steps:

Building of a database

The database is composed from two, closely related, modules. The first database contains the site/stand characteristics (e.g. altitude, exposition, slope, soil, species composition, age, d.b.h., height, volume etc.) organised by forest sub-compartments (basic evidence units). The second database, organised by the same evidence units, contains the data about the tree mortality caused by bark beetles in successive years from the period taken into consideration. One of the most important requirements in this phase is the possibility of data acquisition from local forestry administration (in this case – two Tatra

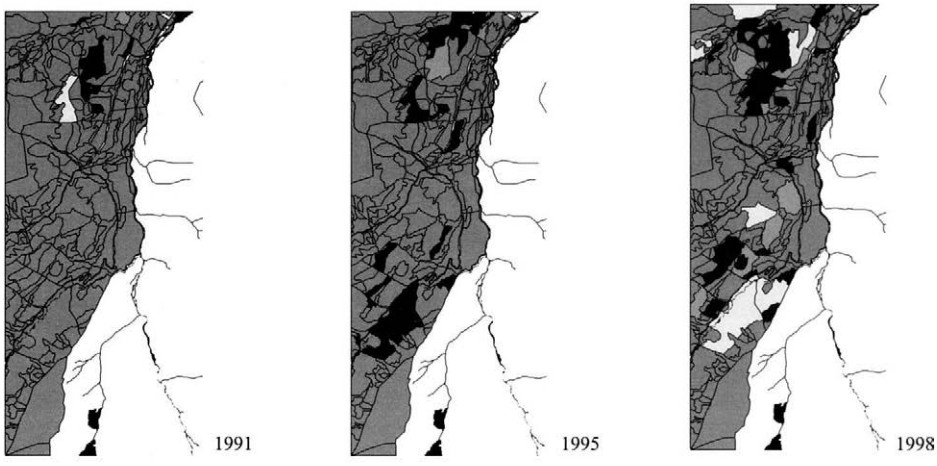

Fig. 1. Spatial distribution of the stands attacked by bark beetles in Tatra NP (Poland) in the years 1991, 1995, 1998. The mostly attacked stands are marked as dark

national parks) following the same methodology and using the same units. The most important advantage is the possibility of the comparative analysis done for two parts of the same mountain massif, but laying in two countries with different nature protection regulations.

Digital Elevation Model and database-related thematic layers

Using the basic maps (digital elevation model – DEM and the layer containing the basic evidence units) it is possible to demonstrate the dynamics and spatial spreading of the tree mortality caused by bark beetles (Fig. 1). It is also possible to find the relationships between the localisation of the bark beetle foci and the stand characteristics (using the appropriate layer), orography or climatic conditions (e.g. solar irradiation). The range of potential interactions to be established is very large, but closely related to the range of data organised in a database.

LOCAL SCALE – FOREST MANAGEMENT

The State Forests in Poland are introducing GIS supported system into the forestry practices. There are more and more Forest Inspectorates using digital maps and related databases, containing data on both forest planning and current forest activity. Unfortunately, at present stage the forest protection information is not fully organized and accessible – mostly the data on forest cuttings (including sanitary felling resulting from bark beetle-caused tree mortality) are available. In some cases, also data on the distribution of fungal root diseases (*Armillaria* spp., *Heterobasidion annosum*) are included into the database, but this kind of data is not as accurate as the data from felling. The data included into the database

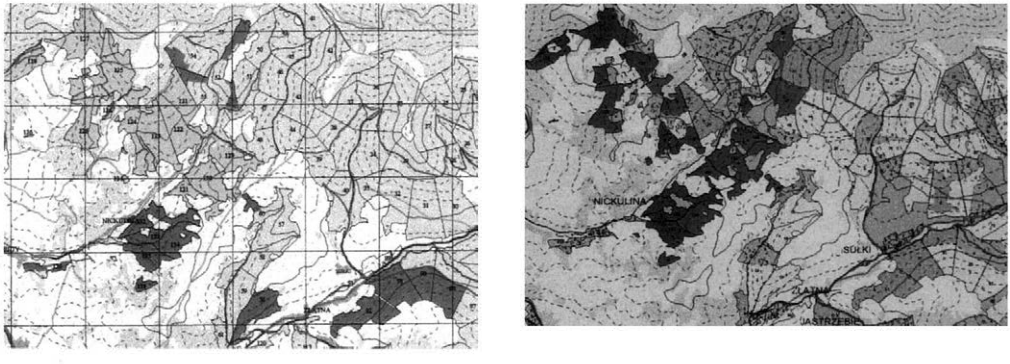

Fig. 2. Spatial distribution of the stands affected by *Armillaria* spp. (left) and attacked by bark beetles in 1998 (right). (Source: State Forest Inspectorate Ujsoly, Beskidy Mts., Poland)

can be easily visualized using GIS tools, and some relations between particular layers can be found. For example, the spatial distribution of attacked by bark beetles is closely related to the root disease intensity (Fig. 2). Easy and fast visualization of the data from particular years, as well as clustered data from various periods, can be an excellent tool in the forest planning and management, including the application of forest protection measures.

REGIONAL → INTERREGIONAL → INTERNATIONAL SCALE

As it results from above described GIS possibilities, there is a need to involve these technologies into the forest insect and disease survey. Such approach is already applied – maps (even – the digital ones) are commonly in use in many countries and for many purposes. Practically in each country, however, the visualisation of forest insect and disease occurrence is based on any kind of maps, related to any kind of databases. Some examples, concerning insects' infestations can be shown from Poland (GRODZKI, JACHYM 2001) or Czech Republic (KAPITOLA, KNÍŽEK 2001). Analysing the spatial distribution of the biotic agents in the forest stands of Central Europe one can see, that there are common problems affecting adjacent areas in particular countries. The data seems to be comparable as well. To be more precise – there is a need of the unification of the data formats, which can enable further data joining.

Thus, a clear proposition can be expressed:

- let's try to build a common database on selected insects' occurrence in Central Europe,
- let's try to join the maps from particular countries using GIS tools to visualise these phenomena in European scale.

First steps are already done. The general overview of the situation in the forest protection of the European countries was presented during last 3 workshops (Ustroń – 1998, Sion – 1999, Busteni – 2000); the results are published and accessible. The real, common output from Sion workshop is the list of insect species monitored in the Central European countries – ready to be used as a base for the selection of species for future data joining (FORSTER et al. 1999). The next steps to be done are as follows:

- the list of "agents of interest" (based on the importance & range) has to be established,
- the criteria for data gathering (especially the units of measure) should be determined,
- the possibilities of the map joining (availability, scale) should be examined,
- the common database is to be built up and filled by the data,
- the common data visualisation, based on common database and map will be possible.

The major needs of unification are in data format, database format and range, database software (MS Excel, MS Access?), map format and GIS software (ArcView?).

RESULTS

After the roundtable discussion, done during the workshop, the proposition is as follows:

Species group to be used for the first attempt of the common data analysis:

- Spruce bark beetles
- Pine bark beetles
- Nun moth *Lymantria monacha* (L.)
- Oak decline.

The units of measure which can be used are:

- Spruce bark beetles: m^3/ha and score of importance (0 – absent, 1 – present, not a pest/disease, 2 – moderate pest, 3 – medium pest, 4 – severe pest)
- Pine bark beetles: m^3/ha and score (as above)
- Nun moth: score (as above) and the percentage of defoliated stands' area (if possible)
- Oak decline: score (as above).

Spatial resolution

- The finest resolution at which the data can be gathered within the country. The data aggregation from more to less detailed level is always possible.

Further steps

- Sending questionnaires on data availability (species, units, spatial scale, format, etc.)
- Compiling questionnaire answers
- Gathering data available for the year 2001
- Building a pilot GIS database by the next meeting in Krakow
- Preparation of an EU project (VI FP, COST, ??? – to be discussed later) in order to get any material possibilities to finish this job.

The above action is proposed as a first attempt of the development of some common product of our activity in European scale. In this stage, the method development is the most important question; the selection of insects or diseases being the subject of interest is rather secondary, under methodological objective. The success of this first step will determine future success of the whole action.

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Forecast of the threat by *Cephalcia* spp. in Beskidy Mountains (Poland), on the basis of digital map and GIS analysis

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ABSTRACT: This article contains the proposition of a new method of the evidence and forecast of forest stands infestation by *Cephalcia* spp. with the use of digital map and GIS analysis. An example of digital map and database on *Cephalcia* spp. occurrence is presented. As a main point of evidence and forecast of the pest, the autumn seeking for the larvae diapausing in the soil was considered. By means of GIS software and query expression the area of threatened stands in four threat degrees (premonitory, soft, medium and strong) was obtained. The another aim of the study was to prove and demonstrate the possibilities of the use of GIS based technology for the evidence and forecast of forests insect pests, in order to introduce this kind of analysis into the system of multivariable analysis of forests health, and risk rating. Digital map with layer of elevation and aspect of elevation allows the observations dynamics of species occurrence and its variations of threatened areas.

Among the species from the genus *Cephalcia* known from Poland, there are tree related with Norway spruce (*C. abietis* L., *C. alpina* KLUG, and *C. arvensis* PANZ.), occurring in the outbreak form and causing damage in the stands, especially in the mountains (JACHYM, KOSIBOWICZ 1998). In the end of the seventies an outbreak of the web-spinning sawfly *C. alpina* took place in the Beskid Śląski where this insect with other *Cephalcia* species occur to the present day still remaining a grave problem in Norway spruce stands.

MATERIAL AND METHODS

THE EXISTING METHODS OF THE EVIDENCE AND FORECAST

The research concerning reasonable methods of evidence and forecast of the occurrence of web-spinning sawflies was conducted in Forest Research Institute, Department of Forest Management in Mountain Regions in Cracow, in 1986–1993 (KOSIBOWICZ, KOZIOŁ 1995).

As a main point of evidence and forecast of the pest, the autumn seeking for the larvae diapausing in the soil was considered. Currently, the autumn seeking is carried out in damaged stands. The stands are divided into 5 ha sections, and then 8 trees are selected in each one. The degree of stand threat is estimated basing on the average quantity of pronymphs in 8 soil samples from each 5 ha stand section (JACHYM 1999).

ALTERNATIVE METHOD OF THE EVIDENCE AND FORECAST BY THE USE OF DIGITAL MAPS AND GIS ANALYSIS

The digital map was completed in Forest Research Institute in Warsaw and has been continuously updated. It covers the area of Forest Inspectorate Ujsoły in Beskid Żywiecki, bordering on south with the Slovak Republic. Topology of the map was mostly based on polygons, including also linear and point layers. The map is divided into two forest areas: the Ujsoły area and the Rycerka area, each area being composed of compartments and subcompartments. Each compartment covers from 15 to 25 ha of land, with subcompartments covering several hectares. The subcompartments are the smallest area units in the forest map.

Apart from the topological part, the map covers the descriptive databases with 3,543 records in case of polygons, with information on the area, ID of subcompartments and compartments and KOD of compartments and subcompartments used for combining new SQL databases. KOD columns cover the combined numbers of compartments and subcompartments written as one number. Additionally, forest addresses have been included, which are used in SILP, the State Forest Informatics' System used also for merging ready-made data generated within the SILP system (Fig. 1).

Apart from the vector map with polygons, a raster layer (GRID Theme) and the TIN layer has also been prepared showing land shaping and the layer of expositions in reference to geographical directions.

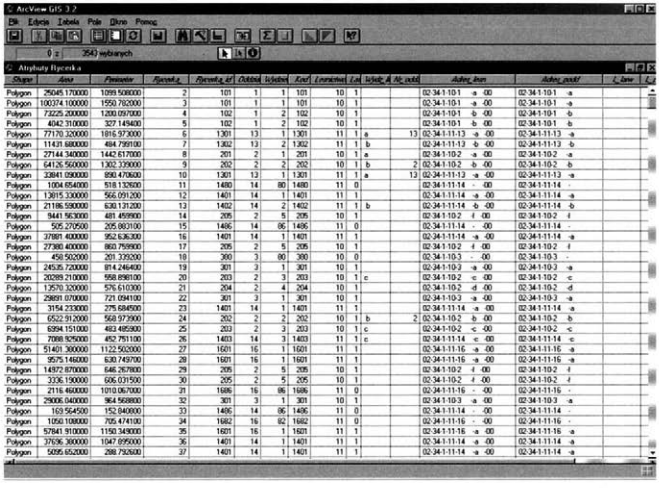
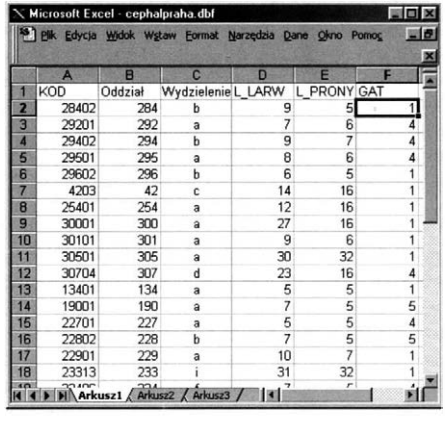


Fig. 1. The descriptive database of Forest Inspectorate Ujsoły

The table with the data, related to the autumn searching for diapausing larvae, was prepared by forest services employees directly in the concerned area. It contains numbers and areas of the subcompartments and the KOD column used for merging the information with the numeric map database. The table contains also the information on the number of larvae found in the given selected account, the number of pronymphs as well as the species marked with numbers (Fig. 2).

Two databases are merged with the common KOD column with the numbers of selected plots of land. For the evidence and forecast ArcView with Spatial Analyst and 3D Spatial extensions were used.



Microsoft Excel - cephalpraha.dbf

Plik Edycja Widok Wstaw Format Narzędzia Dane Okno Pomoc

	A	B	C	D	E	F
1	KOD	Oddział	Wydzielenie	L_LARW	L_PRONY	GAT
2	28402	284	b	9	5	1
3	29201	292	a	7	6	4
4	29402	294	b	9	7	4
5	29501	295	a	8	6	4
6	29602	296	b	6	5	1
7	4203	42	c	14	16	1
8	25401	254	a	12	16	1
9	30001	300	a	27	16	1
10	30101	301	a	9	6	1
11	30501	305	a	30	32	1
12	30704	307	d	23	16	4
13	13401	134	a	5	5	1
14	19001	190	a	7	5	5
15	22701	227	a	5	5	4
16	22802	228	b	7	5	5
17	22901	229	a	10	7	1
18	23313	233	i	31	32	1

Arkusz1 / Arkusz2 / Arkusz3 /

Fig. 2. The table with the number of larvae and pronymphs found in the subcompartments

RESULTS

After merging the two descriptive databases, the occurring events may be visualised in the map. With query

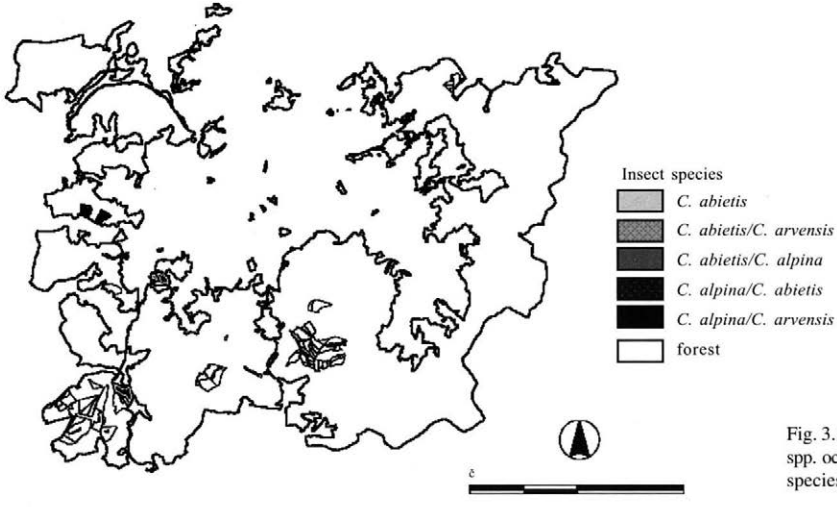


Fig. 3. The area of *Cephalcia* spp. occurrence by particular species

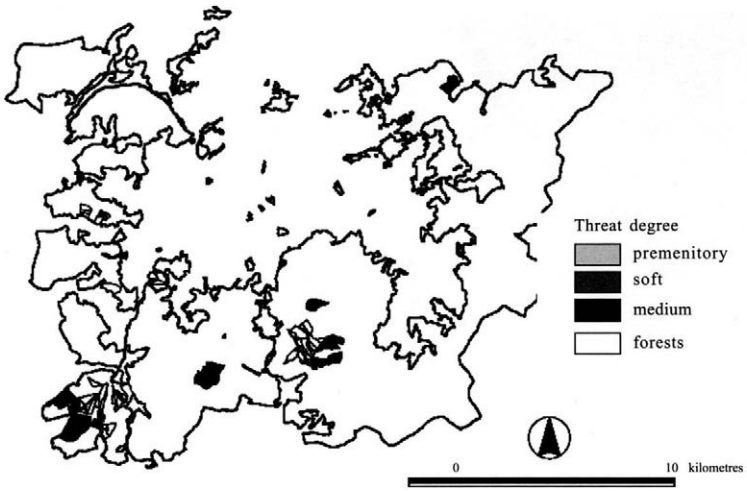


Fig. 4. The area of stands threatened by *Cephalcia* spp. by threat degrees

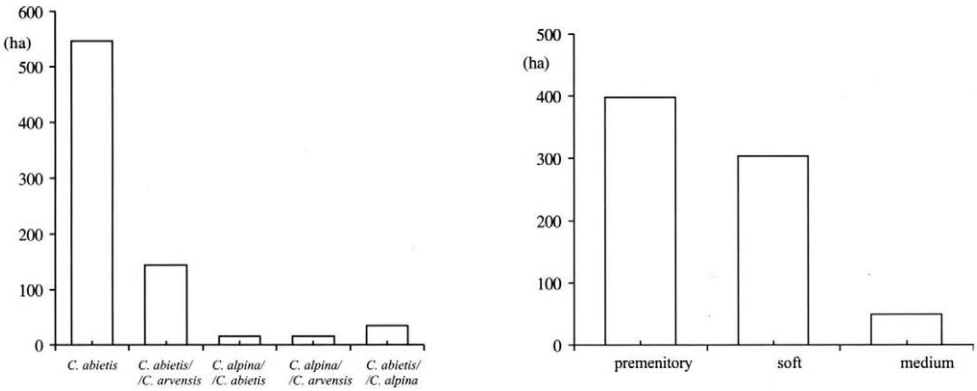


Fig. 5. Histogram of occurrence and threat degrees by *Cephalcia* spp.

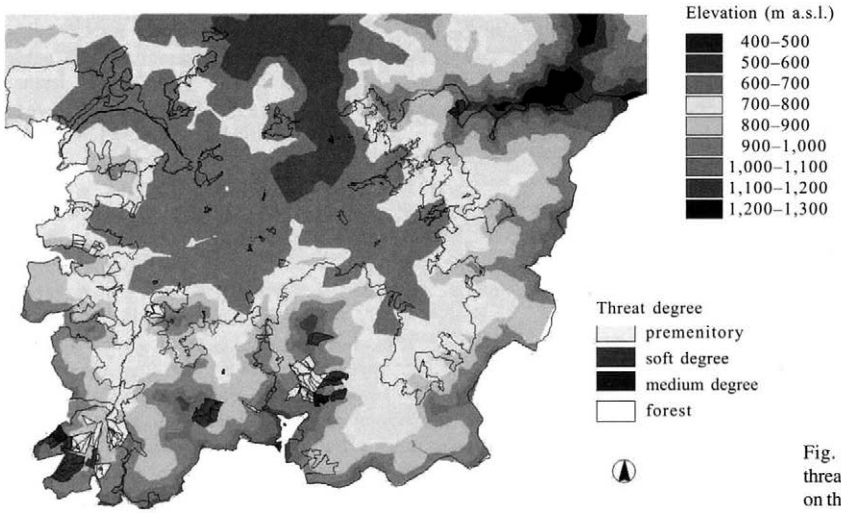


Fig. 6. The area of stands threatened by *Cephalcia* spp. on the elevation background

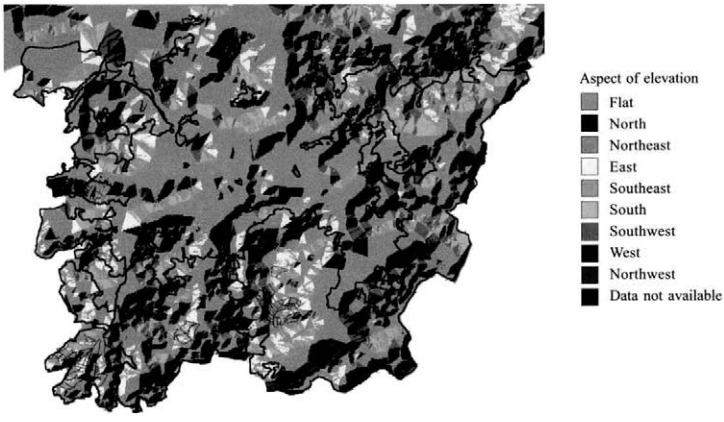


Fig. 7. Aspect of elevation

expressions in ArcView, the subcompartments were chosen from the database, in which the insect larvae were found during the autumn searching. The information displayed in the map show the range of *Cephalcia* occurrence.

Additionally, the Legend options allow to display the column with the existing species of *Cephalcia* spp., thus returning the information on distribution of particular species and groups of species (Fig. 3).

Depending on the number of pronymphs found and the threat degrees, the obtained information was classified and a map of Norway spruce stands threatened by *Cephalcia* – caused damage was generated (Fig. 4).

With the data on the area of occurrence of particular species, also a table-form summary can be displayed by species and by areas threatened by these species (Fig. 5).

The land shape layer allows the definition of particular species occurrence by altitudes, which is related to the insect feeding behaviour (Figs. 6, 7).

CONCLUSIONS

- New method of the evidence and forecast with the use of digital map allows better and easier data management and analysis.
- Digital map with layer of elevation and aspect of elevation allows more detailed analysis of the dynamics of species occurrence and variations of threatened areas.
- ArcView with extensions is a good tool for evidence and forecast of the occurrence of some insect pest.

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A GIS approach to understand a case of beech decline in Trentino

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ABSTRACT: A case of beech decline due to unknown causes was studied by means of a GIS approach. Looking for a confirm of a drought stress, several thematic maps were geo-referred to the Digital Elevation Model of the interested area and analysis carried out. Facing of the declining areas could be considered sound with a warmer site situation while both slope and elevation appeared not significant. Soil showed a prevalence of dryness conditions and gravel texture in the affected areas. Comparison of diseased area and phytoclimatic belts clearly showed that the dieback interested trees located outside the optimal range of beech, in a warmer and xeric vegetation area. Only Moisture Index and Wetness Index, both based on geo-morphological characters, indicated a better moisture condition for the declining area, in contrast with the hypothesis. The GIS approach, together with accurate ground survey, permitted a better understanding of the observed situation; it proved to be quite good, relatively easy, quick and cheap for the presence of a lot of available data, even if some important environmental factors were not mapped.

The presence of beech (*Fagus sylvatica* L.) is limited in Trentino woods, interesting only the 3.8% of the mass in the high forest woodland and not more than 29% of the surface in the coppice areas. Its importance is mainly ecological rather than economical and it plays a potential role in the context of the naturalistic management of woods adopted by the Forest Service, aiming to restore the natural characteristics of the woodland which are specific to each environment and so working to obtain mixed woods with an increasing presence of broadleaves.

Few phytosanitary problems were reported till now in beech woods both in Trentino and in Italy, but in the last years decline phenomena were suddenly observed in some localised coppices areas located in the Southern valleys of the Province. Symptoms were a-specific as crown dieback, with top and branches dying, small leaves and yellowing of foliage and, eventually, stem death. Field observation permitted to exclude the presence of root rot agents as *Phytophthorae* or *Heterobasidion annosum* (Fr.) Bref. and *Ustulina deusta* Fr. observed in other cases of decline respectively in Germany (HARTMANN, BLANK 1998) and in Italy (MARESI et al. 1998). The symptoms were also different from those reported for a beech wood in Southern Italy (MORIONDO et al. 1999). No fungi were constantly associated to dead or declining wood tissues but only several saprophytic ones as *Diatrype disciformis* (Hoff.) Fr. were randomly recorded. The presence of *Xyleborus dispar* (F.) was detected on many branches but this insect is considered a weak parasite, pullulating only on stressed trees. During ground surveys also suffering *Fraxinus ornus* and *Ostrya carpinifolia* were observed, without evidence of parasite attacks. On these basis the hypothesis of a drought stress was formulated to explain the observed phenomenon.

To enforce this hypothesis a GIS approach, collecting several mapped environmental data, was performed for one of the affected area in the locality of Terlago (Lakes Valley) located in the Southern part of the Province.

MATERIAL AND METHODS

Cartographic data were referred to the administrative limits of Terlago village community where decline was first recorded. Maps and data were organised by the Forest Service and by the SIAT (Sistema Informativo Ambiente Territorio) of the Autonomous Province of Trento who made them available in computerised format for research institutes and for environmental technicians.

Among the environmental data mapped and digitalised, the following thematist were chosen:

- the Digital Elevation Model (DEM) made up on the basis of the topographic maps,
- the map of the Woodland Management Plans (WMP) compartments: for each compartment, a quite homogeneous section of wood, a database was associated with about 120 different environmental, dendrological and silvicultural parameters. These data are collected by ground surveys and regularly revised every ten years, following standard criteria. In the study only the coppice compartments with more than 10% of beech were considered.

The map of phytoclimatic belts, according to SCHMID (1963) for the area "Trento South" (CONCI, ZAMBANINI 1986) was digitalised and geo-referred.

A complete map of the disease coppices was obtained by accurate ground survey carried out in 2001 summer. Also this map was digitalised and geo-referred.

On the basis of the DEM two different index of soil humidity were elaborated:

– the Moisture Index following the formula

$$\ln(\text{Flow accumulation} + 1)/(\text{Slope} + 1)$$

according to ANDERSON, MERRIL (1998),

– the Wetness Index calculated by the formula

$$\ln(a/\tan\beta)$$

where: a = upslope contributing area per unit contour and tang β = local slope angle as indicated by WESTERN et al. (1999) and QUINN et al. (1995).

Overlaying of maps and data analysis was performed by means of ArcView GIS (ESRI-USA). The surface of declining beech was compared with the healthy beech surface.

Rainfall data were obtained from S. Massenza pluviometric station (Hydrografic Service of the Autonomous Province) and located in the same valley at 7 kilometres from the infected area.

RESULTS

The overlay of the different maps was easily performed because of a good geo-referencing of each layer: the declining surface appeared as a quite compact area between the total area of beech woods (Fig 1).

Declining beech coppices were located mainly between 800 and 1,250 m a.s.l., on low slope. No difference were observed with the healthy surface that in some case was found at the same and lower elevation and that vegetated on steeper slope too.

The diseased stands showed all a South and South-east facing while the healthy ones distributed mainly on South-west facing.

The overlaying of the affected area on the map of phytoclimatic belts showed as they stretched mainly in Q pub. Q.T.A. belt (80%) and Q pub. Q.T.A. F.A. one (20%) (Fig. 2). In both this transition belts beech can be considered out of its optimal range while prevalence of species as *Q. pubescens*, *Fraxinus ornus* and *Ostryia carpinifolia* suggest a more xeric vegetation. The healthy surface ranged between F.A. (*Fagus abietum*) and the cited belts.

From the application of Moisture Index, the declining surface seemed ranging on wetter class than the healthy one. It did not appear in the xeric class and it was more present than the healthy area in the wetter ones (Fig. 3). The same result was obtained by the application of the Wetness Index, that showed a good potential humidity in all the affected areas. It is to notice that both the considered index work only on geo-morphological data.

Examining WMP soil description and considering soil-water classes, declining surface appeared related to condition of dry and arid soil with 78% and 22% respectively, while the healthy stands ranged between wet (8%), dry (89%) and arid (3%) classes. The frequency in soil texture classes of the declining beech was 14% on clayey, 60% on gravelly and 26% on stony. Healthy beech stands frequency was: 17% clayey, 8% sandy, 63% gravelly and 12% stony soil.

Rainfall data showed an evident decrease in winter months, especially in February and March, for the last years respect the climatic data. Period of lower precipi-

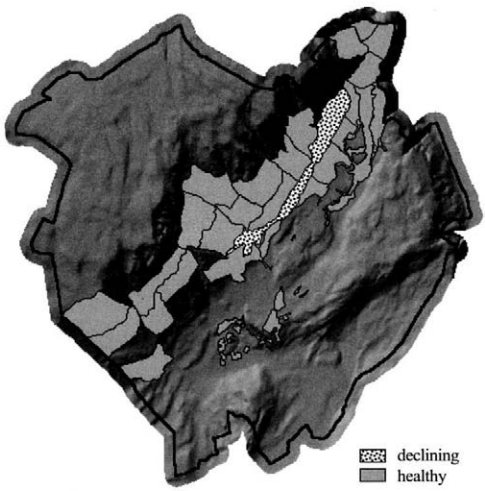

Fig. 1. DEM of study area with WMP beech compartments and declining area

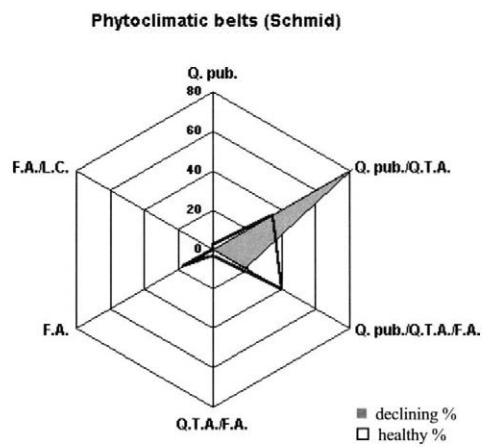

Fig. 2. Percentage distribution of healthy beech compartments and declining area in the different phytoclimatic belts

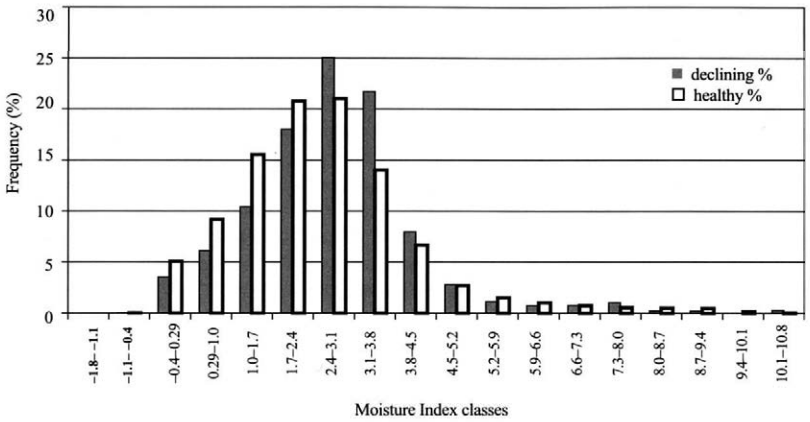

Fig. 3. Percentage distribution of healthy beech compartments and declining area in the different classes of Moisture Index. Moisture is increasing from left to right

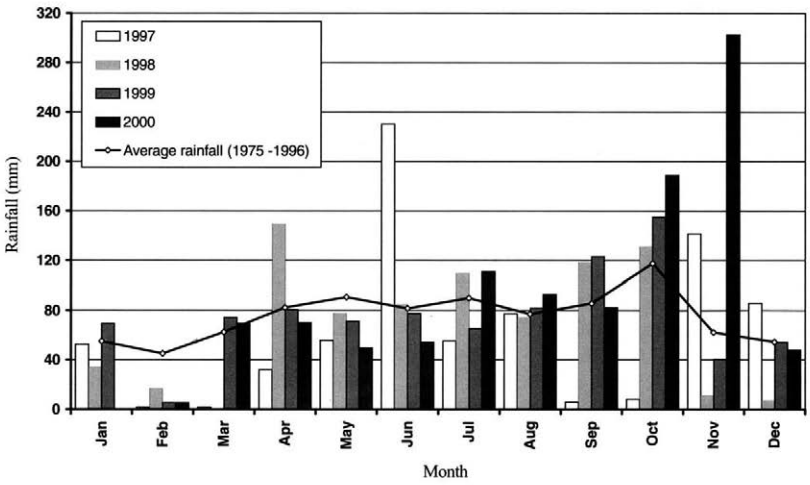

Fig. 4. Monthly rainfall at S. Massenza pluviometric station

tation amounts were present also during summer months (Fig. 4).

DISCUSSION AND CONCLUSIONS

The hypothesis of a drought stress involved in the examined case of beech decline found some fundaments by means of the GIS approach. Particularly the exam of DEM data showed as the facing of the declining areas can be considered sound with a warmer site situation while both slope and elevation appeared not significant respect the healthy stands. Soil conditions and the morphological location of the affected coppices resulted also interesting to explain a not good site situation for beech growth even if the dryness and the texture of soil were not well evidenced by the GIS for the lack of a detailed map.

A more encouraging result was obtained by the comparison of diseased area and phytoclimatic belts map in which it is clearly showed that the dieback interested trees located outside the optimal range of beech, in a warmer and xeric vegetation area.

The applied Moisture and Wetness Index seemed not sound with the drought hypothesis enhancing a good wetter situation as assessed by morphological parameters. But this better humidity condition may be annulled by the soil condition and by the presence of other factors as strong and constant wind, all able to augment evapotranspiration and soil water deficiency. The better moisture condition due to morphology may, on the contrary, explain the survival of beech in not optimal vegetation belt; in this context, even a small change in rainfall distribution as observed in this area can enhanced a stress condition.

The GIS approach to study this kind of problem proved quite good, relatively easy and quick; in this case the presence of a lot of data directly available allowed a cheap use of the method. On the contrary, even if in this

good starting condition, the lack of some fundamental data as pedological and geological ones can stop the research to preliminary steps.

In the contest of a mountain area as Trentino, where environmental differences can be very significant also in few kilometres, it is very important the accuracy of ecological factors mapping. Also it is to notice that the spread of diseases rarely follow the WMP compartments and mainly appears as punctual or localised. A good mapping of the attacks by means of GPS (Global Position System) technology and/or ground surveys is fundamental to obtain significant analysis.

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GIS-technology in evaluation of forest pests distribution in Ukraine

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ABSTRACT: GIS technology can be applied for forest condition analysis and prediction, investigation of certain agents role in the stands damage, different pests distribution, probability, frequency and intensity of their outbreaks, influence of weather conditions etc. Using databases on pest population dynamics, site and stand parameters, weather indices, the maps of pest distribution are built on the level of country, regions, forest enterprises, stands, forest blocks and plots. Analysis on the level of stand allows to make more precise the area and boundaries of pest control measures.

Determination of area with different probability and amplitude of pest outbreaks and forest damage in the scale of country, regions, forest enterprises and particular stands is necessary for survey organisation, threat prediction and control measures planning.

In Ukraine GIS technologies are developed for forest inventory (BOGOMOLOV et al. 2000), distribution of radioactive contamination (GAVRILOV et al. 1994), assessment of global climate change impact on forests (SIDOROV et al. 1997), pest dissemination and forest condition prediction (BOGOMOLOV et al. 2000; MESHKOVA 1998, 1999, 2000a,b; SIDOROV et al. 1999).

To use GIS technology for forest condition analysis and prediction, investigation of certain agents role in the stands damage, different pests distribution, probability, frequency and intensity of their outbreaks, influence of weather conditions etc. one must have respective databases as well as the set of points with known geographical coordinates or contour maps linked to geographical coordinates.

Map contours were digitised using software which was developed by Department of New Information Technologies of Ukrainian Research Institute of Forestry and Forest Melioration (BOGOMOLOV et al. 2000; SIDOROV et al. 1999). Databases on pest foci dissemination and forest damage for more than 50 years were taken from Information & Search System "Forest Protection" using respective software (MESHKOVA 1998).

The data in the bases can be attached to the objects of one of the two types.

The first type includes area objects (country, region, forest enterprise, forestry, forest block, forest plot). In the large scale (country, region, forest enterprise) forest covered area, percent of certain tree species, damaged or threatened area may be evaluated. In the scale of forest block (500 × 1,000 m or 50 ha) more detailed characteristics of site, stand and damaging agents may be given. Forest plot is the finest unit of forest inventory. Its area is approximately 2 ha and detailed description of site and stand condition in it is assessed regularly during forest inventory. The data attached to area objects can be used for different thematic maps creation.

The second type includes the points with determined geographical coordinates. The data on pest density, trees defoliation and mortality, site and stand condition are obtained for pest monitoring points and different weather indices are determined for the points of meteorological stations location.

The data that are obtained for the points, can be used for building the sets of isolines which describe the dissemination of weather parameters, population density, stand threat level through the territory as well as for determination the meanings of these indices in any given point. This allows to use statistic methods for calculation the correlation indices and regression coefficients for different parameters that are known for the same set of points.

Thematic map creation is the most simple task. It requires only the digitised contours of regions, stands or plots (not obligatory linked to geographical coordinates) and the database with the meanings of certain parameters estimated for these units.

Qualitative parameters describe the existence of the certain pest species or drying of the certain tree species in given area object (Yes/No), presence of different soils, site conditions, stand age. There may be also the set of thematic maps which show pest existence in different forest plots, stands or regions during several successive years.

Pest foci area (hectares or percents from forest covered area), pest outbreak frequency (probability), defoliation (percents or ranges), outbreak phases (progradation, culmination, crisis) are the examples of quantitative parameters.

The above mentioned approach can give imagine of pests, diseases or other damaging agents distribution in different scales.

At the same time GIS application allows to solve more complex tasks, for example, isolines building. Those are isotherms (lines which link the points with equal temperature), isophens (lines which link the points with similar dates of certain phenological event), the lines of similar altitude, defoliation or pest density.

For this purpose every point of the map on every level (country, region, stand, forest block and plot) must be characterized by geographical coordinates. In this case if we know the meanings of parameter for set of points, then we can calculate them for other points with certain degree of significance.

The main idea of GIS use is simultaneous analysis of various information connected to certain geographical points or area. If we have the meanings of different parameters for the same points then we can evaluate the dependence between them (for example, between pest dissemination, damage intensity and environmental indices) using statistical approaches.

According to the scale we can distinguish different levels of GIS application.

On the macroregional level, thematic maps characterise pest foci dissemination, population waves intensity, outbreaks development probability, threat level for stands. The contours of regions, districts, boundaries of forest enterprises or forestries are the cartographic background for such maps. Separate layer of the map contains the isolines of meteorological parameters (temperature, precipitation, integral indices of humidity etc.). Statistical analysis on this level allows to evaluate spatial & temporal dynamics of processes as well as to create multiple regression models to predict threat for the stands on the regional level.

To solve the tasks on such level, we use the data that describe area objects (for example, area of pine defoliators foci in given region). But sometimes we must evaluate influence of parameter which is obtained for points (temperature) to parameter that describes area object. In this case we assume that last one is linked to the center of area object and calculate respective coordinates using functions *CentroidX*(*obj*) (returns the *x*-coordinate of the object's centroid) and *CentroidY*(*obj*) (returns the *y*-coordinate of the object's centroid). For example, the meanings of altitude were calculated for central point of every forest plot from digitized map of relief (Fig. 1). This allowed to evaluate the impact of water availability on forest condition in different parts of stand (calculated correlation index for pine defoliation on sandy soils and altitude in the Steppe zone was equal to 0.56).

The map of Geometridae foci dissemination in Ukraine is shown in Fig. 2. Boundaries of zones with different outbreak intensity were estimated by the means of statistical section of GIS-analysis.

On the microregional level population dynamics and stands damage are evaluated in the frame of separate stands. Stands boundaries contours are the cartographic background for such analysis and representation. Additional map layer contains the boundaries of forest blocks and plots. Layers with contours of relief, hydrographic net, soils dissemination can be included into analysis and points of these layers are also linked to geographical coordinates (Fig. 3).

GIS-technology was used also for determination of potential epicenters of pest outbreaks. In forest protection practice, survey cannot be carried out in all plots. Therefore definition of the points for obligatory pest assessment is one of the most important tasks.

The method of evaluation of site and stand conditions availability and preferences for pests-defoliators survival and propagation was developed (MESHKOVA 2000a).

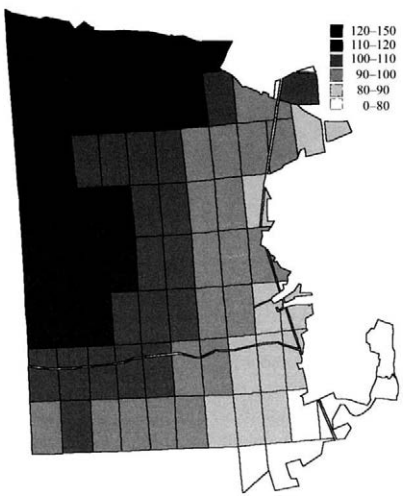

Fig. 1. Estimated altitude (m above sea level) for different forest plots (Izumskij Forest Enterprise, Kharkov region)

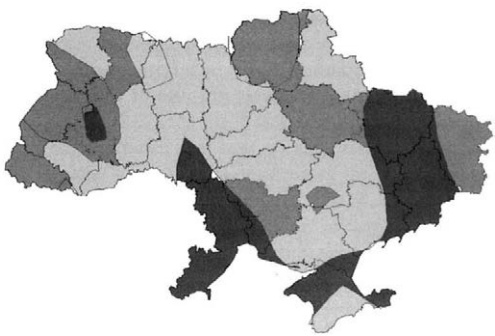

Fig. 2. Different levels of Geometridae outbreaks probability in Ukraine (the most dark area shows the highest level)

Fig. 3. Digitised map of stands including boundaries of forest plots and altitude isolines in separate layers (Izumskij Forest Enterprise, Kharkov region)

Taking into account parameters of site and stands, *Panolis flammea* Schiff. density was predicted for different forest plots in the same forest block (BOGOMOLOV et al. 2000).

After traditional assessment, the predicted forest damage by *P. flammea* exceeded 30% for the whole plot which presupposed control measures on the 55.41 ha. Taking into account the above mentioned method we created query in the database where non-preferable meanings of site and stand parameters were excluded. There were plots after total felling, roads, paths, firebreaks, unclosed plantations (younger than 5 years old), stands of natural origin older than 80 years old etc. After this only 6 forest plots were predicted to be damaged by *P. flammea*. Area of these plots was equal to 27.7 ha that was almost 50% from total area of forest block. Pupae number was assessed in the litter of every plot in this block and the map of their distribution was similar to predicted map of forest damage (BOGOMOLOV et al. 2000). This proves that GIS approach provides exact estimation the area which must be treated by pesticides with rather low expenses.

The advantages of GIS technology for pest dissemination analysis and stands damage prediction may be used more effective when achievements of research would be widely implemented in practical forestry. It may be done only after digitising of stands contours for the whole country which demands involving considerable amount of funds.

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First experiences of using GIS in forest protection in Saxony

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ABSTRACT: In the paper are shown several examples of application for the geographical information system (GIS) to problems of forest protection in Saxony. All examples are illustrated with maps. In the first example debarking and browsing data were prepared in special maps. By the help of such information, spatial different sylvicultural and hunting activities could be planned. The second example described a proposal for the reduction of the number of sample stands for soil search, a monitoring method for harmful insects in pine stands. Special parameters such as the attack risk, the suitability, the owner and the distance to the next sample stand in state owned forests were calculated for every sample stand and characterised the importance of the stand for the monitoring. Actual results show the reduced sample grid could be used for forecast in future too. An other example dealt with the evaluation of forest fire danger. The north part of Saxony was divided into 3 risk zones on basis of the forest districts in the past. The use of financial support for forest fire control, prevention and fighting by the European Union demanded a classification into 4 levels on basis of the municipalities. On the other side, the importance of the burning reasons have changed. A new level for forest fire danger was calculated with analysis of discriminants and adjusted to the boundaries (HELBIG 1999). The used parameters were climate conditions, portion of pine stands and military used forests in the municipalities, mean frequency of fires and mean burned area in the period 1971–1997 and other. In the 4th example a risk assessment for spruce bark beetle attacks is described. The spatial pattern of the attack spots and the volume of infected trees were digitised and analyzed for a forest district in the western part of the Ore Mountains for the period from 1993 to 1999 (SONNEMANN 2001). Risk factors for spruce bark beetle attacks for single stands were calculated based on the following stand features: site type, stand structure type, stand density, diameter at breast height and portion of spruces with red ring rot. The calculation method is described for one feature. In a second step these risk factors were applied and verified in a neighbouring forest district. The comparison between the calculated risk and the occurred attacks in the period 1996–2001, the possibility to estimate the risk in the future in dependence on different silvicultural methods (mixed stands, older spruces and so on) and the use of risk maps in the practise are discussed.

A geographical information system (GIS) is a useful tool for:

- depiction of damages and forecast results in maps (LYONS et al. 1997),
- description and analysis of their spatial pattern (WICHMANN, RAVN 2001),
- connection with other data, e.g. on the structure of forest stands (HALL et al. 1998).

Since 1997 a working group of the forest research institute has provided topographical and special forest information in a forest GIS. Now some information is available for the whole country, the other only for some forest districts. In the departement of forest protection some of these possibilities are used, as the following examples show:

1st example: Description of the spatial pattern from damages

In Saxony, expert reports for the development of shooting plans of roe deer and red deer are demanded by the forest law. Therefore, special surveys are carried out in a three years period. The survey method is based on a systematic sample in a 1 × 1 km geographical grid. Debarking and browsing data could be presented with the help of GIS in special maps. Some areas with high damages become apparent, where the hunting activities have to be forced. Different information about browsing such as the degree of damage, the damaged tree species group, protection methods for a forest district is shown in Fig. 1.

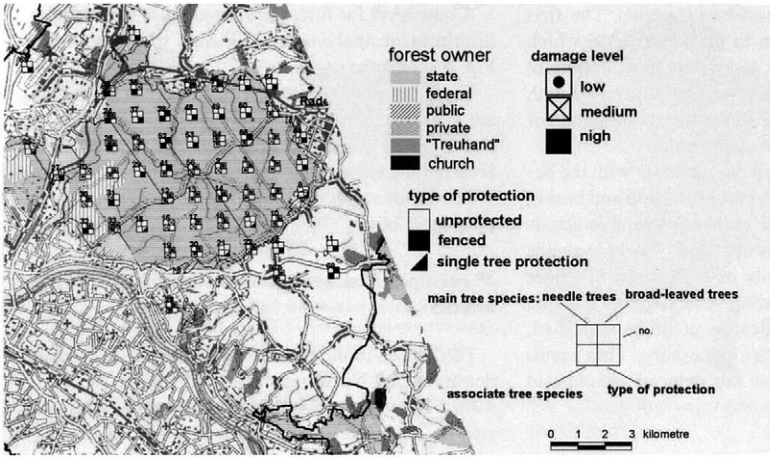

Fig. 1. Browsing damages in the forest district office Dresden in 2000

In the south-eastern part of this forest near Dresden, the young broad-leaved tree species show a low level of browsing, also natural regeneration is possible and the number of fenced regenerations is low. Higher damages on needle tree regenerations and more fenced and chemically protected areas are typical in the north-western part. With help of such information, spatially different hunting activities could be planned (OTTO, KÖNIG 2001).

2nd example: Proposal for the reduction of the number of sample stands for soil search in pine stands

In Saxony, 32% of the forest area is covered by pine stands, mostly in pure stands. These areas are concentrated in the northern part of the country. They are a part of the large spreading areas of dangerous defoliators such as *Lymantria monacha, Dendrolimus pini, Panolis flammea, Bupalus piniarius* and *Diprion* spp. in the neighbouring countries Poland and Brandenburg. In these regions a permanent monitoring of these species is necessary. The foresters use traditional methods for monitoring and forecast, such as pheromone traps and soil search for pupae/larvae. For example, 650 pine stands were used for soil search every autumn/winter until 1998. Particularly the soil search needs a lot of time and therefore it is a very expensive method. On the other hand, this region is characterized by a high percentage of private forests and so named "Treuhandwald". These forests are held in trust by the forest districts, but shall be sold to private owners in the near future. Therefore the number of forest workers have decreased in these forest districts rapidly and it was necessary, to reduce the number of observed stands. That was realized with help of GIS.

The following parameters were calculated for every sample stand:

- The attack risk on the basis of the frequency of high population densities (values more than 20% from the critical level) for the important species *D. pini*, *P. flammea*, *B. piniarius* and *Diprion* spp. in the period 1995–1998.
- The suitability of the stand (age, stand structure, minimum area).
- The owner (state, private a.o.).
- The distance to the next sample stand in state owned forests.

Every parameter was splitted into 4 levels (Table 1). These levels show the importance of the stand for the

Table 1. Description of the used parameters and their splitting into 4 levels

Parameter	Levels			
	1	2	3	4
Attack risk (% of high density values)	> 75	> 50–75	> 25–50	< 25
Suitability factors 40–70 years old pure stands > 2 ha area	all 3 factors	2 factors	1 factor	other stands
Owner	state and federal forests	public forests	"Treuhand"-forests	private forests
Distance to the next sample stand in state forest (m)	> 3,000	> 2,000–3,000	> 1,000–2,000	< 1,000
Points for calculation	4	3	2	1

monitoring. They were assessed with points. The first level gets 4 points and so on to the fourth level which gets only 1 point. The attack risk is the most important parameter, therefore the points were multiplicated with the factor 3. The map in Fig. 2 shows the classification of all sample stands based on the point sum.

The forest district offices, in co-operation with the department of silviculture and forest protection and basing on this proposal, reduced the number of sample stands from 650 to 480 in 1999. This new grid of sample stands indicated an increasing density of *P. flammea* in winter 1999 to 2000 and in the following year. Together with the other forecast methods the location could be identified, where control measures were necessary. This result shows that it is possible to use this reduced sample grid for forecast also in future.

3rd example: Evaluation of forest fire danger

The northern part of Saxony with dry climate, poor sites and mostly pure pine stands is characterised by areas susceptible to forest fires. This region was divided into 3 risk zones for special monitoring and preventive measures in the past. The basis for that splitting were data about the frequency of fires and the burned forest area registered in forest fire statistics for forest districts (Fig. 3).

The use of financial support for forest fire control, prevention and fighting by the European Union demanded a classification into 4 levels on basis of the municipalities. On the other side, the importance of the burning reasons have changed. For instance the number of fires, caused by military activities have decreased. A new assessment method was developed (HELBIG 1999). The used parameters were:

- climate conditions,
- portion of forests in the municipalities,
- portion of pine stands in the municipalities,
- portion of military used forests in the municipalities,
- mean frequency of fires in the period 1971–1997,
- mean burned area in the period 1971–1997.

A new level for forest fire danger was calculated with discriminant analysis and adjusted to the boundaries. Fig. 4 shows the result.

The percentage of areas with a low forest fire danger are similar according to both systems (60% old system and 64% new system) in the whole country. Also the high level has the same value with 18%. But by the new system 7% of the area were characterized as very high exposed to the danger of fire.

4th example: Risk assessment for spruce bark beetle attacks

The forests in the mountainous regions of Saxony are dominated by Norway spruce (*Picea abies* [L.] Karst.). 44% of the total forest area are composed of spruce stands. Therefore the spruce bark beetle (*Ips typographus* L.) is one of the most important insect pests. An outbreak of this species did not take place in the last 10 years. The volume of infested trees ranged between 1,400 m^3 and 24,500 m^3 per year. The actual registration of the attack spots and the volume of infested trees in special maps is one part in our integrated pest management strategy. For the forest district Schönheide these data were digitized and analyzed for the period from 1993 to 1999 (SONNEMANN 2001). The characteristic data for this forest district in the western part of the Ore Mountains are listed in Table 2.

The inventory-data of the forest management planning were also digitized as a part of the forest GIS in Saxony. Risk factors for spruce bark beetle attacks for single stands were calculated based on the following stand features:

- site type,
- stand structure type,
- stand density,
- diameter at breast height,
- portion of spruces with red ring rot.

For every class of these stand features a risk factor (*rf*) was calculated. They are calculated as:

$$rf_{m,n} = fa_{m,n}/p_{m,n}$$

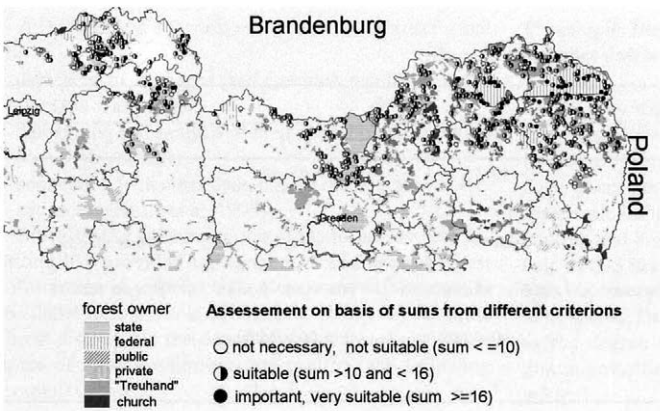

Fig. 2. Suitability of the sample pine stands for soil search

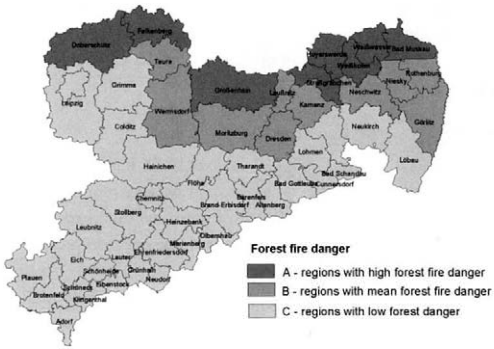

Fig. 3. Forest fire danger splitted into 3 levels for forest districts (old system)

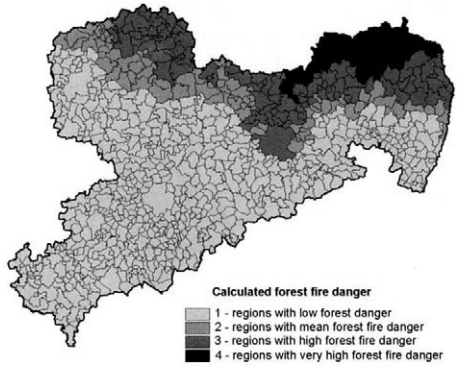

Fig. 4. Forest fire danger splitted into 4 levels for municipalities (new system)

Table 2. Data about the analysed forest districts

	Schönheide	Eibenstock
Forest management area (ha)	7,902	8,567
Portion of state forests (%)	91	95
Portion of spruce stands (%)	88.5	94.2
Ridge mountainous regions, > 900 m a.s.l. (%)	–	19.3
Higher mountainous regions, 700–900 m a.s.l. (%)	5.7	64.1
Mean mountainous regions, 500–700 m a.s.l. (%)	94.3	16.6
Spruce > 60 years (ha)	2,987	3,956
Calculated cut (solid cubic metre of standing crop)	7.3	6.4
Volume of infested spruces mean [m^3/year] (min–max) 1991–2000	405 (118–1,089)	833 (229–2,241)
Number of spots of attacks mean (min–max)	84 (32–195)	150 (67–263)

where: m – the stand feature
n – the class of the stand feature m
$fa_{m,n}$ – the frequency of attacks for stand feature m in class n
$p_{m,n}$ – the portion of stand feature m in class n of the forest district area

Depending on practical experiences the calculated factors were modified. The different categories can be interpreted as

$rf = 0$	no risk,
$rf > 0$ and < 1	low risk, no suitability,
$rf = 1$	mean risk, mean suitability,
$rf > 1$ and ≤ 2	mean risk, increasing suitability,
$rf > 2$	high risk, high suitability.

Table 3 shows the results of the calculation for the example "diameter at breast height".

On the basis of the single risk factors, the risk was calculated for every stand in the forest district as:

$$\text{risk} = \prod_{z=1}^{m} rf_{z,n}$$

In Fig. 5 the result of the risk calculation and the observed spots of attacks is shown for the whole forest district office Schönheide.

In a second step these risk factors were applied and verified in the neighbouring forest district Eibenstock (Table 2). Fig. 6 shows the comparison between the calculated risk and the occurred attacks in the period 1996–2001.

65% of the 481 observed spots of attacks during the examination period occurred in stands with a high calculated risk. 26% in stands with a mean risk, 1% in stands with a low risk and 8% with no risk areas. This result shows that it is possible to estimate the risk for spruce bark beetle attacks with this method.

The digitised site data in a GIS makes also possible to estimate the risk in the future in dependence on different silvicultural methods (mixed stands, older spruces and so on). The risk map could help the forester to concentrate his observations in the endangered areas.

This method is the first step on a long way to calculate the spruce bark beetle attack risk in a territory.

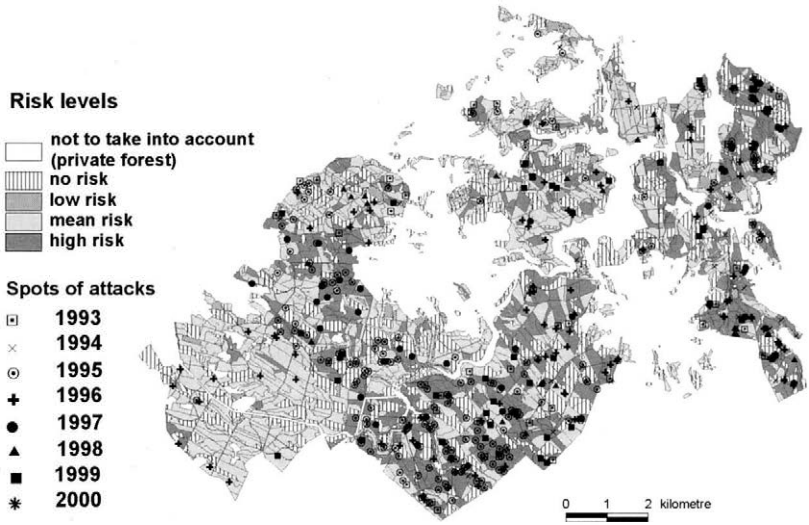

Fig. 5. Spots of attacks in the forest district Schönheide and with its calculated risk levels

Table 3. Calculated risk factors for the stand feature "diameter at breast height" in 9 classes

Class	Number of attacks between 1993–1999	Frequency of attacks (%)	Portion of the area (%)	Risk factor calculated	Risk factor modified
20–24 cm	1	0.2	1.5	0.13	1.0
25–29 cm	2	0.4	7.9	0.05	1.0
30–34 cm	43	8.2	18.8	0.44	1.0
35–39 cm	123	23.5	27.8	0.84	1.0
40–44 cm	251	48.0	25.5	1.88	1.9
45–49 cm	82	15.7	8.7	1.80	1.8
50–54 cm	8	1.5	0.83	1.85	1.8
55–59 cm	11	2.1	0.58	3.60	3.6
> 59 cm	2	0.4	0.13	3.08	3.1

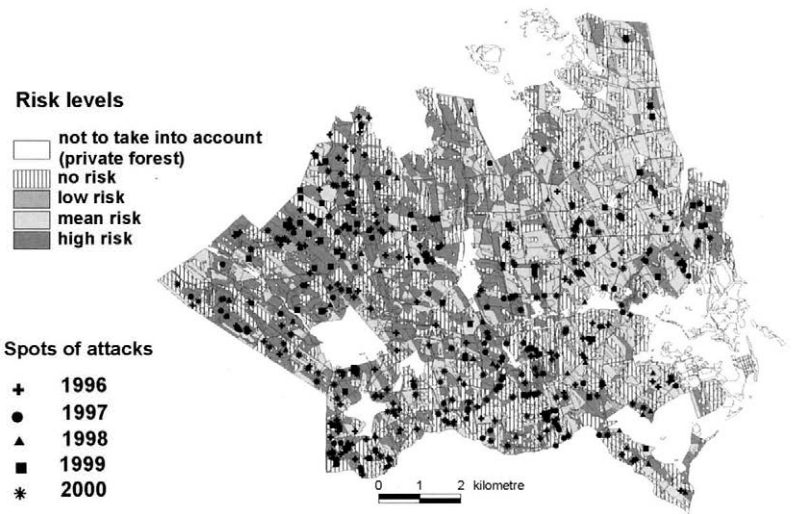

Fig. 6. Calculated risk levels in the forest district Eibenstock and occurred spots of attacks

These examples show, that GIS is a useful tool to solve some problems in forest protection. The user get the possibility to analyse old data again and connect them with new information and investigation results.

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GIS study of Sitka spruce dieback in Wales

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ABSTRACT: In the summer of 1991 a report was received on the poor condition of Sitka spruce, *Picea sitchensis*, in the Tywi (North) block of Ceredigion Forest District in Central Wales. Overall the needle colour was a mid- to light green rather than the normal blue-green. In addition severe yellowing, browning and loss of needles coupled with twig dieback was evident throughout the area. As a result of a preliminary site visit a minor project was set up involving investigation of fungal pathogens, climatic influences, nutrient levels, damage distribution and monitoring of damage development. Reinforcing these investigations was an MSc project at Leicester University using GIS techniques. The results indicate that the problem is site-related with climatic conditions being the main trigger. Two pairs of drought years ('83–'84 and '89–'90) created severe drought stress on trees normally growing in very wet peat or peaty-gley soils. This led to an induced potassium deficiency that resulted in marked yellowing of older needles. The presence of the needle fungus *Lophodermium piceae* as an endophyte in these needles led to their rapid death and loss. Where needle loss involved all ages of needles then twig dieback often occurred. Results from the assessment of plots showed that the situation started to improve in 1992 and by 1996 the needle retention was very good and had stabilised. Overall colour of the trees had also improved and no new dieback was recorded.

BACKGROUND

The problem was first notified to the Disease Diagnostic & Advisory Service (DDAS) in June 1991 by staff at the Ceredigion Forest District who were concerned by the poor colour and considerable needle loss on Sitka spruce over an area of ca 1,000 ha of the Tywi (North) block. There was also reference to a few instances of deaths of dominant trees in the crop, and epicormic growth and multiple budding on trees with marked defoliation or twig dieback. An examination of a branch sample that was sent with the initial notification showed that in addition to needle loss there was death of many 1990 shoots. A site visit was arranged in September 1991 with local Forest District staff and following this visit a minor project was set up to investigate the problem over the next five growing seasons.

DESCRIPTION OF SYMPTOMS

The overall impression of Sitka spruce in this block was of trees that were a much lighter green than elsewhere in mid-Wales. Typical blue-green foliage was little in evidence over the area and in addition to colour differences in green foliage there was a high level of yellowing needles of all ages. Much of this yellowing was found on needles of 3 years or older and had typical characteristics of potassium deficiency. Commensurate with the yellowing was browning and eventual needle loss, often quite severe. The browning needles had darker brown bands indicating the presence of *Lophodermium* sp. On some trees defoliation has been extensive and there was significant twig dieback. On a purely visual inspection the worst damage appeared to be in the mid-crowns of ride-side trees and the lower parts of the upper crowns of trees within compartments. There were a small number of dead trees scattered through the area and it was noted that virtually all of them were situated at junctions between two converging drain lines.

INVESTIGATIONS CARRIED OUT

Five lines of enquiry were undertaken to establish the factors that might be involved in this case and to provide a framework to bring them together in a valid hypothesis to explain the damage.

Pathological investigations

Samples of needles were collected from a number of trees in the area to check for the presence of fungi. Needles of all colour ranges were selected – green needles of the three main colour types, yellow needles and brown needles. All the needles were still attached to shoots when sampled. In addition samples of dying shoots and twigs were cultured for possible pathogens.

Nutrient status

The general nutrient status of the trees in the area was assessed by reference to foliar analyses carried out for a Silviculture Branch fertiliser experiment. The experimental

area is almost in the centre of the study area and has been assessed annually since 1985.

Meteorological data

Mean monthly data on rainfall, effective precipitation, soil moisture deficit and temperature were collected. This was done using an extrapolation program on data from official meteorological stations in the area for the period April 1984 to September 1995 (this being the period for which data are available).

Permanent plots

The study area is situated on the west facing side of a long valley. Two transects running from the high point (ca 580 m) in the east down into the valley (400 m) in the west were selected following the lines of existing rides. Along each transect five plots of ride-side trees were marked out at regular intervals. These were linear, single-row plots of 24 consecutive trees. For each plot details of altitude, soil type and aspect were recorded and the plots were assessed each October in 1991, 1992, 1993, 1994, 1995 and 1996. Each tree was assessed in terms of colour of green needles, amount of needle yellowing, browning and retention, and amount of twig dieback. These values were recorded for each of the three crown sectors (low, mid and high).

Aerial survey

Given the size of the study area and the nature of the crop, an effective ground-based survey was not possible. It was, however, essential to get some idea of the extent of the problem, particularly in the centre of compartments. Fortunately a neighbouring part of the forest was to be flown for an aerial survey linked to wind-throw assessment. At very little extra cost it was arranged to fly an extra transect to cover Tywi (North) and to mount an additional 35mm camera loaded with false colour (Near Infra-red or NIR) film. As the problem was one of needle colour and needle loss the advantages of NIR images were felt to be significant. It was hoped that not only would it show up obviously damaged areas but it would also indicate the relative vigour of trees throughout the study area. Another fortunate coincidence arose when an MSc student from Leicester University, Mr D. Adams, wrote to Pathology Branch looking for a project suitable for evaluation using Geographical Information System (GIS) techniques. The study area was flown, at a scale of 1:10,000, in late May 1992 and the resulting photographs were passed to Mr Adams at Leicester for incorporation into the GIS.

RESULTS OF INVESTIGATIONS

The results from the five lines of investigation became available from November 1991, in the case of the pathological investigations, up to the present time. Some results from the final assessment of the permanent plots have yet to be processed but will be incorporated in a final version of this report.

Pathological investigations

Samples of needles were collected from a number of trees in the area to check for the presence of fungi. Needles of all colour ranges were selected – green needles of the three main colour types, yellow needles and brown needles. All the needles were still attached to shoots when sampled. The results of culturing are shown in the following table :

Fungus	Percentage of needles		
	Green	Yellow	Brown
Lophodermium piceae	40	50	90
Rhizosphaera kalkhofii	10	5	0
Sclerophoma pithyophila	0	10	50
Cryptosporiopsis	0	0	25
Phacidium coniferarum	15	15	0
Other	10	20	35
No growth	25	0	0

Cultures taken from dying shoots produced few fungi, mostly *Sclerophoma pithyophila*, *Phacidium coniferarum* and *Penicillium* species.

Nutrient status

Foliar nutrients for current year's needles in October for the years 1985 to 1992 were assessed. All nutrients were above deficiency levels with the exception of potassium for the years 1988 and 1992. However potassium is very mobile, often moved from older to younger needles at times of reduced availability. So the levels in current needles may not reflect the overall level of nutrient in the full complement of needles.

Meteorological data

Data on rainfall, effective precipitation, soil moisture deficit and temperature were collected for the period 1980–1995. As the values were based on extrapolated data they should be treated with a certain amount of caution. In particular differences in the altitude of the reference stations and the study area may have given incorrect values, especially for temperature. However the data do show that the area was probably subjected to particularly severe soil moisture deficits in 1984 and again in 1989 and 1990.

Permanent plots

Data for the years 1991 to 1996 covered details of needle colour, yellowing, browning, retention and twig dieback. What was clear from these results is that the mid-crown sector has shown the most amount of damage. Improvements in the above were recorded in 1992 continuing through 1993, 1994 and stabilising in 1995 and 1996.

Needle colour

In 1991 no trees were recorded as blue-green and there was no colour change between crown sectors. By 1992 some mid and high sectors had developed a good blue-green colour but there had also been an increase in light green colour in all crown sectors. It was also clear that there was now variation between crown sectors within trees. The situation in 1993 and 1994 was broadly the same but in 1995 and 1996 the overall colour of all crown sectors was blue-green.

Yellow needles

Between 1991 and 1992 there was a marked increase in the number of trees with moderate needle yellowing in the lower and mid crowns. Severe needle yellowing increased only slightly and was confined to the mid-crown in both years. From 1994 there was a marked reduction in yellow needles and by 1995 yellow needles were few in number and almost always confined to older shoots.

Brown needles

In this case there was a marked reduction in needle browning in 1992 with no trees scoring severe browning. The best improvements were in the high and mid crown sectors. This improvement continued over the years with only a few brown needles being recorded in 1995 and 1996, mostly from the 6-year old and 7-year old shoots.

Needle retention

Needle retention improved between the two years with the low and mid sectors producing the greatest changes. The maximum needle retention increased from 6 to 7 years in the two years to 1992 and by 1995 this was the maximum age of retention in all plots and in all crown sectors.

Twig dieback

All sectors showed a worsening between 1991 and 1992 with increases in the 5–20% and 20–50% classes. The highest recorded class in both years, 50–75%, did not increase. This level of dieback was broadly the same in 1993 but dramatically improved in 1994. By 1995 dieback was confined to the lower crown sectors and was in the 5–20% class.

Aerial survey and GIS project

A set of 35mm transparencies was produced as a result of the aerial survey and from which two sets of large format (A4) prints were made. One set was made available to Mr Adams for incorporating into his GIS project. These were returned on the completion of the project and were then handed over to Ceredigion Forest District. The resolution obtained with the NIR photographs was excellent with clear colour intensity variations over the whole area. Preliminary ground checks indicated that known areas of damage had registered as stressed areas in the photographs. The GIS project was completed in October 1992 and copies are provided with this report. By scanning in details from the photographs and then looking for correlations with other spatial data, such as soil type and windthrow hazard, it was hoped to reveal possible causes of the damage. The study established that there was a strong positive correlation between peat soil types and stress and a negative correlation with slope and stress. Relative exposure and altitude also produced statistically significant positive correlations.

CONCLUSIONS

The GIS study indicated that damage was most severe on the flatter peat-based soils with altitude and relative exposure tending to increase the severity. The relatively flat, peaty areas are those in which drainage is likely to be poor and thus result in shallow rooting systems. Under normal conditions water retention on these sites would not be a problem. But in the exceptional drought periods noted above these areas dried out very considerably leaving much of the root systems well above available moisture supplies. Direct drought effects would seem to be responsible for the scattered deaths of trees while in less severe cases trees were weakened and subjected to induced nutrient deficiency. Needle yellowing was typical of that caused by potassium deficiency and this has been confirmed by foliar analysis. Unfortunately as the analysis was confined to current years needles (sampled in October of each year) it does not give a clear picture of the nutrient profile through the whole range of needle ages. The results from the plots showed that subsequent needle browning and loss was significant and isolations from green, yellow and brown needles revealed high levels of *Lophodermium piceae* in all classes and this probably accelerated this process. Severe defoliation has led to the death of a number of twigs, particularly in the mid-crown and lower part of the top crown sectors. The 1992 data from the plots indicates that the situation may be improving and this was confirmed by data from 1993 to 1996. The onset of the damage in 1990 or 1991, the correlation with flatter peaty areas and the existence of unusually high soil moisture deficits at this time, all point to climatic conditions as the main trigger. Since 1992 deficits have improved and there has been an improvement in tree condition.

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Compensatory reactions of oaks to defoliation

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In the past decade when ecological investigations have been centred mainly on carbon and energy cycles, the strategy of plant behavior responding to herbivory has attracted increasingly attention in studies on interactions between components of natural communities. This is due to the fact that features of these interactions can influence the pattern of carbon accumulation and allocation in plant parts followed by changes of carbon cycle in a whole ecosystem. A theory exists that compensatory and defensive traits of plants are power-consuming alternatives, therefore a plant can use only one of them, dependent on combination of external and internal factors. It has been proposed (STRAUSS, AGRAWAL 1999) that plant tolerance to herbivory in natural populations has only recently received attention, whereas defensive responses are considered rather completely. Only now it is noticed that the tolerance of plants to herbivory reflects the degree to which a plant can regrow and reproduce after damage from herbivores. At present time compensatory reactions of plants are under raised attention, but most studies are made for herbaceous species, small shrubs and semi-shrubs, while tree species (including oaks, despite of their frequent damage by insects) are still not clearly understood.

Usually when analyzing the influence of defoliation upon stands the emphasis is on the loss of stem wood increment. Compensatory and physiological processes in damaged trees are scantily known, and data about root response to defoliation are very scarce. Some authors working with the problem note that the strategy of crown organization is always relatively moldable, and the same species can demonstrate considerable variation of crown structure after defoliation depending on environmental factors, tree age and state, and others. This gives evidence of the complexity of the problem and is responsible for the fact that its detailed research is now at the starting point. In Russia some aspects of refoliation in oaks and other tree species are considered in works of YERUSALIMOV (1979, 1994) and others.

From the above, our long-term investigations are aimed at research on: 1. features of foliage regrowth after defoliation of different rate; 2. quantitative parameters which could be used for the analysis of influence of defoliation on tree state and functions; 3. quantitative analysis of relations between defoliation and annual stem growth in oak trees of different stand types; 4. photosynthesis rate of foliage and sap flow in stem of oaks influenced by defoliation; 5. behavior of oak roots under conditions of defoliation with different rate followed by refoliation.

Beginning in 1983, our investigations are being carried out on permanent plots in the Tellerman oak grove situated in the southern part of the forest-steppe zone (Voronezh region, Russia). This region is characterized by dry continental climate. The mean annual air temperature is +4.8°C, mean annual precipitation is 486 mm, 26% of it falls in summer, and 47% from November to March. Springs are often dry, with hot dry winds. Late spring frosts are common in the end of May, and first autumn frosts – in September. The usual level of 222 mm of rain precipitation in a growing season is observed during last 30 years.

The Tellerman oak grove consists of several types of stands. Main of them are: an upland ash goutweed/sedge oak stand; solonets and solonets-like oak stands (all stands are situated on the upper part of landscape); an *Acer campestre*/oak stand; an *Euonimus* oak stand (both are on riverbanks); a floodplain lily-of-the-valley/dewberry oak stand. Oak trees belong to three phenological varieties: an early oak (*Quercus robur* var. *praecox* Czern.), a late oak (*Q. robur* var. *tardiflora* Czern.) and intermediates between them. The difference between the time of bud bursting of the early oak and the late oak ranged between 15 and 25 days. Our investigations have been executed for the early oaks predominantly because they are exposed to insect invasions more often than others (RUBTSOV, RUBTSOVA 1984). The influence of weather conditions and insect defoliations on stem wood increment of different phenological varieties and types of oak stands is thoroughly studied in our works (RUBTSOV, RUBTSOVA 1984; RUBTSOV, UTKINA 1995a, b; RUBTSOV 1996).

Research on refoliation was carried out mainly in the floodplain lily-of-the-valley/dewberry oak stand aged 80–95 years. An outbreak of the winter moth (*Operophtera brumata* L.) and the green oak roller (*Tortrix viridana* L.) took place there in 1986–1991 and 1998–2001.

We selected and marked a lot of trees (nearly 80) for annual visual estimations of the degree of defoliation at the end of larval development. Tree damages were usually irregular in pattern, so estimates were made separately for 2–3 strata of the crown, and averaged. We called this calculated estimate a conventional degree of defoliation (CDD) used as an argument for regression analysis. Some trees were damaged for several successive years, and we estimated their CDD both for the current year so for further two and three years. These indices of combined defoliation were also used in the regression analysis.

Some of the survey trees with moderate (35–50%) and heavy (50–100%) defoliation were selected for a detailed study of refoliation in relation to stem wood increment. Sample branches of 1 m in length were cut off in the upper and bottom layers of crown of these trees monthly over a growing season. Every branch was measured as to the number of buds, shoots and leaves, the latter two divided into spring, summer or regenerative. Both total dry mass and leaf area were estimated for each leaf generation. The total twig length was considered as well, with all calculated parameters converted per 1 m of twig length.

Cores were taken by an increment borer from all observed trees, with the annual wood increment measured to 0.05 mm for a 30-year long period in the early wood and late wood separately and combined.

Separating regenerative shoots into two groups with different pattern of growth: replacement (originated from dormant and auxiliary buds) shoots and secondary (originated from new buds) shoots is principal new; by doing so the proportion of replacement shoots can be taken as a quantitative parameter of refoliation rate. It is found that this parameter depends on rate, terms and repeatness of defoliation, state and individual features of trees. The results of these studies are given in our previous works (UTKINA, RUBTSOV 1989, 1994; RUBTSOV, UTKINA 1993; RUBTSOV et al. 1999, and others.). They show the complex relation between state of oak trees, environmental factors, the pattern of defoliation and rate of compensatory processes in crowns.

It is revealed that in the first and second years of insect attack the earlier and heavier is foliage damage and the less the trees are weakened, the earlier compensatory mechanisms begin to work. This leads to the more participation of replacement shoots in crown recovery and, finally, to the more rapid and full restoring the photosynthetic surface of the crown (Fig. 1). However, if heavy defoliation takes place in the third year and later, or trees

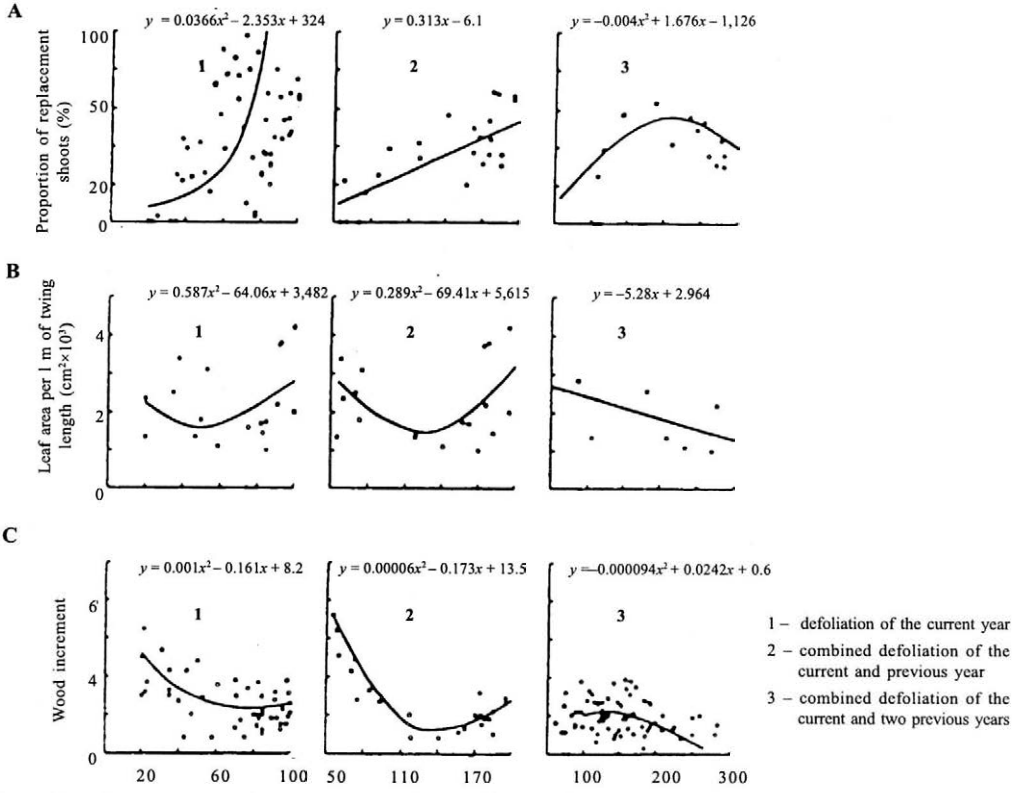

Fig. 1. Relations between the defoliation rate (CDD), proportion of replacement shoots (A), total leaf area (B) and annual wood increment (C)

were weakened before insect attack, compensatory mechanisms become weaker. The proportion (and the total number) of replacement shoots sharply diminishes (Fig. 1A), that leads to insufficient recovery of leaf area (Fig. 1B) and the further weakening of trees. Similar conclusions can be made basing on comparison between values of dry mass and area of leaves per 1 m of twig length (Fig. 2). The revealed relations accord well with the estimates of stem wood increment (Fig. 1C).

The analysis of response of the early oaks' stem wood increment to defoliation by means of specially devised mathematical model (RUBTSOV, UTKINA 1995b; RUBTSOV 1996) shows that in the forest-steppe the most part of increment resulted from heavy defoliation is lost by the upland ash goutweed/sedge oak stand, solonets and solonets-like oak stands (in a downward direction), the least one – by the floodplain lily-of-the-valley/dewberry oak stand. Floodplain and riverbank oaks were less sensitive, even if floodplain oaks were more frequently damaged, especially during early spring. These stands probably at most realize a defence against early damage through a quick recovery of leaf area. It is common for all oaks (along with other tree species) but is the most effective in healthy stands and under favourable conditions.

The scientist of the Institute of Forest Science, our colleague A. G. Molchanov measured in 1996–1998 the rate of photosynthesis in foliage of trees endured manual defoliation within an experiment in the solonets oak stand (RUBTSOV et al. 1996, 1999). Fig. 3 presents light curves for trees with different experimental defoliation in 1996. Light curves were drawn from measurements in the mornings in June, July and August. It can be seen that the photosynthesis rate at plato stage was the most (about 20 mg CO_2 dm^2/h) in trees with 75% defoliation comparing to control values (12.5 mg CO_2 dm^2/h). The most photosynthesis rate of regrowth foliage in trees with 100% defoliation was 12 mg CO_2 dm^2/h, but it significantly decreased under full sun illumination because of leaf age. It is likely that the defoliation of 75% is the level of maximum intensity of interacting an oak tree with environment when it relatively easily overcomes the sequenses of defoliation stress, recoveries the photosynthetic area (sometimes overcompensates) and stores reserve matters.

The decrease of functional activity of roots brought on by unfavourable factors, including defoliation, can give impetus to diminished tolerance, weakening and decline of a tree. So the research on growth activity of roots, along with their respiration and decay, is an important part within explorations on energy and mass exchange and stability of oak stands.

In 1997–2001 we together with V. V. Mamaev, the scientist of our institute, tried to estimate the impact of defoliation on growth of absorbing roots in oaks. Some results for the floodplain oak stand are received (MAMAEV et al. 2001). It is found that the oak root system responses to the state of foliage very tactfully. Therefore it is neces-

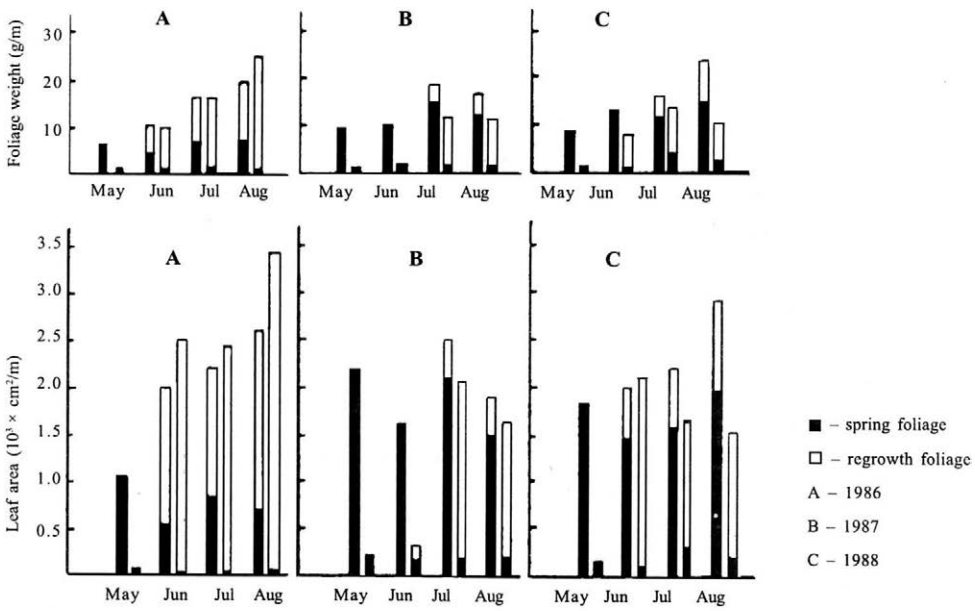

Fig. 2. The foliage weight (over-dried) and leaf area per 1 m of twig length in oak trees with 30–50% defoliation (left columns) and 75–100% defoliation (right columns) in the 85-year-old floodplain lily-of the-valley dewberry oak stand in 1986–1988 years

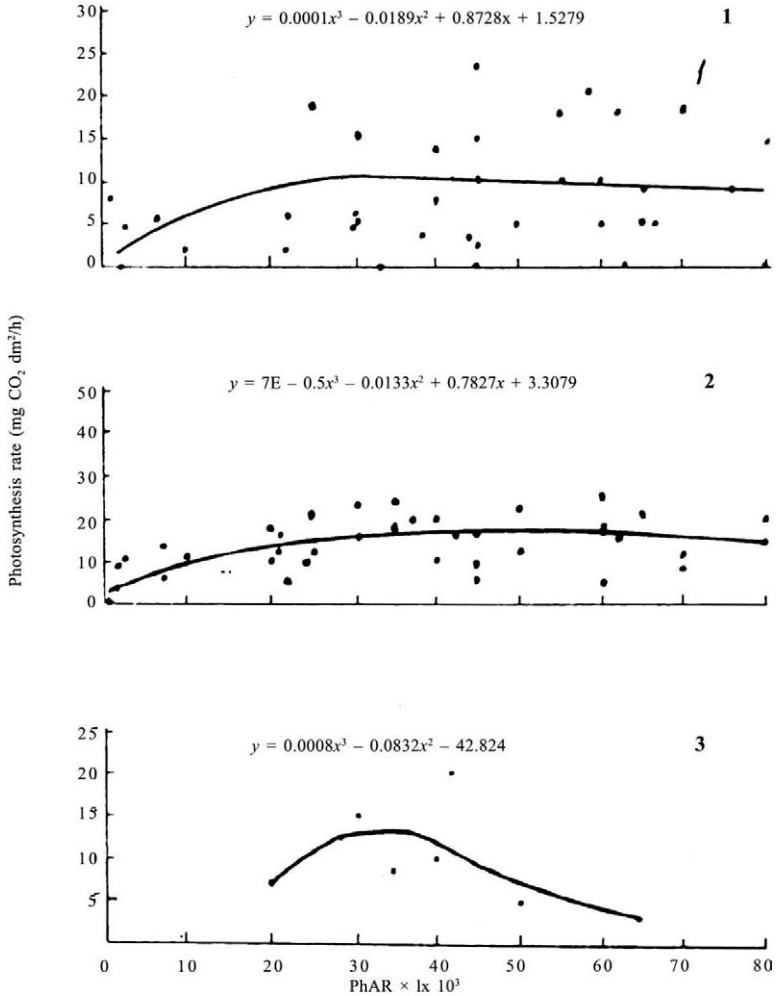

Fig. 3. Light curves for oak trees with defoliation rate of 0% (1), 75% (2) and 100% (3) in the solonets oak stand in 1996

sary to take into account the rate of defoliation of a tree or a stand. Defoliated trees have their own rhythm of formating mycorrhiza. The root system quickly responses to defoliation by intense formation of new mycorrhiza. However, as foliage begins to regrow the rate of root growth abruptly diminishes with the least value during the period of the most intense refoliation. Undamaged and moderately damaged trees have at the same time the maximum of root growth.The least difference between damaged and control trees is observed in the end of a growing season. The obtained data clearly demonstrate the close relation of root absorbing system with the state and development of foliage. The variability of root responses to defoliation is mainly determined by physiological state of trees, the intensity, time and repeatness of defoliation.

Changes of root growth in defoliated trees can be considered as the result of adaptive processes directed mainly to survive under stress conditions.

The executed studies confirm that adaptative responses of oaks to defoliation are manifold and based on high regenerative ability of trees provided by great number of dormant and auxiliary buds as source of replacement shoots and by changes of physiological processes during refoliation. So, in the two successive years of herbivory, the earlier and heavier is foliage damage, the earlier compensatory mechanisms begin to work through the more participation of replacement shoots in crown recovery that leads to the more rapid and full restoring the photosynthetic surface of the crown. If defoliation repeats in the third year and later the number of replace-

ment shoots sharply diminishes. The obtained results help in better understanding reasons of good adaptation of oaks to 1–2-fold heavy damage and hard impacts of repeated defoliations for a stand.

Acknowledgements

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Analysis of parameters of crown recovery in oaks after insect defoliation

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The necessity of quantitative estimating parameters of reestablishment of tree vitality goes back to studies of interactions between herbivores and their host trees. The selection of criteria for estimation that excepts or smooths the influence of individual features of trees (size of crown, density of branching, and others) is of great importance by doing so. These parameters simple to determine and suitable for different tree species are not found to the present day.

We attempted to find indirect parameters which are the best for reflecting one of the most important compensatory responses in oaks, the level of crown recovery. Various parameters devised for concrete goals and objects are supposed in scarce publications on this problem. However, they are insufficiently substantiated and are not compared to one another. The main difficulty in solution of the problem is that the process of crown refoliation occurs differently and depends on the character of leaf damage (intensity, time and others), environmental conditions and tree state.

Our research on crown refoliation in common oak is being carried out since 1983 in the Tellerman oak grove (Voronezh region, the south of the forest-steppe zone in the European Russia). The main leaf-eating species in different years of this period were: the green oak leaf roller (1982–1983, 1986–1989, 1993–1995), the gypsy moth (1988–1990), the winter moth (1983–1985, 1998–2001). Traits of refoliation are one part of the considered problem, alongside stem wood increment, the rate of photosynthesis, sap flow in stems, responses of root system, starch reserves in wood of shoots and stems under condition of defoliation.

Explorations were made for the early variety of the common oak, mainly in the floodplain lily-of-the-valley/dewberry oak stand and in the upland solonets and solonets-like oak stands. Sample branches of 1 m in length were cut off monthly over a growing season from the upper and bottom layers of crown of trees with different rate of damage, from 20% to 100%. Every branch was measured as to the number of buds, shoots and leaves, the latter two divided into spring, summer or regenerative (Utkina, Rubtsov 1989, 1994). Length of shoots and leaves, total dry mass of foliage and shoots, and leaf area were estimated for each leaf or shoot generation separately and in total. The total twig length was considered as well, with all calculated parameters converted per 1 m of it.

Long-term works allowed to gain a great deal of experimental data and to find distinctive types of compensatory reactions of oak foliage dependently on the rate and repeatness of defoliation. They are given in Fig. 1. The rate of defoliation is taken as an argument, the coefficient $\alpha = M_{def}/M_0$ is taken as a function; M_0 is the mass of foliage per 1 unit of accounting (for example, per 1 m of twig length) without defoliation, M_{def} is the total mass of foliage after refoliation per the same unit of accounting. We reason that the value of a can be used as an objective parameter for the level of leafage of a crown after refoliation. In the first year of damage healthy trees do not practically respond to weak (up to 25%) defoliation (Fig. 1 – AI). With the more significant damages (Fig. 1 – AII, III) refoliation takes place with reaching the maximum at 85–90% defoliation and even "overcompensation" under favourable environmental conditions. In the second successive year of defoliation trees are already weakened; compensatory reaction begins at the lower level of defoliation (Fig. 1 – BI), but occurs with the less intensity (Fig. 1 – BII). The 3-year-successive defoliation of moderate and heavy level leads to the more significant decrease of compensatory abilities of trees to the point of their full suppression (Fig. 1 – C).

So, α is the objective parameter of the level of defoliation. However, it cannot be determined due to some reasons when an outbreak of mass propagation of leaf-eating insects occurs (we cannot directly estimate M_0). Therefore it is the concern of searching for the best indirect parameter which reflects the level of crown recovery with the most adequacy. This parameter must be closely related with α, be most stable in time in various ecological situation and be relatively easy for estimation in field conditions. In the solution of the problem, nearly 30 different parameters were analyzed, including dry mass, leaf area and number of leaves per 1 m of sample branch, also per 1 cm^2 of the branch basal area, per 1 m of total length of

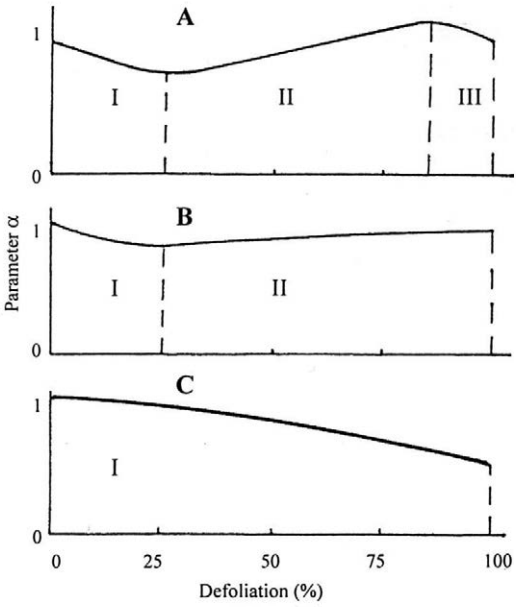

Fig. 1. Typical compensatory reaction of foliage against rate and repeatness of defoliation in the first years (A), the second successive year (B) and the third successive year (C) of defoliation

lateral twigs, per 1 g of dry mass of a branch, per 1 shoot, per 1 cm of length of current year shoots, per 1 g of dry mass of current year shoots, number of shoots and their total length, the averaged length and mass of 1 shoot and 1 leaf, and some others. The analysis was made separately for spring, replacement and secondary shoots and leaves, and totally. It was estimated by statistical methods that the value of dry mass (area) of foliage per 1 cm of total length of current year shoots was the most close and stable in time relation with α. It is this parameter that is worth to be estimated in field conditions. We used it as an argument in a probability model for estimating the level of refoliation which is a function of distribution of probabilities of α dependently on input parameters of the model: the level of crown defoliation, the indirect parameter of the level of refoliation, the parameter of weather conditions (the hydrothermal coefficient for May–June). It is appropriate to note that searching for optimal indirect parameter of the level of refoliation is a key moment, this is worthy of estimating it for all tree species endured to invasion of phyllophagous insects. This allows the more precise estimating the role of phyllophagous insects in turnover of organic matter and functioning of forest ecosystems.

Acknowledgements

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Intercept™ Panel Trap modified for monitoring forest Cerambycidae

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ABSTRACT: The Intercept™ Panel Trap, was modified and field tested for enhanced monitoring of forest Coleoptera, and especially for family Cerambycidae. The trap is made from corrugated plastic. It is light-weight, water proof, and durable. Field experiments measured capture of forest Cerambycidae in five different prototypes of Intercept Panel Trap and in Phero-Tech 12-unit Multi-funnel Trap. Captures of longhorn beetles were significantly higher in two modifications of the new prototype of the Intercept Panel Trap than in the old version of the trap or the Funnel Trap. The best performance of the Intercept Panel Trap for monitoring longhorn beetles was achieved by using: (1) trap with 5 cm hole in the collecting funnel, (2) wet-cup option of collection cup, and (3) increased slipperiness of the trap surfaces.

HISTORY

In 1996 Philipp Kirsch, the owner of IPM Technologies and entomologist, initiated the construction of the Intercept Panel Trap. Mr. Kirsch invited into cooperation Dr. Darrell Ross from Department of Forestry of Oregon State University in Corvallis, Oregon and Dr. Gary Daterman from United States Forest Service in Corvallis, Oregon. In the period of 1996–1998 several prototypes and modifications of the trap has been built and evaluated. These prototypes had cylindrical shape with large ventilation holes located across entire trap surface. Although trap showed initial promises for capturing bark beetles, it performance did not meet expectations of the designers. In 1998 Dr. Darek Czokajlo joined the IPM Technologies and took over trap design, built, and manufacturing. In the spring of 1999, with ongoing cooperation from Drs. Ross and Daterman and IPM Technologies' stuff, IPM Technologies commercially launched first prototype of the Intercept Panel Trap (Fig. 1). In 1999–2000 the trap has been tested at several different locations throughout United States and Canada for spruce beetle (*Dendroctonus rufipennis*), Douglas fir beetle (*D. pseudotsugae*), Western pine beetle (*D. brevicomis*), Western balsam bark beetle (*Dryocetes confusus*), larger pine shoot beetle (*Tomicus piniperda*) (Fig. 3), pine sawyers (*Monochamus* spp.), Buprestid beetles (Fig. 4), pine bark beetles (*Ips* spp.), wood wasps and several other exotic forest pests, and in China for Asian longhorn beetle (*Anaplophora glabripennis*). This trap prototype already met IPM Technologies expectations toward its field performance. However, the company has been searching for a trap that would effectively capture longhorn beetle. In 2000, some features of the trap have been modified. The bulky body of the previous trap prototype has been replaced with light, two-panel part (Fig. 2). In addition, IPM Technologies has been looking at other modifications such as enlarging hole size in the collecting funnel that is immediately

Intercept Panel Trap

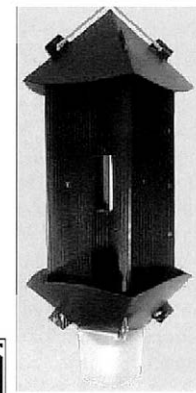

Fig. 1. Old prototype

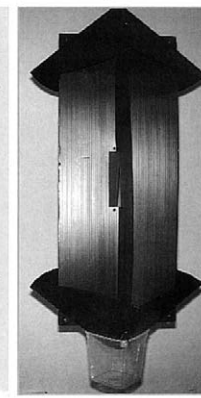

Fig. 2. New prototype

connected to the collecting cup, use of the cup filled with water (wet-cup) instead of cup with the drain at its bottom, and add extra slipperiness to the body of the trap. The 2001 field assays demonstrated that increasing slipperiness of the trap and using wet-cup option indeed increased longhorn beetle captures and significantly outperformed other trap prototypes and Lindgren Multi-funnel trap (Figs. 5–7).

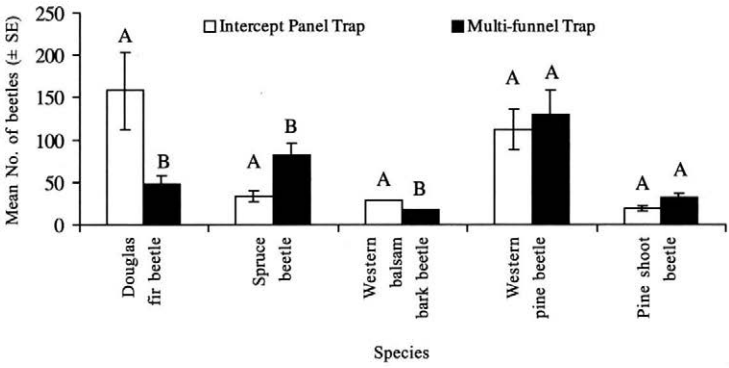

Fig 3. Trap catches of various bark beetles in Intercept Panel Trap and Lindgren Funnel Trap. Bars within the same species followed by the same letters are not significantly different (LSD test, $n = 5–10$, $P < 0.05$)

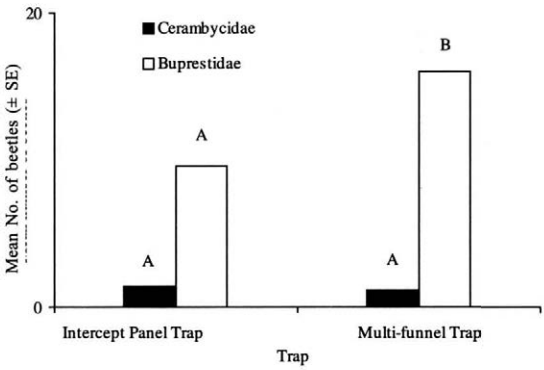

Fig. 4. Trap catches of Cerambycid and Buprestid beetles in Intercept Panel Trap vs. Multi-funnel Trap, near Barrie, ON, 2000. Means within species followed by same letters are not significantly different (LSD test, $n = 10$, $P < 0.05$)

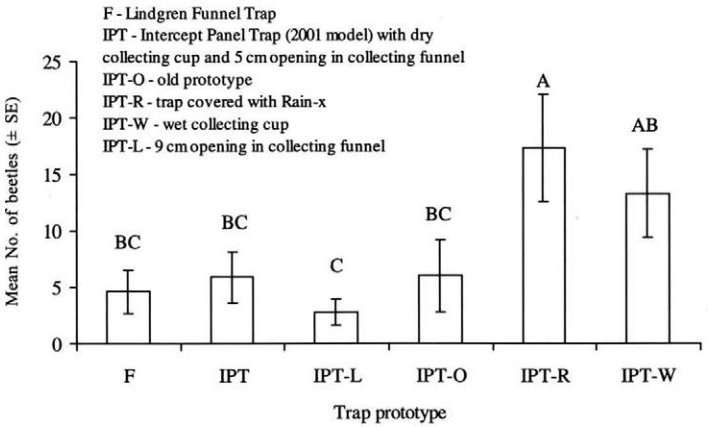

Fig. 5. Captures of longhorn beetles in various prototypes of Intercept Panel Trap and Lindgren Funnel Trap, North Carolina, USA. Bars with the same letters are not significantly different (LSD test, $n = 5–10$, $P < 0.05$)

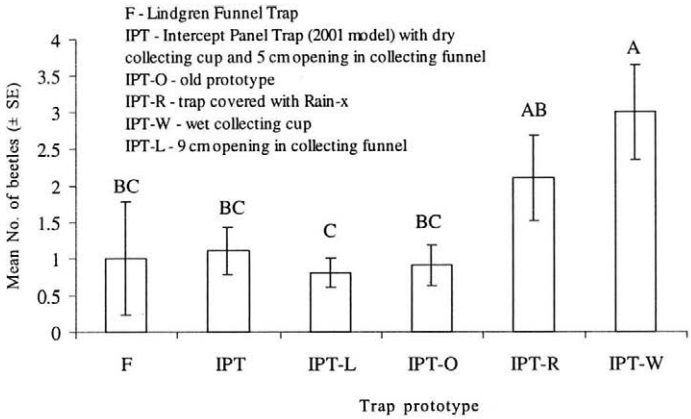

Fig. 6. Captures of longhorn beetles in various prototypes of Intercept Panel Trap and Lindgren Funnel Trap, Minnesota, USA. Bars with the same letters are not significantly different (LSD test, $n = 5–10$, $P < 0.05$)

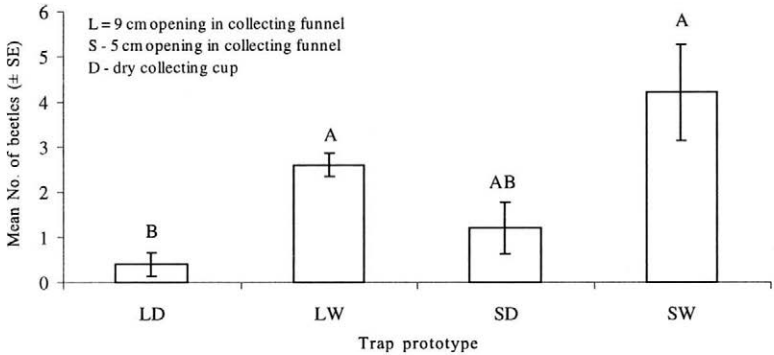

Fig. 7. Captures of longhorn beetles in four modifications of Intercept Panel Trap covered with Rain-x. Bars with the same letters are not significantly different (HSD test, $n = 5$, $P < 0.05$)

FEATURES

While simulating a tree of large diameter, the Intercept Panel Trap provides a large surface area to maximize trapping. The Intercept Panel Trap for bark beetles offers light-weight and durability. It is easy to assemble. The trap is water- and weather-resistant. The Intercept Panel Trap is easy to set up and fold for infield operations and occupies a minimal amount of space for of season storage when flattened.

RESULTS

Using previous prototype of the Intercept Panel Trap the trap catches of Douglas fir beetle and Western balsam bark beetle were significantly higher in the Panel Trap (Fig. 3). There was no significant difference between Panel and Funnel Traps in captures of Western pine beetle, larger pine shoot beetle (Fig. 3) and Cerambycid beetles (Fig. 4). Captures of spruce beetle (Fig. 3) and Buprestid beetles (Fig. 4) were significantly higher in the Funnel Traps compared with the Panel Trap.

The trap captures of longhorn beetles were significantly higher in two modifications on the new prototype of the Intercept Panel Trap than in unmodified old and new version of the trap, and then in Lindgren Funnel Trap. The trap captures were enhanced by 1. increased slipperiness of trap body and 2. using collecting cup filled with water (Figs. 5 and 6). The modifications such as previous trap prototype or enlarged hole in the collecting funnel did not have any influence on trap performance (Figs. 5 and 6). Finally, the best performance of the Intercept Panel Trap for monitoring longhorn beetles was achieved by using: 1. trap with regular 5 cm hole in the collecting funnel, 2. wet-cup option of collecting cup, and 3. body trap with increased slipperiness of surface (Fig. 7).

DISCUSSION

The Intercept Panel Trap is an effective tool for monitoring Cerambycids, as well as Scolytids, Buprestids, and other forest Coleoptera and Hymenoptera. The new modifications to the trap substantially increased trap captures of longhorn beetles. Panel traps were very robust under rigorous field conditions, light-weight to carry, weather and water proof, and easy to install. Intercept Panel Trap outperformed Lindgren Funnel Trap for most tested insect species. Panel traps dissemble rapidly, can be stored flat, and use less storage space than Funnel traps. The Intercept Panel Trap is now commercially available and is first commercially available and effective trap for the Cerambycid beetles.

JOURNAL OF FOREST SCIENCE, *47*, 2001 (Special Issue No. 2): 37–39

Monitoring of bark beetles and wood-borers on windthrown trees in France after December 1999 storms

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ABSTRACT: Two storms crossed France in December 1999 resulting in 140 million cubic meters of windthrown trees. A two-level monitoring system was designed to record insect colonisation: a) an extensive, qualitative Level 1 assessment, conducted by Forest Health Department observers on a large number of plots (898) but involving few trees and no more than 3 observations per year; b) an intensive, quantitative Level 2 assessment, entrusted to research organisations and devoted only to spruce in the Northeast and to maritime pine in the Southwest. The first results are briefly summarised. It appears, in September 2000, that 60 % of the damaged trees were colonised by insects with considerable differences between tree species and among large ecological regions. The heterogeneity within the plots was very marked.

The storm LOTHAR crossed the North of France on December 26th, 1999 with high wind speeds, peaking at more than 200 km per hour. It was followed two days later by MARTIN, which crossed the South of France on December 28th.

As a result, French foresters began the year 2000 with 140 million cubic meters of windthrown trees, mostly in the Northeast and in the Southwest (Fig. 1). This volume represents three times the average annual harvest. It was obvious that harvesting would take several years, that an important part of the wood would stay in the forests and that windthrown trees would be colonised by many insects during the first years. There was also a serious risk of attacks on standing conifers during the following years.

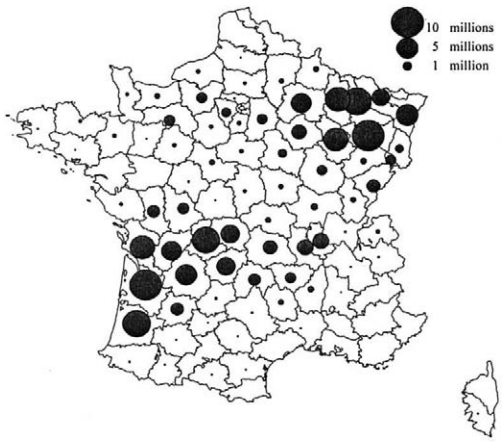

Fig. 1. December 1999 storm damage in France, by department

Forest owners and managers had many questions and were worried about the situation. Many of them thought that all the damaged trees would be colonised by bark beetles before the end of the first spring.

Even if this event was quite exceptional, most of the teachings of former storms (NAGELEISEN 2000) seemed forgotten. It therefore appeared necessary to precisely record the health trends of the damaged trees over time to obtain a concrete picture of phytosanitary state, to keep all concerned people immediately informed and to record these events for the future.

The first step was to record bark beetles and wood-boring colonisation.

The monitoring we were about to do had to be precise enough to take into account the great heterogeneity of the French territory, and light enough to take into account the low availability of forestry workers during this period of time and the impossibility of knowing how soon the stand could be harvested.

The lack of time and of qualified entomologists among the DSF correspondents limited the monitoring to qualitative observations, without a precise count of attacks nor of populations.

That is why we opted for a two-level monitoring system:
- an extensive, qualitative Level 1, conducted by the DSF on a large number of plots with few trees and no more than 3 observations per year;
- and an intensive, quantitative Level 2 monitoring, entrusted to research organisations and devoted to 2 topics only: spruce in the Northeast, and maritime pine in the Southwest.

MATERIAL AND METHODS

Level 1 monitoring consisted of 898 plots of 5 trees each, covering the most important tree species over the whole storm area for 2 years.

On each plot, the stand and the damages were described, and five windfelled and windbroken trees were chosen, in proportion to the damage observed.

On each sampled tree, there were six observation points on the trunk, 2 at the bottom, 2 in the middle and 2 at the top, on opposite sides of the trunk. One observation was also conducted on branches.

At each observation point on the trunk, signs (holes) of bark beetles and wood boring insects were searched for within a zone of approximately 4 square decimeters. If insects were present, bark was removed to identify the species.

The same operations were conducted on some branches.

There was no counting; the notation was only in terms of presence or absence.

Other data were gathered: presence or absence of hot spots of bark beetles among standing trees around conifer plots and, in 2001, the condition of the five sample trees.

These observations were made three times in 2000, but in April for pines only, to record attacks of *Tomicus*. They were repeated three times in 2001, but, only for pines and spruces in April, to record attacks of *Tomicus* and *Xyloterus lineatus* respectively as well as to record recently dying trees around the plots.

The observations were stopped on hardwood plots after harvesting of the windthrown trees and continued around conifer plots even after.

Level 2 monitoring was a set of different surveys and research programs:

- bark beetles on maritime pine by INRA Bordeaux;
- different projects on *Ips typographus* on Norway spruce by INRA Orléans, ULB (Université libre de Bruxelles, in Belgium), ENGREF & DSF.

Level 2 monitoring of spruce in the Northeast consisted in 15 plots of 10 damaged Norway spruces observed every 2 months from the beginning of June to the end of November for 2 years with the same observations as for Level 1 and with quantitative observations.

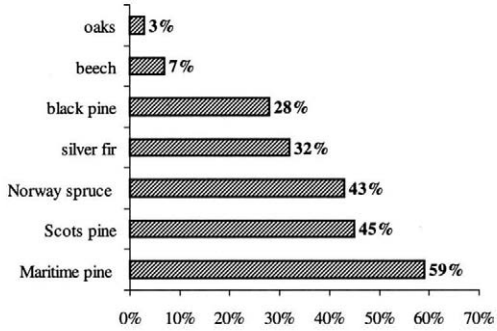

Fig. 2. Percentage of trees colonised before September 2000

Bark samples were collected on windfelled trees attacked by bark beetles with an iron ring of one square decimeter, on 3 sides of the trunk, every 2 meters from the base to the crown. Insects were identified and counted on the bark samples gathered.

SOME RESULTS AND COMMENTS

First, it was shown for the whole Level 1 network that 60% of the damaged trees were free of bark beetles and wood boring insects 9 months after the storm, in September 2000. But the situation is very contrasted between the different tree species (Fig. 2).

The rate of colonisation of Norway spruce in 2000 is very interesting (Fig. 3).

A great many trees were attacked during the first swarm but we observed few attacks on each tree: the trees seemed very attractive and the aggregation was weak.

Spruce was strongly attacked in the Jura, probably because of the presence of 100,000 cubic meters previously broken by ice in February 1999. As the plots in the Jura account for an important part in Level 1 study in the Northeast, we observed large differences between the 3 figures.

In August–September 2000, the 3 figures correspond well, with almost 60% of damaged spruce free of bark beetles.

Finally, for Level 2, twice as many colonised spruces were observed in November as at the beginning of autumn. Unfortunately, no observation was conducted on Level 1 after September and it was not possible to confirm this trend.

For spruce, as for the other species, the heterogeneity within the plots was very important. Some very infested plots were recorded close to uninfested plots.

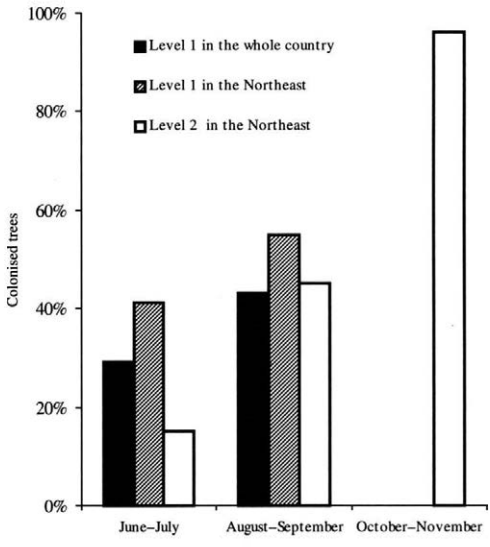

Fig. 3. Rate of colonisation of spruces

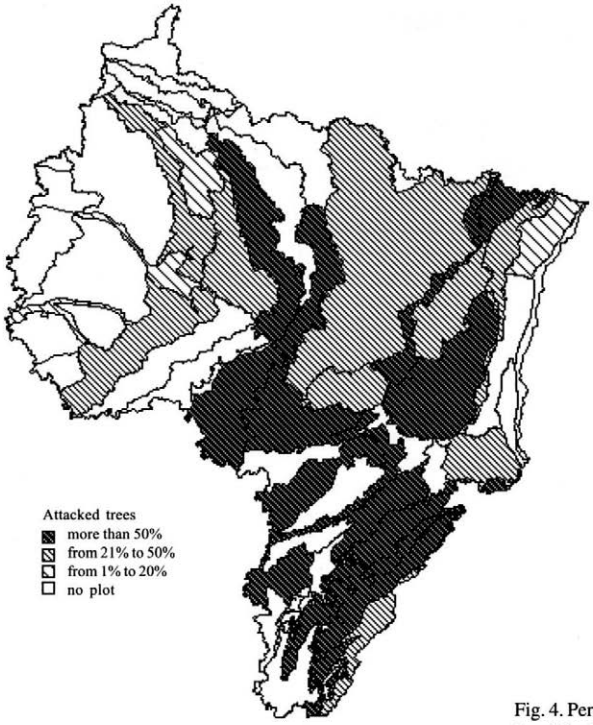

Fig. 4. Percentage of spruce trees attacked in September 2000 on Level 1 plots in the Northeast of France

There were significant differences within large ecological regions. The percentage of attacked trees in September 2000 among spruce plots, was:
– 32% in the Massif Central,
– 38% in the Northeastern plains,
– 47% in the Vosges,
– and 67% in the Jura.

The differences were also significant within the smaller forest regions defined by the National Forest Inventory, as illustrated for spruce in the Northeast of France (Fig. 4).

CONCLUSIONS

To conclude, even before the whole data set is analysed, the monitoring has shown interesting and reliable results at a relatively low cost of time and money.

As we could predict, we observed, during spring and summer 2001, a great many hot spots on spruces and on maritime pines with very high damage.

Perspectives include the start of a new project, with the same partners, devoted to early detection of hot spots and to damage monitoring, using various tools: soil surveys, aerial surveys (sketch mapping, numerical camera attached to a plane, infrared aerial pictures), remote sensing.

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Spruce bark beetle, *Ips typographus* (L.), in Sweden: monitoring and risk assessment

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ABSTRACT: Since 1995, pheromone traps on fresh clearcuts have been used to assess *Ips typographus* density and activity. During 1996–1999, also pheromone-baited spruce trees have been used to assess the damage level caused by the spruce bark beetle. The number of trees killed in stand edges rarely exceeds 10 per km when trap catches are below 15,000 beetles/three traps. Above 15,000 beetles/three traps the number of dead trees may exceed 10 per km but not necessarily. When the number of dead trees including the baited one at a baiting site is less than one, less than 10 killed trees per km stand edge are observed. If adjacent trees to the baited one are killed, the number of dead trees per km often exceeds 10 per km. The high correlation between trap catches in May–June and during May–August implies that the damage level of the current year may be predicted in a region using trap catch data from the period May–June.

BACKGROUND

Substantial tree killing caused by *Ips typographus* has occurred in Sweden during the last decades. Reproduction in windfallen spruce trees and heat/drought favouring flight and colonisation of standing trees are the main causes of these damages. New regulations in late 1970s in the Forestry act prohibits storage of unbarked timber and limits the number of fallen trees and logging residues after clearcutting and thinning to be left in the forest. Regionally sanitation cutting of attacked trees has been demanded.

Until recently all damaged trees were presupposed utilised by man as timber, pulpwood or fuel and therefor being cut and transported out of the forests. This management was also in accordance with the policy of forest protection to maintain low populations of bark beetles to avoid damages on living trees caused by *Tomicus* spp., *Pityogenes chalcographus* and *I. typographus*.

Since 1994, the policy in Swedish forestry, governed by the Forestry act, aim to secure both forest productivity as well as to maintain biodiversity in the forests. Increased amounts of dead wood in the forests is essential to promote the multitude of species dependent on this kind of substrate e.g. bark- and wood living insects, but also fungi, lichens and mosses.

The forest ecosystem is supplied with large amount of dead wood as a result of disturbances such as stormfellings, forest fires and snow brakes. At present, forest owners are not allowed to leave more than 5 m^3 damaged conifer trees (defined as suitable breeding material to the species mentioned above) per hectare. Also in the process of certification (Forest Stewardship Council) a recommended amount of not less than 3 m^3 damaged trees per hectare should be left in the forest. These regulations aim to increase the amount of dead wood in the forests. This implies general higher populations of bark beetles produced in e.g. windthrown spruce trees. Raised populations of *I. typographus* may utilise a substantial proportion of downed, low resistant trees after a storm leading to mass production or intense flight and attack of living trees in dry/hot summers. Thus, an increased risk for attack on and killing of growing spruce trees by the spruce bark beetle may be expected from now on. In these circumstances there is a demand for a system to monitor the spruce bark beetle populations and assess the risk for attack on growing trees. In 1995, a project was started aiming to evaluate the use of pheromone traps and pheromone baited trees for this purpose.

MONITORING

Spruce bark beetle population density and activity is assessed using pheromone traps on fresh clear-cut areas. The same system of monitoring used by WESLIEN et al. (1989) was selected to get comparable data. In four regions, areas about 20,000 hectares were selected. In each area 5 clear cuts are selected every year and on each clearcut three traps (Norwegian pipe trap, model 1979 without funnel) are operating during May–August. The traps are baited with Pheroprax/Typosan the first of May and rebaited once. Traps are emptied four times during the trapping period (1 May–15 August). Catches are counted by means of volume/number. In the same area one living spruce tree is selected at five sites at a northern faced stand edge and baited. The colonisation success of the

baited tree and adjacent trees are registered. In the area a number of old spruce stand edges facing against one or two year old clear-cuts are surveyed during autumn and all attacked and dead spruce trees within 10 meters are counted and these figures are used as a general level of beetle damage in the area. Data are now available from 1985–1986 (WESLIEN et al. 1989) and 1995–2000.

In this paper we present some preliminary results.

RESULTS AND DISCUSSION

During the period 1995–2000, 1998 and 2000 have been exceptionally rainy and cool. The number of favourable flight days for *I. typographus* was lowest in 1998 in all areas. Especially the number of days > 22°C were few during May–August.

On the other hand, both 1997 and 1999 were hot and dry, especially in June–August. However, the yearly trap-catches seems not to be much influenced by these varying conditions in different years. In the southernmost regions there is however, a substantial decrease in the number of killed trees in 1999. This may be attributed to the bad flight and attack (?) conditions in 1998.

During 1995–1999, trap catches were higher compared to 1985–1986. This is also in accordance with data from the ongoing long term monitoring programme in Norway since 1980 (BAKKE et al. 1995), showing low catches during the mid 1980s in an area bordering Sweden (Fig. 1).

The number of trees killed in stand edges rarely exceeds 10 per km when trap catches are below 15,000 beetles per three traps (Fig. 2). Above 15,000 beetles/three traps the number of dead trees often exceeds 10 per km.

When the number of dead trees including the baited one at the baiting sites is less than one (which means that some of the baited trees are not successfully colonised and killed) less than 10 trees per km stand edge are observed. If adjacent trees to the baited ones are killed, the number of dead trees per km often exceeds 10 per km (Fig. 3). Thus the population level measured in these two ways reflects the damage level within an area.

No correlation between the trap catches and the damage level the year after was found (Figs. 4 and 5).

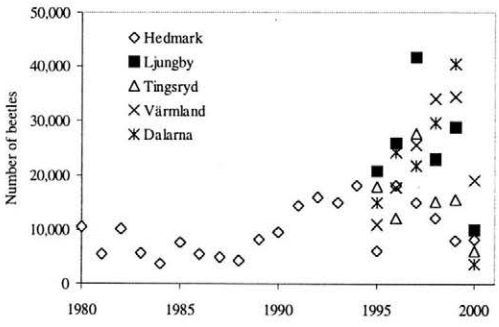

Fig. 1. Trap catches in Norway (1980–2000) and Sweden (1995–2000)

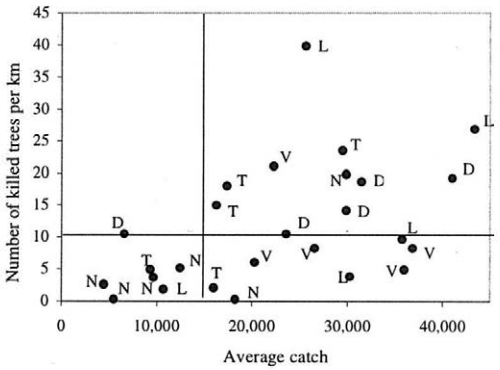

Fig. 2. Average number of beetles caught and number of trees killed per km stand edge. Ljungby (L), Tingsryd (T), Värmland (V), Dalarna (D) 1996–2000, Nordic study (N) 1984–1986

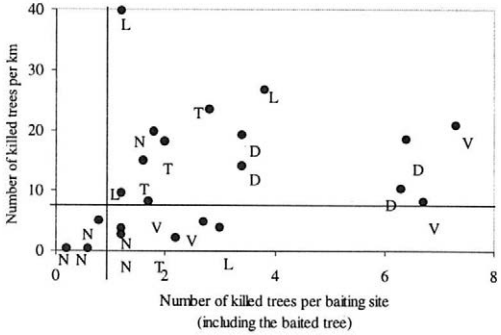

Fig. 3. Baited tree + killed trees on baiting site and number of killed trees per km stand edge. Ljungby (L), Tingsryd (T), Värmland (V), Dalarna (D) 1996–2000, Nordic study (N) 1984–1986

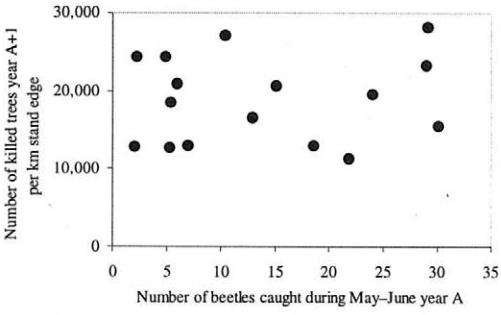

Fig. 4. Correlation between the number of beetles caught in May–June in year A and the number of killed trees per km stand edge in year A + 1

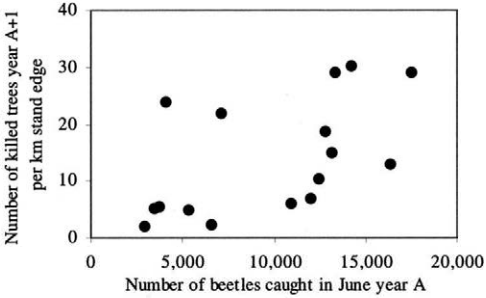

Fig. 5. Correlation between the number of beetles caught in June in year A and the number of killed trees per km stand edge in year A + 1

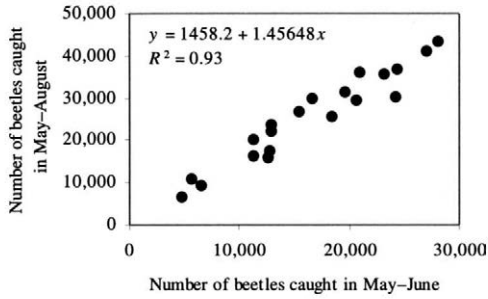

Fig. 6. Correlation between the number of beetles caught in May–June and the number of beetles caught in May–August

It is a high positive correlation between the number of beetles caught during the flight in May–June and the number caught during the whole flight period (Fig. 6).

Both the number of beetles caught in pheromone traps as well as the number of trees killed on baiting sites can be used to predict the general level of damage (number of killed trees in stand edges) in a region.

Earlier statement "so far, data also indicate that a prediction one year ahead seems possible" does not seem promising today. The predictive value of trap catches seems to be low but further analysis are needed.

Tree baiting is controversial since many forest owners hesitate to put up pheromone dispensers on living trees and take the risk to get many trees attacked and killed. One reason for this is practical problems to cut and transport these trees out of the forest in time before the new generation emerges. Therefore, tree baiting was only performed during 1996–1999.

The high correlation between catches in May–June and during May–August implies that the damage level of the current year may be predicted in a region by just measuring the flying population in pheromone traps during May–June. This is an important information for decision whether or not to survey the forest and search for attacked and colonised trees to be cut and taken out before the new generation emerge.

The monitoring system used in Sweden will be operating the coming years although no tree baiting will be done.

CONCLUSIONS

- Low levels of trap catches indicate small damages.
- High levels of trap catches may indicate severe damages.
- Risk assessment one year in advance does not seem very promising.
- Tree baiting is difficult to perform.
- The monitoring of *I. typographus* using pheromone traps will continue in Sweden.

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Monitoring of *Ips typographus* (L.) population in the Eastern Ukrainian Carpathians

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ABSTRACT: The results of three years investigations of bark beetle population in Ukrainian Carpathians are presented. Assessment in the trap trees show that the largest part of bark beetles population was concentrated in the sections II and III (in the middle between the tree base and crown base and at the level of the crown base respectively). Total amount of beetles captured by pheromone traps was the highest in 2000. It was higher in object 1 in 1998 and 2000 and higher in the object 2 in 1999. Three waves of beetles fluctuations were found each year in the both objects but these waves were rather sharp in 1998 and 1999. Population density has changed more slowly in 2000. The data obtained using pheromone traps did not differ significantly from those obtained using trap trees. Taking into account that pheromone traps allow to obtain more detailed information during the season without felling the trees we would like to recommend to use more widely the pheromone traps in Ukrainian spruce stands.

Norway spruce *Picea abies* (L.) Karst. is the most widespread forest species in the Ukrainian Carpathians. *Ips typographus* (L.) is the main pest of spruce stands here (SLOBODYAN 1998, 1999). To investigate dissemination and to develop the methods of *I. typographus* assessment, a network of experimental plots was established. It was shown that comparing with 1991, *I. typographus* number increased in 1992 by 3.4, in 1993 by 4.2, in 1994 by 5.8, in 1995 by 6.3, in 1996 by 6.6 (SLOBODYAN 1998).

The aim of this investigation was data collection for International Program IUFRO – SPDC Carpathians Project (Part: Bark Beetles) in conditions of Ukrainian Carpathians.

I. typographus population was investigated in 2 plots which were located at the distance of 3–5 km from ozone monitoring points. The object 1 is located in the Mokhnatske forestry, Borins'kij State Forest Enterprise (breeding specialisation), Lviv region. The object 2 is located in the Sinevir-Polyanske forestry, National Nature Park Sinevir, Transcarpathians region. The both objects are located in the area of spruce stands, each one occupies more than 50 ha.

Two methods were used for bark beetles monitoring. After the first method bark beetles were assessed in four sections of the trap trees (I – 0.5–1 m above the ground, II – in the middle between the tree base and crown base, III – at the level of the crown base, IV – in the middle of the crown). After the second method standard traps of "Theysohn" and standard lures "Pheroprax" were used. In 1998, 1999 and 2000 pheromone traps were installed at 10 traps per object (at 2 lures per 1 trap). Distance between traps was equal to 15 m, distance from traps to forest edge was 20 m. Bark beetles caught in the traps were collected every 10 days (SLOBODYAN et al. 2000). Data were processed by PC software Microsoft Excel for Windows 95.

BARK BEETLES ANALYSIS IN THE TRAP TREES

Every year we selected the trap trees which looked weakened and belonged to the 2nd Kraft class. Their weakening was connected with root rot damage which was found in the 7 from 10 felled trees. In 1998, 4 weeks after felling, the number of mother galleries of *I. typographus* was equal to 1.7 per 1 dm^2. The number of larvae on the separate sections amounted to 55 per 1 dm^2. The bark beetles were the most numerous in the middle part of stem. At the same time, substrate mastering was not equal in the different parts of rings. The beginning of nest forming was observed on the lower and lateral surface of felled trees on the upper part of ring.

On the first turn, the bark beetles colonised the trees which were weakened by root rot. The healthy spruces were almost not attacked. It was found that young *I. typographus* beetles had additive feeding on 2 trap trees in object 1.

Trap trees analysis done 8 weeks after felling showed high population of *I. typographus* almost in all sections. Generally, during observation period *I. typographus* and *Pityogenes chalcographus* (L.) predominated on the trap trees, *I. amitinus* (Eichhoff) was observed in insignificant number.

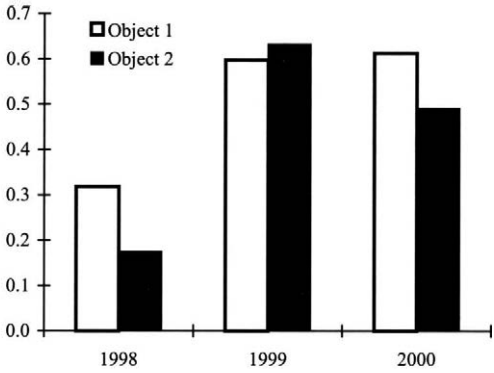

Fig. 1. Dynamics of *Ips typographus* population (av. per 1 dm²) after trap trees analysis

Calculation of average *I. typographus* number per 1 dm² of different trees, sections and plots allows to analyse its distribution.

Bark beetles' density was considerably higher in the trap trees of object 1 in 1998 and 2000 and almost similar in 1999 (Fig.1). The highest increase in populations was observed in the both objects in 1999 (by 1.88 and 3.62 times in objects 1 and 2 respectively). In 2000, population growth had almost stopped in object 1(1.03 increase) and considerably decreased in object 2 (0.78).

Analysis of bark beetles' distribution in different sections of model trees shows that in average for 1998–2000 it wasn't distinct considerably. There were about 40% at section II and another 40% at section III. The lowest part showed section IV. Average number per 1 dm² was a bit higher in the sections I and II in the object 2 and this index was almost twice higher in the section IV of object 1 (Fig. 2).

The most part of bark beetles population in the both objects was found in section III in 1998. In 1999 it has decreased but the parts of population in sections I and IV have increased. In 2000 infestation of section I has decreased and that of section IV was increased (Fig. 2).

RESULTS OF *IPS TYPOGRAPHUS* ASSESSMENT IN PHEROMONE TRAPS

Analysis of three years investigations on bark beetles catch in pheromones traps shows the very high level of *I. typographus* population. Engraver beetle *P. chalcographus* was trapped by these pheromone traps too, but its number was considerably lower. The maximal number (98 beetles per 1 trap) was counted on the 23rd of June 1998. Sometimes *I. duplicatus* beetles were found in Pheroprax-baited traps in insignificant quantity. We have found some entomophages of stem pests in pheromone traps, namely *Thanasimus formicarius* L., *Rhizophagus dispar* Payk., but their number was not more than 3–5 specimens per trap for 1 decade of trapping.

Total amount of captured beetles was the highest in 2000. It was higher in object 1 in 1998 and 2000 and higher in the object 2 in 1999. In 1998 the amount of bark beetles caught was higher in the object 1 in all data of assessment, in 1999 it was higher in object 2. In 2000 this index was higher in the object 1 at the beginning and at the end of the season and it was higher in the object 2 in the middle of the season.

In 1998 three waves of high beetles number were registered – in the middle of June, at the beginning of July and at the end of August. The time interval between maxima of swarming was equal to 20 days (Fig. 3).

In 1999 the first peak of swarming was registered at the beginning of June, the second one – after 30 days and the last one after 20 days (Fig.4). Both in 1998 and 1999 there

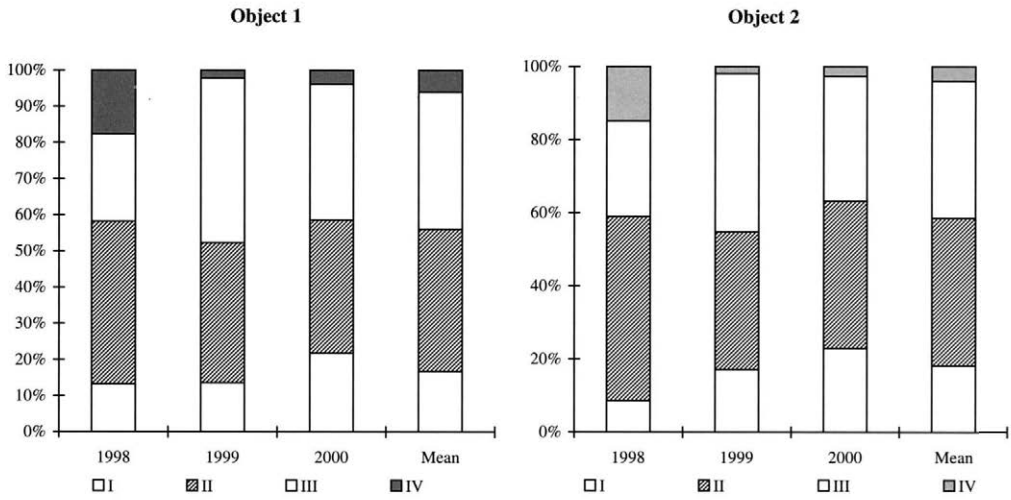

Fig. 2. Bark beetles distribution in different sections of trap trees

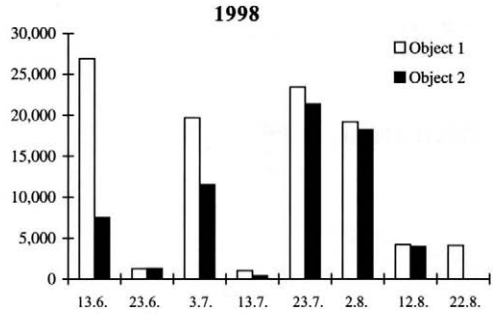

Fig. 3. Results of *Ips typographus* assessment in pheromone traps in 1998

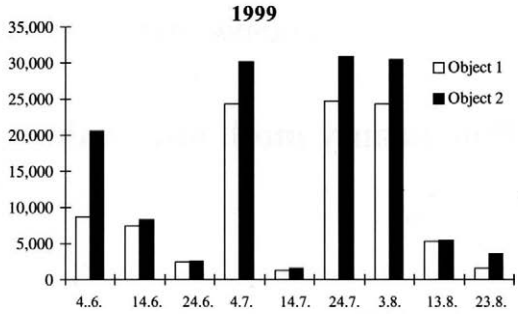

Fig. 4. Results of *Ips typographus* assessment in pheromone traps in 1999

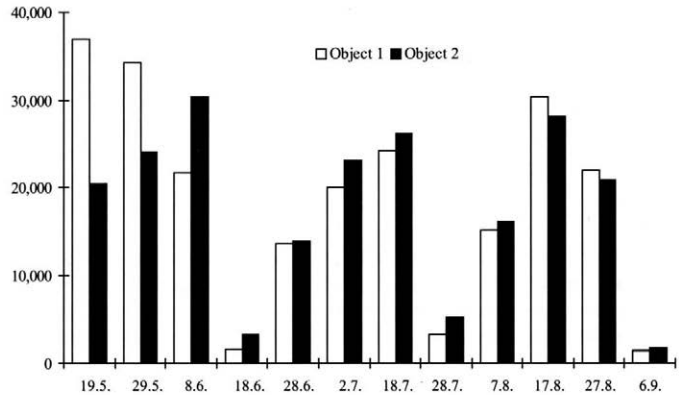

Fig. 5. Results of *Ips typographus* assessment in pheromone traps in 2000

was sharp increase and decrease of beetles number during 1st and 2nd waves but the third wave was longer.

In 2000 all three waves of beetles' swarming were registered for several weeks, the increase of population was slow. The periods of low number of captured beetles were registered in June 18, July 28 and September 6 (Fig. 5).

CONCLUSIONS

Bark beetles density was considerably higher in the trap trees of object 1 in 1998 and 2000 and almost similar in the both objects in 1999. Assessment in the trap trees show that the largest part of bark beetles population was concentrated in the II and III sections and the lowest part at the IV section. Average number of specimens per 1 dm^2 was a bit higher in the sections I and II in the object 2 and this index was almost twice higher in the section IV of object 1.

Total amount of beetles collected by pheromone traps was the highest in 2000. It was higher in object 1 in 1998 and 2000 and higher in the object 2 in 1999.

Three waves of beetles fluctuations were found each year in the both objects but these waves were rather sharp in 1998 and 1999. Population number was changed more slowly in 2000.

The data obtained using pheromone traps did not differ significantly from those obtained using trap trees. Taking into account that pheromone traps allow to obtain more detailed information during the season without felling the trees we would like to recommend to use more wide the pheromone traps in Ukrainian spruce stands.

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Pine beauty moth outbreak in Lithuania, 1999–2002

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ABSTRACT: Three pine beauty moth *(Panolis flammea* [Schiff.]) outbreaks have ocurred in Lithuania earlier in the 20th century. Pest population started to increase in 1998, defoliation in 1999 was slight and no actions were taken. In 2000 only part of forest areas, prescribed for pest control, were handled due to lack of funding, total 6,450 ha of pine stands were treated with conventional and microbial insecticides. Outbreak expanded to 44,800 ha, 4,000 ha of which were totally defoliated. Desperate efforts in 2001 were not as succesfull as desired: lack of funding allowed to treat 18,620 ha (about half of required). Natural enemies impact was not as essential as anticipated; unfavourable meteorological conditions during early stages did not cause collapse of pest population. Pest expanded to new territories: severe defoliation (> 70%) was recorded in the area of 1,716 ha, high (50–75%) – 3,311 ha, significant (30–50%) – 7,245 ha of pine stands. Defoliation forecast for 2002 predict severe defoliation in the area of 5,320 ha, high – 4,310 ha, significant – 4,485 ha.

Pine forests dominate in Lithuania and cover area of 702 thousand hectares (37% of forest area) comprising 348 mln m^3 timber (37% of all growing stock, Lithuanian statistical... 2000). It has high economical, protective and social value, therefore pine pests are always in the focus of attention. Especially this is true for the southern part of Lithuania with poor sandy soils, on the whole covered by pine stands, incorporating Dzukijos National Park and Cepkeliai Nature Reserve.

There are historical evidence of few outbreaks of pine beauty moth (*Panolis flammea* Schiff.) in the pine forests of Lithuania in 20th century. Although it is hard to judge about the data compatibility and say which criteria were used for a stand to be considered as damaged, it is clear that defoliation should be more than 50%. Period of about twenty years, long enough to forget former occurrences, is also clearly evident. One exception in 1975–1976 may be assumed as initial stage of greater extended outbreak in 1978–1980 (Table 1). Such a long period is unusual for defoliatiors, where 7–10 years outbreak cycles dominate (IL'INSKIJ, TROPIN 1965). It is also obvious that outbreak area have been increasing in time, spreading out to new territories.

First signals about increasing pest population level came in 1998: larvae of pine beauty moth were found on many pine trees during regular surveys of pine sawfly in southern part of the country. First alerts reported only 2–5 larvae per pine tree (Annual report... 1998), but surveys in former outbreak areas were carried out. Very limited number of pine beauty moth pupae was found in eastern part of country, showing no threat in this area in the nearest future. In the southern part of Lithuania, near the places, where during previous outbreak 27 thousand ha of forest were damaged, increased pest population levels were discovered. Defoliation forecast, based on overwintering pupae counting, showed defoliation of 0–15% in the next year.

In 1999 no control actions were undertaken. Surveys in the autumn revealed further increase of pest population (Annual report... 1999) in pine forests of all ages. Sex ratio of pupae was close to 1:1, parasite and disease caused mortality – only 2–4%, female weight matching peak outbreak stage. Forecast predicted significant damage (30–50% defoliation) in the area of 980 ha, high (50–70%) – in 4,360 ha, and severe (70–100%) – in 1,400 ha of pine forests. Very uneven spatial distribution of overwintering pupae, causing scattered results of broad range, was also mentioned. Area-wide measures were recommended.

Year 2000 was the time of mass damage and expansion of an outbreak. Due to lack of funding, only a part of prescribed forest areas were handled. Total 6,450 ha of pine stands were treated from aircraft: 2,510 ha with conventional chemicals (pyrethroids) and 3,940 ha with mi-

Table 1. History of *Panolis flammea* damage in Lithuania

Year	Damaged area
1922–1924	1,100 ha
1952–1954	4,200 ha
1975–1976	500 ha
1978–1980	27,000 ha
1999–2001	44,000 ha

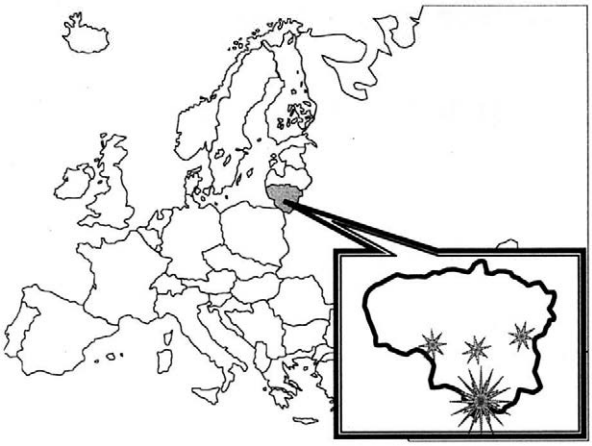

Fig. 1. Location of pine beauty moth outbreak. Big star represents current outbreak of 1999–2002, small – location of surveys (previous damage)

crobial insecticide Foray 48B, and no noticeable defoliation was recorded in the treated areas. However, these limited control measures have not stopped pest escalation. Outbreak expanded and by the middle of the summer damage of various level was recorded at the area of 44,800 ha of untreated forests, 4,000 ha of which were totally defoliated (Annual report... 2000).

Extensive surveys were performed by the end of season. Again, variation of data was very high. Sex ratio of pupae was close to 1:1, mortality due to parasitism or diseases – 13–73%. Increased numbers of tachinid flies and ichneumonids have been mentioned. Forecast, based on the number of female pine beauty moth pupae in the litter, tree age, current defoliation and abundance of natural enemies, predicted significant damage in the area of 8,500 ha, high – of 10,300 ha, and severe – of 19,100 ha of pine forests. Area wide suppression was prescribed to the area over 30 thousand ha, primarily to the stands that have experienced severe damage to avoid defoliation in two consecutive years.

Desperate efforts in 2001 were not as successful as desired. Main reason of failure, yet again lack of funding, allowed to treat only about half of required area: pyrethroids were sprayed over 15,470 ha of forests, Foray 48B – 3,150 ha. Results were good: 98% of pest suppression with chemicals, 88% – with Foray 48B. Natural enemies impact was not as essential as anticipated. Meteorological conditions have not favoured the pest, cold and rainy weather predominated in May and held development of second instar larvae for three weeks. Later pine beauty moth larvae recovered and continued development. This case oppose the widely spread opinion that unfavourable weather conditions during early stages cause starvation and collapse of pest population (IL'INSKIJ, TROPIN 1965). However, all negative factors could not stop outbreak and pest expansion to new territories: severe defoliation (> 70%) in fall was recorded in the area of 1,716 ha, high (50–75%) – 3,311 ha, significant (30–50%) – 7,245 ha of pine stands. Defoliation forecast for 2002 predict severe defoliation in the area of 5,320 ha, high – 4,310 ha, significant – 4,485 ha. It is recommended to apply area-wide control measures in 12,900 ha of forests, predominantly using biological means (microbial insecticide Foray 48B and hormonal Dimilin), as most of forests under the risk of damage have protective status (watershead protection, recreational, reserves, etc.) restricting use of conventional chemicals.

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Tree Doctor – an interactive CD-ROM diagnostic tool

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ABSTRACT: Tree Doctor is a multi-partnership project established under the Leonardo Da Vinci scheme promoted by the EU. The partners are representative organisations in France (the main co-ordinating partner), Italy, the Netherlands and United Kingdom each responsible for producing their own language version. Tree Doctor is a CD-ROM based disease and pest diagnostic program aimed at the teaching, diagnostician and tree management markets. The program covers 49 tree genera and 460 diseases, disorders and pests and utilises a multimedia approach. It is envisaged that subsequent revisions of the program will expand on the range of genera and damaging agents.

BACKGROUND

Over the last decade tree diseases have become more widespread due to business on an international scale, the influence of pollution, drought, and various types of forestry systems that are practised.

Professionals (firms working in the areas of parks/gardens and forestry, local authority parks and gardens department, specialists and managers of publicly-owned and private estates) are confronted by an increasing number of diseases, especially in town environments where specific constraints exacerbate the phenomenon. In this domain therefore, they wish to improve their methods and be able to consult the most up-to-date information.

At the present time, there is no "specialist" tool available allowing them to improve and update their knowledge and the skills necessary for the mastery of pathological diagnosis, disease prevention or treatment. This mastery is however indispensable for the quality of the professional services they offer in an area, which, on a European scale under the effect of a greater environmental awareness, is undergoing rapid development. This is likely to create jobs where the demand for quality grows in relation to the likelihood of increased funding.

At the same time, there are great demands for up-to-date knowledge by the universities and training colleges involved in forestry and arboriculture. The main drawback is that available research data is dispersed and not easily accessible. From this point of view, non-specialists of pathology (students and teachers of plant physiology, population biology and ecosystems, fruit and ornamental arboriculture, forestry, agronomy and horticulture) are of the opinion that it would be very useful to bring together these various branches of knowledge so as to be able to obtain the maximum benefit from them.

The main partners of this project (Development institutes and training organisations involved in professional arboriculture and forestry), who by the very nature of their missions are in an interface situation between the two poles of research and the work place, are directly subjected to these demands and would like to address them. The diversity of these potential customer groups, and their levels of knowledge and the training on which they depend, justify the use of transparent methods, leaving the way open for self-training.

This approach is also designed to be consistent with the harmonisation of professional qualifications, previously initiated by the same partners, in the area of ornamental arboriculture. This will lead to the gradual setting up of a certification process and highlights the need for developing teaching tools facilitating self-training in a work situation.

SUPPORT

The project was supported by the European Commission under the Leonardo Da Vinci system of project management. EC funding was available to prime the project but a significant proportion was provided by the partner countries.

OBJECTIVES

The development of a multimedia, interactive tree disease diagnosis software package (Tree Doctor CD-ROM) enabling:

- the improvement and appraisal of professional skills with regard to the prevention and treatment of pests and diseases of forest and ornamental trees. The target users are arboriculturalists dealing with parks and gardens, the forestry sector, local authority parks and gardens departments, specialists, and managers of publicly-owned and private estates;
- the development of knowledge and understanding in these same areas or associated areas for teachers, students and trainers;

– the setting up and implementation of the early beginnings of a European database on pests and diseases of trees.

SUCCESS MEASUREMENTS

The success of the project will be assessed by the following criteria.

– Wide range of tree genera and pests and diseases
To be effective the program must provide a useful database of trees and their associated pests and diseases.
– Relevant and marketable in the partner countries
The tree genera and pests and diseases must be relevant in as many of the partner countries as possible. Projected sales must be in the region of 1,000 copies for each partner.
– High quality making full use of multimedia facilities
The program will be competing against traditional printed field guides of which a number have been published in recent years.

SCOPE

The idea is to allow users to simply observe symptoms, to localise them on the drawing of a tree displayed on the screen (by clicking for example on "Genus", then "leaves", then "cankered areas") and to be led gradually to the disease or pest. In this way, by knowing the Genus to which the tree to be diagnosed belongs, the user will then find the cause of the problem and the most suitable ways of combating it taking into account the legislation in force.

The programme is able to help the user correctly differentiate between diseases that have a series of similar symptoms to ultimately find the discriminating element (based on the principle of *systematic discriminating keys*). It is designed to be open-ended in such a way as to allow updating of its constituents parts, and inclusion of a thesaurus will enable translation into languages other than the original four.

The programme has been created using the latest information on pests and diseases relying on the expertise of European specialists. This programme has been carefully prepared under the control of a **Scientific Council** guaranteeing the suitability and precision of the product being developed. At the same time, a **Quality Group**, made up of potential users, both scientific and professional, will evaluate its practical appropriateness to the stated objectives.

PARTNERS

Institut pour le Développement Forestier (IDF)

Project proposer and overall coordinator

The Institut pour le Développement Forestier is a professional institute for applied research and development administered by specialists in trees and forestry and with a strong technical and educational reputation in the field. As a recognised training establishment it provides a publishing and information distribution service of national renown. It has a close working relationship with national scientific establishments (Universities, INRA) and with both hands-on professionals and development specialists.

Centre de Formation Professionnelle Forestière (CFPF)

Technical coordinator

An environmental and forestry agency operating as an integral part of the Chamber of Commerce in the department of the Drôme, France, since 1980. The CFPF is known throughout the profession for its expertise in plant environments. The CFPF is involved with a number of professional associations and groups, such as "SEQUOIA", a quality control group which includes 50 tree surgery and tree care contractors, and the Société Française d'Arboriculture (the French branch of the International Society of Arboriculture). The CFPF also holds the chair of the inter-professional federation of forestry in the Drôme and Ardèche départements and is an administrator of FIBRA (the inter-professional federation in the Rhône-Alpes.)

Centre National d'Études et de Ressources en Technologie Avancée (CNERTA)

Prime contractor for Information Technology

As part of ENESAD (Etablissement National d'Etudes Supérieures Agronomiques de Dijon – the National Higher Education Centre for Agriculture in Dijon), CNERTA acts as a skills and resource centre for all areas of agricultural training and education and specialises in information and communication technology. It produces, edits and distributes educational resources, based especially on interactive media in which it possesses state-of-the art expertise in alerting and technology transfer.

Instituto per le Piante da Legno e l'Ambiente (IPLA)

Main project partner – Italy

A non-profit-making environmental agency financed by the Piedmont and Aosta Valley Region, IPLA provides advice and technical assistance to public and private organisations in the areas of planning, definition and implementation of activities relating to the environment and nature conservation. As well as being active in research, the Institute organises training and information packages for a variety of regional and national audiences, especially in the areas of arboriculture and forestry (municipal officials, technicians, etc.).

Instituut voor Boos en Natuuronderzoek (IBN DLO Wageningen)

Main project partner – the Netherlands

The IBN-DLO institute of pure and applied research is involved in nature conservation, forestry management and urban ecology (conservation, restoration and development) and is very active internationally in these areas. The Institute has developed two information and data base systems that are directly relevant to the disciplines

covered by this project – DRYADE (urban trees) and AGRALIN (insects) – and is preparing a CD-ROM on specific insect pathogens affecting forests and urban trees.

Disease Diagnostic and Advisory Service (DDAS)

Main project partner – United Kingdom

A professional service created in 1962 by the Forestry Commission, the DDAS is publicly funded through Forest Research, an agency of the Forestry Commission. Its goal is to provide an efficient, effective and impartial diagnostic and advisory service on tree diseases and disorders throughout Great Britain. It operates from two centers, one at the southern research station in Hampshire in England and one at the northern research station near Edinburgh in Scotland. A more recently formed (1975) Insect Identification and Advisory Service (IIAS) compliments the work of the DDAS and works closely with it to diagnose tree problems. Although originally set up to deal with problems in woodlands and forests, the DDAS now takes in trees on farmland and publicly and privately owned amenity trees. It publishes Information Notes on specific diseases from time to time and provides data for more detailed studies of tree diseases.

Tetropium fuscum brown spruce long horn beetle – response to an exotic insect

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Tetropium fuscum, a European pest, was identified for the first time in North America in an urban park in Halifax, Nova Scotia. Response to the pest involved the cooperation of federal, provincial and municipal agencies. The pest appeared to be behaving more aggressively in association with North American native species (red spruce, *Picea rubens*, black spruce, *Picea mariana* and white spruce, *Picea glauca*) than literature suggested that it does in Europe, since it was killing apparently healthy trees. It was decided that the potential risk to the native forest required that authorities attempt to eradicate this species before it enters the native forests which are near to Halifax.

Response currently includes surveys for infested trees, removal of infested trees, quarantine zone imposition and management, and research projects to increase information on this insect. Research topics include the biology of the species in North American hosts, detection and control methodologies and other aspects which may influence the potential impact of the species in North America. Efforts in all aspects of the response are ongoing.

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Rating the risk from exotic pests – the Exotic Forest Pest System for North America

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The Exotic Forest Pest System for North America is a project of the North American Forestry Commission, initiated by the Insect and Disease Study Group. This group has representation from the Forestry and Plant Quarantine agencies of all three countries in North America, Canada, the United States and Mexico.

The project was born out of an increasing awareness of the threats associated with exotic forest pests and the need for a database of information to serve North America. We need to be able to collect, store and retrieve information on the pests and we need a consistent system for rating the risk associated with these pests. All three countries have been moving towards regulation of forest products from off-continent, and more recently, the need to regulate dunnage, packing material and crating has been put into sharp focus by the increasing numbers of interceptions and actual establishments of pests. Asian longhorned beetle is a pest of current great concern, but there are many others.

The purpose of the system has been seen from the first as being to provide information to three groups of people, the regulators, the forest managers and the research community. The regulators need the information to provide a clear scientific basis for regulation, to help harmonise regulations among the three North American countries and thus to facilitate trade, and to bring North America into line with other parts of the world which are undertaking the same type of database construction. The forest managers need to be able to identify the threats associated with the various pathways on which pests may move, so that they can take steps to reduce those risks. They can start pro-actively addressing the need for detection of possible threats to their resource. The concerns of forest manager leads to the identification of research priorities in the forestry area.

What types of information do we envisage this system supplying? It is available in all three official languages of North America, and the whole system is species-based. It contains information on pest life cycles, biology and distribution as well as recognition and detection. However, that is not the only information the system. To help people decide if the pest is worth regulating, controlling or working on, the database supplies a risk assessment, using the information available on the pest. It gives a broad qualitative rating of high, medium or low risk.

The system will contain information on pests of trees of any part of North America. We intend it to include all types of pests, including insects, nematodes, fungi, bacteria, viruses, or any other type of disease organism, but not weeds. Weeds are outside the area of expertise of the Insect and Disease Study Group and although we recognize them as a very important threat to the forests of North America, we think they will have to be someone else's project.

The steering committee for this project has one great hope, that people with knowledge will recognize that this project is necessary and timely and will get involved. We have a number of risk assessments which have already been carried out in all three countries, and we hope to put all the pests identified in those assessments onto the database. It is quite a large body of information, but is far from comprehensive. And we do not have a team of dedicated writers for this project. We are hoping that the people who have information about forest pests will be motivated to contribute their knowledge to the database. Many North American scientists may have international contacts developed over the years through various cooperative projects with foreign scientists, or by means of trips to other countries. We hope that people who are familiar with pest insects in other countries may be canvassed for information and will be willing to share it with others.

You can log onto the Internet at www.exoticforestpests.org and find guidelines for making a contribution. We have an editor and a review committee who will be responsible for making sure that all contributions are consistent in their interpretation of the meaning of high, medium and low, as well as editing for spelling and grammar. There are data entry forms which you can down load from the web, so that you can work on your own computer, in your own time. You can also request the guidelines and entry forms on diskette, from the coordinator or the editor. When you have a contribution ready, it can be sent e-mail, or on diskette or even in hard copy. The database

uses Microsoft Access and an interactive system called Coldfusion. There is a custom data entry program, and Microsoft frontpage was used for the presentation. You can down load the material in Word or Word Perfect. There are four ways to down load, depending on whether you have Access 2, Access 95, Access 97 or no Access at all.

The outline of the pest facts sheet is organized much as you would expect, to provide a place to put all the information which you may have. At the moment we have no funds to hire people to write facts sheets, but facts sheets will be credited to the author and we hope that will be some inducement to contribute, as well as the more altruistic motives. Completing the pest facts sheet should be a relatively straight-forward exercise, except for the usual complaint that you do not have enough information, which we have to live with.

The risk assessment is based on the information in the facts sheet, but the author can carry out the risk assessment on the organism either before or after completing the facts sheet itself. The risk assessment is in two steps. First the pest is put through an initial screening. We want the database to contain potential quarantine pests, that is ones which are either not in North America, or if they are here, could spread further, and are capable of causing economic or environmental damage. New strains of old pests, which may have a different level of risk, can also be included. The screening process is designed to prevent you spending time on other types of pest.

If the organism passes the initial screening, you pass on to Step 2, the actual Pest Risk Assessment. There are three criteria, establishment potential, economic impact potential and environmental impact potential.

Under establishment potential, the author considers the factors which would aid the organism in getting established. Does it have suitable hosts in North America, and could it establish everywhere that they occur or is it limited by temperature or humidity? We do not ask you to estimate how quickly it would spread. Often pests move by human agency much faster than they could by themselves.

Economic and environmental impact potential are often difficult to estimate. A 'best guess' is often as much as can be given, if there is no good evidence from literature or the author's own knowledge.

The ratings under all of the criteria are qualitative, expressed as high, medium or low, but they can be converted simply into a numerical rating. Once the author has given these ratings, the computer program will calculate the overall rating of the pest. The establishment potential is multiplied by the economic and environmental ratings combined. What the author has to supply, however, is the level of uncertainty associated with the ratings. Where a lot of consistent data is available, the level of comfort with the values assigned in the ratings may be high, but where information is contradictory or lacking, it may be low.

Once we get a lot of information in the database, we want people to retrieve it and use it. You will be able to get out various types of reports, by host, pest names and areas of the world. You will be able to get lists of pests and pest facts sheets.

This is an ambitious project and we need a lot of people to get involved with it if it is to succeed. The official launch date was November 12 1998, at the joint meetings of the Entomological Society of America and the American Phytopathology Society, in Las Vegas. We hope people will log onto the system and will give us comments on what they like and what they do not like. Please give it a try.

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GIS representation of *Corythucha arcuata* (Say) distribution in northern Italy

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ABSTRACT: In spring 2000 *Corythucha arcuata* (Say), a nearctic species feeding on oaks, was first recorded in northern Italy. From October 2000 to February 2001 the distribution in Italy of *C. arcuata* was studied. All the data collected were processed using a GIS (Geographic Information System) to obtain a thematic map of *C. arcuata* distribution at the beginning of 2001. This pest is established over an area of about 7,000 square kilometers extending over Lombardy and Piedmont regions.

In the spring of 2000, the Oak lace bug *Corythucha arcuata* (Say) (Heteroptera: Tingidae) was recorded for the first time in northern Italy and Europe (BERNARDINELLI, ZANDIGIACOMO 2000a).

This pest, accidentaly imported from the nearctic region, feeds mostly on different species of the genus *Quercus*, causing leaf discoloration and wilting (DRAKE, RUHOFF 1965). In Italy *C. arcuata* attacks *Q. robur*, *Q. petrea*, *Q. pubescens* and presumed hybrids between *Q. robur* and *Q. petrea* (BERNARDINELLI, ZANDIGIACOMO 2000b).

In 1964 another nearctic species of the genus *Corythucha* Stål, the Sycamore lace bug *C. ciliata* (Say), was found in northern Italy (SERVADEI 1966). In a few years this pest colonized southern and Central Europe (PÉRICART 1983; MACELJSKI 1986), causing severe injuries to *Platanus* spp. and it is still a problem for such trees (MAZZON, GIROLAMI 2000).

Oaks are suffering a dramatic decline all over Europe due to several phytopathological agents (TOMICZEK 1993; SCHLAG 1994). *C. arcuata* infestations could make this situation even worse; for this reason the distribution of this pest in northern Italy was studied, beginning from the area where it was first found.

MATERIAL AND METHODS

A grid of squares 24 × 24 km large was superimposed on a topographic map of northern Italy. Sampling began in the area where *C. arcuata* was first recorded and proceeded to the nearby squares as long as no infested trees had been found. Other squares far away from the area where *C. arcuata* is established were also investigated because they are located near some of the main motorways in northern Italy. In certain squares (Fig. 1: squares E3, H2 and H3) sampling sites, as intended below, could not be found.

The sampling was carried out from mid October 2000 to the end of February 2001. Inside each square, at least one sampling site was investigated.

A sampling site consisted in a group of at least five oaks belonging to the species *Quercus robur* or *Q. petrea*.

Two different sampling methods were used depending on the season: (1) before leaf wilting (autumn), three twigs were cut from each of five oaks per sampling site and almost 100 leaves were collected; (2) after leaf wilting (winter), 300 wilted leaves were collected from the ground (or sometimes from the plants) in each site, picking them up under each group of five oaks.

The leaves were observed first in the field then in the laboratory under a stereo microscope to look for adults, nymphs, exuviae, eggs or dead specimens of the bug.

All the data collected were put in a GIS (Geographic Information System) database (MapInfo Professional) to elaborate the map showing where *C. arcuata* is already established.

RESULTS

C. arcuata was found in 12 of the 35 squares investigated, corresponding to an area of about 7,000 km^2 extending over Lombardy and Piedmont (Fig. 1), the city of Milano being approximately in the centre of this area.

The pest has also been observed on the leaves of an isolated oak tree in the province of Como near the Swiss border along an important road on the northern side of Lake Como (Fig. 1: square G2). In the nearby sampling site with more than five oaks no lace bugs or their remains were found.

DISCUSSION

The size of the area over which *C. arcuata* has spread suggests that the introduction of this pest into Italy is

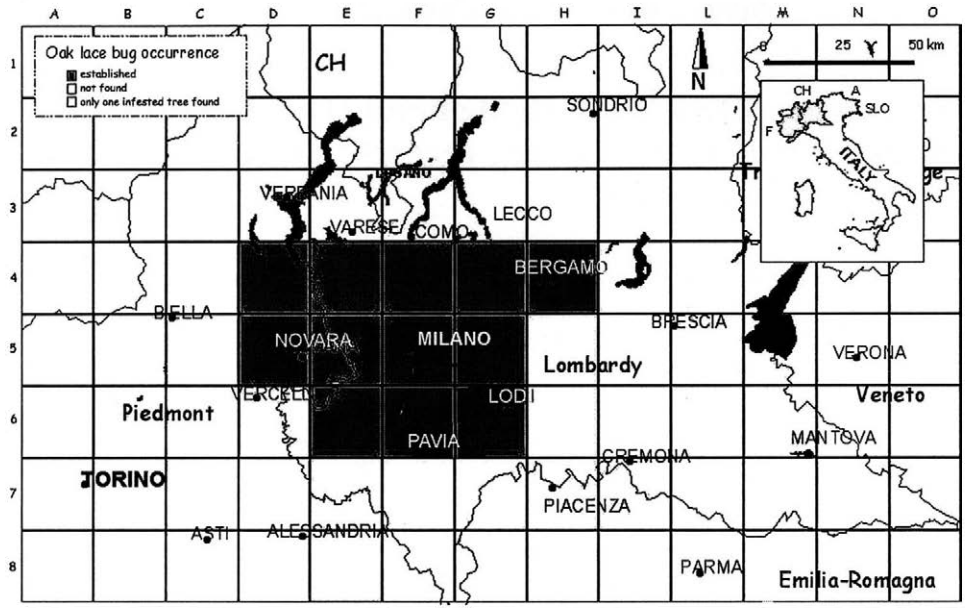

Fig. 1. Distribution of *Corythucha arcuata* (Say) in northern Italy at the beginning of 2001

not recent, for this reason any attempt to stop further spread would probably be unsuccessful.

The observation of some *C. arcuata* specimens on an isolated tree along a busy road, in an area where the insect was not otherwise found, suggests that vehicular transportation could be involved in the dispersal of the pest.

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APPENDIX

A wealth of information on *Corythucha arcuata* (Say) is available on the following web pages:

European and Mediterranean Plant Protection Organization. http://www.eppo.org/QUARANTINE/Alert_List/alert_list.html

Ohio State University Extension Fact Sheet. Lace bugs. http://www.ag.ohio-state.edu/~ohioli-ne/hyg-fact/2000/2150.html

Pennsylvania State Entomology Department. Entomological Notes. Lace bugs on deciduous woody ornamental plants. http://www.ento.psu.edu/extension/factsheets/lace_bug_woody_orn.htm

University of Georgia. The Bugwood Network. Oak lace bug. http://www.forestpests.org/oak/lacebug.html

University of Minnesota. The insects of Cedar Creek. http://cedarcreek.umn.edu/insects/album/020014007ap.html

University of Vermont Extension. Lace bugs by G.R. Nielsen. http://ctr.uvm.edu/ctr/El/el153.htm

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Leptoglossus occidentalis Heidemann (Heteroptera, Coreidae): a conifer seed bug recently found in northern Italy

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ABSTRACT: In 1999 the Leaf-footed conifer seed bug *Leptoglossus occidentalis* Heideman (Heteroptera, Coreidae) was found in northern Italy. This nearctic species feeds mainly on seeds of many coniferous species. Some notes on the morphology, life history, damages, host plants and distribution are given.

No species of the genus *Leptoglossus* Guérin-Méneville (Heteroptera, Coreidae) were known for the European fauna up to end the 1990s. The nearest species is *Lep-toglossus gonagra* (Fabricius) that has a pan-tropical distribution and it is present in the Canary Islands (MOULLET 1995). In 1999 the Leaf-footed conifer seed bug *Leptoglossus occidentalis* Heidemann was first collected near Vicenza (northern Italy) (TESCARI 2001). Up to now several specimens (adults and nymphs) of this nearctic species have been observed in different localities of northern Italy (VILLA et al. 2001).

In North America *L. occidentalis* is considered a severe pest of conifer seed orchards (BATES et al. 2000; CONNELLY, SCHOWALTER 1991; SCHUN, SLATER 1995) sometimes causing alarm when large numbers of adults suddenly invade houses looking for overwintering sites (BLATT 1994).

MORPHOLOGY

The adults of *Leptoglossus occidentalis* (Fig. 1) are generally between 9 mm and 18 mm long; females are larger than males. The overall colour is a warm reddish-brown.

Fig. 1. Adult of *Leptoglossus occidentalis* Heidemann

Four-segmented antennae, large compound eyes and a pair of simple eyes are present. The wings lie flat on the back. A distinctive inverted white V-marking is present on the fore wing (RIDGE-O'CONNOR 2000). The hind tibiae have leaf-like expansions and the hind femora are often also swollen and bear heavy spines. The dorsal side of the abdomen is yellow or light orange with five transverse black patches; this pattern is revealed during flight (JACOBS, EMMEN 1995).

The young nymphs are orange and brown, becoming reddish-brown to brown as they develop.

LIFE HISTORY

In North America this species is monovoltine (JACOBS, EMMEN 1995). In spring the adults emerging from overintering sites move to coniferous trees where they feed on the developing seeds and early flowers. Females lay rows of barrel-shaped eggs on the needles of the host trees in mid to late spring. Eggs hatch in about two weeks. The nymphs feed on tender cone scales and sometimes needles in tree tops throughout the summer. Nymphs pass through five instars and reach adulthood by late summer. New adults feed on ripening seeds until early autumn; then they aggregate in overwintering quarters (i.e. tree cavices, bird nests, buildings).

In Mexico this species is polyvoltine (CIBRIÁN-TOVAR et al. 1986).

DAMAGES AND HOST PLANTS

The Leaf-footed conifer seed bug uses mouthparts to pierce the cone and sucks out the seed endosperm, causing a high incidence of conelet abortion and a reduction in the yield and quality (viability) of seeds.

Host plants include white pine (*Pinus strobus*), red pine (*P. resinosa*), Scots pine (*P. sylvestris*), Austrian pine (*P. nigra*), mugo pine (*P. mugo*), lodgepole pine (*P. con-*

torta), white spruce (*Picea glauca*), Douglas-fir (*Pseudotsuga menziesii*), several other conifers (KLASS, KOWALSICK 2000; RIDGE-O'CONNOR 2000), and pistachio (*Pistacia vera*) (RICE et al. 1985).

DISTRIBUTION

L. occidentalis was first described in 1910 in California and Utah, at that time the species was widely distributed from Colorado to California and north to British Columbia. In 1969 its distribution in North America was: southern British Columbia and Alberta southwards to Arizona, New Mexico and Texas, eastwards to Iowa (ALLEN 1969). By the 1970s it was established in Wisconsin and Illinois, and by the mid 1980s was found in Indiana, Minnesota, Michigan and Ontario (MCPHERSON et al. 1990; MARSHALL 1991). In 1990 this species was collected in New York State and in 1992 it was found in Pennsylvania (JACOBS, EMMEN 1995). It is also present in Mexico (CIBRIÁN-TOVAR et al. 1986).

In 1999 it was first found in Italy (Europe). Up to the present many specimens (males, females and nymphs) have been collected in different localities of northern Italy in Lombardy and Veneto regions (Table 1 and Fig. 2).

Table 1. Records of *Leptoglossus occidentalis* in northern Italy

Region and locality	Adults	Nymphs	Sampling period	References
LOMBARDY				
Abbiategrasso (MI)	17		29.9.2000–14.1.2001	VILLA et al. 2001
Abbiategrasso (MI)		1	20.10.2000	VILLA et al. 2001
Arcore (MI)	1		10.2000	VILLA et al. 2001
Corbetta (MI)	1		6.10.2000	VILLA et al. 2001
Gessate (MI)	2		20.10.2000; 2.11.2000	VILLA et al. 2001
Milano, loc. Baggio (MI)	1		15.10.2000	VILLA et al. 2001
Milano	2		30.9.2000; 10.2000	VILLA et al. 2001
Villasanta (MI)	1		8.9.2000	VILLA et al. 2001
Vimercate (MI)	2		15.9.2000; 9.2000	VILLA et al. 2001
Cologno al Serio (BG)	1		–	VILLA et al. 2001
Montevecchia (LC)	1		14.9.1999	VILLA et al. 2001
Landriano (PV)	1		27.10.2000	VILLA et al. 2001
Siziano (PV)	1		14.9.1999	VILLA et al. 2001
Garbagnate Milanese (MI)	5		3.9.2000–18.3.2001	this work
Garbagnate Milanese (MI)		1	3.9.2000	this work
Garbagnate Milanese (MI)	10		9.2001	this work
VENETO				
Arcugnago (VI)	3		13.10.1999	TESCARI 2001
Arcugnago (VI)	4		23.10.2000–28.10.2000	TESCARI 2001
Isola Vicentina (VI)	1		5.9.2000	VILLA et al. 2001

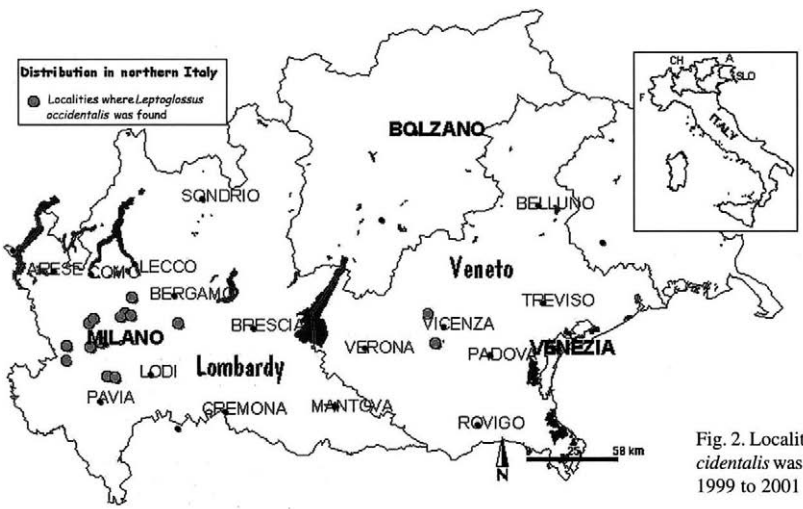

Fig. 2. Localities where *Leptoglossus occidentalis* was found in northern Italy from 1999 to 2001

This data suggests that populations of this pest are permanently established in northern Italy.

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The influence of natural limitative factors on the outbreak of *Apethymus abdominalis* Lep. (Hym., Tenthredinidae) from oak forest Heltiu – Romania

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ABSTRACT: The defoliator *Apethymus abdominalis* Lep. (Hym., Tenthredinidae) started its gradation in Romania in 1994, infesting oak stands in the Forest District Caiuti (Forest Direction Bacau). In the years 1999–2000 the infestations intensities in this area were middle to strong. In this paper we present the results of studies regarding the influence of some natural limitating factors on the evolution of this defoliator gradation. Among these very important are biotical factors (egg parasitoids of genus *Trichogramma*, larvae predators like insectivorous birds and red mites, different eonymphae predators from soil fauna) and abiotical factors (extreme summer and winter temperatures, droughts).

The defoliator *Apethymus abdominalis* Lep. (Hym., Tenthredinidae) was detected for the first time in Romania in 1994 in the forest Heltiu (forest district Caiuti – Bacau) on a surface of 150 ha. In the period 1995–2000 the insect spread in many other forests from Siret river basin (East part of Romania) causing moderate to heavy infestations. In the main infestation area from Heltiu forest, the outbreak was controlled by chitin inhibitor treatments (Dimilin, Rimon). In 1999 and 2000, 3,300 hectares were sprayed with good results.

However, it is very important to identify the natural mortality factors and to establish their role in extinction of pest outbreak.

METHODS

In the laboratory we made analyses of oak branches in order to establish the level of infestation with *Apethymus* eggs and the degree of parasitism and percentage of unhatched eggs.

The food spectrum of forest birds was studied by analyzing the stomachal content of some of them when *Apethymus* was in larval stages.

In the field we digged soil sondages (1 m^2) for determination pest density in eonympha stage and used pitfall traps for soil fauna.

For the inventory of birds population we used Ferry and Frochot method.

RESULTS

NATURAL MORTALITY IN EGG STAGE

As a result of the two consecutive treatments with Dimilin and Rimon the density of *Apethymus* eggs decreased very much in the Heltiu forest (from 95% in the spring 2000 to 0.5% in the spring 2001). Also, in the two oak forest (Păltinata and Cornătel) of forest district Caiuti the density of *Apethymus* eggs is low in the spring of 2001 (under 1%).

In the year 2000 we found the first oophagous parasitoids (mainly from genus *Trichogramma*), with 21% parasitism in Heltiu forest, 12% in Păltinata forest and 7% in Cornătel forest (Fig. 1).

In the year 2001 the percentage of egg parasitism decreases, but increases the percentage of unhatched eggs (unknown causes).

PREDATORS OF *APETHYMUS* LARVAE

In the Heltiu forest succesive bird inventories showed a great variety of birds predators. 23 insectivorous species were registred (72%).

The analyse of the stomach contents of some birds species (9) demonstrated that some of them feed on *Apethymus* larvae (2 species of hollow nesting birds: *Ficedula albicolis* and *Fringilla coelebs* and 2 species of woodpecker: *Dendrocopos major* and *Picus canus* – Table 1).

Table 1. Stomachal contents of some species of birds from Heltiu forest (May 2000)

No.	Species of birds	No. ex	Stomachal content													
			Apethymus (L)	*Gasteropoda*	*Aramidae*	*Acarina*	*Coleoptera* (neid)	*Carabidae*	*Cantaridae*	*Curculionidae*	*Chrisomelidae*	*Staphilinidae*	*Lepidoptera* (L)	*Formicidae*	*Heteroptera*	Seeds
1.	*Dendrocopos major*	2	+				+	+	+	+			+	+		
2.	*Emberiza citrinela*	1		+			+			+				+		+
3.	*Ficedula albicollis*	2	+				+					+			+	
4.	*Fringilla coelebs*	2	+				+						+			+
5.	*Parus caeruleus*	1			+		+						+			
6.	*Parus major*	1				+	+						+			
7.	*Passer montanus*	1					+									
8.	*Picus canus*	2	+				+						+			
9.	*Sturnus vulgaris*	1					+	+			+		+			

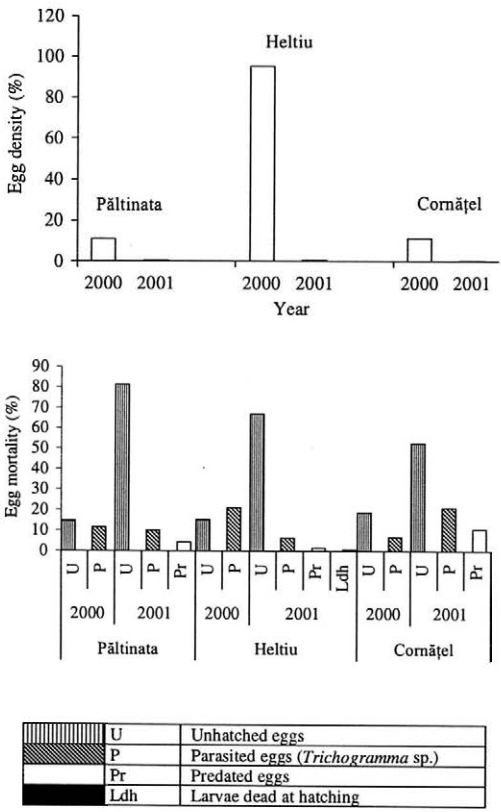

Fig. 1. Natural mortality of *Apethymus* eggs in the period 2000–2001 in oak forests from forest district Caiuti

A lot of *Apethymus* larvae L_6 are attacked on the soil surface by species of *Eutrombidium* (red mite).

NATURAL MORTALITY OF EONYMPHA STAGE

Mortality values of *Apethymus* eonymphae are different in the three studied oak forests.

These are higher in the Păltinata forest (91.0% in winter; 66.9% in spring–sumer), where *Quercus petraea* represents 80% in composition, middle in the Heltiu forest (43.2% in winter; 39.5% in spring–summer), where *Quercus petraea* represents 100% and lower in the Cornătel forest (9.5% in winter; 10.5 % in spring–summer), where *Quercus petraea* represents 20% in composition (80% *Fagus sylvatica*) (Fig. 2).

Winter mortality can be caused by low temperatures and drought. We suppose that spring–summer mortality can be an effect of various factors, among them several agents of the soil fauna.

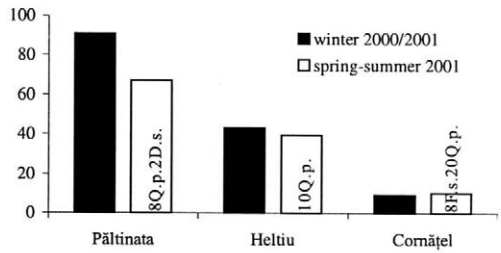

Fig. 2. Natural mortality of *Apethymus* – eonymphae

Q.p. = *Quercus petraea*
F.s. = *Fagus sylvatica*
D.s. = Different species (*Fagus, Carpinus, Populus*)

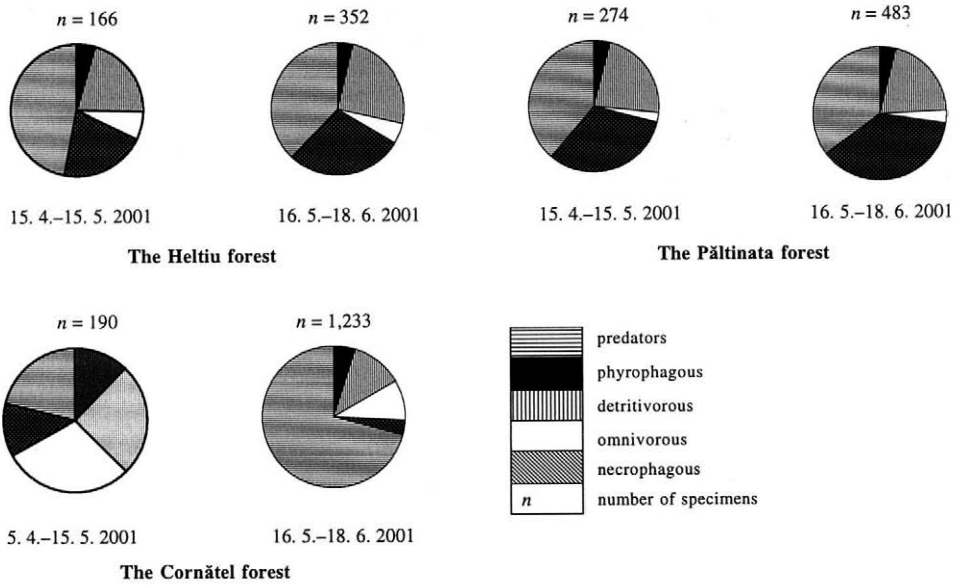

Fig. 3. Categories of alimentar regimen identified within soil fauna in oak forests infested by *Apethymus abdominalis*

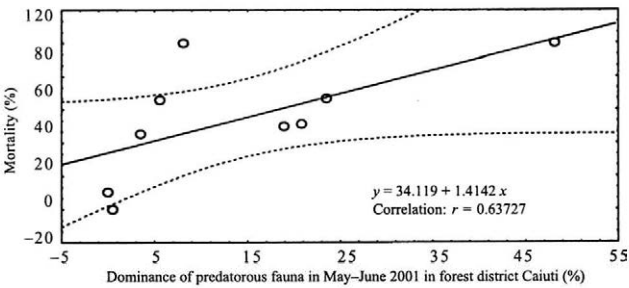

Fig. 4. Correlation between dominance of predatorous fauna and mortality of *Apethymus* eonymphae

Soil fauna analyses showed a high percentage of predators species (38–47% in the forest Heltiu, 34–37% in the forest Păltinata and 21–71% in the forest Cornătel) in the period 15. 4.–18. 6. 2001 (Fig. 3).

INFLUENCE OF PREDATOROUS SOIL FAUNA ON *APETHYMUS* EONYMPHAE

There is a close correlation observed (r = 0.637) between values of dominance of predatorous soil fauna and mortality of *Apethymus* eonymphae in summer time of 2001 (10^{th} of June–6^{th} of September) in oak forest Caiuti forest district (Fig. 4).

The main predators belong to the families Carabidae (*Carabus granulatus*, *Harpalus pubescens*, *Molops piceus*, *Pterostichus oblongopunctatus*, different carabide larvae) and Staphylinidae (*Philontus chalceus*, *Staphilinius oleans*, different staphilinide larvae).

CONCLUSIONS

A series of biotic and abiotic natural limitative factors although new in oak forest fauna of forest district Caiuti, began to act on the defoliator *Apethymus abdominalis*.

The eggs are attacked by parasitoids of genus *Trichogramma*, and a great part of them do not hatch.

On the larval stage some species of insectivorous birds (*Fringilla coelebs*, *Ficedula albicolis*, species of woodpeckers), acts in the crown of the trees, and on the soil surface the larvae are atacked by red mites (*Eutrombidium* sp.).

The eonymphae from soil are affected by abiotic factors (extreme temperatures, drought) and possibly by biotical factors (especially insects from the families Carabidae and Staphylinidae, which are dominant in soil fauna in the studied forest stands).

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Intercept™ Panel Trap, a novel trap for monitoring forest Coleoptera

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ABSTRACT: A novel trap, the Intercept™ Panel Trap, was developed and field tested for monitoring forest Coleoptera. The trap is made from corrugated plastic. It is light-weight, water proof, and durable. Field experiments measured capture of several forest Coleoptera in comparison to the Phero-Tech 12-unit Multi-funnel Trap. Target species: spruce beetle (*Dendroctonus rufipennis*, Douglas fir beetle (*D. pseudotsugae*), Western balsam bark beetle (*Dryocetes confusus*), pine bark beetles, larger pine shoot beetle (*Tomicus piniperda*), pine sawyers (*Monochamus* spp.), Asian longhorn beetle (*Anaplophora glabripennis*), Buprestid beetles, wood wasps, and several other exotic forest pests. For most bark beetle species, the Intercept™ Panel Trap captured equivalent or higher numbers, except for spruce beetle and larger pine shoot beetle when compared to the Multi-funnel Trap. Intercept™ Panel Traps captured a substantial numbers of Cerambycid and Buprestid beetles, and Siricid wood wasps. In comparative tests in Oregon, the Intercept™ Panel Trap captured substantially more exotic forest pest species of greater diversity than the Multi-funnel Trap.

A novel trap, the Intercept Panel Trap, has been developed for monitoring forest Coleoptera. The trap is made from corrugated plastic. It is light weight, water proof, and durable. Trap efficacy in capturing several forest Coleoptera was meast in field trials in comparison to the Phero Tech 12-unit Multi-funnel Trap. Field trials targeted: spruce beetle (*Dendroctonus rufipennis*), Douglas fir beetle (*D. pseudotsugae*), Western pine beetle (*D. brevicomis*), Western balsam bark beetle (*Dryocetes confusus*), pine bark beetles (*Ips* spp.), larger pine shoot beetle (*Tomicus piniperda*), pine sawyers (*Monochamus* spp.), Asian longhorn beetle (*Anaplophora glabripennis*), Buprestid beetles, wood wasps and several other exotic forest pests.

OBJECTIVES

– To assess comparative trapping efficacy and field performance of the Intercept Panel Trap for multiple forest Coleoptera.

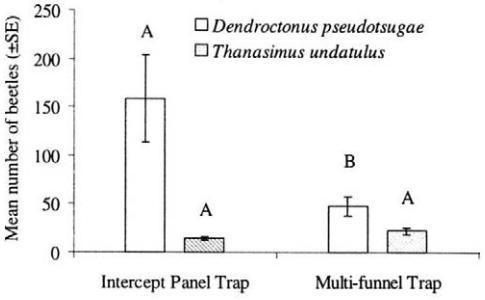

Fig. 1. Comparative trapping of *Dendroctonus pseudotsugae* and *Thanasimus undatulus* in Intercept Panel Trap vs. Multi-funnel Trap, Idaho Panhandle National Forest, Avery Ranger District, May 13–August 31, 1999

Means within species followed by same letters are not significantly different (HSD test, $n = 8$, $P < 0.05$)

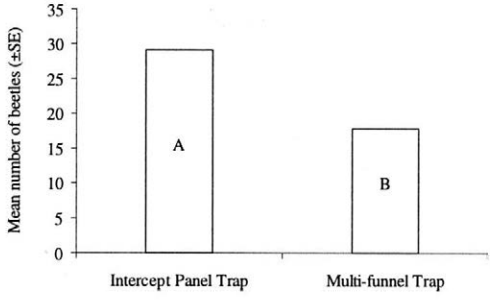

Fig. 2. Trapping comparison of *Dryocetes autographus* in Intercept Panel Trap vs. Multi-funnel Trap, Idixie National Forest, Logan, UT, July 1–September 7, 1999

Means followed by same letters are not significantly different (1-way ANOVA, $n = 5$, $P < 0.05$)

– To evaluate performance parameters and trap durability in diverse climates and environments.

MATERIAL AND METHODS

Field performance of Intercept Panel Trap was compared to Multi-funnel Trap baited with species – specific pheromone lures in replicated paired trials.

RESULTS AND DISCUSSION

1. Trap catches of Douglas fir beetle and Western balsam bark beetle were significantly higher in the Panel Trap (Figs. 1, 2). There was no significant difference between Panel and Funnel Traps in captures of Western pine beetle (Fig. 3), larger pine shoot beetle (Fig. 5) and Cerambycid beetles (Fig. 6). Captures of spruce beetle (Fig. 4) and Buprestid beetles (Fig. 6) were significantly higher in the Funnel Traps compared with the Panel Trap.

2. Panel Traps capture fewer non-target beneficial predators compared to Funnel Traps (Fig. 1).

3. The Intercept Panel Trap (Fig. 7) captured a substantial number of Cerambycid and Buprestid beetles, and Siricid wood wasps. Trap captures of mountain pine beetle, *Ips* spp., exotics and wood wasps have not been processed and are not available. In proof of concept trials targeting surveillance of exotic forest pests in Oregon, the Intercept Funnel Trap captured substantially more insect species than the Multi-funnel Trap.

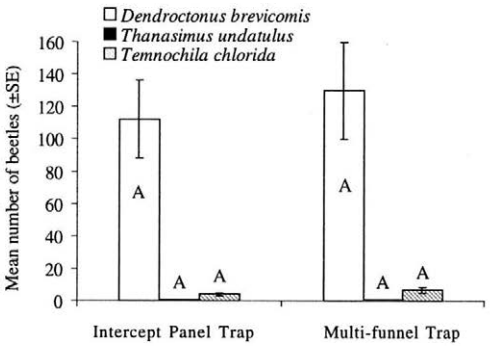

Fig. 3. Comparative trapping of *Dendroctonus brevicomis*, *Thanasimus undatulus*, and *Temnochila chlorida* in Intercept Panel Trap vs. Multi-funnel Trap, Idaho Panhandle National Forest, Avery Ranger District, May 20–September 7, 1999

Means within species are not significantly different (1-way ANOVA, $n = 5$, $P < 0.05$)

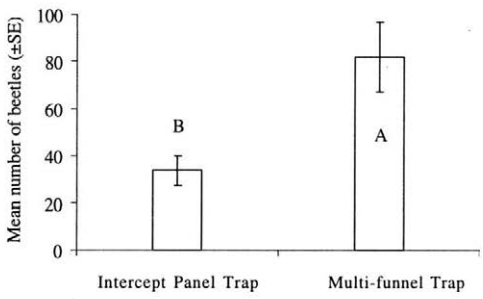

Fig. 4. Comparative trapping of *Dendroctonus rufipennis* in Intercept Panel Trap vs. Multi-funnel Trap, Dixie National Forest, UT, May 2–August 30, 1999

Means followed by same letters are not significantly different (HSD test, $n = 5$, $P < 0.05$)

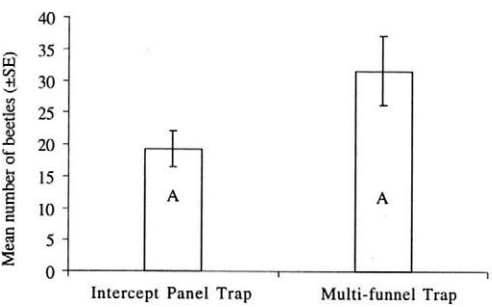

Fig. 5. Comparative trapping of *Tomicus piniperda* in Intercept Panel Trap vs. Multi-funnel Trap, Barrie, ON, Canada, February 2000

Means are not significantly different (1-way ANOVA, $n = 5$, $P < 0.05$)

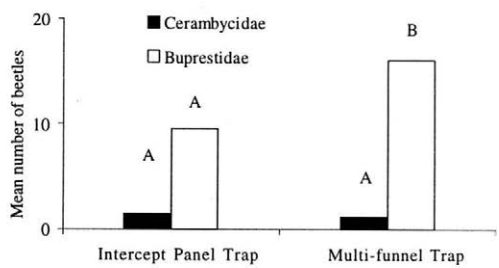

Fig. 6. Comparative trapping of beetles from families Cerambycidae and Buprestidae in Intercept Panel Trap vs. Multi-funnel Trap, near Barrie, ON, 2000

Means within species followed by same letters are not significantly different (LSD test, $n = 10$, $P < 0.05$)

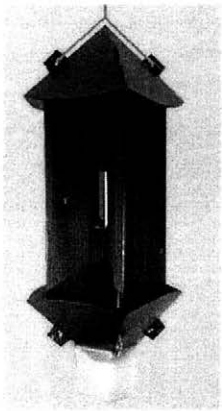

Fig. 7. Intercept Pranel Trap

CONCLUSIONS

The Intercept Panel Trap is an effective tool for monitoring Scolytids, Cerambycids, Buprestids, and other forest Coleoptera. Panel Traps were very robust under rigorous field conditions, light-weight to carry, weather and water proof, and easy to install. Panel Traps dissemble rapidly, can be stored flat, and use less storage space than Funnel Traps. The Intercept Panel Trap is now commercially available.

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Attract and Kill technology for management of European pine shoot moth (*Rhyacionia buoliana*) and Western pine shoot borer (*Eucosma sonomana*)

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ABSTRACT: An attract and kill bait matrix was deployed for management of European pine shoot moth (*Rhyacionia buoliana*), and Western pine shoot borer (*Eucosma sonomana*) in pine plantations and tree nurseries. *R. buoliana* is an introduced pest of native and ornamental pines throughout the Northeastern and Northwestern United States and adjacent Canadian provinces, and a serious pest of pine plantations in South America. *E. sonomana* causes substantial economic losses in ponderosa, lodgepole, and Jeffrey pine in the Western United States. Due to the cryptic larval habits of these shoot borers, conventionally sprayed insecticides are not very effective. A&K technology very selectively removes male moths of the target species from the ecosystem with negligible impact on non-target organisms. Baits combine the selectivity of pheromone (only 0.21 g/ha, compared to 3.5 to 20 g/ha for mating disruption) with rapid toxicity of insecticides (only 7.92 g/ha, compared to 500–800 g/ha for conventional sprays). This bait retains the insecticide within a hydrophobic matrix that precludes run-off or drift, thus preventing ecosystem contamination and damage. Trap catch data indicated that in comparison to number of male *R. buoliana* captured on untreated plots male moth population on plots treated with formulation containing 0.16% (w/w) of pheromone was reduced by 86.6% to 100%. Trap captures of male *E. sonomana* in A&K treated blocks were reduced more than 80% in comparison to untreated blocks.

An attract and kill bait matrix was deployed for management of European pine shoot moth (*Rhyacionia buoliana*), and shoot borer (*Eucosma sonomana*) in pine plantations and tree nurseries. Due to the cryptic larval habits of these shoot borers, conventionally sprayed insecticides are not very effective. A&K technology very selectively removes male moths of the target species from the ecosystem with negligible impact on non-target organisms. Baits combine the selectivity of pheromone (only 0.21 g/ha, compared to 3.5–20 g/ha formating, disruption) with rapid toxicity of insecticides (only 7.92 g/ha, compared to 500–800 g/ha for conventional sprays). This bait retains the insecticide within a hydrophobic matrix that precludes run-off or drift, thus preventing ecosystem contamination and damage.

OBJECTIVES

- To determine 1) treatment efficacy, optimal formulation, and application rate, and 2) placement of Last Call formulation in the field;
- To test 3) biological and 4) chemical properties of aged and fresh droplets.

MATERIAL AND METHODS

1. Field application of two Last Call formulations, 0.016% and 0.16% pheromone content (w/w): *R. buoliana* – 50 droplets/tree on small groups of trees or 1,200 droplets/acre on plantations; *E. sonomana* – at a rate of 600 and 1,200 droplets/acre, respectively. Moth populations were monitored with A-traps baited w/rubber septa pheromone lures. Damage by *E. sonomana* was estimated at the end of the growth season. Damage by *R. buoliana* will be determined in May 2001.

2. Male moths of both species were trapped at three different heights of the same trees.

3. Male moths of both species were monitored with A-traps baited with 5-week-old and fresh Last Call droplets.

4. Fresh and laboratory aged Last Call droplets were analyzed for residual pheromone content over time.

RESULTS AND DISCUSSION

1. Trap catches of *R. buoliana* were reduced 56–95% and 83–100% on plots treated with 0.016% and 0.16% formulation (respectively) when compared to untreated plots

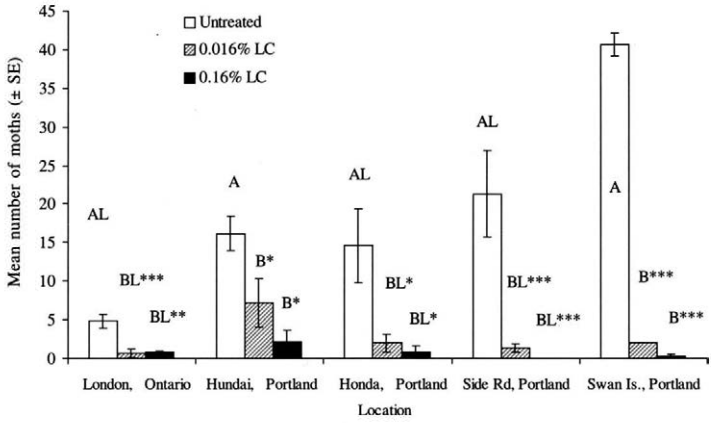

Fig. 1. Trap catches of *Rhyacionia buoliana* in Last Call (LC) treated pine blocks, Portland, OR, USA and London, ON, Canada. May 23–July 20, 2000

Bars within same location with the same letters are not significantly different (Tukey HSD test, n = 3–6, $*P < 0.01$, $**P < 0.005$, $***P < 0.001$, L – analysis performed on log-transformed data)

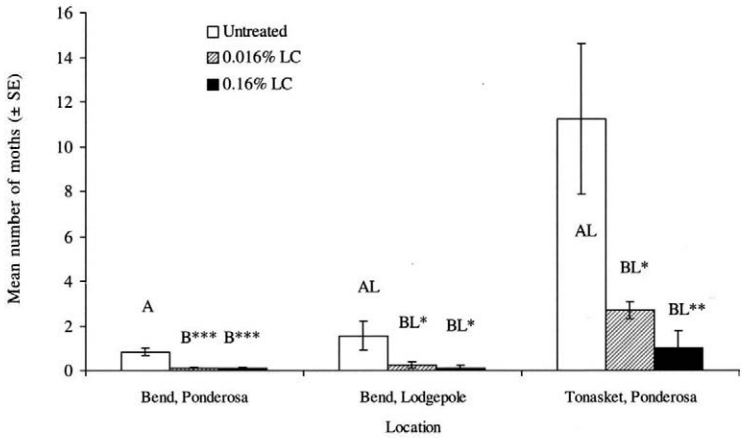

Fig. 2. Trap catches of *Eucosma sonomana* in Last Call (LC) treated pine plantations near Bend, OR, and Tonasket, WA, May 10–June 20, 2000

Bars within same location with the same letters are not significantly different (Tukey HSD test, n = 9–20, $*P < 0.05$, $**P < 0.005$, $***P < 0.001$, L – analysis performed on log-transformed data)

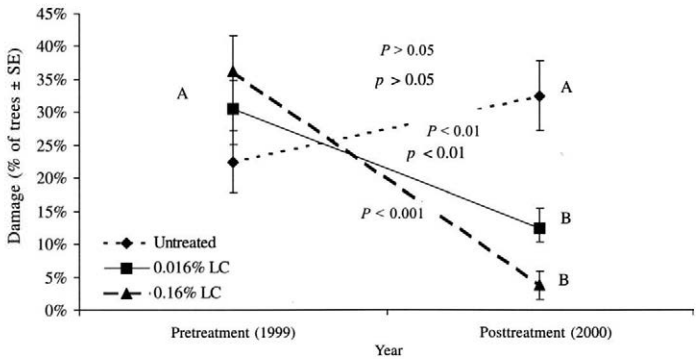

Fig . 3. Damage of ponderosa pine by *Eucosma sonomana* in Last Call (LC) treated plantation near Bend, OR, 1999–2000

Damage within same year with the same letters are not significantly different (Tukey HSD test, n = 80, $P < 0.001$). 2-way interaction $F_{(2,556)} = 11.45$, $P < 0.001$

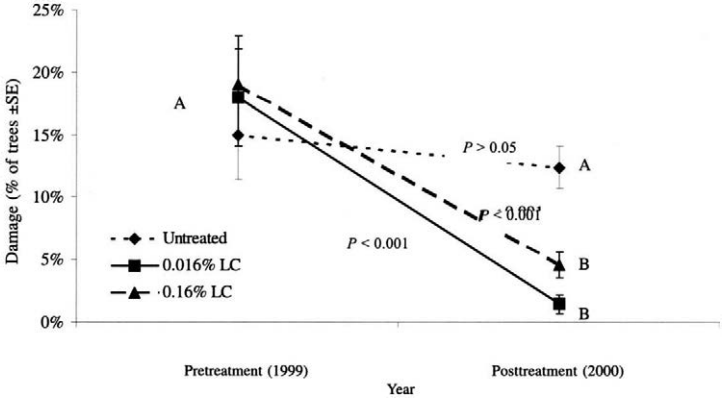

Fig. 4. Damage of ponderosa pine by *Eucosma sonomana* in Last Call (LC) treated plantation near Tonasket, WA, 1999–2000

Damage within same year with the same letters are not significantly different (Tukey HSD test, n = 100–400, $P < 0.001$). 2-way interaction $F_{(2.1476)} = 5.36$, $P < 0.0048$

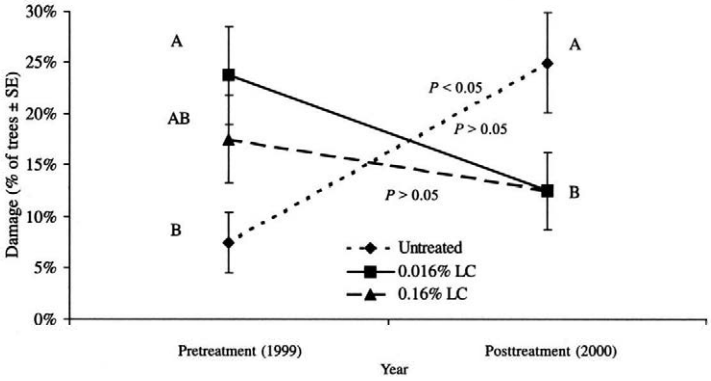

Fig. 5. Damage of lodgepole pine by *Eucosma sonomana* in Last Call (LC) treated plantation near Bend, OR, 1999–2000

Damage within same year with the same letters are not significantly different (Tukey HSD test, n = 80, $P < 0.05$). 2-way interaction $F_{(2.474)} = 6.76$, $P < 0.0013$

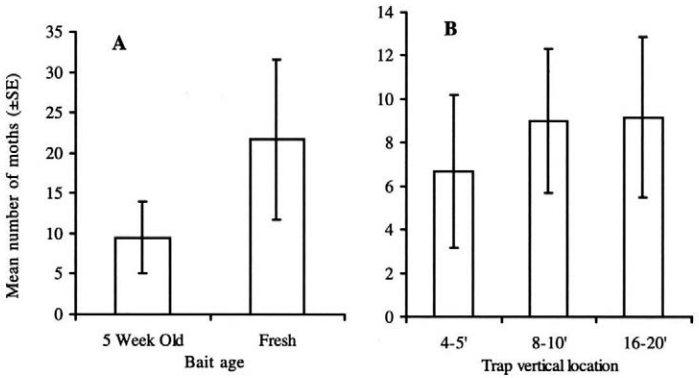

Fig. 6. Trap catches of *Rhyacionia buoliana* in traps baited with aged and fresh Last Call (0.16%) drops (A) and traps at different heights (B). Portland, OR. June 23–July 10, 2000

A – Trap catches were not significantly different (1-way ANOVA, $n = 6$, $P > 0.05$)

B – Trap catches were not significantly different (1-way ANOVA, $n = 6$, $P > 0.05$)

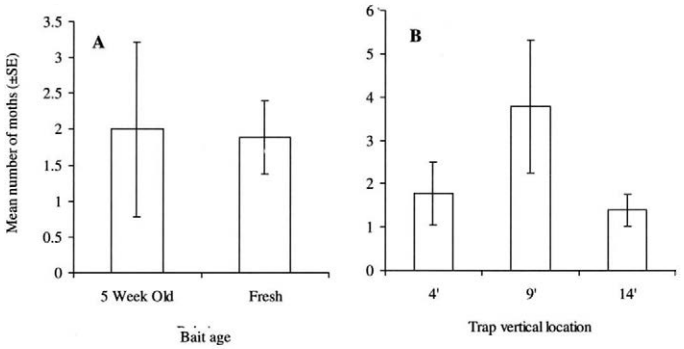

Fig. 7. Trap catches of *Eucosma sonomana* in traps baited with aged and fresh Last Call (0.16%) drops (A) and traps at different heights (B). Bend, OR. June 6–18, 2000

A – Trap catches were not significantly different (1-way ANOVA, $n = 10$, $P > 0.05$)

B – Trap catches were not significantly different (1-way ANOVA, $n = 9$, $P > 0.05$)

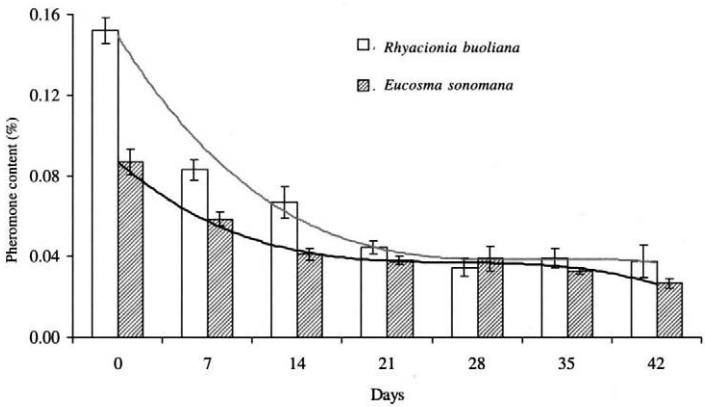

Fig. 8. Pheromone content in Last Call droplet over 42 days in the laboratory

Standard Last Call pheromone load = 0.16%

(Fig. 1). Trap catches of *E. sonomana* were reduced 76–90% and 90–93% on plots treated with 0.016% and 0.16% formulation (respectively) when compared to untreated plots (Fig. 2).

Damage by *E. sonomana* in two plantations was significantly reduced on plots treated with either Last Call formulation while moth populations did not change in the untreated plots (Figs. 3, 4). Damage on Last Call treated plots in the third plantation was not significantly reduced while moth populations significantly increased in the untreated plot (Fig. 5).

2. Catches of both moth species were independent of trap height in the tree (Figs. 6, 7, right). However, the majority of *E. sonomana* were captured in traps placed nine feet above the ground.

3. Trap catches of both moth species did not differ significantly between traps baited with 5-week old and fresh Last Call droplets (Figs. 6, 7 left).

4. The Last Call formulation retains and protects the integrity of both *R. buoliana* and *E. sonomana* pheromone for ar least 42 days (Fig. 8).

CONCLUSIONS

Last Call technology is a effective, alternative method for management of *R. buoliana* and *E. sonomana.*

The material is based upon a work supported by the Cooperative State Research, Education and Extension Service. U. S. Department of Agriculture under Agreement No. 00-3 3610 -885 9.

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Monitoring of *Melolontha hippocastani* F. at the Upper Rhine Valley, Germany

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ABSTRACT: Since the 1980s, the cockchafer has again caused increasingly damage in the forests of the northern Upper Rhine Valley. Consequently, monitoring of the cockchafer populations has been reintensified. This has been done by determining the larvae density per square metre of soil using sample excavations. Up to now the sample excavations have been carried out along lines which are definitely positioned in flight area stands. Considering the large and steadily increasing cockchafer infested area, it is important to optimise the relation between a high information level and an acceptable labour intensity for the excavations. In order to achieve a comprehensive overview of the endangered forest area a pilot project is examining, whether a spatial grid sampling procedure might be advantageous compared with the line sampling technique.

MOTIVE AND OBJECTIVES

Since the eighties of the past century, the cockchafer (*Melolontha hippocastani* F.) again has caused increasingly damages in the forests of the northern Upper Rhine Valley (DELB 2000, SCHMID-VIELGUT et al. 1992; SCHRÖTER 2000). On sandy sites dominated by Scots pine, in particular deciduous trees present in the rejuvenation phase (Fig. 1) and in the understory (Fig. 2) are concerned. The aims of close-to-nature forestry management are endangered by the larvae which feed on roots. At present the infested area which is delineated by the site conditions for egg-laying, the stand characteristics and by flight observations, comprises a forested surface area of about 10,000 hectares (Fig. 3).

Consequently monitoring of the cockchafer populations was re-intensified. This is done by determining the larvae density per square metre (m^2) in the soil by means of sample excavations. The resulting data mainly aim at
– prognosticating the cockchafer flight,
– observing the development of cockchafer populations,
– estimating the current silvicultural risks.

Fig. 1. Dead beech trees in a natural regeneration, forest district Kandel, August 2001

Fig. 2. Dead beech trees in the understorey, forest district Philippsburg, May 2000

Fig. 3. Cockchafer infested area in the northern Upper Rhine Valley, Germany

Using the cockchafer densities in the soil estimated in the fall before the flight year, the spatial occurrence and intensity of the flight can be assessed. By considering the larvae densities of the first to the third larvae stage (L1, L2, L3), data on the development of the populations are obtained. Primarily the larvae data serve also the evaluation of the current silvicultural risks in forest practice, particularly in view of the regeneration and the understory of deciduous trees.

STANDARD METHOD: LINE SAMPLING PROCEDURE

Up to now the sample excavations are carried out along lines which are definitely positioned in stands of the flight area (Fig. 4). Forest stands which show significant swarm activities in the year of adult cockchafer occurrence in connection with severe defoliation and observable egg-laying, are called flight areas. By following roughly the course of the lines, about 3 to 10 excavations are fit in at equal distances. The excavated soil is checked for larvae or adults at a surface of a ¼ square metre (30 × 80 cm) down to a depth of about 80 cm (Figs. 5, 6). At present 1,600 excavations are carried out annually.

PILOT PROJECT: GRID SAMPLING PROCEDURE

INITIAL SITUATION

In order to achieve a comprehensive overview of the surface of the endangered forest area, the inclusion of the whole infested area in representative sample excavations is required. For example the current silvicultural risk for planting young beech trees in the understory of pine forests may be calculated or the success of control activities may be assessed for the whole area in this way. Although the unsystematic structure of the excavation lines from the years before reflects the tendencies of population developments well, the statistical comparability of the data is hindered however. In this point of view, the spatial grid sampling procedure might be advantageous as compared to the line sampling technique, too.

Considering the wide and permanently increasing cockchafer infested area, it is an important task to optimise the relation between a high level of information and an acceptable labour intensity for the excavations. Grid sampling offers the possibility to react flexibly in view of changing basic conditions and questions, which can be overcome by enlarging or compressing the grid width depending on the available working capacity in accordance with the accuracy requested.

PROCEDURE

At the beginning of excavating, the extension of the infested area is fixed temporarily. Afterwards the grid is projected on a forest map within the boundaries of this area (Fig. 4). The grid intersecting points are integrated to the Gauß-Krüger coordinate system at right angle. In the field the entry to the grid is commenced at a clearly de-

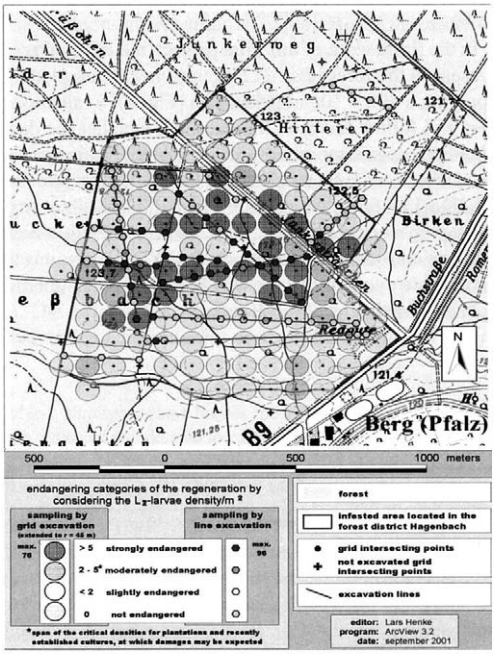

Fig. 4. Results of the line sampling in comparison with the grid sampling, L_2 – larva densities/m² (critical densities: cf. SCHWERDTFEGER 1981)

Fig. 5. Sample excavation at the forest district Kandel, August 2001

Fig. 6. Result of the sample excavation (Fig. 5): 6 individuals of the 3rd larvae stage

fined location by using a compass and the length of one's stride. Starting from this point the following sample plots are surveyed. Excavating is carried out analogously to the line sampling technique. If any larvae or adults are found in the last excavation before the boundary of the temporarily defined infested area, the grid will be extended until further findings will fail to appear.

PROSPECT

In the framework of this pilot project, the infested area present in the forest district Hagenbach was sampled by applying a 100 × 100 m grid width (Fig. 4). Evaluations that will follow focus on the question, whether the data obtained by grid sampling provide a higher information level when compared with those of the line sampling method, thus justifying the probably higher labour intensity. Moreover, when applying a 200 × 200 m grid width, which means a considerable reduction of sampling plots, it is to investigate exemplarily for which questions the obtainable information level is still sufficient.

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Bark beetles (Scolytidae, Col.) and their insect bioregulators in mountain spruce stands

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ABSTRACT: The biodiversity and abundance of the bark beetles and their predators and parasitoids on spruce has been studied since 1998 in the area of Modrava. Among the 13 identified bark beetle species dominated: *Polygraphus poligraphus, Crypturgus pusillus* and *Ips typographus*. The most abundant predatory and parasitoid species included: *Roptorocerus xylophagorum, Rhopalicus tutella, Cosmophorus klugii, Dendrosoter middendorffii* (Hymenoptera, fam. Pteromalidae, Braconidae), *Medetera signaticornis, Lonchea bruggeri* (Diptera, fam. Dolichopodidae, Lonchaeidae), *Placusa pumilio* (Coleoptera, fam. Staphylinidae). The quantitative occurence of bioregulators in samples varied from 7 to 83 % (100 % = all insects in the sample). In the samples with high population density the bioregulators were able to reduce the bark beetles significantly.

One of the first studies focused on insect bioregulators of *Ips typographus* was published by Fleischer in 1875. Since that time, *I. typographus* was investigated mainly as a pest of spruce monocultures with relatively little attention paid to its natural enemies. Papers published by Pfeffer (1955), Martínek (1961), Zumr (1995), Zahradník, Knížek (2000), Kolubajiv (1962), Kalina (2000) and Boháč (1999) include data from the Šumava Mountains. A general rewiew on bark beetle bioregulators was published by Mills (1983).

Since 1998, our work has focused on the spruce bark beetles and their insect bioregulators in Šumava Mountains. Our preliminary publications (Zelený 2001; Hulcr 1999; Doležal 2000; Zelený, Doležal 2000) concerned spruce stands at lower altitudes. Data collected at higher altitude of the Šumava Mountains are presented in this poster. Results obtained in the most western Carpathian range, Bílé Karpaty, are shown for comparison.

MATERIAL AND METHODS

Our research started in 1998 in the area of Modrava. The localities are situated in the second protective zone, close to its border with the first zone. The development of all bark beetle stages was followed in the field and the results were verified in the laboratory culture. Relationship between the diapause and overwintering was in the center of our interest.

The course of bark beetle swarming was assessed from the catches in pheromone traps. The biodiversity and abundance of the bark beetles and their enemies were estimated using logs cut from the trap trees and kept in fotoeclectors. Samples were taken from the localities of different bark beetle population densities and different logging practices (intensive logging, no logging, clearcuts etc.). Quantitative ratios of bark beetles and their insect bioregulators are regarded as an indicator of the effectivity of bark beetle's enemies.

RESULTS

It is impossible to generalize the significance of predatory and parasitoid insects for the regulation of bark beetle populations (Table 1). Among the 13 identified bark beetle species dominated: *Polygraphus poligraphus, Crypturgus pusillus, I. typographus, Pityogenes chalcographus, P. conjunctus, Xyloterus lineatus* (Figs. 1 and 2). The difference in number of generations per year was observed in *I. typographus*. In 1998 there were two gener-

Table 1. Numbers of bark beetles and their enemies emerged from logs collected at indicated localities in the Šumava Mountains

Sample	Year	Scolytidae	Enemies*
St/22	1998	155/27.4%	411/72.6%
ČH/18	1998	105/92.9%	8/ 7.1%
4)	1998	59/17.5%	278/82.5%
22)	1999	1212/99.4%	7/ 0.6%
SHR/1	1999	31/31.3%	68/68.7%
AN/2	1999	177/30.3%	407/69.7%

*Representatives of Diptera and Hymenoptera except for sample ČH/18 that contained exclusively Coleoptera

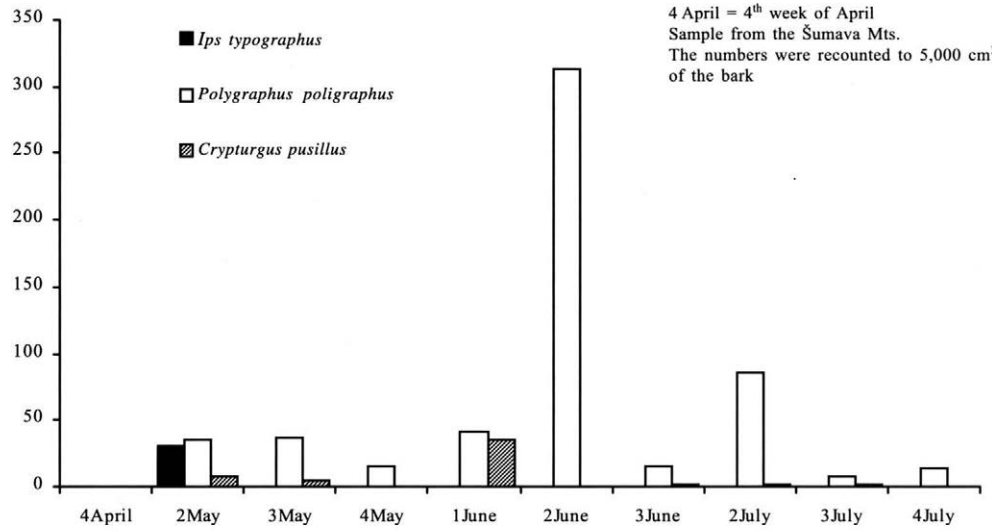

Fig. 1. Numbers of beetles emerged from isolated logs in one week intervals. Each week is specified by its number in the month

ations, in 1999 a partial second generation and in 2000 one generation only, although this year was in average usually warm. The trap tree analysis revealed that the delay in spring swarming and the low June temperatures determined monovoltine development.

The identified bioregulators of the bark beetles included 10 Coleoptera species from 5 families (Staphylinidae, Nitidulidae, Cleridae, Rhizophagidae, Trogositidae) and 4 Diptera species with predatory larvae (Cecidomyiidae, Dolichopodidae, Pallopteridae, Lonchaeidae) and one species of Heteroptera (Anthocoridae). Another bug *Scoloposcelis pulchella* was found only in 2000. This species was very abundant in the samples from lower altitudes, but only very few adults were found in the mountain samples. No representatives of Raphidioptera were found. Eleven parasitic species of Hymenoptera from fams. Braconidae and Pteromalidae were recorded. The most common species of Hymenoptera and Diptera included:

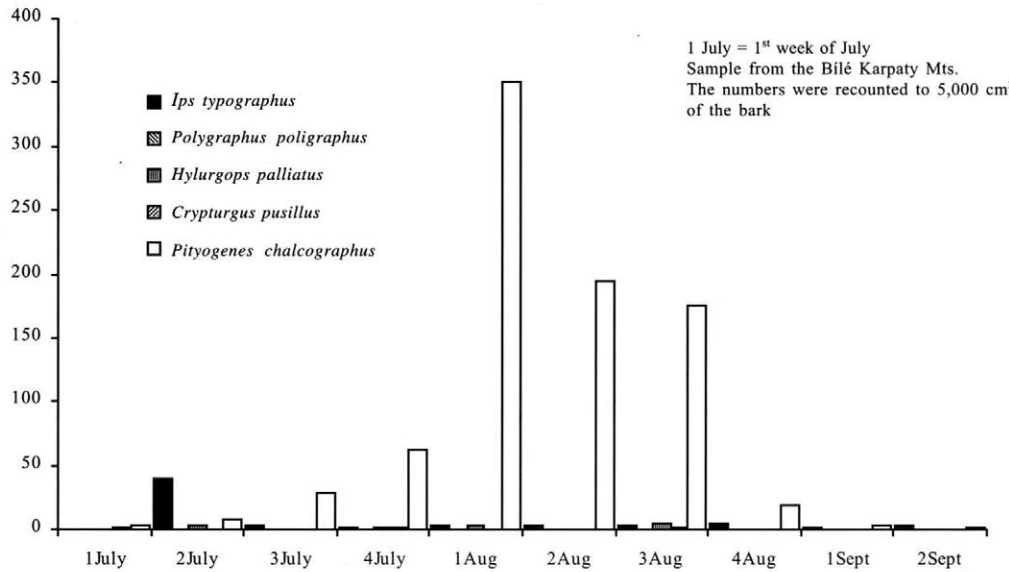

Fig. 2. Numbers of beetles emerged from isolated logs in one week intervals. Each week is specified by its number in the month

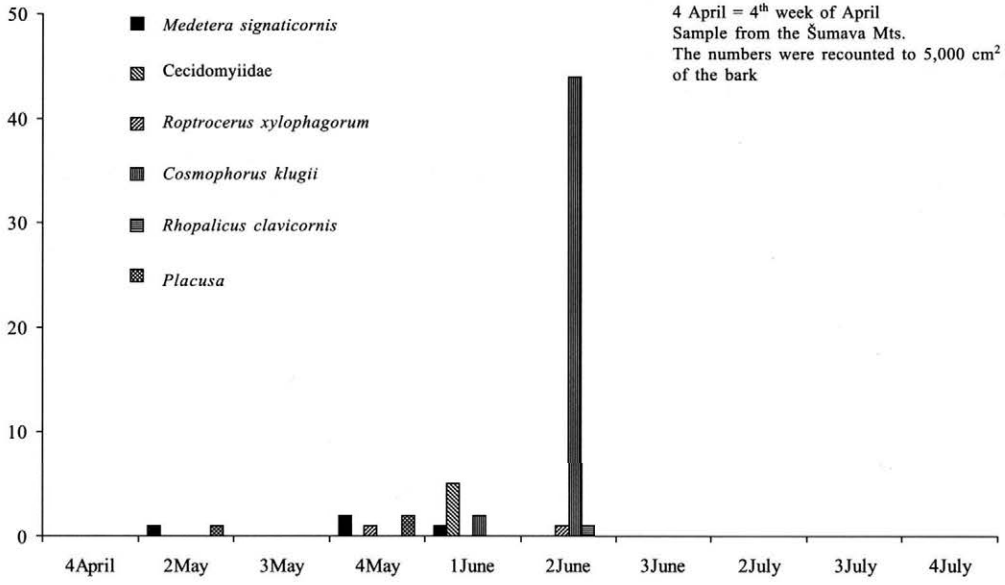

Fig. 3. Numbers of bioregulators emerged from isolated logs in one week intervals. Each week is specified by its number in the month

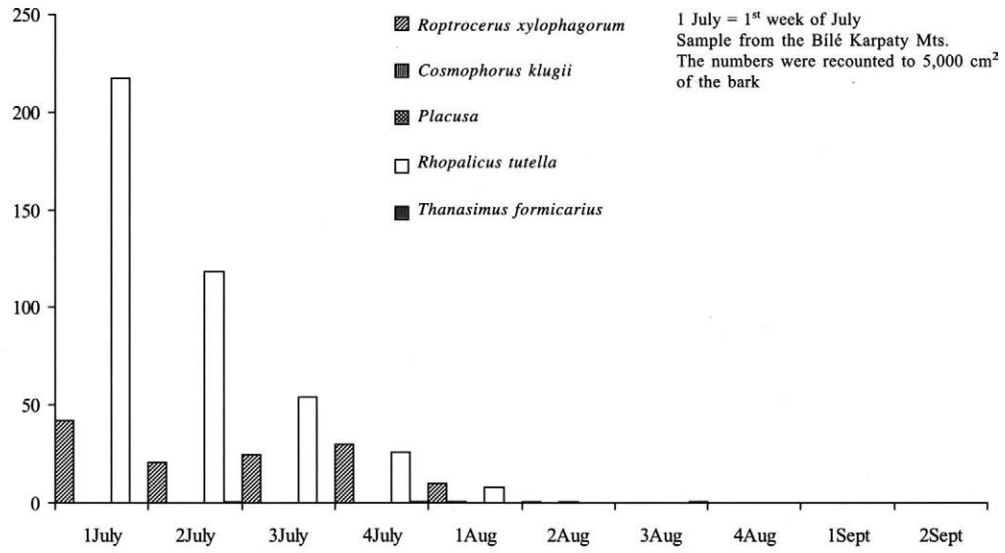

Fig. 4. Numbers of bioregulators emerged from isolated logs in one week intervals. Each week is specified by its number in the month

Roptrocerus xylophagorum, *Medetera signaticornis*, *Lonchaea bruggeri*, *Rhopalicus tutella*, *Cosmophorus klugii*, *Tomicobia seitneri*, *Dendrosoter middendorffii*. Two staphylinid beetles *Placusa pumilio* and *Placusa tachyporoides*, were the most common predators. Slightly less abundant were the adults and larvae of *Thanasimus formicarius* (Figs. 3, 4). Adults of this species were often observed on the logged trees infested with bark beetles.

CONCLUSIONS

It is impossible to generalize the significance of predatory and parasitoid insects for the regulation of bark beetle populations. Sometimes the bioregulators were able to reduce the bark beetles significantly (82.5% bioregulators), in other cases, when their population density was low (7.1% bioregulators), they had almost no influence (100% = all bark beetles and bioregulators in the sample).

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Forestry Images.org: High resolution image archive and web-available image system

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ABSTRACT: Over 4,500 photographs and other images of more than 800 insects, diseases, plants, wildlife, and management practices taken by over 170 photographers are available. Most images were digitized from high-resolution 35mm slides. Multiple levels of jpeg format images are downloadable and may be copied and used for any non-profit, educational purpose with appropriate credit and copyright notice. Although most images are of North American forested systems and species, there are many images from other areas of the world in the system as well. The images are in this system to be used! Forestry Images.org: utilizes a fully searchable, relational database-driven system to track and provide scientific, descriptive and photographic credit information. Several search and browse options are available to help locate images, including: scientific and common names, and "key word" searches of descriptive information about the image. Forestry Images.org: is an ongoing project supported by The USDA Forest Service, Forest Health Technology Enterprise Team and Washington Office, Forest Health Protection Staff, many images and new features will be added in ensuing months.

"A picture is worth a thousand words"! Correct identification of insects, diseases, weeds and management practices with an understanding of the complex biology of the ecosystem in which they exist is critical in making management decisions on forest and natural areas. Educators need to utilize all available techniques and methodologies available to provide and disseminate materials to widely dispersed clientele who have very diverse educational backgrounds and interests. Correctly identified photographs and images can be invaluable educational programming aids. A good photograph of an insect, disease organism, damage or of a management practice will enable the educator and IPM practitioner to make correct decisions, or perhaps as important, not make incorrect management decisions (BARGERON et al. 1999).

Many talented photographers throughout the years have taken many high-quality photographs of forested system organisms and management practices. These photographs typically exist as 35mm slides in various laboratories, agency offices and individuals' slide files. Unfortunately, as individuals retire or are promoted, or as offices and personnel change, these images are misplaced or are no longer available. Additionally, unless individuals make duplicates of these slides and these duplicates are distributed to others, they are not available for use by anyone other than the individual who holds the original slide. In many cases, even if duplicates are made and distributed to other individuals, critical information such as: the photographer, the correct identification information, common name, etc. is often not carried along with the duplicate slide, and hence, not available to other users.

Information and Communications Technologies (ICT), including the Internet and World Wide Web (WWW), portable computers and presentation equipment (such as Microsoft PowerPoint) and desktop/publishing software systems, provide exciting opportunities for educators to deliver timely and quality information to diverse audiences (DOUCE et al. 2001a,b). Additionally, most printed materials used by educators are now developed and delivered to printers via computer software, which again requires images to be in digital form. However, because of the high expense of professional printing in color, many publications now produced by educators must be in black and white, which reduces their educational impact. Materials provided via the WWW can be in color and, if desired, users can print them in color on relatively inexpensive home/office inkjet printers now available.

NEED

We believe that it is extremely important for educators to have ready and easy access to correctly identified, quality images that can be used as identification aids.

Forestry Images.org: The Source for Forest Health and Silviculture Images http://www.ForestryImages.org/.

Limitations to anyone desiring to use photographs and images in information and communications technology applications include:

1. finding the desired photograph/image;
2. reliable access to the photographs/images when needed;
3. obtaining the image in the form and format suitable for the desired application – size, shape, format, color depth, etc;
4. obtaining the correct biological and descriptive information to identify the image – What is it? Who took it? What does it show?;
5. having the ability to easily use the images in the desired application;
6. having the ability to use the image for the desired educational application without the need to obtain further legal releases.

SYSTEM DESCRIPTION

Forestry Images is a web based, fully-searchable image archive and retrieval system that the authors developed in conjunction with the US Forest Service to serve Forest Health educational and support activities across the US. The system was developed by the authors and colleagues to support location and retrieval of images by the user community and contains such elements as:

1. the original scan of the photograph/image digitized and archived as a Kodak PCD PhotoCD file (Eastman Kodak Company 2001);
2. full scientific classification for the organism;
3. photographer name and address;
4. legal releases for educational applications;
5. image resolutions available: (3,072 × 2,048, 1,536 × 1,024, 768 × 512, 384 × 256, 192 × 128) in JPEG format.

Forestry Images was developed by the authors and was released to the public on July 9, 2001 (http://www.Forestry-Images.org/). Currently, 4,500 images taken by over 170 photographers are available to users. An additional 3,000 additional images on a variety of topics taken by 80 more photographers are being processing and will be available in the system in the ensuing months.

The Forestry Images system backbone is a Microsoft SQL Server enterprise-level database running on a Microsoft Windows 2000 server located within the Bugwood Network offices. The web interface for to the database was written in the Macromedia ColdFusion 5.0 language and uses Macromedia ColdFusion 5.0 server and Microsoft Internet Information Services as the database connector and web server.

The database contains over 2,300 subject codes with scientific classification (Class, Order, Family, genus, species, identifier . . . etc. as appropriate). Approximately 225,000 pages of information were served to over 14,000 Forestry Images users during the time period of July 9 to October 10, 2001. The system has 1,085 members who have registered for full use of the system and for e-mail updates.

Forestry Images has been under development for a number of years, and is the result of the efforts of a large number of people. In the mid-1990s authors Douce and Moorhead recognised a need for quality photographs of forest insects and disease organisms to use in information technology applications, and began exploring ways to address this need (DOUCE et al. 1996).

The overall objective of Forestry Images is to provide an accessible and easily used archive of high quality images related to forest health and silviculture, with particular emphasis on educational applications. We interpret forest health quite broadly, to include natural and managed areas and the organisms and management practices that occur in these areas.

There is no charge to users for any educational application as long as credit is given to the photographer or agency and to Forestry Images as the delivery mechanism. The photographs and images in Forestry Images are either publicly-owned images, or have been released by "private" photographers to allow the images to be used with no royalty or fee charges in educational applications. For each image, we must receive legal release documentation stating that we, representing The University of Georgia, have the right to distribute the image without restriction as long as appropriate credits are given, and that the image may be used for educational purposes without royalties and fees. For commercial applications, the potential user must contact and obtain release from the photographer or contact person/agency. However, the photographer retains full rights to his/her images, The University of Georgia, for legal purposes, have copyright to the delivery/packaging process.

FUTURE

We will continue to work with foresters, forest entomologists, forest pathologists and others to expand content and scope of forestry information on the various web sites maintained by The Bugwood Network. We envision the image archive as being central to evolution of web-based educational information technology systems that will be developed and served by The Bugwood Network. We believe that Forestry Images will be a valuable resource for educators, practitioners, regulators, students and scientists into the future.

The Bugwood Network (DOUCE et al. 2001a) currently includes educational web sites such as: Forestpests.org, Barkbeetles.org, Invasive.org, GAIPM.org, The Department of Entomology web site, Georgia Exotic Pest Plant Council, Southeastern US Exotic Pest Plant Council, Georgia Cooperative Agricultural Pest Survey Program, etc. (all available through www.bugwood.org home page). The Bugwood Network is a non-profit, educational unit of The University of Georgia, College of Agricultural and Environmental Sciences and Warnell School of Forest Resources, Georgia, USA.

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Ips acuminatus: experiences from an outbreak in Southern Switzerland

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ABSTRACT: In the region of Brusio, Canton Graubünden, an outbreak of *Ips acuminatus* Gyll. can be observed. During the last 8 years, twenty hectares of pine stands were killed. The affected pine stands are important protection forests, but control measures are almost impossible. The landscape aspect will change and the risk of natural hazards will be more difficult to calculate for several years.

In the region of Brusio, Poschiavo Valley, Canton Graubünden, an ongoing outbreak of *Ips acuminatus* Gyll. can be observed. Mass attack started after the dry summer of 1992. In the year 2001 still no end is in sight. Every year new infestation spots emerge and some existing spots expand. Until 2000 twenty hectares of pine stands were killed, corresponding to 15% of the local pine forests.

GENERATION CYCLE

In Southern Switzerland, two generations of *I. acuminatus* can be observed. Young adults overwinter in the branches of infested trees with still green crowns. Discoloration of the needles starts only in May, after the emergence of the overwintering beetles. Spring attack is first visible by fading shoots. In June, freshly attacked trees turn red, only a few days or weeks before the first generation emerges. In July the second generation starts its development up in the branches of newly infested trees, invisible from the ground. These beetles of the second generation overwinter in the crowns.

NO CONTROL MEASURES – THE BEST SOLUTION?

Control measures are almost impossible. An infestation of the second and overwintering generation can not be detected prior the beetles take flight. It is also very difficult to locate, fell and process in time infested trees of the first generation. There is no way to destroy the brood in the branches inside the stand. The steep slopes and the danger of forest fires do not permit to burn the infested material. Quick access and harvesting would only be possible by helicopter, a method too expensive and with still no guarantee that all infested material would be removed in time. So the decision was NOT to fight this gradation. Only dead trees directly above roads and railway lines are felled for security reasons.

FOREST DYNAMICS AND FOREST FUNCTIONS

The affected pine stands are important protection forests. In the present situation they have no commercial function. By chance the slopes are relatively stable and the risks of rockfall and avalanches are tolerable. The dead trees fulfill their protection function for several years, hopefully enough time to create new and mixed stands, mostly by natural regeneration. Clearcuts would again be favorable for pure and vulnerable pine stands.

Under the canopy of the dead pines nature will create mixed stands. The landscape aspect will change and the risk of natural hazards will be more difficult to calculate for several years.

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Monitoring of widespread forest diseases in Friuli-Venezia Giulia (North-eastern Italy)

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ABSTRACT: Since 1994 a continuous survey of forest health, called BAUSINVE, is active in Friuli-Venezia Giulia district (North-eastern Italy). Any kind of tree damage due to insects, diseases, rodents, etc., as well as windthrows, avalanches and floods, is recorded. In order to improve the knowledge of existing relationships between pest/disease occurrence and environmental conditions, as well as to predict and/or prevent outbreaks, all data coming from the survey sheets are loaded in a database supported by a GIS. However, as several permanent diseases affect trees in the FVG stands, a specific monitoring program has been launched in 1998 mainly in permanent plots. In particular, the specific surveys concern the witches' brooms of silver fir disease (*Melampsorella caryophyllacearum* [Link] Schroeter), the chestnut blight disease (*Cryphonectria parasitica* [Murrill] Barr), the *Sphaeropsis sapinea* (Desm.) Dyko & Sutton disease, the Dutch elm disease (*Ophiostoma* spp.) and the oak decline.

Since 1994 a continuous survey of forest health, called BAUSINVE, has been active in Friuli-Venezia Giulia district, North-eastern Italy (STERGULC, FRIGIMELICA 1997). Any kind of tree damage due to insects, diseases, rodents, etc., as well as windthrows, avalanches, floods, is recorded by BAUSINVE. About 60 officers of the forest service, properly trained and supervised by a team of experts, check out the forest phytosanitary conditions. Each officer, who surveys a forest area of about 5,000 ha, reports in a specific survey sheet all kinds of tree damage overcoming an established threshold value. Some pests causing outbreaks are monitored using also specific tools, as pheromone traps. The survey sheet includes all information concerning the occurrence of pests/diseases (or climatic damage), host plant (both tree and shrub species), stand parameters (i.e. elevation, slope facing, soil origin, forest type), disturbance factors (i.e. delay in the removal of felled or windthrow trees). A complete list of the symptoms, the likely damaging agent and the amount of damage (in hectares, number of affected trees and/or volume of wood losses) are also reported by the officer who has filled out the sheet. In order to improve the knowledge of existing relationships between pest/disease occurrence and environmental conditions, as well as to predict and possibly prevent outbreaks, all data coming from the survey sheets are checked by supervisors and loaded in a database supported by a GIS. So far, a total of 1,175 survey sheets have been already loaded. In addition, a report of BAUSINVE activities, containing all the main results, is annually published by the Friuli-Venezia Giulia (FVG) forest service. However, as several permanent diseases affect trees in the FVG stands and cannot be recorded at each survey because of lack of time, a specific monitoring program has been launched in 1998 mainly in permanent plots. In particular, the survey of the witches' brooms of silver fir disease (*Melampsorella caryophyllacearum* [Link] Schroeter) in 1998, the chestnut blight disease (*Cryphonectria parasitica* [Murrill] Barr), the oak decline and the *Sphaeropsis sapinea* (Desm.) Dyko & Sutton disease survey in 2000, the Dutch elm disease (*Ophiostoma* spp.) in 2001. The data regarding the widespread forest diseases are collected each year, producing two different kinds of survey sheet: the standard BAUSINVE sheet for the stand parameters and another one for detailed monitoring in the permanent plot. A short description of the monitoring methods applied in FVG for each widespread disease is reported.

CHESTNUT BLIGHT

Cryphonectria parasitica, the agent of chestnut blight, was reported in the district for the first time in 1940 (MITTEMPERGHER, RADDI 1975). At present the disease occurs in the orchards and coppice stands of chestnut, but it may affects oak species as well (*Quercus robur* and *Q. pubescens*) (FRIGIMELICA, FACCOLI 1998). The significant cases of oak infection by *C. parasitica* and serious events of disease recrudescence in chestnut stands are reported by the standard survey.

Causal agent: *Cryphonectria parasitica*
Host tree: *Castanea sativa*

Purpose of the survey: the purpose of the specific monitoring program is evaluating the trend of the disease in representative *Castanea sativa* coppice stands.

Beginning of survey: 2000

Season of survey: once per year in summer, between June and September.

Method of survey: permanent plots are established in chestnut coppice stands at this purpose. The plot occupies an area of approximately 400 m^2. Thirty living trees of about 10 cm in diameter at the beginning of the survey, were randomly selected among several stumps. The diameter of 10 cm shoot has been chosen because the trees had survived after intraspecific competition within a stump. Every sample tree and stump is individually numbered. Moreover all the other trees growing up in the stump are also counted and divided according to diametric classes (< 2.5 cm, 2.5–10, > 10 cm) and phytosanitary status (a. healthy trees; b. living diseased trees with presence of stem cankers at different level; c. dead trees killed by the disease or by other mortality factors).

Survey sheet:
- The data are collected producing two different kinds of survey sheet: the standard BAUSINVE sheet for the stand parameters and another one for detailed monitoring in the permanent plot.
- The specific sheet is divided in two separate parts, the first for the thirty sample trees and the second for the other trees growing in the stumps.

Set of data collected for every plot:
- Stand parameters (e. g. elevation, exposure, soil, forest type, stand development...).
- Amount of damage, on the basis of total number of dead trees for *C. parasitica* attacks in the sample stumps.

Set of data collected for every stump:
- Total number of living trees, divided according to diameter classes and phytosanitary status.
- Total number of dead trees, divided according to diameter classes and cause of death.
- Presence of new coppice shoots.
- Diameter growth, changes in the phytosanitary status and/ or mortality occurring on sample trees.

DUTCH ELM DISEASE

The native elm species (*Ulmus minor* and *U. glabra*) in FVG district have been seriously decimated by the two well-known Dutch elm disease pandemic events occurred in the twentieth century. Data related to the presence and distribution of the species and races of *Ophiostoma* in the district are not available. It is likely that both Eurasian and North American strains of the more aggressive species, *Ophiostoma novo-ulmi* Brasier, occur in the region, as it happens in the rest of Italy (MITTEMPERGHER et al. 1998). However, the possibility that the less pathogenic species, *Ophiostoma ulmi* (Buism.) Nannf. is also present cannot be disregarded.

Causal agent: *Ophiostoma ulmi*, *Ophiostoma novo-ulmi*
Host tree: *Ulmus minor*, *U. glabra*

Purpose of the survey:
- Evaluate the trend of disease on *Ulmus minor* and *U. glabra* in mixed broadleaved stands.
- Collect information about percentage of crown infections.
- Collect information about percentage of infections transmitted by root grafts.
- Collect information about species of bark beetles vectors found on dead or diseased elms in different forest conditions.
- Obtain a set of *Ophiostoma* spp. isolates, adequate to characterise the local populations of the pathogen.

Beginning of survey: 2001

Season of survey: Once a year in summer, no later than middle of July.

Method of survey:
- The survey is based on a net of permanent plots, enough wide to include a sample of four to ten healthy elms, having diameter higher than 7.5 cm and fully visible crown. All sample trees are individually numbered.

Survey sheet:
- The data are collected producing two different kinds of survey sheet: the standard BAUSINVE sheet for the stand parameters and another one for detailed monitoring in the sample elms.
- The nearby presence of elms infected or dead, from which the infection may be transmitted by root graft, is also noted. For each dead elm the way of spread of symptoms (discoloration of the sapwood) on the stem and the presence of galleries of bark beetles is pointed out.

Set of data collected for every plot:
- Stand parameters (e.g. elevation, exposure, soil, forest type, stand development).
- Presence of diseased/dead elms.
- Presence of *Armillaria* root rot on dead elms.
- Presence of elm regeneration.
- Presence of mature, healthy elms.
- Amount of damage, on the basis of number of dead elms.

Set of data collected for every living sample tree:
- Stem diameter and height.
- Amount and location of disease symptoms (wilting of leaves and twigs, dead branches, epicormic shoots).
- Progression of discoloration of the sapwood on dead or wilting branches of living sample trees.
- Nearby presence of elms infected or dead, from which the infection may be transmitted by root graft, is also noted. For each dead elm (both sample tree and nearby one) the way of spread of symptoms (discoloration of the sapwood) on the stem and the presence of galleries of bark beetles is pointed out. In addition, samples of discoloured phloem are collected, to obtain pure cultures of *Ophiostoma* spp.
- Quantification of the damage, performed on the basis of the percentage of the foliage loss and dieback of branches and twigs.

WITCHES' BROOMS OF SILVER FIR

Melampsorella caryophyllacearum is a heteroecius rust fungus which produces witches'-brooms on the branches and swellings on the stems of silver fir (*Abies alba*). The disease is widespread everywhere in the Italian fir stands, with a preference for stands with high summer rainfall or wet sites (CELLERINO, ANSELMI 1992). In FVG district there is common knowledge that a high percentage of the fir trees is diseased in particular stands, but data about the real incidence of the disease are lacking.

Causal agent: *Melampsorella caryophyllacearum*

Host tree: *Abies alba*

Purpose of the survey:
- Assess the incidence of the disease in the silver fir stands.
- Identify the stand types correlated with high incidence of disease.
- Evaluate the loss of timber caused by the presence of swellings on stems.

Beginning of survey: 1998

Season of survey: At any time from March to November.

Method of survey:
- Because the infection is perennial and consequently there are not clear changes in the disease year by year in a given stand, the survey is based on temporary plots. Every plot covers an area of 2,500 m^2.

Survey sheet: The data are collected by the standard BAUSINVE survey sheet.

Set of data collected for every plot:
- Stand parameters (e.g. elevation, exposure, soil, forest type, stand development...).
- Total number of silver firs growing in the plot.
- Number of silver firs with swellings on the stem.
- Presence of witch's brooms.
- Incidence of disease on the basis of the percentage of silver firs with swellings on the stem.

OAK DECLINE

Oak decline is associated with a variety of etiological agents (FRANCESCHINI et al. 2000; TIBERI 2000). At the present time, the survey is restricted to pedunculate oak (*Quercus robur*), the prevalent oak species in the district. Moreover *Quercus robur* has been chosen because it appears to be the species most affected by severe decline events in Northern Italy (RAGAZZI et al. 2000).

Purpose of the survey:
- Understand the trend of decline of *Q. robur* in the FVG.
- Identify the characteristic set of *Q. robur* decline symptoms.
- Identify most recurring biotic agents associated with *Q. robur* decline.

Beginning of survey: 2000

Season of survey: Once a year in summer, no later than middle of July.

Method of survey:
- Permanent plots. Every plot includes ten mature oak trees with fully visible crown.

Survey sheet:
- Standard BAUSINVE survey sheet, together with photographic documentation of crown decline.

Set of data collected for every plot:
- Stand parameters (e.g. elevation, exposure, soil, forest type, stand development...).

Set of data collected for every tree:
- Species of harmful insects and fungi identified at the time of the survey.
- Photographic documentation of crown status.
- Quantification of the damage, performed on the basis of the percentage of the foliage loss and dieback of branches and twigs.

CROWN WILT OF PINE

In FVG district the occurrence of *S. sapinea* as an agent of mortality in artificial *Pinus nigra* stands was detected since the seventies. Other pine species growing in the secondary stands of the district were also attacked by the disease, but usually were not seriously damaged (FRIGIMELICA 1997).

Causal agent: *Sphaeropsis sapinea*

Host tree: *Pinus nigra*

Purpose of the survey:
- Evaluate the trend of the disease in Austrian pine stands, in relation to the climatic conditions which took place during the monitoring period.
- Assess the infection spreading in each diseased tree.

Beginning of survey: 2000

Season of survey: Once per year in autumn, between September and October, when the disease symptoms are more evident.

Method of survey:
- Permanent 400 m^2 large plots were established in young, mature and old Austrian pine stands. Every living tree growing up in the plots is individually numbered. In the year 2000, at the beginning of the survey, the trees which were already dead were counted but not numbered.

Survey sheet:
- The data are collected filling two different kind of survey sheet, the standard BAUSINVE sheet and another one for specific monitoring in the investigated plot.

Set of data collected for every plot:
- Stand parameters (e.g. elevation, exposure, soil, forest type, stand development...).
- Number of living, healthy trees.
- Number of living trees with disease symptoms.
- Quantification of the damage, performed on the basis of the number of dead trees.

Set of data collected for every living tree:
- Stem diameter and height.
- Amount and location of dead branches.
- Amount and location of wilting shoots.
- Quantification of the damage, performed on the basis of the percentage of the foliage/shoot loss and percentage of dead branches.

Set of data collected for every dead tree:
- Location and progression of blue-staining wood on trunk and branches.
- Presence of insect damage
- Presence of root-rot disease associated agents.

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Distribution of insect by trophic groups in mid-aged pine stands of Lithuania

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Objective of the study was to examine distribution of insects by trophic groups in different elements of forest biocenosis. Insects were collected in 1991–1997, in *Pinetum vaccinossum* type, 50–70 years old pine stands which make 22% of all Lithuanian forests. Pitfall traps were used to collect litter insects, entomological sweep net was used to mow grass layer, stem insects were collected from bark samples, canopy living insects were sampled from model branches and night flying insects were trapped using light traps.

Phytophagous insects make major part of grass layer (67%) and pine canopy (61%) insects. In pine crown 79% were sucking and 21% – defoliating phytophagous species. *Cinara pineti* Mordv. (Homoptera) dominated between sucking phytophages. In grass layer suckers (mostly from Homoptera and Hemiptera orders) make only 7% of all insects. Phytophagous insects were found to make 58% of all night-flying insects, and only 1% of them were feeding on needles; dominated grass, shrub and broadleave trees consuming insects. In litter only 3% of insects could be ascribed as phytophagous.

Xylophagous beetles dominated in bark samples making 80% of all insects. They were representatives of Scolytidae, Curculionidae and Cerambycidae families.

Entomophagous insects were dominating in forest litter making 92% of all collected insects and mainly representing Carabidae family. The abundance of predators in litter indicate that they effect not only litter phytophages, but successfully pick up insects descending from trunks and canopy. Only very small part of pine stand insects overwinter in crowns, majority go down to the litter, and the contact with entomophagous insects is inescapable.

In pine crowns predating insects make 31%, in grass entomocomplex – 23% of all insects, dominated by representatives of Formicidae family; in light trap catches there were 19% predators and order Neuroptera was dominating. Parasitic insects make 10% of all insects in light trap catches, 8% of grass, 7% of bark and 2% of crown entomocomplex.

However, all pine forest insects are tightly bound together, and ratio of various trophic groups may vary and change under the influence of biotic and/or abiotic factors.

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The response of *Ips typographus* (L.) populations in polluted and non-polluted spruce stands in the Carpathian Mountains region

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ABSTRACT: The poster presents the results of a research project realised in the Carpathian Arch by an international team composed by active IUFRO WP 7.03.10 members. The abundance and dynamics of *I. typographus* populations was evaluated in above 60-year old Norway spruce stands occurring on more and less polluted sites in five countries within the Carpathian range. Bark beetle populations were estimated using the volume of infested trees and the captures of beetles in pheromone traps and through the dissection of infested trees. The possible role of industrial pollution as a predisposing factor to attack by this species is discussed.

Ips typographus (L.) (Coleoptera: Scolytidae), a serious pest of spruce monocultures in Eurasia causes recurring outbreaks that may encompass thousands of square kilometres and result in the death of millions of spruce trees. Like most bark beetle species, *I. typographus* is not always an aggressive or primary killer of healthy trees, however outbreaks can develop rapidly in spruce stands that are damaged by wind, frost, snow, drought, or air pollution.

In 1998–2000 the international research on the response of *I. typographus* to various air pollution level was carried out in the Carpathian Arch, in 5 European countries. This research was a part of an international study within the IUFRO SPDC project "Effect of Forest Health on Biodiversity with Emphasis on Air Pollution in the Carpathian Mountains". The bark beetle research team was composed mainly by the scientists actively involved in the IUFRO WP 7.03 10.

The objective of the presented study was to evaluate the response of bark beetle populations to disturbance interactions related to environmental stresses with emphasis on air pollution.

METHODS

- The 50-ha study plots have been selected and established in Norway spruce stands in relation to previously estimated ozone level (BYTNEROWICZ et al. 1998); a pair of plots (more and less polluted) was selected in each country (Table 1).
- The volume of sanitary cuttings in 5-years period was used as an index of tree mortality.
- *I. typographus* beetles were captured in sets of 10 Theysohn traps baited with Pheroprax®.
- Infestation density in 4 half-meter sections (I – at the base of the stem [0.5–1.0 m above ground], II – between the stem base and the crown base, III – just below the base of the crown, IV – in the middle of the crown) was estimated on dissected trees.
- The infestation density of *I. typographus*, expressed as the number of mating chambers per 1dm^2, was determined.
- The presence of other bark and wood-boring species was recorded.

The plots from the whole set have been ranked into two groups: "high" and "low" regarding the O_3 level. The relationships between air pollution (mainly O_3) level and spruce bark beetles' populations were examined and discussed.

Table 1. Characteristics of stands in 10 research plots in the Carpathian Mountains

Country	Locality (number)	Pollution level	Altitude (m)	Exposition	Spruce (%)	Stand age	O_3 concentrations (µg/m³)		
							1998	1999	1997–1999
Czech Republic	Velká Javorina	less poll.	720–740	SE	100	62–80	79.0	73.0	75.3
	Bílý Kříž	more poll.	700	N	60	58–90	89.0	80.0	84.7
Slovak Republic	Hriňová	less poll.	680–750	NE, E	95	70	127.0	104.0	111.7
	Novoveská Huta	more poll.	700–800	E, NE	80	80	123.0	106.0	113.7
Poland	Tatry	less poll.	1,100	E	100	100	79.0	78.0	78.7
	Bieszczady	more poll.	600–700	E	100	100	88.0	93.0	91.0
Ukraine	Sinevir	less poll.	1,050	S	mixed	45–120	84.0	78.0	73.0
	Mokhnatske	more poll.	950	S	mixed	55–80	104.0	94.0	85.0
Romania	Rarau	less poll.	978	N	60	90	72.0	62.0	65.0
	Stana de Vale	more poll.	1,270	W	80	100	91.0	92.0	94.3

RESULTS

1. Tree mortality – sanitary cuttings:

- no statistically significant differences have been found between the groups of plots belonging to "high" and "low" group;
- the relationship between these groups was variable depending on the altitude: below 800 m, higher volume of sanitary cuttings was related to "high" ozone level, whereas above 800 m, the situation was reversed.

2. Captures in pheromone traps:

- higher values were recorded in the plots ranked as "more polluted" ($F = 49.39$***);
- higher captures were recorded in the plots with "high" ozone level ($F = 5.34$*).

3. Infestation density on standing trees:

- in the most cases, the mean infestation densities from the dissected trees were higher in "more polluted" than in "less polluted" areas (statistically n.s.);
- statistically significant differences occurred between "low" (0.45 m.ch./dm²) and "high" (0.60 m.ch./dm²) plots (ANOVA $F = 7.30$**);
- the difference was significant in 1998 ($F = 12.20$**) but not in 1999.

4. Co-occurrence of the other bark and wood boring insects:

- in total the occurrence of 16 bark and wood-boring insect species has been found (Scolytidae – 10, Cerambycidae – 4, Curculionidae – 1, Buprestidae – 1); the association of 3 species: *I. typographus*, *I. amitinus* and *P. chalcographus* was the most frequent one;
- the infestation densities of *I. typographus* decreased significantly in sections that also were infested by *P. chalcographus* (ANOVA $F = 15.27$***) or in the sections that were infested by all 3 species (ANOVA $F = 5.07$*).

CONCLUSIONS

- Analyses of the data indicate the differences in the research localities between all indices of bark beetle populations and the indices for pollution ranked as either "more polluted" vs. "less polluted" or as with *high* and *low* ozone concentrations.
- This relationship, however, is not linear, which is resulting from the Spearman rank correlation coefficients.
- Further investigations are needed that should include a larger number of research localities representing a range of site and stand conditions.
- This research should also recognize the changes in insect communities that occur over time and how they are related to measures of environmental pollution.

The above materials have been presented during the NATO Advanced Research Workshop at Stará Lesná (Slovakia), May 22–26, 2001; the full paper containing the results and conclusions will be published in the book of proceedings (in print).

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Fungi associated with the decline of black locust (*Robinia pseudoacacia* L.) plantations in Hungary

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ABSTRACT: From the pathological material of black locust trees showing the symptoms of wilting of the foliage or canker of the bark the following fungi species was isolated: *Cucurbitaria elongata* (Fr.) Grev., anamorph: *Camarosporium robiniae* (Westend.) Sacc., *Diaporthe oncostoma* (Duby) Fuck., anamorph: *Phomopsis oncostoma* Höhn., *Nectria cinnabarina* (Tode. ex Fr.), anamorph: *Tubercularia vulgaris* Tode., *Fusarium avenaceum* (Fr.) Sacc., *Fusarium lateritium* Nees., *Fusarium semitectum* Berk. & Rav., *Fusarium solani* (Mart.) Sacc., *Fusarium sulphureum* Schlecht. (syn. *Fusarium sambucinum* Fuckel f. 6 Wollenw.), *Massaria anomia* (Fr.) Petrak, *Verticillium* sp. The results of the provocation infections of one-year old black locust seedlings showed that only *Massaria anomia* and *Fusarium solani* has insignificant pathogenecity on this tree species. In the cases of *Nectria cinnabarina* and *Fusarium sulphureum* the shoot above the point of inoculation died in 2–4 weeks in the case of 30% of the seedlings infected with *Nectria cinnabarina*. In the case of *Fusarium sulphureum* the rate of the dead plants was lower, but the withering of lateral shoots was observed on each seedlings infected with this fungus in 2 weeks. Very often only the apical shoot survived, but the growth rate of this shoots decreased considerably. The dimensions of necrosis in the phloem caused by the infection of this fungus were equivalent to 80 % of the mean plant high. The *Fusarium semitectum* isolated from withered black locust tree also caused cankers on significant area and were characterized a depressed and very dark-coloured bark. In the terminal season penetration infection were initiated on fresh green shoots and on older bark surfaces without opening a gap into the stem. It was found that *Fusarium sulphureum* and *Fusarium avenaceum* were the most successful fungus species among the tested ones to penetrate healthy bark tissues.

The black locust (*Robinia pseudoacacia* L.) native in Atlantic North America was introduced in Hungary in 1710. It is actually one of the most important tree species for the forestry in Hungary, occupying about 20% of the forest area in the country and this rate will probably increase in the future thank the reprivatization and the growing demand for its wood.

During about the 300 years since its introduction more and more indigenous pests and pathogenes attacked and colonized this tree species, which process was facilitated by frost susceptibility of black locust and the establishment of pure stands on large areas regardless of the site conditions. Among the pests *Parthenolecanium corni* Bché. living on weakend shoots of black locust growing in dry sites caused the first panic in professional circles at the end of 19th century. Nowadays the surprising fast spreading of two introduced leaf miner moth (*Parectopa robiniella* and *Phyllonorycter robiniella)* endangers the future healthy state of black locust stands. Among the pathogens the following species were best known: *Robinia mosaic virus* and *Phloeospora robiniae* (Desm.) Höhn. on leaves, *Nectria cinnabarina, Diaporthe oncostoma* and *Cucurbitaria elongata* on shoots and branches, *Perenniporia fraxinea* (Bull. Ex Fr.) Ryv., *Phellinus robustus* (P. Karst.) Bourd. Et Galz., *Laetiporus sulphureus* (Bull. Ex Fr.) Murill and *Armillaria* species as wood decaying agents in stem.

In recent years, some health problems have appeared in young afforestations and in certain stands of different age, as well. The most typical symptoms are: foliage withering in the spring, die-back of the branches and the canker of the bark.

MATERIAL AND METHODS

The symptoms of the decline as well as the fungi associated with and the factors influencing the decline are discussed on the basis of the findings of the investigations carried out in plantations, shelterbelts and treelines situated in Győr-Moson-Sopron, Pest, Somogy and Szabolcs-Szatmár-Bereg counties in the period of 2000–2001.

The fungi were isolated from diseased twigs and branches after placing surface-sterilized bark or wood chips on PDA medium in agar plates taken from the margin of the dead and healthy tissue. In other case the branches bearing mature fungal fruit bodies were incubated in wet chamber for 2–4 days. The method of isolation was to transfer small section of fruit bodies without the host tissue or place inoculum from spore mass to the PDA. The identifi-

cation on the fungi was done on the basis of microscopical morphological characters of fruit bodies and spores from fresh plant material, using several identifications works (BÁNHEGYI et al. 1985; BARR 1978; GROVE 1935; MUNK 1957; PETRESCU 1960). The identification of *Fusarium* isolates was based on morphological and cultural characters on PDA media under natural day–night rhythm in the laboratory at 20–22°C (BOOTH 1971; GERLACH, NIRENBERG 1982).

Inoculation experiments were carried out on 1-year old pot-grown seedlings from 17th of April in 2001. The plants were inoculated in groups of 15 with a total of 9 fungal strains. The plants were irrigated three times a week to filed capacity to ensure appropriate water availability. At the time of inoculation the mean plant size was 50 cm tall with a 8 mm stem diameter measured 10 cm above the substrate level. The superficial wound (5 mm in diameter) was made on the bark of each plant at 10 cm above the ground level with sterile scalpel. The mycelial plug obtained from the margin of a fungal colony was placed in the wound, with the mycelium facing the stem, and the wound was wrapped with Parafilm®. 15 additional control plants were treated similarly with sterile PDA plugs. The lengths of vascular necrosis were measured upwards and downwards from the point of inoculation after three months.

The inoculation by contact were carried out on different bark surfaces (on green shoots, on greenish-brown shoots and on older brown bark surface in 5 replication) of 2-year old seedlings in August of 2001. The evaluation of the experiment was made after 2 weeks.

RESULTS AND DISCUSSION

By different symptom arrays the following fungus species were isolated and identified.

- Where the symptom was that older trees died shortly after the bursting of buds in the spring, the fungi isolated were *Fusarium semitectum*, *Fusarium sulphureum* and *Verticillium* sp. It is likely that the wood-boring insects (chiefly long-horn beetle larvae in the wood and moth larvae in the bark) occurring on each investigated stem played a central role in the infection. *Fusarium solani* also was isolated from a withered tree infected by *Fusarium semitectum*, but this fungus probably lived in the xylem as a secondary wound parasite and did not contribute to the triggering of the withering symptoms.
- On hill-crests and at dry sites in general, where the symptom array consists of the die-back of the crown top and the grey discoloration of the branches in the upper part of the crown, the fungi isolated were *Cucurbitaria elongata* in most of the cases, but with a lower frequency of occurrence there were also *Phomopsis oncostoma* and *Nectria cinnabarina* as well as *Massaria anomia*. Under the dead top part of the crown a dense branch formation was often observed. These infected trees were shorter than the noninfected trees. From a dead branch attacked by the *Xyleborus dispar* the *Fusarium lateritium* was isolated. The sporodochia were near the gallery, so I suppose the beetle has a vector role in the spreading of the fungus.
- The most frequent problem in black locust stands in terrain depressions and in valleys between hills is canker formation on the stem and on the branches. This type of canker formation mostly occurs around the stipule-thorns and at the basal section of lateral branches. These bark die-off phenomena were earlier thought to be caused by frost, only. Anyhow, according to the findings of my investigations, the fungus species *Phomopsis oncostoma*, *Nectria cinnabarina*, *Fusarium avenaceum* and *Fusarium sulphureum* play a key-role in the development and aggravation of the symptoms. On the base of field observations the latter two species are able to infect the young shoots through lenticels as well. The most of the infections happen through the fissures at the bifurcation and the spots of the bark caused by frost. The characteristic symptoms of the canker caused by *Fusarium sulphureum* is the whitish-yellow mycelia developing on the surface of the infected bark and wood.

  The *Phomopsis oncostoma* first infects the thin lateral shoots weakened or killed by frost, and later on it infects even through the intact bark surfaces at the base of the lateral shoots causing lens-shaped necrosis and canker respectively. This canker if occurring on the stem of young trees (2 or 3-year old ones) might even make the trees break in two, since the fungi also attack the xylem.
- In nurseries, in the case of one-year old seedlings the most frequent symptom is that the bark dies off at the base of the stem all around, right above the soil surface. From these necroses the *Nectria cinnabarina* and the *Fusarium avenaceum* were isolated. While investigating a case of a one-year old black locust plantation which completely died, in addition to the *Fusarium avenaceum* and *Fusarium solani* also a *Verticillium* species was isolated, which caused necroses on the roots and attacked the root-wood as well.

The results of the provocation infections of two-year old black locust seedlings showed that the following species are able to cause considerable necrosis in living bark and phloem among the tested fungus species: *Fusarium sulphureum*, *Fusarium avenaceum*, *Fusarium semitectum*, *Fusarium lateritium*, *Nectria cinnabarina*, *Phomopsis oncostoma*, *Verticillium* sp.

In the cases of *Nectria cinnabarina* and *Fusarium sulphureum* this necrotic process was very fast. The part of the shoot situated above the point of inoculation died in 2–4 weeks in the case of 30% of the seedlings infected with *Nectria cinnabarina*. The wilting of the seedlings followed the production of the bright red-coloured sporodochia on the surface of the infected bark. On the stems of the survivor seedlings deeply depressed cankers appeared with 5.5 cm length.

In the case of *Fusarium sulphureum* the rate of the dead plants was lower, but the withering of lateral shoots was observed on each seedlings infected with this fungus in 2 weeks. Very often only the apical shoot survived, but the growth rate of this shoots decreased considerably. In the beginning the infected bark was orange brown-coloured, but later on the edge of the necrosis a very dark discoloration was observed on significant areas spreading upwards from the point of infection. Mean vascular necrosis were the largest of all the inoculation treatments (36 cm). The dimensions of these lesions were equivalent to 80–90% of the mean plant high. The fungus attacks the xylem as well and it spreads very fast upwards with the help of water flow. In the infected xylem a long, drop shaped black discoloration can be seen. Two month after the infection a lot of orange coloured sporodochia appeared on the surface of infected bark near the point of infection.

The *Fusarium semitectum* also caused cankers on significant area and were characterized a depressed and very dark-coloured bark. The mean necrosis length is 7.7 cm. The fungus did not cause the withering of shoots, but the growth rate of the seedlings decreased as well.

The cankers caused by *Fusarium avenaceum* were strongly apparent as well, but not so big as in case of the three aforementioned species. They measured 3.3 cm. The infected bark was red-brown coloured with a dark, narrow outline.

In the case of *Fusarium lateritium* usually only little external discoloration of the bark was observed. In some cases a 1–2 cm long longitudinal split appeared on the bark above the point of inoculation. In spite of this fact sometimes there was a significant necrosis (14 cm) in the phloem. The mean length was 4.3 cm.

The feature of cankers caused by *Phomopsis oncostoma* after one month was only a pale discoloration and the depression of the infected bark, but later it became yellowish brown with dark brown contour. The mean length of lesions was 1.8 cm.

The symptoms of the infection caused by *Verticillium* sp. slowly developed. On the infected bark a pale liver coloured discoloration was observed. The mean necrosis length was 1.9 cm.

In comparison with the other fungi the remaining inoculated strains (*Fusarium solani* and *Massaria anomia*) produced small bark canker limited to 1–2 mm around the point of inoculation and the relatively minor lesions soon healed up.

In the terminal season penetration infection were initiated on fresh green shoots and on older bark surfaces without opening a gap into the stem. It was found that the *Fusarium sulphureum* and *Fusarium avenaceum* were the most successful fungus species among the tested ones to penetrate healthy bark tissues.

The results of the provocation and penetration infection are shown in the Table 1.

In all cases of the fungi tested in the provocation infection the lateral shoots growing from that section of the stem situated under the place of infection and the shoots growing after the cutting back of the seedlings were healthy.

Cucurbitaria elongata, *Diaporthe oncostoma*, *Massaria anomia* are common on black locust in Hungary and in other European countries as well. Data about pathogenical character of these fungi were published in Romania (PETRESCU 1960), Serbia (MARINKOVIC 1969) and Hungary (SZABÓ 2000) and their pathogenecity was confirmed by inoculation experiments in Greece (MICHA-

Table 1. The results of provocation infection carried out on one-year old black locust (*Robinia pseudoacacia*) seedlings

Taxa	Infection through the gap of the bark and phloem (n = 15) (evaluation after 3 months)					Penetration infection (n = 5) (evaluation after 2 weeks)		
	The number of seedlings showing the following mentioned symptoms (pc)			Average length of the necrosis (cm)		The number of successful infection		
	Dieback of the apical shoots above the point of infections	The withering and dieback of the lateral shoots and lateral branches	Canker	On the bark	In the phloem	On green shoots	On brownish green shoots	On brown bark
Control	0	0	0	0.6	0.6	–	–	–
F. avenaceum 14	0	0	15	2.9	3.3	4	3	3
F. lateritium 1	0	0	4	1.7	4.3	0	0	0
F. semitectum 2	0	0	15	4.7	7.7	2	1	0
F. solani 1	0	0	0	0.8	1.1	0	0	0
F. sulphureum 4	2	13	13	10.1	36.2	5	5	5
Massaria anomia 1	0	0	0	0.7	0.7	0	0	0
Phomopsis oncostoma 3	0	0	9	1.6	1.8	1	0	1
Tubercularia vulgaris 2	3	0	12	4.0	5.5	2	2	1
Verticillium sp.	0	0	0	1.7	1.9	0	1	0

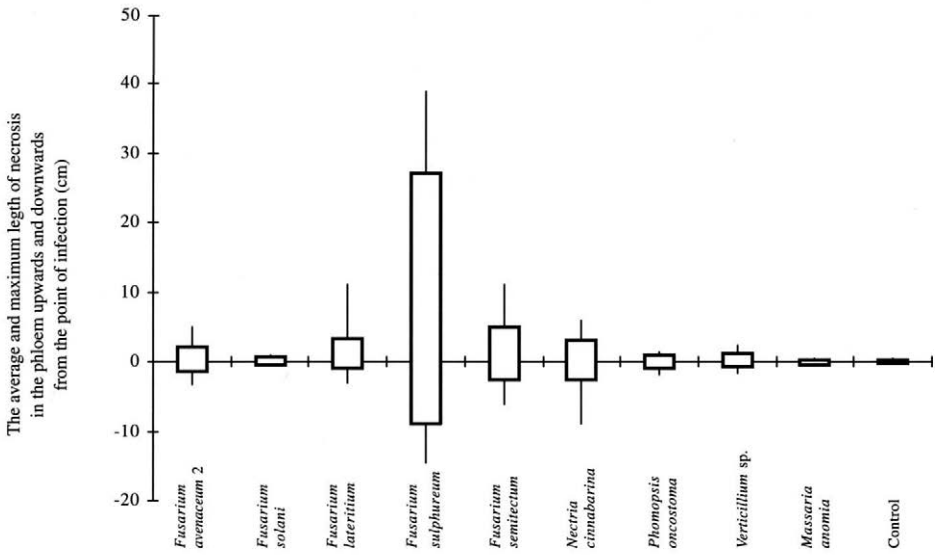

Fig. 1. The results of provocation infection of 1-year old black locust (*Robinia pseudoacacia*) seedlings after 3 months

LOPOULOS et al. 1999). In Italy experimental inoculations by wounds showed that the *Phomopsis oncostoma* have a stronger pathogenic action on weakened plants. The inoculation by contact have never reproduced the disease (RIBALDI 1954).

The *Nectria* canker causing serious problems in nurseries and plantations was reported from Hungary and other countries as well (IGMÁNDY 1965; VAN SICKLE 1974).

The *Fusarium* canker probably is not a new disease in black locust stands. *Fusarium sambucinum*, *Fusarium avenaceum* and *Fusarium lateritium* were reported from England as a pathogenes causing stem canker on two-year old *Robinia pseudoacacia* seedlings (TALBOYS, DAVIES 1983). *Fusarium oxysporum* and *Fusarium solani* were also found as a pathogenic fungi of canker of black locust in China (HONG, JI 1996). *Fusarium solani* f. *robiniae* was shown as a casual agent of twig blight of *Robinia pseudoacacia* in Japan as well (MATUO, SAKURAI 1965). The occurrence of *Fusarium lateritium*, and *Fusarium sulphureum* on black locust is documented in Hungary (UBRIZSY 1952), but without mentioning its pathological role. SZABÓ (2000) in her investigations showed that *Fusarium avenaceum* and *Fusarium lateritium* proved to be wound pathogenes infecting the host at the lesions caused by frost and their presence and activity resulted the perennial canker deformations of the black locust stems. Any literature data was not found about the *Fusarium semitectum* causing the withering symptom of black locust.

In case the decline of black locust stands partly caused by the aforementioned pathogenes the most important predisposing factors seem to be the unfavourable site and climate condition, the repeated shooting of the host, which decrease the vitality of the trees. The inciting factors are the frost causing fissures and lesions of the bark and the death of young shoots, the drought, the attack of wood boring insects and the game damage (browsing and fraying). In the case of shelter belts and tree lines the burning of the grass is one of the most important factor. The role of the green pruning of the lateral branches is problematical from the point of view of spreading of pathogenes (mainly in the cases of *Fusarium sulphureum* and *Fusarium avenaceum*).

In forestry conditions the preventive control has the most important role. We have to avoid the establishment of black locust stands on unsuitable sites (frost hollow, dry sites on the crests of sand hills). After planting we have to cut back the seedlings. Otherwise they have a lower resistance to drought due to the disadvantageous foliage-root rate. The young 1–4 year old stands are the most susceptible to frost, because the fast growing green shoots have a longer growing season. So the stands of this age growing on suitable sites accidentally can suffer serious frost damage as well due to an extreme weather. In this case we have to cut back the damaged stand and we have to carry out root ripping in the given area. The fast growing root-shoots soon compensate the lag and if they manage to avoid serious frost in the future these stands will be more healthy and give better stem quality than the untreated stands suffering from several pathogens.

It is not only the economic significance of black locust that makes it necessary to study the pathogenes occurring on this tree species. The black locust spreading rapidly with vegetative regeneration through root-shoots endangers the existence of several native forest associations in nature reserves. Since the application of chemi-

cals is forbidden in these reserves these invading black locusts ought to be controlled by an efficient species specific pathogene. In my future work I examine the applicability of *Fusarium sulphureum* and *Fusarium semitectum* for the controlling of black locust sprouts.

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Serious damage in turkey oak (*Quercus cerris*) stands in Hungary caused by frost effect (sun scald) and *Armillaria* attack

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ABSTRACT: In the beginning of November of 1993 a sudden and considerable cooling (–15°C) caused serious bark damage in the turkey oak (*Quercus cerris*) stands of Hungary – chiefly in young and middle-aged stands. The bark depression occurred at the stem base and damaged surfaces covered by callus were observed. The length of the scalds varied between a few centimetres and two metres. The base of the stem was often swollen, but in some cases the bark and the phloem die all around the stem and the stem base remains naked. On the surface of the scalds often rhizomorphs of *Armillaria* species could be found. In the given area (Csővár) the *Armillaria gallica* was identified and in the young stems the *Botryosphera stewensii*, anamorph: *Diplodia mutila* made the thin bark and the young phloem die. The rate of the damaged trees was much higher on the southern slopes, crests and at the forest edges (20–50% (80%)) than on the northern slopes and at the valley bottoms (0–10%), so the sunshine had significance in the development of the bark damage. Probably the rapid melting of tissues after being frozen caused the damage and injuries i.e. sunscalds of the tissues.

The turkey oak (*Quercus cerris*) plays a significant role in the forest utilisation of southern slopes in the hilly and mountainous regions of Hungary, occupying about 11.4% of the forest area in the country. In the stands situated at the cool and wet sites (on northern slopes and at valley bottoms) the *Inonotus nidus-pici* and frost crack cause serious damage.

In the recent years, chiefly in young and middle-aged stands several tree individuals were found on which bark depression occurred at the stem base and damaged surfaces covered by callus were observed. The length of the scalds varied between a few centimetres and two metres. The average length was about 20–40 cm. The base of the stem was often swollen, but in some cases the bark and the phloem die all around the stem and the stem base remains naked. On the surface of the scalds often rhizomorphs of *Armillaria* species could be found. Only sometimes did these trees show the symptoms of the scanty or wither foliage, nevertheless they were sensitive to windfall due to the intense white rot caused by *Armillaria* species.

In 1998, intensive surveys were carried out at the Forest Management Unit of Vác in order to determine the causes and the degree of this damage. On the basis of the results of annual ring analysis it was concluded that the bark died in 1993 in all cases. The rate of the damaged trees was much higher on the southern slopes, crests and at the forest edges (20–50% [80%]) than on the northern slopes and at the valley bottoms (0–10%). The trees of the dominant storey and younger stands also seemed to be more susceptible to this damage. The direction of the scalds on the stems did not show any regulation. In the given area the *Armillaria gallica* was identified and in the young stems the *Botryosphera stewensii*, anamorph: *Diplodia mutila* made the thin bark and the young phloem die. The identification of the fungi was done of the basis of morphological characters of fruit bodies and cultures in the case of *Armillaria gallica* (Guillaumin et al. 1985; Kile, Shaw 1991) and microscopical morphological characters of fruit bodies and spores in the case of *Diplodia mutila* (Vajna 1986).

The data supplied by the Meteorological Station of Balassagyarmat have shown, that in 1993 the unusually warm, rainy October and early November was followed by a sudden, considerable cooling, starting from November 10th. Within eight days the daily minimal temperature dropped from +9°C to –16°C. When the cooling reached the temperature about 0°C, it snowed in large quantities (34 mm), but after this, a clear and cloudless weather prevailed with daytime temperature up to +3°C, and night temperature about –16°C.

On the basis of the survey and the meteorological data it can be claimed, that the cause of this damage was the sudden frost, which probably found the cells of trees in activity. The trees of the dominant storey and those trees standing on southern slopes and on crests and ridges

Fig. 1. The symptoms

probably had longer growing seasons due to the dry summer and unusually warm and rainy autumn which might explain the aforementioned results of survey. The warm autumn has a significance in other aspect as well. The frost susceptibility of the trees changes from autumn to spring continuously. The autumn weather with temperature about 0°C induces the increasing of the quantity of absorbing and protecting materials (glucose) in the protoplasma, so this cool period has a significant role in the development of the hardy state of the plants (BERNÁTH et al. 1982; SCHWERDTFEGER 1970; SZALAY 1974). Nevertheless, in the southern slopes the high intensity sunlight could heat up the dark tree trunks. This could force cells to come out of dormancy and become active. The sunlight was partly reflected from the surface of the snow and was subsequently absorbed by the dark-colour bark of the trees further multiplied this heating effect. After sunset the temperature drop killed active cells and the conductive tissues. The rapid melting of tissues after being frozen also causes damage and injuries i.e. scalds to the tissues (HARACSI 1989). In this case the protoplasma of the cells is not able to restore its original structure and can not absorb the water arising in large quantities. Then the lack of oxigen cause the death of the cells.

About the long growing season of turkey oak can be found data in literature. The ripening of secondary shoots and the falling of the leaves of turkey oak happen in late autumn and in the cases of young trees the leaves fall only in spring (GENCSI, VANCSURA 1992). The growth of roots ends later than the growth of the shoots (GENCSI 1980) so the roots are the most susceptible to fast cooling (SCHWERDTFEGER 1970). PREIFER ((SCHWERDTFEGER 1970) and LEWITT (SZALAY 1974) showed that the fast cooling cause more serious damage at the same temperature, than the slow.

This symptom of the turkey oak was known earlier as well, but the cause of this damage was attributed to the grazing (IGMÁNDY 1955). Similar symptoms were observed on chestnut caused by frost effect and *Armillaria* attack (SIMON 1962). On black locust stem frequently can be seen these scalds which can be explain by the long growing season and susceptibility to early frost of this tree.

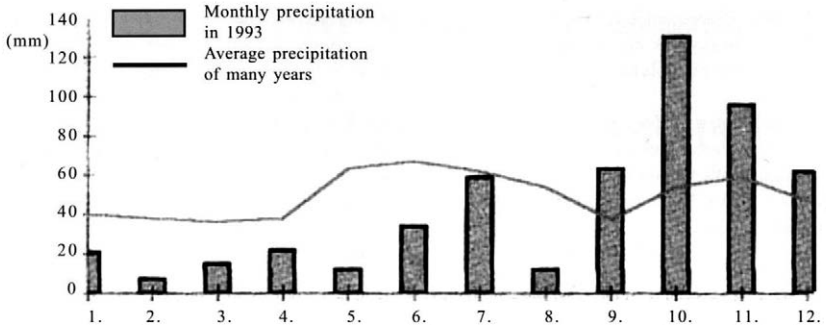

Fig. 2. The change of the amount of monthly precipitation in Balassagyarmat in 1993

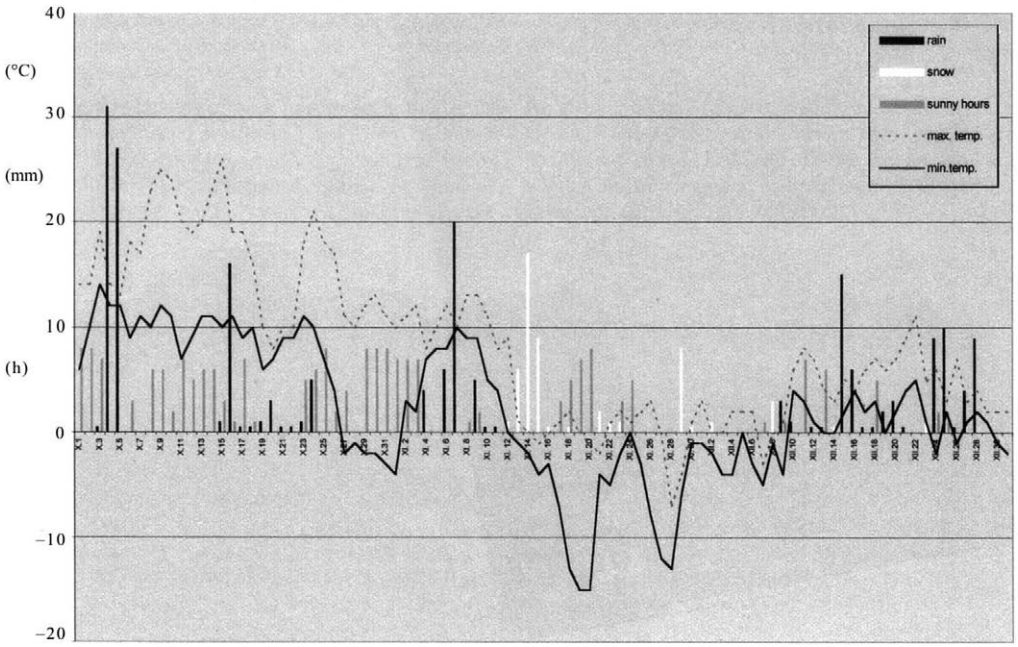

Fig. 3. The change of weather in Balassagyarmat in the period of October–November in 1993

This case has proven that establishing pure turkey oak stands on southern slopes means running a high risk as well. Mixing with Scots pine (*Pinus sylvestris*) and black pine (*Pinus nigra*) probably could decrease the frequency of such damage.

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Current status of bark and wood boring insect pests in Poland

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ABSTRACT: The status of bark and wood boring pests populations in Poland is estimated based on infested dead wood harvested in 2000 during period 1. 4.–30. 9. and till the end of July 2001. The main factors determining volume of dead wood harvested in 2000 were wind and snowbreaks. Damaged trees left in the forests resulted in distinct increase of especially spruce bark beetles activity in spring and summer 2001.

Currently the status of bark and wood boring pests populations in Poland is estimated mainly on amount of the infested dead wood harvested every year during period 1. 4.–30. 9. The main factors determining volume of dead wood harvested in 2000 were wind and snowbreaks which have occurred most frequently especially in northern and south-eastern part of Poland. These events started from snowbreaks in the and of 1999, through snow and windbreaks in winter and early spring in 2000 and finished with hurricanes in June 2000.

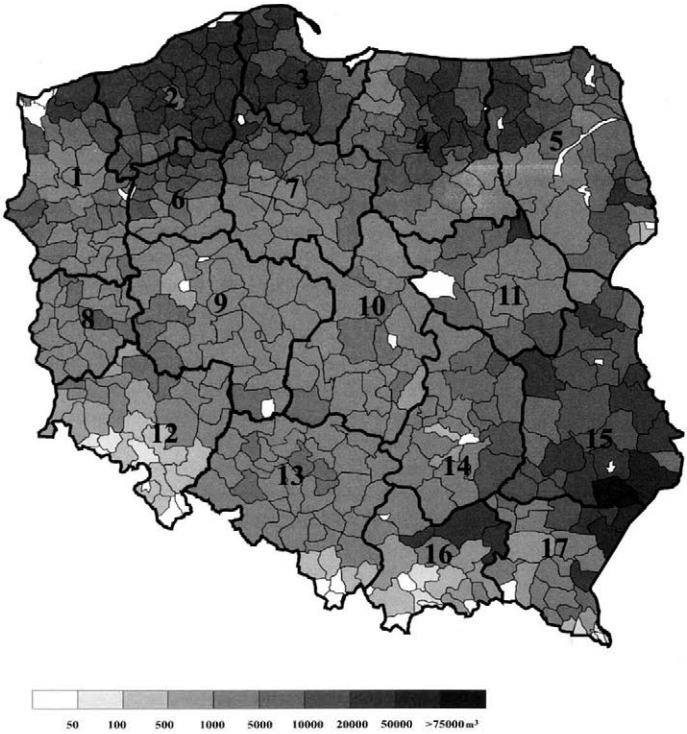

Fig. 1. Sanitary cutting (m^3) in Scots pine stand in forest districts in the period 1. 10. 1999 to 30. 9. 2000

Regional Forest Directories (RDLP):

1 – Szczecin, 2 – Szczecinek, 3 – Gdańsk, 4 – Olsztyn, 5 – Białystok, 6 – Piła, 7 – Toruń, 8 –Zielona Góra, 9 – Poznań, 10 – Łódź, 11 – Warszawa, 12 – Wrocław, 13 – Katowice, 14 – Radom, 15 – Lublin, 16 – Kraków, 17 – Krosno

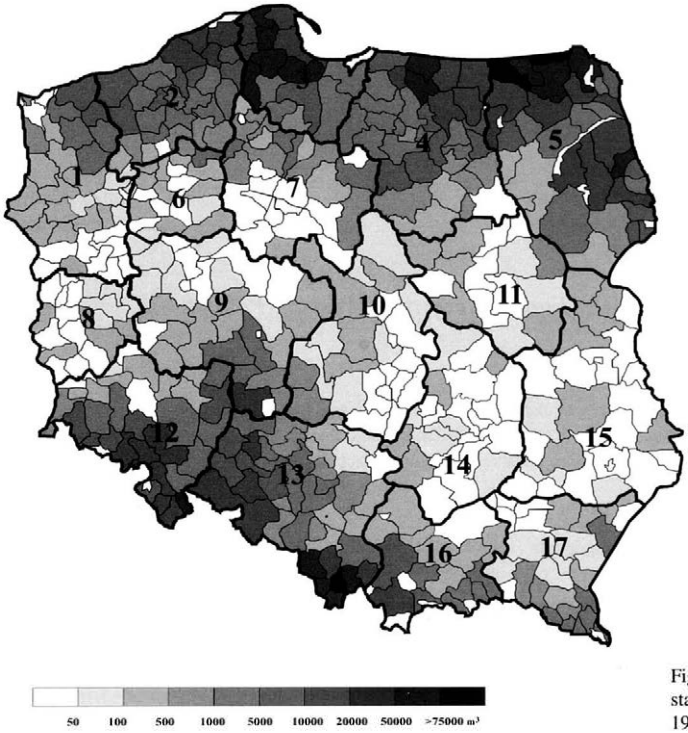

Fig. 2. Sanitary cutting (m^3) in Norway spruce stands in forest districts in the period 1. 10. 1999 to 30. 9. 2000

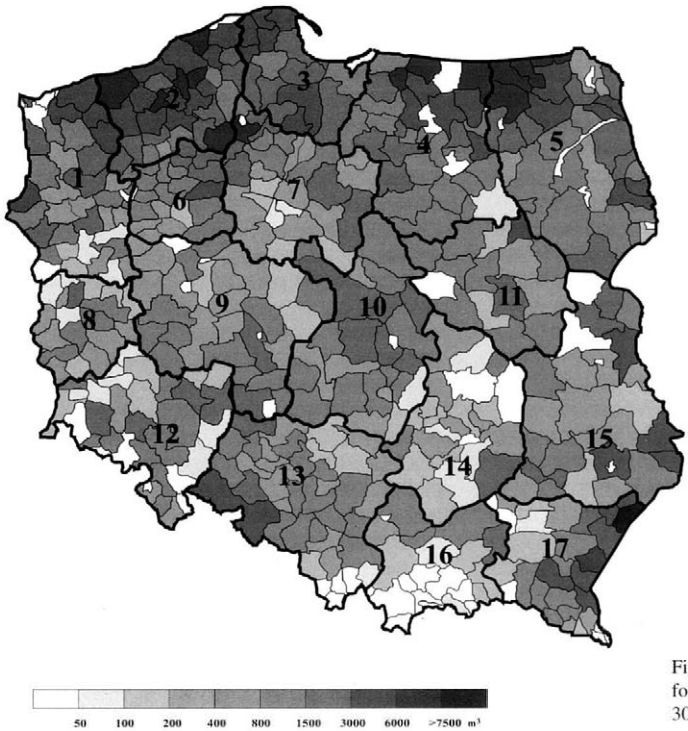

Fig. 3. Sanitary cutting (m^3) in birch stands in forwest districts in the period 1. 10. 1999–30. 9. 2000

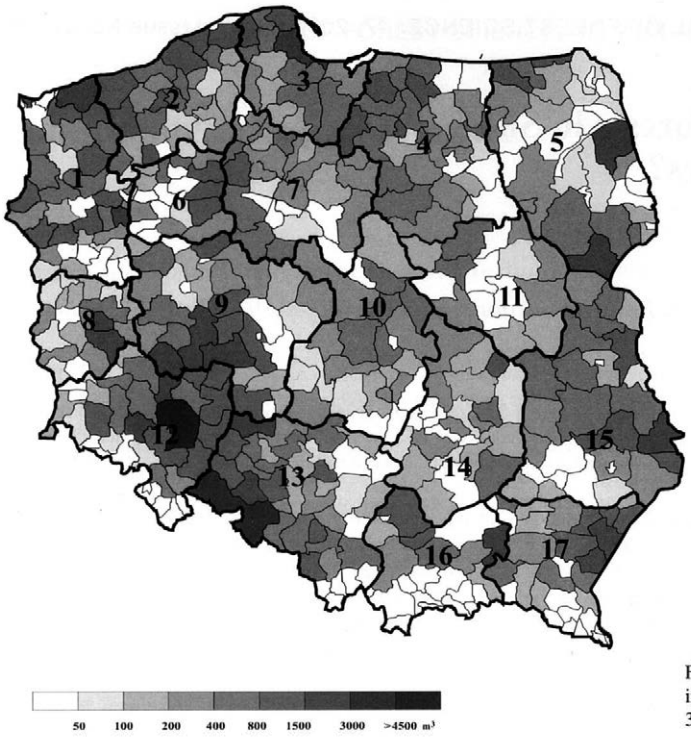

Fig. 4. Sanitary cutting (m³) in oak stands in forest districts in the period 1. 10. 1999–30. 9. 2000

The most of the losses have been recorded for Scots pine (Fig. 1). In the most severely damaged Regional Forests Directories (RDLP) of Szczecinek and Lublin, 0.7 and 0.5 million cubic meters were harvested respectively. In spite of the abundance of the wood material only about 30% of harvested Scots pine wood were infested by secondary pests, mainly *Tomicus piniperda, Acanthocinus aedilis* and *Phaenops cyanea* what indicates that beetle populations were rather small. Nevertheless open spaces and forest edges created by hurricanes are very good habitats for secondary pests development, what accompanied by the favourable weather conditions in May and June 2001 resulted in the increase of pest population (especially *P. cyanea*) in many RDLP.

Losses from abiotic factors have been recorded in Norway spruce forests as well, again mainly in northern Poland (Fig. 2). Only in Białystok RDLP 0.5 million cubic meters were harvested, similar situation were observed also in Gdańsk, Olsztyn and Szczecinek RDLP. However, part of broken and fallen trees left in the forests resulted in distinct increase of spruce bark beetles activity in spring and summer 2001. From Białystok and Olsztyn RDLP increased activity of *Ips typographus* and *I. duplicatus* have been signalised and reflected in dead wood amount harvested in 2001. Only in RDLP Białystok 100,000 cubic meters of infested Norway spruce trees were removed from the forest till the end of July 2001.

In southern mountain part of the country damage from wind and snow where insignificant. The infested spruce volume harvested in 2001 was similar to previous years' volume and for example in Katowice RDLP reached 70,000 cubic meters. Most of the trees were infested by *Pityogenes chalcographus* and *I. amitinus* with the minor role of *I. typographus*.

Snow and wind breaks in northern and eastern Poland concerned also deciduous species. Amount of dead deciduous wood harvested in 2000 reached 1 million cubic meters. However only about 30% of that wood were infested by bark and wood boring beetles. Especially birch suffered from wind and snow damage (Fig. 3) and volumes of dead wood harvested in 2000 were 3–4 times higher than in previous years although with minor part of infested material.

The similar situation was observed in oak forests of many RDLP (Fig. 4) but in case of Wrocław, Radom, Poznań, Zielona Góra the oak decline was associated mostly with the disturbance of soil water level and activity of secondary pests. This phenomenon concerned mainly susceptible for infestation over 80 old stands where increased activity of *Agrilus biguttatus*, *A. sulcicollis* and *Scolytus intricatus* was recorded. *A. biguttatus*, attacking stems and killing living trees appeared to be the most important. It was observed often in mentioned RDLP.

From 1999 a distinct increase in dead wood volume harvested is observed. It is expected that favourable climatic conditions for insects and serious problems with sale of wood will result in increase of bark and wood boring pest hazard.

Is dying of spruce forests in Silesia a result of drought, fungi or bark beetles?

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ABSTRACT: The decline of spruce forest in the eastern part of the Czech Republic is probably a result of several predisposition and immediate damage factors. Now we suppose that in the majority of area the main mortality factor is the attack by honey fungus. Bark beetles often consequently colonize forest stands abundantly attacked by honey fungus.

Declining and dead trees have occurred in thousands of hectares in the eastern part of the Czech Republic since 1997 (agricultural area with forest coverage 9–40%, where Norway spruce is the predominant tree species). In the spring of 2000, almost 20% of spruce did not bud. As a result of intensive logging of declining trees, tree feet are permanently damaged by logging machines. The stand density decreases and forest weeds spread.

In accordance with the Manion's theory, the decline of spruce forest is probably a result of several pre-disposing agents (foreign origin of spruce, soil acidity [pH 4], nutrient deficit origin – low reserve of K and Mg and very low reserve of P and Ca, water deficit – periods of drought during last years, mechanical damage by logging machines, chronic insect – tenthredinids infestation during last 50 years, pathogen damage by honey fungus) and immediate damage factors. The fitness of forest stands decreased by drought is additionally stressed by decreased water-supply as a result of broken roots by drying up of soil. Fungi infection is than obvious. Forest stands abundantly attacked by honey fungus are often consequently colonized by bark-beetles. *Pityogenes chalcographus* and *Pityophthorus pityographus* are the most abundant in the young forest stands while species of the genus *Ips* (*I. duplicatus, I. typographus, I. amitinus*) together with *Pityogenes chalcographus* are predominant in mature forests.

The whole area is probably a mosaic of sites where various mortality factors are of key importance. Now we suppose that in the majority of area the main mortality factor is the attack by honey fungus. But the drought probably kill the trees in some places (or in some periods of year), because syrrocium of honey fungus covers the stem base up to several meters without total decay.

In spite of the intensive forest protection (enormous number of tree-traps and permanent elimination of dying trees), the abundance of bark beetles has increased, but only the control of *I. typographus* is effective. In the future the danger of mass outbreak of bark beetles is possible because of the high number of stressed trees.

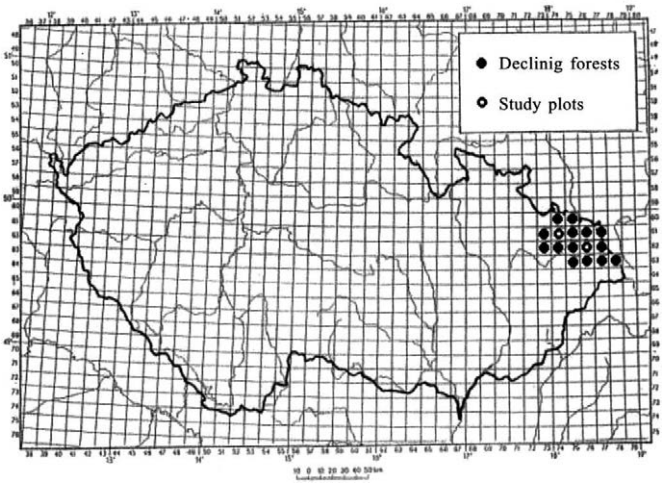

Fig. 1. Occurrence of declining spruce forest in the Czech Republic

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Important Heteroptera on oaks

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ABSTRACT: In 1999–2001 the fauna of Heteroptera on oaks has been observed. Heteroptera have been collected individually under the bark of old oaks, further by means of sweeping, and catching to Malaise traps or to "Geolas" collar traps. In the mentioned period a total of 72 species of Heteroptera of 16 families have been caught. Dominant species have been represented by the genus *Psallus* and the species *Rhabdomiris striatellus*, *Phylus melanocephalus*, *Cyllecoris histrionius*, *Orthotylus tenellus*, *Dryophilocoris flavoquadrimaculatus*. The main occurrence period of these species includes months from April to July. *Rhabdomiris striatellus* and *Cyllecoris histrionius* are regarded as beneficial, zoophagous species, which can regulate populations of leaf-eating pests on oaks, such as *Tortrix viridana*.

Crowns and stems of oaks create very convenient conditions for the wide spectrum of insect fauna representatives, of which also the order Heteroptera has an important place. Many small-sized species of Heteroptera, especially from the family Miridae and Anthocoridae, which has not received adequate attention in the biological forest protection, are predators of harmful insect species.

A thesis on the theme "Forestry important oak-living species of Heteroptera" has a target to clarify the bionomics of the species *Rhabdomiris striatellus* and *Cyllecoris histrionius*. The first phase of this work was concentrated on the investigation of Heteropteras' fauna on oaks. In next years the work will continue in the more detailed monitoring of the bionomics and food requirements of the species *Rhabdomiris striatellus* and *Cyllecoris histrionius*.

METHODS OF HETEROPTERAS COLLECTION

Specimens was obtained by common entomological techniques from *Quercus petraea* (Mattusch.) Lieblein and *Quercus robur* L.

1. Individual collection under the bark of old oaks

This collection was carried out under the loose bark of solitery centennial oaks in the winter period in the locality Lednice-Janův hrad.

2. Sweeping from oaks (Fig. 2)

It is an excellent method for collecting from trees, which can show the species living on leaves and thinner branches. Insects were collected up to 5 m by means of a net with the diameter of 40 cm.

3. Malaise traps (Fig. 3)

Malaise traps were installed to the lower part of the crown. Among the insects caught the representatives of the orders Hymenoptera, Diptera and Coleoptera were in majority. In case of the monitoring of true-bugs fly activity these traps did not bring expected results.

4. "Geolas" collar traps (Fig. 5)

This is an equipment used for trapping of insects living and climbing on the stems, which enables to monitor the moving activity of their nymphs (and partly adults as well).

RESULTS

Cyllecoris histrionius (Linnaeus, 1767) – Fig. 4

According to KOLUBAJIV (1948), on small branches with hibernated eggs of *Tortrix viridana* the hatching of *C. histrionius* larvae was observed in spring. The total period of the evolution in laboratory conditions lasted approximately from 20 to 25 days. True-bugs from the family Miridae are described as nimble predators often running their prey. Especially the species *C. histrionius* has very movable nymphs and adults. This species also inclines to cannibalism.

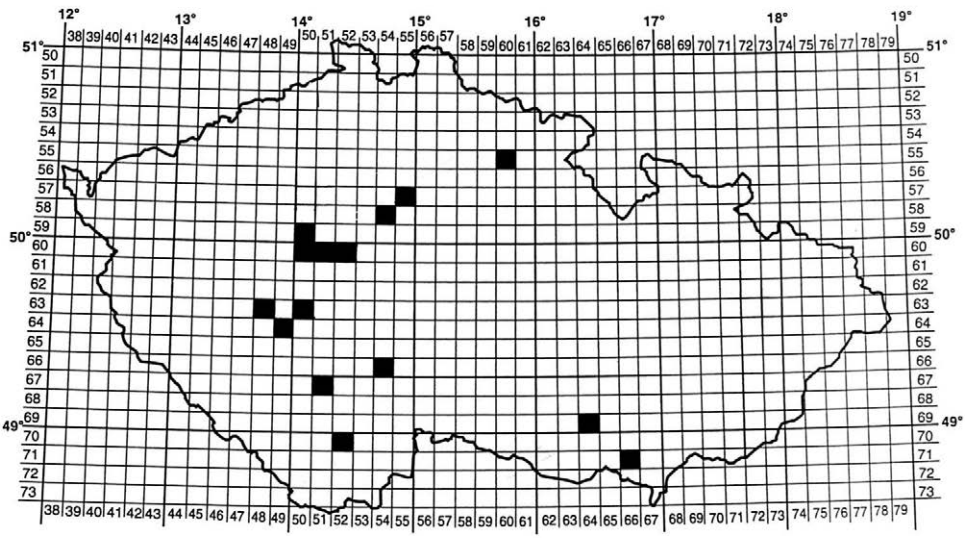
This species was found in own collections only sporadically in 1999–2001; it is 7.6% of all specimens of Miridae.

Rhabdomiris striatellus striatellus (Fabricius, 1794) – Fig. 7

Some authors found this species repeatedly in cocoons of *Tortrix viridana*, where it attacked caterpillars and pupae of this moth. With regard to that not only adults but also larvae are predators, their influence on the fauna of leaf-eating species is larger. In addition to *Psallus* spp., *R. striatellus* was the most numerous species in the spring in years 2000–2001. It creates 15.2% of specimens of Miridae.

Table 1. Review of Heteroptera caught on oaks in years 1999–2001

Family	Number of species	(%)	specimens	(%)	Family	Number of species	(%)	specimens	(%)
Acanthosomatidae	2	2.56	3	0.21	Nabidae	2	2.56	15	1.03
Anthocoridae	1	1.28	25	1.71	Pentatomidae	10	12.82	71	4.86
Aradidae	–	–	2	0.14	Piesmatidae	1	1.28	6	0.41
Berytidae	1	1.28	1	0.07	Reduviidae	1	1.28	1	0.07
Coreidae	2	2.56	9	0.62	Rhopalidae	3	3.85	5	0.34
Cydnidae	1	1.28	1	0.07	Saldidae	1	1.28	1	0.07
Lygaeidae	17	21.80	96	6.57	Scutelleridae	1	1.28		0.07
Miridae	31	39.74	1,193	81.66	Tingidae	4	5.13	32	2.19
In total: 16 families	78	100.00	1,461	100.00					



Legend to the map:

Town	District	Number of map field	Altitude (m a.s.l.)
České Budějovice	České Budějovice	7052	381
Dobřichovice	Praha-západ	6051	205
Dolní Břežany	Praha-západ	6052	334
Praha-západ	Praha-západ	5950; 5951	408
Lednice	Brno-venkov	7166; 7266	173
Lipník	Mladá Boleslav	5755	258
Miletín	Jičín	5560; 5660	334
Moravské Bránice	Brno-venkov	6964	205
Myšenec	Protivín	6751	396
Planá nad Lužnicí	Tábor	6654	395
Praha-Hloubětín	Praha	5853; 5953	208
Roblín	Praha-západ	6051	368
Řevnice	Praha-západ	6051	218
Stěžov	Příbram	6350	486
Strnady	Praha-západ	6052	353
Tochovice	Příbram	6349; 6449	487
Věšín	Příbram	6348	551
Vrané nad Vltavou	Praha-západ	6052	196

Fig. 1. Black squares represent localities in surroundings of the mentioned towns

Table 2. Heteroptera caught from oaks (*Quercus* spp.) in years 1999–2001

	No. of specimens
Miridae Hahn, 1833	
Adelphocoris lineolatus (Goeze, 1778)	1
Adelphocoris quadripunctatus (Fabricius, 1794)	1
Agnocoris rubicundus (Fallén, 1807)	1
Capsus sp.	1
Closterotomus biclavatus biclavatus (Herrich-Schaeffer, 1835)	4
***Cyllecoris histrionius* (Linnaeus, 1767)**	**91**
Deraeocoris (*Deraeocoris*) *ruber* (Linnaeus, 1758)	1
Deraeocoris (*Deraeocoris*) *trifasciatus* (Linnaeus, 1767)	1
Deraeocoris (*Knightocapsus*) *lutescens* (Schilling, 1837)	47
Dryophilocoris (*Dryophilocoris*) *flavoquadrimaculatus* (De Geer, 1773)	93
Globiceps (*Globiceps*) *sphaegiformis* (Rossi, 1790)	4
Harpocera thoracica (Fallén, 1807)	35
Horistus (*Primihoristus*) *orientalis* (Gmelin, 1790)	1
Charagochilus weberi Wagner, 1953	2
Liocoris tripustulatus (Fabricius, 1781)	1
Lygus pratensis (Linnaeus, 1758)	1
Lygus rugulipennis Poppius, 1911	9
Megacoelum infusum (Herrich-Schaeffer, 1837)	4
Miris striatus (Linnaeus, 1758)	2
Orthops spp.	2
Orthotylus (*Orthotylus*) *tenellus* (Fallén, 1807)	111
Phyllus (*Phylus*) *melanocephalus* (Linnaeus, 1767)	107
Phytocoris (*Ktenocoris*) *austriacus* Wagner, 1954	1
Phytocoris (*Phytocoris*) *confusus* Reuter, 1896	1
Phytocoris (*Phytocoris*) *dimidiatus* Kirschbaum, 1856	1
Pilophorus cinnamopterus (Kirschbaum, 1856)	1
Pilophorus perplexus Douglas a Scott, 1875	26
Pilophorus sp.	1
Plagiognathus sp.	10
Psallus (*Hylopsallus*) *perrisi* (Mulsant and Rey, 1852)	5
Psallus spp.	437
Reuteria marqueti Puton, 1875	3
***Rhabdomiris striatellus striatellus* (Fabricius, 1794)**	**181**
Stenodema (*Stenodema*) *laevigata* (Linnaeus, 1758)	4
Stenotus binotatus (Fabricius, 1794)	1
Strongylocoris leucocephalus (Linnaeus, 1758)	1
In total	1,193
Scutelleridae Leach, 1815	
Eurygaster maura (Linnaeus, 1758)	1
Pentatomidae Leach, 1815	
Aelia acuminata (Linnaeus, 1758)	4
Aelia klugii klugii Hahn, 1831	1
Arma custos (Fabricius, 1794)	2
Carpocoris fuscispinus (Boheman, 1849)	1
Carpocoris purpureipennis (De Geer, 1773)	1
Carpocoris sp.	1
Dolycoris baccarum (Linnaeus, 1758)	8
Neottiglossa pusilla (Gmelin, 1789)	4
Palomena prasina (Linnaeus, 1761)	35
Palomena sp.	4
Pentatoma rufipes (Linnaeus, 1758)	5
Pentatomidae indet.	2
Piezodorus lituratus (Fabricius, 1794)	2
In total	70
Anthocoridae Fieber, 1836	
Anthocoridae indet.	21
Anthocoris nemoralis (Fabricius,1794)	1
Anthocoris spp.	3
In total	25

	No. of specimens
Lygaeidae Schilling, 1829	
Aphanus rolandri (Linnaeus, 1758)	1
Eremocoris plebejus (Fallén, 1807)	1
Ischnodemus sabuleti (Fallén, 1826)	2
Kleidocerys resedae (Panzer, 1797)	4
Lamprodema maura (Fabricius, 1803)	1
Lygaeus equestris (Linnaeus, 1758)	1
Megalonotus chiragra (Fabricius, 1794)	1
Megalonotus sabulicola (Thomson, 1870)	2
Metopoplax origani (Kolenati, 1845)	3
Nysius senecionis senecionis (Schilling, 1829)	2
Oxycarenus pallens (Herrich-Schaeffer, 1850)	2
Plinthisus sp.	2
Raglius alboacuminatus Goeze, 1778	58
Rhyparochromus vulgaris (Schilling, 1829)	12
Scolopostethus decoratus (Hahn, 1833)	1
Taphropeltus contractus (Herrich-Schaeffer, 1835)	1
Trapezonotus (*Trapezonotus*) *arenarius arenarius* (Linnaeus, 1758)	1
Tropistethus holosericus (Scholtz, 1846)	1
In total	96
Aradidae Brullé, 1836	
Aradidae indet.	2
Berytidae Fiber, 1851	
Berytinus sp.	1
Rhopalidae Amyot & Serville, 1843	
Brachycarenus tigrinus (Schilling, 1829)	3
Rhopalus (*Rhopalus*) *parumpunctatus* (Schilling, 1829)	1
Stictopleurus abutilon abutilon (Rossi, 1790)	1
In total	5
Coreidae Leach, 1815	
Ceraleptus lividus Stein, 1858	1
Coreus marginatus marginatus (Linnaeus, 1758)	8
In total	9
Tingidae Laporte, 1832	
Dictyla echii (Schrank, 1782)	26
Dictyla humuli (Fabricius, 1794)	1
Physatocheila dumetorum (Herrich-Schaeffer, 1838)	4
Tingis (*Neolasiotropis*) *pilosa* Hummel, 1825	1
In total	32
Acanthosomatidae Stal, 1864	
Elasmostethus interstinctus (Linnaeus, 1758)	2
Elasmucha grisea grisea (Linnaeus, 1758)	1
In total	3
Reduviidae Latreille, 1807	
Empicoris vagabundus (Linnaeus, 1758)	1
Nabidae A. Costa, 1853	
Himacerus (*Himacerus*) *apterus* (Fabricius, 1798)	1
Himacerus (*Aptus*) *mirmicoides* (O. Costa, 1834)	4
Nabidae indet.	10
In total	15
Piesmatidae Amyot & Serville, 1843	
Piesma maculata (Laporte, 1883)	6
Saldidae Amyot & Serville, 1843	
Saldidae indet.	1
Cydnidae Billberg, 1820	
Tritomegas sexmaculatus (Rambur, 1842)	1
Total number of specimens	1,461

Fig. 2. Sweeping from oak

Fig. 3. Malaise trap

PRELIMINARY CONCLUSIONS

1. In the study period a total of 72 species of Heteroptera of 16 families have been caught.
2. Dominant species have been represented by the genus *Psallus* and the species *Rhabdomiris striatellus*, *Phylus melanocephalus*, *Cyllecoris histrionius*, *Orthotylus tenellus*, *Dryophilocoris flavoquadrimaculatus*.

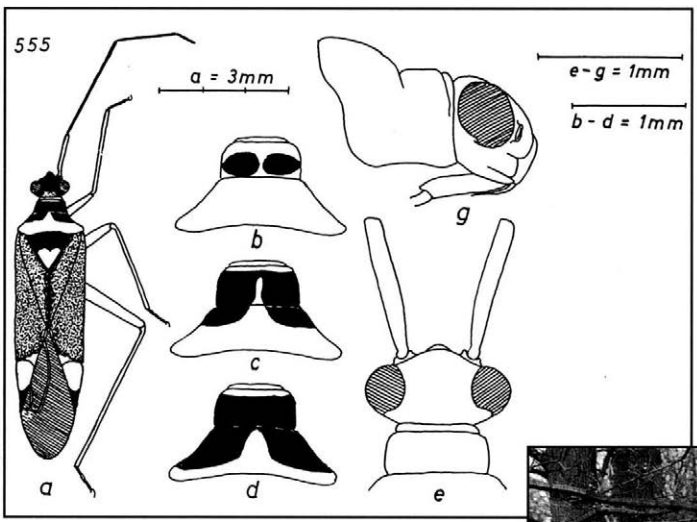


Fig. 4. *Cyllecoris histrionius* (Linnaeus, 1767) (According to WAGNER [1973])

a – body; b–d – pronotum; e – hand and 1. antennal segment; g –head and pronotum

Fig. 5. "Geolas" collar trap

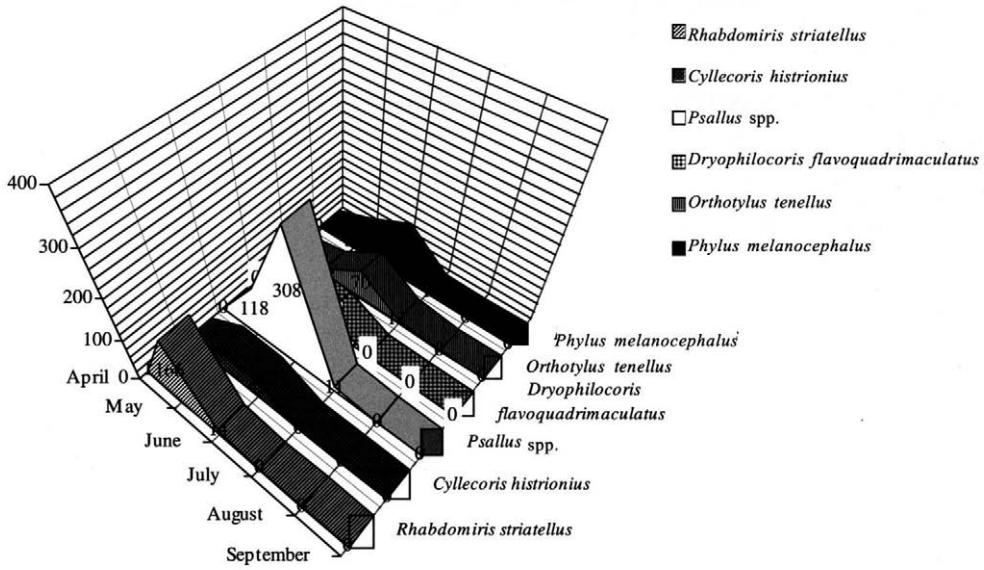


Fig 6. Seasonal dynamics of important species of the family Miridae Hahn, 1833 (Heteroptera)

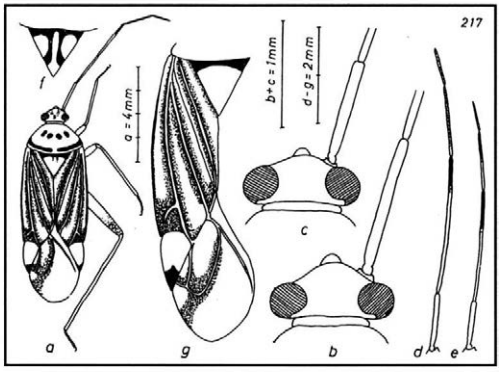


Fig. 7. *Rhabdomiris striatellus striatellus* (Fabricius, 1794) (According to WAGNER [1970/1971])

a – male; b + c – head and 1. antennal segment; d + e – antennae; f – scutellum; g – left hemelytra and scutellum

3. *Rhabdomiris striatellus* and *Cyllecoris histrionius* are regarded as beneficial, zoophagous species, which can regulate populations of leaf-eating pests on oaks.

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Mark and recapture trial on *Ips typographus* (L.) population in NW Croatia

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ABSTRACT: Pure spruce stands in Croatian environment occupy far less forested area compared to some other European countries. Nevertheless, recent dry and warmer than average years initiated local outbreaks of the two most dangerous spruce bark beetles. Part of the research targeted to better utilization of pheromone trap combination in monitoring and suppression tactics dealt with spatial and temporal aspect of *Ips typographus* (L.) response to pheromone source. Basic method in both parts of described trial was the release and recapture of uniquely marked beetles. Experimental design aimed to get data on spatial relations consisted of singular pheromone source surrounded by twelve release sites positioned in attacked spruce stand along three azimuths and in three distance radii. Temporal aspect was researched through precise release of 45 uniquely coloured beetles and their equally precise collecting at the pheromone trap 50 meters away. Release rates varied from less than 1% to 13% at "best responding" release site (1,920 marked and released beetles; 1,773 actually took flight from release plates). There was no significant difference between the four azimuths in spite of the fact that three were located in attacked spruce stand and fourth was laid in broadleaved forest. Expected differences were recorded among the three radii, nearly 11% of recaptured beetles at 50-meter radius and around 2% at 200 and 350-meter radius. Average recapture rate calculated for all sites was 5%, which is considered quite high considering the relatively small number of released beetles and relatively diverse habitat in means of forest types and hilly terrain. Results of the temporal response yield median value of 20 minutes for 50-meter distance with minimum of 4 minutes and maximum of 5 h 42 min. Of the 44 beetles that took into air, 7 were recaptured. In both parts of this mark and recapture trial only freshly emerging beetles collected in the bark of felled spruces were used.

The importance of spruce bark beetles in Croatian forests, namely *Ips typographus* L. and *Pityogenes chalcographus* L. is not comparable with quite large number of European countries that have natural or artificially grown large areas of spruce forests. This is mainly so because of the predominantly natural composition of beech and silver fir forests where spruce is growing naturally but is dispersed and not forming coherent single tree species areas. Late periods of very hot summers and extensive droughts initiated some disturbances throughout the area. The most visible were in spruce forests of unnatural origin, some smaller patches (under 10 ha) of spruce cultures in lowland or hilly regions of NW Croatia. Dying of trees caused headaches to local foresters so salvage measures had to be deployed, and some research on pheromone trap-lure efficiency was needed to support the use of these methods already known in European forestry. Results presented here evolve from that part of the research conducted in effort to show the spatial efficiency of pheromone traps in typical Croatian stands affected with *I. typographus* outbreaks.

There is an extensive research data available on many aspects of bark beetle dispersal strategy and their capability to detect pheromone (or kairomone) emiting sources (ANDERBRANT 1985; BOTTERWEG 1982; BYERS 1999). Some of the authors evaluated the potential of pheromone traps in reducing the population levels (DUELLI et al. 1997; WESLIEN 1992). In many cases the experimental design consisted of pheromone traps positioned in circles of growing diameter around the central bark beetle release point. Numerical description and simulation based prediction models based on several research results of this experimental design were done by BYERS (1999). Bearing in mind numerous outcomes of former researches we wanted to test the possible differences in *I. typographus* response due to the diverse habitat in which pheromone traps were set up. This is why we worked the other way around – putting the pheromone source in the center and locating release sites in concentric circles.

MATERIAL AND METHODS

Experimental plot was located in area where *I. typographus* population was still high and dropping from a two year old outbreak. There were some infested spruces in the area as well as clearcuts and marginal belt of spruce

culture. Triple mounted Theysohn® type trap was baited with Pheroprax® pheromone and located on the southern side of the spruce stand, 30 meters from the stand margin and placed in the meadow extending further to the south. Twelve release sites were chosen, nine of these placed inside the spruce stand and three outside, one of these in the nearby meadow and two in the deciduous forest. Three concentric distance rings were basis for release site placement: 50, 200 and 350 meters away from the centrally positioned pheromone trap. In the spruce stand nine release sites were placed in three directions and along these three distance rings. There was a centrally placed, northerly oriented path through the middle of the stand and two alternating paths, both placed along the stand margins and being couple of meters inside the stand. There were altogether seven marginal release sites and two internal (in the stand) release sites. Freshly developing beetles were gathered by removal of infested bark on formerly attacked spruces and covered by specially tailored cloth tents which worked like eclectors. They were placed *in situ* so the actual marking and release of the marked beetles happened during the real flight period in the research area. Marking was done with the marking pens Edding 780 and Uni marker FX-20. Pronota were marked with unique combinations of colours. Trays with sawdust were positioned on the ground at release sites in order to check the beetles that would not take into air. Marked beetles were released on two occasions: first during the spring swarming period, on 4th May (900 marked beetles released) and second during the summer swarming period on 14th July (1920 marked beetles released). Aside from this, 45 beetles were marked with unique colour combinations and released from "best responding" release site (established after data analysis of both release experiments) in order to determine the time needed for 50 m flight toward the trap. This was done by frequent (every five minutes) emptying of the collecting tray while keeping detailed records of the marked beetle take up time at the release tray 50 meters away. All the collected beetles were placed in plastic containers and deep freezed after which analysis was done under a binocular since marking colours sometimes tend to wear off quite quickly. One day after no marked beetles were caught trays at release points were collected, sawdust carefully examined and remaining dead, marked beetles counted.

RESULTS

Obviously, there are many factors affecting bark beetle orientation and flight behaviour in natural environment. In our experiment many factors were not monitored precisely (wind velocity and temperature) and complex habitat made things even more complicated. First marking trial resulted with less than 2% of recaptures therefore we used these only as a rough basis for second (summer) release trial which we are presenting here in full extent. Release of the marked beetles was done during late morning hours and collecting lasted for two more days after which no more beetles were recaptured. Weather was warm and sunny and capture rate of non-marked beetles was assuring that we were in the midst of a swarming period (Fig. 1). Weather conditions during release period were favourable with temperatures well above 20°C and some light breeze. We did not monitor precisely the wind velocity and it was surely over 1 m/s and the positive anemotaxy was very evident at the release sites after beetles took into air and started flying upward and upwind. The case was, that most of the spruce stand release sites were in a downwind position at least during the first day of recapture. Totally 1,920 beetles were marked (160 per one release site) of which 1,773 left the release trays and 87 stayed in sawdust from various reasons and had to be excluded from the calculations. Majority of recaptured beetles were recorded on the same day of the release (84) while the last three specimens flew into the trap the second day. Experiment ended on the afternoon of the third day when no beetles were recaptured and sawdust from release trays was collected for calculating the non-flying beetles. Recapture rates calculated for every single release site varied from below 1% to 13% at "best respond-

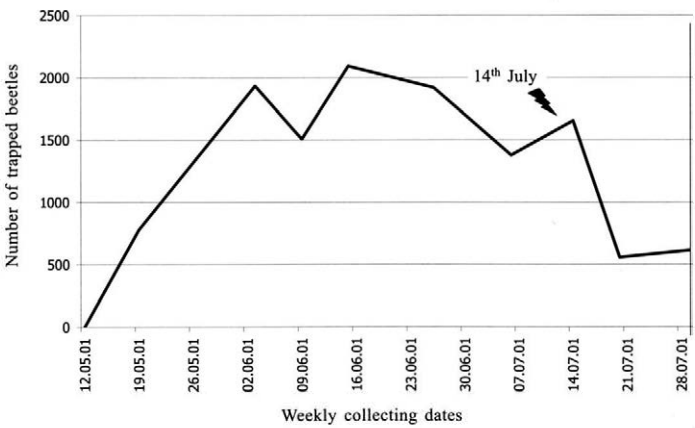

Fig. 1.Weekly catches of *Ips typographus* on monitoring locations in the vicinity of experimental area

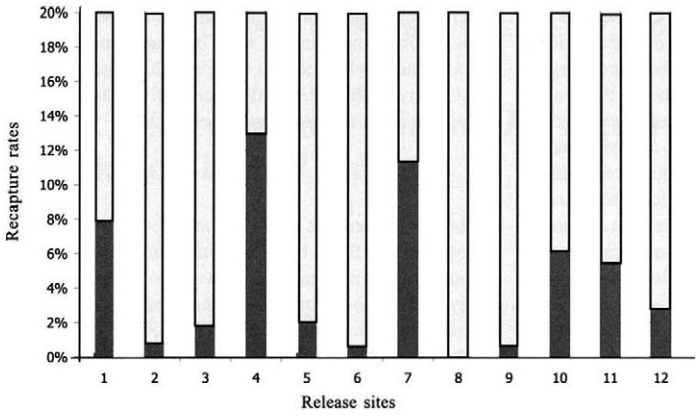

Fig. 2. Recapture rates calculated for every single release site

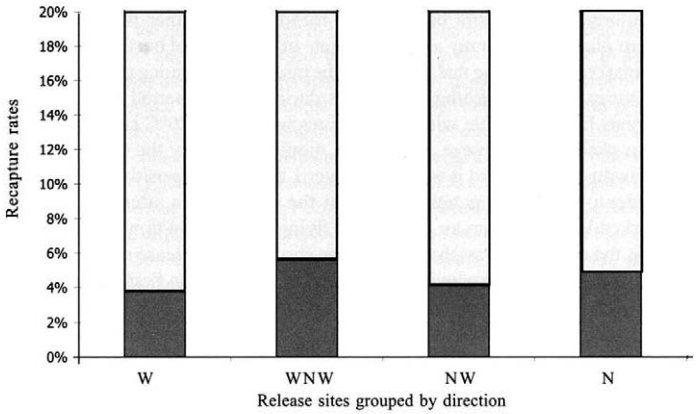

Fig. 3. Recapture rates grouped by four main azimuths (every column representing data for three in-line sites)

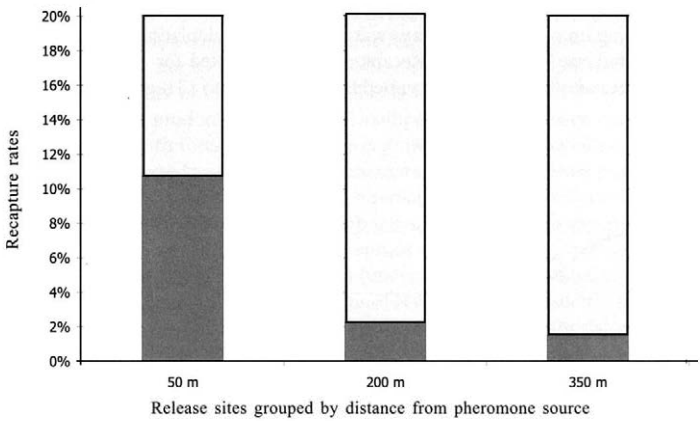

Fig. 4. Recapture rates grouped by three radial distances (every column representing data for four equally distant release sites)

ing" site (Fig. 2). Higher recapture rates were yielded from closer locations and variation among them was due to the microhabitat situation. Relative lower recapture rate for the release site 1 despite being equally close as 4 and 7 can be assigned to the distractive effect of nearby freshly attacked spruces which might have contributed to "loss" of some beetles. General lower recapture rates of spruce stand sites at larger distances (200 and 350 m) compared

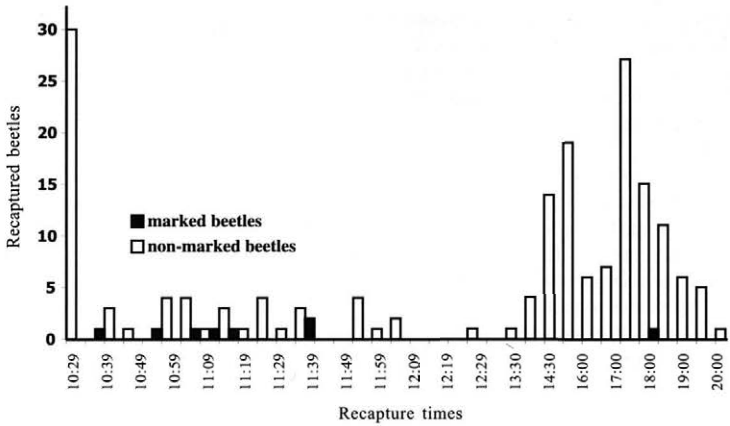

Fig. 5. Recapture of marked and non-marked beetles during flight duration aimed experiment

with equally distanced deciduous sites supports the evidence of competitiveness (pheromone emitting spruces against pheromone traps). Comparative analysis of recaptured beetles by general direction of release sites, ranging from W to N (Fig. 3) revealed interesting fact that there were not big differences among them (recapture rates ranging from 4 to almost 6%). Radial grouping of recaptured beetles showed expected relation of falling rates as distance grew (Fig. 4). Separate experiment targeted the temporal aspect of recaptured beetles. Of the 45 uniquely marked beetles 44 took into air and of these 7 were recaptured. Release started at 10:34 a.m. and recapture control ended at 8:00 p. m. Median value for recaptured beetles (all released from the "best responding" release site number four, at distance of 50 m) was 20 min. The shortest flight time was 4 min and longest 5 h 42 min. Remaining five values equalled 10, 19, 20, 22 and 56 minutes respectively. It is interesting to note that during the release-recapture period capture of non-marked beetles mainly decreased and it grew again in the late afternoon hours (Fig. 5). Causes for this must be in the differences of ambiental temperature during release period that triggers non-marked beetles and physiologically "warmed" marked beetles that were manipulated immediately before the release. Secondly, there is a possibility of wind direction changes that could have caused differences in the non-marked beetle response.

DISCUSSION

The experimental design of the experiment obviously involved too many parameters, many of which have not been monitored closely. Some of them, like the wind velocity and direction, even if taken into account, would be difficult to express since the habitat is so diverse and turbulent streaming is a certainity. On the other hand, precise measurements might not influence the results as expected (BYERS 2000). Compared with other researches, number of marked beetles is significantly lower (BYERS 1999; DUELLI et al. 1997) but in spite of this and the "other way around" design we consider recapture rates not to be too low for making any use of it. In spite of seemingly unpromising field conditions in sense of "complicated" and diverse habitat if compared with experiments conducted in Nordic or Central European surroundings, we still managed to trap some of the released beetles (5% on

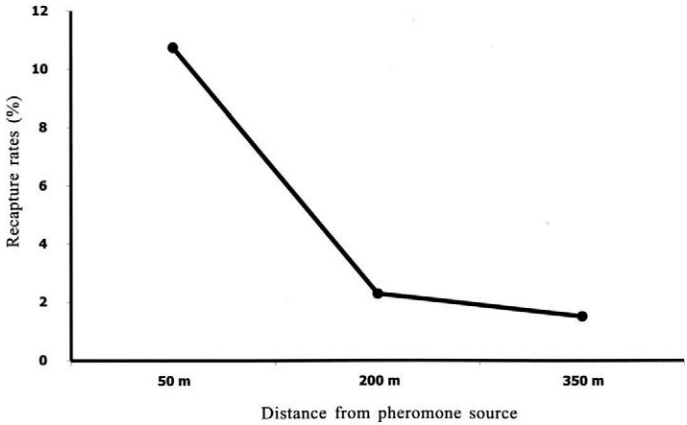

Fig. 6. Average recapture rates grouped by the distance from the pheromone sources

the average). Some similarities in recapture rates are evident and this especially applies to distance – recapture ratio (Fig. 6). It is only a general trend and maybe the downward slope of a curve with actual recapture rates significantly lower should be expected in the area of research and with designed experimental set up. The impact of using non-flown beetles (DUELLI et al. 1997) certainly must be present since there is almost sure that wider area of research (less than 2 km radius) had some beetle foci which are interfering with the experimental plot. Differences in recapture rates analysed on the microlocation basis might give some clues on the importance of undergrowth and microrelief on the orientation of emerging beetles. Some indication of these impacts is evident in former experiments on the efficiency of various trap-pheromone designs (Pernek – unpublished data).

In spite of the relatively low number of recaptured beetles and quite too many parameters involved not being precisely monitored, we consider these results of certain practical value to foresters in their efforts to manage the *I. typographus* outbreaks by combining pheromone trap network with other methods. It gives one some idea of the practical value and the range of activity of Theysohn® type trap baited with Pheroprax® and its use in typical forest stands where spruce decline is occurring in Croatia. Further experiments should concentrate on single affecting factors and together with larger number of marked beetles might reveal some spatial relationships of the population flight patterns.

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A local outbreak of *Cephalcia lariciphila* (Wachtl) in Czechia

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ABSTRACT: The web-spinning larch sawfly – *Cephalcia lariciphila* (Wachtl, 1898) (Hymenoptera: Pamphiliidae) is the only species of the genus *Cephalcia* living on larch (*Larix decidua* Mill.) in Europe. Its epidemics are associated with nonoriginal larch stands, and in Central Europe occur rather rarely. In years 2000 and 2001, a local outbreak of *C. lariciphila* has been recorded in Czechia.

Characteristics of a *Cephalcia lariciphila* outbreak in Czechia in 2000–2001:

Locality:	Větrný Jeníkov near Jihlava (long. 15°30´, lat. 49°28´)
Habitat:	hill country at the altitude of 650–700 m
Area infested:	ca 5 ha
Age of stand:	60–70 years
Major tree species:	*Picea abies* (L.) Karst., *Larix decidua* Mill.
Tree species infested:	*Larix decidua*

Population of *Cephalcia lariciphila*

Density of larvae in the soil:	200–500 per m^2
Main swarming period of adults:	April 20 to May 5 (in 2001)
Occurrence of males and females:	moderate protandry
Egg laying:	singly on needles
Larval feeding:	mid May to mid June; single
Falling period of larvae:	mid June
Depth of hibernation in the soil:	to 8 cm
Voltinism:	prevalence of one-year generation

Fig. 1. Larva (older instar) of *C. lariciphila*

Fig. 2. Larvae taken from the soil (June 21, 2000)

Fig. 3. Pupa in its chamber (April 5, 2001)

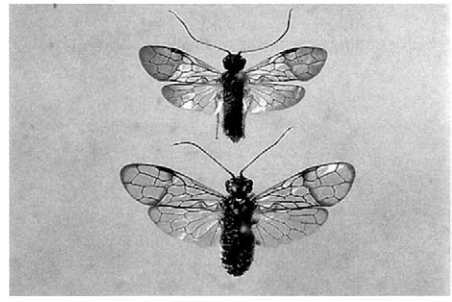

Fig. 4. Male and female of *C. lariciphila*

Fig. 5. Infested groups of larch were almost completely defoliated in both years (June 21, 2000). The damaged trees showed good regeneration

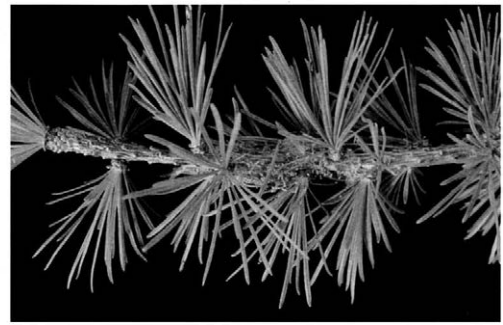

Fig. 6. Silk tubes of young larvae with excrements

Figs. 7, 8. For trapping swarming adults of *C. lariciphila*, sticky bands on trees and yellow sticky desks were used (May 14, 2001)

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Prograd ation of "small spruce bark beetle species"

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ABSTRACT: Among the bark beetles on spruce, besides *Ips typographus* (L.), the most serious species *Pityogenes chalcographus* (L.), *Ips amitinus* (Eichhoff), *Ips duplicatus* (Sahlberg), *Pityophthorus pityographus* (Ratzeburg) and *Polygraphus poligraphus* (L.) are causing damage. The paper gives an example of simple key for determination of the species according to their imaginal habitus as well as to the gallery systems of particular species.

The infestation of conifer stands by bark-boring insects was at low level during the last several years. Only several hundreds of thousands cubic meters of spruce are infested and cut annually, which means, in the conditions of Czech Republic, the endemic state in spruce stands. These sanitary cuttings are caused mainly by attack of *Ips typographus* (L.). But within two or three last years we can record an increase in population density of "small spruce bark beetle species" and consequently higher infestation of spruce stands by these species.

There are following important bark beetles sharing in damage to spruce: *Pityogenes chalcographus* (L.), *Ips amitinus* (Eichhoff), *Ips duplicatus* (Sahlberg), *Pityophthorus pityographus* (Ratzeburg) and *Polygraphus poligraphus* (L.).

It is rather difficult for forest managers to determine the particular species. Because of different bionomy and aggressivity, it would be important to distinguish the morphological difference between particular species, which could be difficult in some cases, for example *Ips duplicatus* versus *Ips amitinus*.

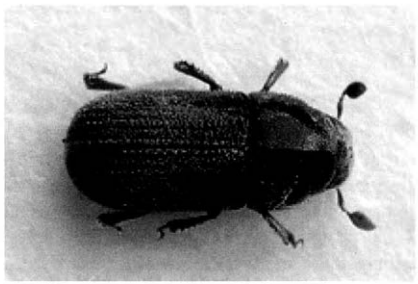

Fig. 1. *Polygraphus poligraphus*

Fig. 2. *Ips amitinus*

Fig. 3. *Ips duplicatus*

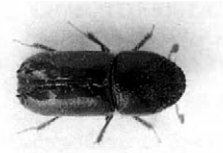

Fig. 4. *Pityogenes chalcographus*

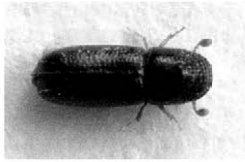

Fig. 5. *Pityophthorus pityographus*

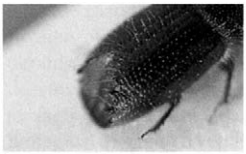

Fig. 6. *Ips amitinus*

Fig. 7. *Ips duplicatus*

Fig. 8. *Pityogenes chalcographus*

Fig. 9. *Pityophthorus pityographus*

Fig. 10. Galleries of *Ips amitinus*

Fig. 11. Galleries of *Ips duplicatus*

Fig. 12. Galleries of *Pityogenes chalcographus*

Fig. 13. Galleries of *Polygraphus poligraphus*

Heavy infestation of all mentioned species was recorded in the territory with severe damage of *Armillaria ostoyae* (Romagn.) Herink to spruce stands, mainly in northern Moravia and Silesia. Slashes, remaining in the stands after logging, are fully attacked by these species, then a new generation develops and infests healthy standing trees in all age classes. Not only forest edges are attacked, but many single trees or those in small groups are killed, which cause the problem in subsequent forest protection.

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Spatial pattern of threats caused to forest in Poland by biotic and abiotic factors

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ABSTRACT: The information both descriptive and graphical (maps of spatial pattern) on the biotic and abiotic factors causing threats to forests in Poland were presented in the paper. The 1966–1990 data on weather condition collected in the network of 56 meteorological stations in the country were used to calculate the Sieljaninow coefficient of the vegetation period. Dry deposit of air pollution (SO_2 and NO_x) was determined as average of 1985–1993 measurements made by forest monitoring service in the network of almost 1,400 points. 1961–96 insect pest control data and 1987–94 fungal disease occurrence data were used to calculate threat indices for forest districts.

Influence of the stress factors on forest environment is complex, often characterized by synergism, and reaction to them is sometimes postponed in time in relation to stimulus appearance. This causes grate difficulty in interpretation of the observed phenomena, especially when it comes to determination of cause-effect relationship. The effect of stress factors influence on forest environment is a derivative of those factors' properties and a resistance of forest ecosystem. In the same time occurrence of many stress factors causes usually constant high disease predisposition of forests and continuity of destruction processes in sylvan environment. Periodical intensification of occurrence of even one factor (insect outbreaks, drought, fires) may lead to the breakdown of biological resistance of sylvan ecosystems and to local or regional occurrence of serious risks and phenomena of ecological disaster. Depending on the type and intensity of stress factors, their occurrence may bring the following effects:

- damage to particular organisms,
- disruption of the natural consistence and structure of forest ecosystem,
- damage to entire forest ecosystem, persistent limitation of habitat productivity and tree increment, and therefore reduction of forest resources and protective functions of forest,
- die-back of forest stands and synanthropization of the whole plant community.

These changes are inseparably connected with simplification of structure and disturbance in functioning of organism communities forming forest: ground flora, undergrowth and tree stand, as well as with changes of strongly dependent on them zoocenoses. Depletion of biological diversity on all levels of organization: genetic, specious and eco-system is a result of that. Polish forests are constantly influenced by stress factors, manifested from time to time by pandemic outbreaks of insect pests and fungal epidemics, large-area fires, or in extreme cases – deforestation (replacement of forest communities with other non forest ecosystems). It is connected with change of plant cover in Poland in comparison to original communities and expressed in decrease of deciduous and mixed stands in favor of planted pine monocultures on the lowland and spruce monocultures in the mountains. Communities of simplified species, age and height structure replaced natural forest communities, adapted to the local environmental conditions (climate, habitat) and featured with high ability of self-regulation. This contributed to the development of forest predisposition to the influence of stress factors and was reflected in dynamic growth of damages caused by all types of stresses in post-war period.

CHARACTERISTICS OF CHOSEN STRESS FACTORS SHAPING HEALTH CONDITIONS IN POLAND

WATER SHORTAGES

Bad condition of forests in Poland is to a significant degree a result of an influence of factors shaping the water balance of forest habitats, including deficit of precipitation lasting for several years, recurrent periods of draught during vegetation season and lowering of groundwater level. As a result of this, the persistent shortages of moisture available for plants occurs over considerable areas of Poland, displaying in progressive stepping processes. As the figure placed below shows, shortage of moisture is characteristic for wide area spreading from Szczecin Lowland, Great Poland Lakeland, Great Poland Lowland and Silesia Lowland on the west, through Mazovia Lowland to Sandomierz Basin and Polesie Lubel-

skie on the east of the country. It is expressed in relatively low level of multi-annual (for years 1966–1990) average value of Seljaninow hydro-thermal indicator for vegetation season (vegetation season total precipitation divided by the sum of daily air temperature). Value of the index did not exceed 1.5 in the areas enumerated above and below 1.2 in Wielkopolska Lowland, what indicates the occurrence of persistent deficit of water available for plants. Moisture shortages underwent further deepening in the decade of nineties. The value of hydro-thermal indicator was lower in the vegetative season of 1992 than multi-annual average on almost entire area of Poland, in 1993 on abut 70%, in 1994 and 1995 on over 65% of the country. This shows that water resources issues in protection of national biological resources, including prevention of diversity are of key importance.

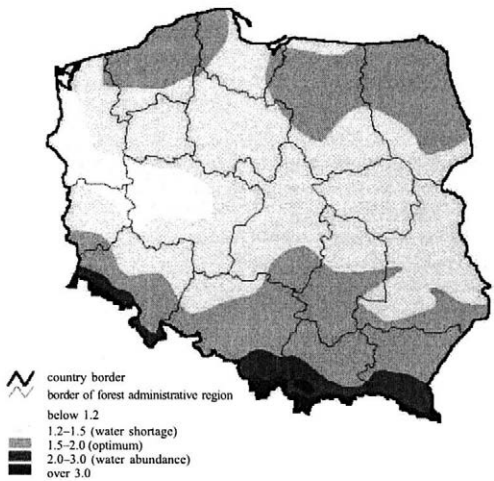

Fig. 1. Spatial distribution of multi-annual (for years 1966–1990) average value of hydrothermal index for the vegetation season

AIR POLLUTION

From among all air pollution types the most significant impact over the forest in Poland have carbon dioxide and nitrogen oxides. It is due to accumulation of pollution emitted in the country with transboundary pollution from Germany and Czech Republic, mainly from the area of so called "black triangle". Air pollution has negative impact on all elements of forest ecosystems and is an initiating factor of multifactor disease processes of forests, leading in extreme cases to their complete die-back. Mechanisms of air pollution impact on forests are still a subject of studies and have found a wide reflection in scientific publications. Spatial distribution and ability to change in time of SO_2 and NO_x deposit have been registered in Poland in the years 1985–1993 within the network of about 1,400 points of so called "forest technical monitoring". Information gathered every month allowed on evaluation of the country area in respect of the amount of contamination deposit and monitoring of trends of deposit changes in the recent years. The basic feature of atmosphere pollution appearing over the whole area of Poland is a big seasonal difference, demonstrated in two or three times higher values for winter season (heating period) than for the summer one. Second feature, characteristic in the recent years, is a significant reduction of the pollutant load. SO_2 emission has declined from 4,200 thousand t in 1987 to 3,210 thousand t in 1990 and 2,645 thousand t in 1994, and NO_x emission from 1,530 t to 1,280 t and 1,120 t respectively. It should be noted that particularly considerable reduction of air pollution took place on the areas of traditionally high deposit level – in provinces of Krakow and Katowice. However, considerable increase of nitrogen oxide deposit occurring in the recent years in certain regions (Gdansk and Toruń provinces) should be mentioned. The cause of that is an intensification of motor transport, which is one of the basic sources of NO_x emission. Spatial distribution of an average, monthly, dry deposit of sulfur dioxide in the years 1985–1993 is presented on the below picture. As it shows the biggest SO_2 deposit loads (values above 50 mg/m^2 per day) occurred in the southwest Poland, in the area of Lower Silesia Pine Forest. Slightly lower values (30–50mg/m^2 per day) on the rest of Lower Silesia, Sudety Mountains, Wielkopolska Lowland, Upper Silesia, Jura Krakowsko-Czestochowska, Krakow province, and locally in the Carpathian Mountains (Silesian Beskid, Żywiecki Beskid, Low Beskid, Przemyśl Plateau, Strzyżowsko-Dynowskie Plateau). The lowest values of SO_2 deposit (lower than 15 mg/m^2 per day) occurred on the area of northeast (Olsztyn, Bialystok, Ciechnow provinces) and north Poland (Torun, Słupsk, Koszalin provinces).

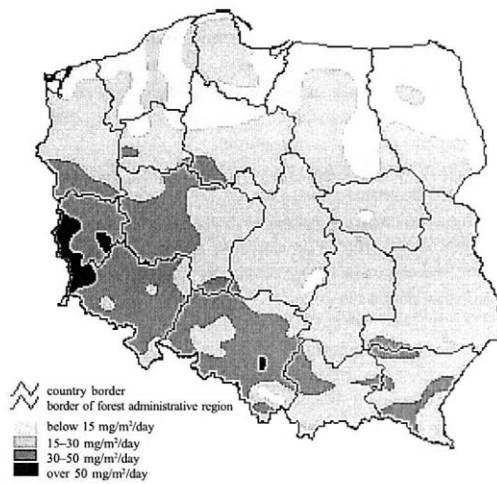

Fig. 2. Dry deposit of SO_2 monthly average from the years 1985–1993

FUNGAL DISEASES

Recent decades were characterized by the constant increase of risk caused to the forests by fungal infectious diseases. In the end of the fifties damages induced by this stress factor were registered on about 100 thousand ha a year, while in the period of 1992–1995 on an average over 500 thousand ha. In 1996 a sudden increase of the area threatened by the fungal pathogens took place, due to occurrence of epiphytosis of pine shoots die-back on the area of almost 1 mil ha. Similar situation had happened in the years 1972–1973 and 1982–1985. This evidences the periodicity of occurrence of this category of infectious diseases.

The second important category of fungal diseases, showing constant increase during the whole post-war period is the root rot caused by the *Armilliaria* spp. and *Heterobasidion annosum*. Spatial distribution of threat of infectious diseases to forests in Poland is presented on the picture.

Hazard to forests of infectious diseases does not occur in distinct zones. Forest districts, where the acreage of damage occurrence exceeds 25% of total forested area (Ciechanów, Leśny Dwór, Runowo, Gniezno, Gostynin, Mrągowo and Złoczew) are scattered and isolated by the area of the lower risk level. The only exception are the mountain forests of the Carpathians and Sudety Foothills, where the root diseases are widespread and common in stands over the major part of the region.

INSECT PESTS

Poland is a country where unfavorable phenomena connected with outbreaks of insect pests, often very sudden and dynamic, occur in exceptionally big diversity and escalation. In the decades of the period 1961–1994 the increase of a number of pest species threatening tree stands and of the area of stands covered with pest control, took place. And so, while in the years 1961–1970 mass appearance of 38 species was observed (20 of them were covered with pest control), and rescue measures were carried out over the total area of about 600 thousand ha, in the decade of 1981–1990 56 species occurred in the form of mass outbreaks (46 of them were covered with chemical pest control), and rescue measures were carried out on the total area of more than 7 mil ha. About 70 mil m^3 of softwood and hardwood settled by pests were removed from forests. Similarly, pandemic foliophage gradations (nun moth gradation in 1993–1994) and gradations of conifer stand secondary pests (in 1993–1994) were characteristic for the nineties.

According to the picture shown above it can be assumed that the stands most threatened by insect pests are located in the north of Poland (western part of Mazovian Lakeland), north-west (Pomeranian Lakeland and Wielkopolska Lakeland) and in three regions in the southern part of the country: the Sudety Mountains, Śląsk Opolski and the Beskid Wysoki Mountains. High risk to forests in the south Poland is determined almost entirely by secondary pests while in the rest of the area primary pest risk (mainly nun moth) prevails. Low risk zone can be distinguished too, which spreads in the form of semicircle from Silesian Lowland in the west of Poland, through the area of Highlands: Krakowsko-Czestochowska, Malopolska (excluding the Swietokrzyskie Mountains), Lubelska, and as far as eastern part of Mazovian Lowland and Mazury Lakeland, in the north-west of Poland.

The share of deciduous stands in the threatened forests is rather insignificant. This is due to the domination

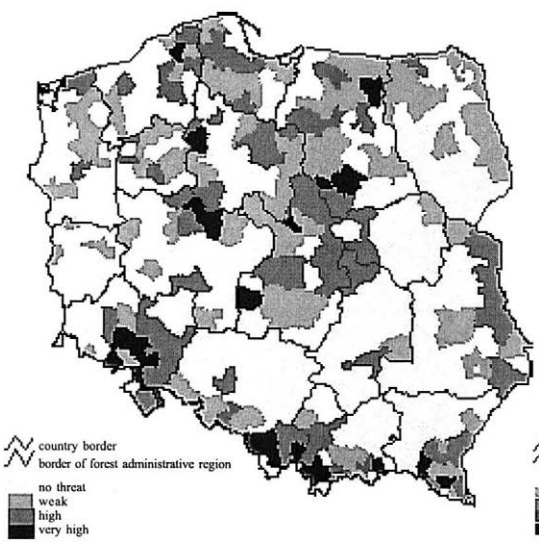

Fig. 3. Occurrence of fungal diseases in Poland

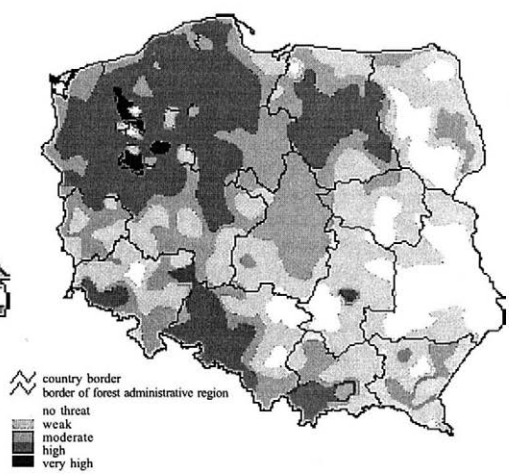

Fig. 4. Insect pest (primary and secondary together) threat zones in Poland (according to KOLK et al. 1996)

of coniferous stands in the acreage of forests in Poland and their higher vulnerability for stress factors.

CONCLUSIONS

The level of threats of any kind continuously changes in space and time. It should be noted that in spite of trends appearing after whole post-war period the indicators reflecting antrophogenic stressing factors decreased during the decade of 90s. The sulfur dioxide emission dropped from 4.2 mil t in 1987 down to 2.7 mil t in 1994 and dry deposit from 26 mg/m^2 per day to 11 mg/m^2 per day. Nitrogen oxides followed similar pattern – decrease of emission and dry deposit between 1987 and 1994 reached about 30%. The symptoms of forest health status stabilization were also noticed. In 1995 the defoliation index assessed within the forest biological monitoring improved for the first time since 1986. The succeeding years brought further recovery of health status of Polish forest however it must be stressed that after 1996 forest were relatively slightly stressed by the insect pest outbreaks and fungal epidemics. Also weather condition were in most of that time (second half of the 90s) favorable for trees.

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Monitoring of *Melampsora* rusts in *Salix*

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ABSTRACT: Numerous species and interspecific hybrids of the genus *Salix* can be infected by members of *Melampsora* willow rusts which are widespread and of economic importance. The genetic variation of *Melampsora* willow rusts is investigated with molecular techniques. First results showed a higher diversity in the *Melampsora* genus than the previous division explained by willow hosts and alternate hosts. By the method of ITS-RFLP 14 haplotypes of willow rusts can be differentiated in Germany. The haplotype with the highest frequency can be distinguished into 5 subtypes using RAPD.

Willows (*Salix*) are widespread in Europe. They occur mainly along rivers and in marches. As fast growing shrub and tree species they are important in the concepts of renewable energy grown in short rotation coppice (SRC) plantations in western and northern Europe. They are also integrated into the concept of gene conservation.

In order to be able to give statements on resistance of selected clones with high productivity, the diseases and their biology must be known. The species of the genus *Melampsora* are widespread and of economically importance in *Salix*. These rust fungi have a complex life-cycle and alternate on different woody and herbaceous plants. The occurrence of the different rust fungi and their virulence depends from the *Salix* species and clones and is influenced additionally by environmental factors.

A differentiation of the *Melampsora* species is hardly possible on the basis of morphological characteristics. The use of molecular genetic techniques offers the possibility to understand the spectrum of the involved rust fungi more exactly (Pei et al. 1997b). Polymerase chain reaction (PCR) based methods have been developed and used as a new tool for the identification and phylogenetic studies of several fungi. For identification studies of genera or species, the ribosomal DNA (rDNA) is known to be useful because it is highly conserved genetically and has large copy numbers in the fungal genomes (Hibbett 1992; Nakamura et al. 1998). White et al. (1990) designed a series of PCR primers based on highly conserved regions of rDNA. The internal transcribed spacer (ITS) region contains non-coding regions that are nested within the rDNA repeat (Gardes, Bruns 1993). The analysis of the rDNA regions provides different sensitivities and resolution for taxonomic and phylogenetic studies (Chen et al. 1992).

MATERIALS AND METHODS

RUST ISOLATION

Leaf samples with uredinial stages of rust from 33 clones belonging to 16 species or species hybrids were collected from 15 sites in Germany between July and October 2000 (Table 1). The spores were taken, put into tubes, dried, and stored at –18°C.

DNA EXTRACTION AND PCR

To extract the DNA about 2 to 3 mg uredospores were put into 2 ml tubes. Glass beads and X 0.5 ROSE-buffer were added. The samples were smashed, incubated and spun. As much of the aqueous phase was transferred into a new tube and cleaned. The primer pair ITS1 and ITS4 were used for the amplification of the ITS regions based on the repetitive units of the nuclear rDNA consisting of conserved coding and variable non-coding sequences. Polymerase chain reactions were carried out in 0.5-ml microcentrifuge tubes. The PCR temperature cycles were controlled by using a DNA thermal cycler (Biometra UNO II Thermocycler) and were repeated 40 times. Efficiency of amplification was monitored by running aliquots of each reaction mixture through a agarose gel followed by staining with ethidium bromide and visualization and photography under ultraviolet light.

RFLP AND RAPD ANALYSIS

The amplified DNA fragments were digested with 5 restriction enzymes (*Taq* I, *EcoR* I, *Dra* I, *Xba* I, and M*bo* I) according to the manufacturer's instructions (Table 2). The digested DNA fragments were separated, electro-

Table 1. Collection sites, number of samples and willow species

Collection site	Latitude (°O)	Longitude (°N)	Altitude (m a.s.l.)	Type	Species/hybrid	Sample number
Eberswalde	13°47'	52°49'	35	clone collection	*S. acutifolia*	32, 174
					S. daphnoides	29, 30, 36, 38, 164
					S. purpurea	7
					S. viminalis	175
					S. aurita × *caprea*	5
District MOL	14°07' – 14°28'	52° 39'	5–49	land-scape	*S. caprea*	136
					S. cineria	135
					S. fragilis	24, 139
					S. triandra	138
					S. viminalis	134, 161
Waldsieversdorf	14°03'	52°33'	50	clone collection	*S. nigra*	183
					S. viminalis	115, 186, 187
					S. × *aquatica*	45, 189, 191
					S. × *dasyclados*	180
					S. × *stipularis*	42
					S. × *hirtei*	184
District FFB	11°20'	48°08'	550	land-scape	*S. aurita*	176
					S. caprea	179
Elbe valley	11°21'	53°04'	15	land-scape	*S. alba*	72
					S. fragilis	74
					S. viminalis	66
Hann. Münden	09°38'	51°28'	140	clone collection	*S. viminalis*	95

phoresed on 8% polyacrylamide gels, and detected by staining with ethidium bromide and visualized under uv light. RAPD analysis was additionally carried out on 18 rust samples using three 10-mer oligonucleotide primers (OPE07, OPE11, OPE16). The amplified products were than separated on a 1.6% agarose gel followed by visualizing.

DATA ANALYSIS

First the DNA fragments were scored for presence or absence of bands showing the same mobility in the gel, regardless of their optical density. Only fragments that could be scored unambiguously were included in the analysis. The pairwise similarities were calculated between samples using DICE similarity index (DICE 1945; NEI, LI 1979), which ignores bands whose two samples are unexpressed. The resulting similarity matrix was used as input for a correspondence analysis (SAS 1989). For constructing a dendrogram of the relationship, cluster analysis was based on distance matrix using the unweighted pair group method analysis (UPGMA) program in SAS software (SAS 1989).

RESULTS

The primer pair ITS1 and ITS4 permitted the amplification of a single DNA fragment of approximately 620 bp in size from each uredinia spore sample of *Melampsora* willow rusts. These fragments were used for subsequent RFLP analysis. The provisional number of bands per restrictions enzyme varies between 4 and 8, those of the total number of variants between 4 and 7 (Table 2). Using the patterns of the 5 restrictions enzymes in combination, in total 14 multilocus patterns can provisionally be distinguished.

The correspondence analysis of 33 isolates based on 31 RFLP loci show three groups (Fig. 1). The dendrogram of cluster analysis (UPGMA) from RFLP results has 14 branches and confirmed the division into three main groups (Fig. 2). 18 samples have the same RFLP pattern. These samples having the same distance are divided into 5 types by RAPD markers.

DISCUSSION

One of the most serious diseases on *Salix* grown in SRC plantations are *Melampsora* rusts. These fungi reduce the biomass yields and decrease the productivity of willow plantations. The rust problem is intensifying as increasingly large-scale SRC plantations with willow are being established to meet growing demand for renewable energy (PEI et al. 1999).

BUTIN (1960) distinguished seven species of *Melampsora* appearing on *Salix* in Germany. One of the most important species on biomass willow clones is *M. laricipitea*, which is divided in a number of subspecies and

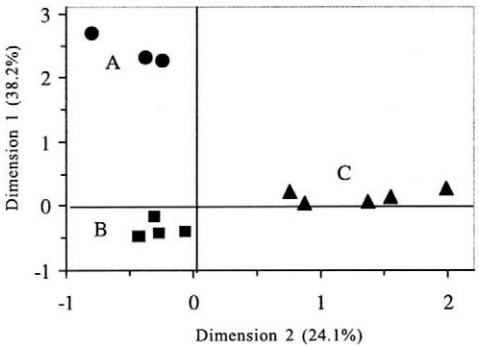

Fig. 1. Correspondence analysis of *Melampsora* willow rusts based on 31 RFLP loci (A, B, C = groups)

pathotypes. The occurrence of pathotypes depends of the frequency of grown clones. The use of single clone plantations promote the selection of new pathotypes with high virulence.

M. larici-epitea requires *Larix* species (especially *L. decidua*) as alternate host. The division into species and subspecies were mainly made by help of willow hosts and alternate hosts. An overlapping of virulence spectrum between a range of willow species is possible (RAMSTEDT 1999). The differentiation of the *Melampsora* species is hardly possible on the basis of morphological characters. This disadvantage can be excluded using molecular genetic techniques – ITS-RFLP and RAPD – which offers the possibility to monitor the spectrum of the involved rust fungi and to identify pathogenic races (HERING 1997). Also in incubation tests using leaf disc techniques to identify pathotypes (PEI et al. 1997a), the used *Salix* clones react differently to the spore origins.

Table 2. Annealing temperature and time of restrictions enzymes, number of RFLP bands and variants

Restriction enzyme	Annealing temperature/time	Total RFLP bands	Total number of variants
Taq I	65°C/3 h	7	7
EcoR I	37°C/20 h	8	4
Dra I	37°C/20 h	6	7
Xba I	37°C/20 h	6	5
Mbo I	37°C/20 h	4	4

Our results reveals that the genetic variability of occurred rusts found in the 33 isolates from natural stands and biomass clones is higher than expected in Germany. In Japan NAKAMURA et al. (1998) identified 11 types of willow rust, in Great Britain 12 types (PEI et al. 1999), and in Sweden RAMSTEDT (1999) reports of more than 20 types. The progress of this work will afford a greater understanding of existing of rust pathogens and their interaction with biomass willows and can contribute both to resistance breeding efforts and to development of disease control strategies.

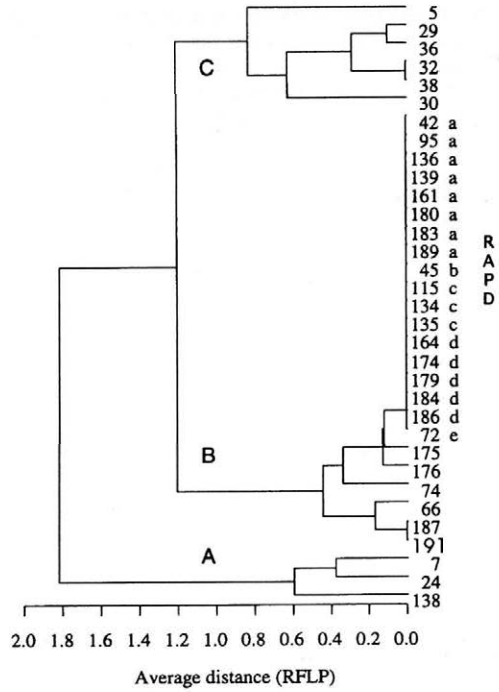

Fig. 2. Dendrogram of cluster analysis (UPGMA) from RFLP results (A, B, C = groups). Samples with the same distance are divided by RAPD markers (a–e)

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Carabids in reforestation areas and in the winter rape field of the forest neighbourhood

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ABSTRACT: During a ten-year study (1990–1999) carried out on clear-cuttings in an intensively managed forest area (forest district of Räpina, Estonia) the rich carabid species composition was established. Specimens from more than 50 different taxonomic group were found. In 2001 in the winter rape field (Puhja, Tartu county Estonia) specimens from the 37 taxonomic groups were found. The species composition was different in different field parts depending on the field boundary. More diverse taxonomic composition and higher activity densities were found in the field parts which bounded with the diverse grass margin and the winter wheat field and also in the clear cut area.

Carabids play a certain role in forest and agro-ecosystems as natural pest-control agents considering their predatory polyphagous nutrition. LINDROTH (1992) considered the genera *Calosoma* and *Cicindela* to be true predators. Among those consuming chiefly animal food, some representing true predators, he also considered the genera *Agonum*, *Bembidion*, *Calathus*, *Carabus*, *Cychrus*, *Dyschirius*, *Elaphrus*, *Notiophilus* and *Pterostichus* (partly). Predominant plant eaters are mainly the species of the genera *Amara*, *Harpalus*. Their larvae are true predators and the amount of animal food in ration of adults is dependent on season (THIELE 1977). In agricultural landscape the abundance and species composition of carabids are dependent on the crop, its cultivation intensity and field boundaries. Higher activity densities and the number of species have been found in organic versus conventional cultivation (HOKKANEN, HOLOPAINEN 1986; KROMP 1989, 1990, 1999). It has been found that most of the species of carabids were significantly more abundant in the boundaries than in the fields, indicating the high importance of boundaries in the agricultural landscape (KROMP 1999). In Estonian conditions it was established that from the ditch edge, which was covered by rich plant coenosis, the migration rate of carabids to barley field was significantly higher than from the pasture and cultural hay which bounded the field from the other sides (NÕMMISTE, LUIK 1999).

For the estimation of the real plant protection role of carabids in different ecosystems, it is important to know their species composition and abundance. Therefore the aim of the present survey in the Estonian reforestation areas and winter rape field was: to establish species composition of the carabids and their activity densities.

MATERIALS AND METHODS

In reforestation areas the study was conducted in the growing seasons in 1990–1999 in an intensively managed forest area of the forest district of Räpina, Estonia. Altogether seven clear-cuttings of former pine-dominated stands (ca 90% of *Pinus sylvestris* and 10% of *Picea abies*) on dry sandy soil, *Vaccinium* site type, were selected as study sites. In the Räpina reforestation area the traps used were a completed modification of the traps constructed originally for trapping click-beetles, *Elateridae* (KUDRYAVTSEV et al. 1993). The ground traps consisted of plastic jars (height 120 mm, upper width 120 mm, bottom width 90 mm, content 1,000 ml) capped with a bottomless click-beetle trap. The caps held glass vials (6.5 ml). The jars were inserted into the ground and were filled with water to 1/3 of their volume. The traps were checked in two week intervals.

In the winter rape field of Puhja, Tartu county the carabids were caught with pitfall traps. Pitfall traps were the plastic jars (height 100 mm, upper width 90 mm, bottom width 75 mm) which were filled with salted (20%) water to 1/3 of their volume. The same type pitfall traps were used in 1999 in the Räpina forest district. The size of the winter rape field was 6 ha. No pesticides were used in the field. From the mineral fertilizers P – 100 kg/ha and K – 50 kg/ha were given in autumn and N – 150 kg/ha in spring, in May. The field was quite long but narrow and bounded from the East and South with mixed forest where on the moist soil *Alnus* was dominating. In one part the forest was cut down. This small clear cut area was covered with high grass. In the North the rape field was bounded with winter wheat field and from the West with diverse plant stripe

Table 1. List of species and the number of specimens (activity densities %) of the carabid beetles (Coleoptera, Carabidae) caught in ground- and pitfall traps in reforestation areas (clear-cuttings), Mooste, 1990–1999

Species	Groundtraps 1990–1999	Pitfalls 1999	Σ	(%)
Notiophilus palustris (Duftschmid, 1812)	1	0	1	0.1
Notiophilus germinyi (Fauvel, 1863)	2	0	2	0.2
Notiophilus sp.	0	2	2	0.2
Carabus arvensis (Herbst, 1784)	12	38	50	5.2
Carabus cancellatus tuberculatus (Dejean,1826)	3	73	76	8.0
Carabus nemoralis (Müller, 1764)	3	9	12	1.3
Carabus hortensis (Linnaeus, 1758)	16	0	16	1.7
Carabus glabratus (Paykull, 1790)	8	34	42	4.4
Carabus nitens (Linnaeus, 1758)	4	1	5	0.5
Carabus violaceus (Linnaeus, 1758)	3	4	7	0.7
Cychrus caraboides (Linnaeus, 1758)	2	5	7	0.7
Cicindela sylvatica (Linnaeus, 1758)	23	0	23	2.4
Cicindela hybrida (Linnaeus, 1758)	4	0	4	0.4
Blethisa multipunctata (Linnaeus, 1758)	1	0	1	0.1
Clivina sp.	0	1	1	0.1
Broscus cephalotes (Linnaeus, 1758)	10	3	13	1.4
Miscodera arctica (Paykull, 1790)	0	1	1	0.1
Trechus sp.	0	22	22	2.3
Asaphidion sp.	1	2	3	0.3
Bembidion quadrimaculatum (Linnaeus, 1761)	2	0	2	0.2
Bembidion sp.	4	15	19	2.0
Pterostichus lepidus (Leske, 1785)	18	12	30	3.1
Pterostichus cupreus (Linnaeus, 1758)	27	110	137	14.3
Pterostichus versicolor (Sturm, 1824)	61	0	61	6.3
Pterostichus aethiops (Panzer, 1797)	11	9	20	2.1
Pterostichus oblongopunctatus (Fabricius, 1787)	148	29	177	18.5
Pterostichus niger (Schaller, 1783)	12	1	13	1.4
Pterostichus strenuus (Panzer, 1797)	0	1	1	0.1
Pterostichus sp.	0	13	13	1.4
Calathus ambiguus (Paykull, 1790)	1	0	1	0.1
Calathus erratus (Sahlberg, 1827)	58	5	63	6.6
Calathus melanocephalus (Linnaeus, 1758)	0	1	1	0.1
Calathus micropterus (Duftschmid, 1812)	7	0	7	0.7
Calathus sp.	0	1	1	0.1
Synuchus vivalis (Illiger, 1798)	0	1	1	0.1
Agonum ericeti (Panzer, 1809)	1	0	1	0.1
Agonum sp.	0	2	2	0.2
Amara similata (Gyllenhal, 1810)	1	0	1	0.1
Amara communis (Panzer, 1797)	1	0	1	0.1
Amara eurynota (Panzer, 1797)	1	0	1	0.1
Amara municipalis (Duftschmid, 1812)	2	0	2	0.2
Amara quenseli (Schönherr, 1806)	22	0	22	2.4
Amara bifrons (Gyllenhal, 1810)	4	0	4	0.4
Amara apricaria (Paykull, 1790)	3	0	3	0.3
Amara consularis (Duftschmid, 1812)	1	0	1	0.1
Amara sp.	3	8	11	1.2
Harpalus rufipes (De Geer, 1774)	5	6	11	1.2
Harpalus smaragdinus (Duftschmid, 1812)	1	0	1	0.1
Harpalus rufipalpis (Sturm, 1818)	6	0	6	0.6
Harpalus sp.	1	40	41	4.3
Unidentified *(Carabidae* spp.)	13	0	13	1.4
Total	507	449	956	100

Table 2. List and the number (Nr.) of carabids (and their activity densities %) in winter rape field of Puhja (caught with pitfall traps June–July 2001 in different locations of the field, bounded with different margins and in the clear cut area in the neighbourhood)

Species	Field center		Diverse grass margin		Wheat field		Forest border		Clear cut	
	Nr.	%	Nr.	%	Nr	%	Nr.	%	Nr.	%
Notiophilus palustris (Duftschmid, 1812)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2
Carabus cancellatus (Dejean, 1826)	0	0.0	7	0.9	9	1.1	1	2.3	2	0.5
Carabus nemoralis (Müller, 1798)	1	0.3	0	0.0	1	0.1	0	0.0	0	0.0
Carabus granulatus (Linnaeus, 1758)	23	8.0	18	2.3	3	0.4	0	0.0	2	0.5
Loricera pilicornis (Herbst, 1784)	11	3.8	16	2.1	18	2.3	1	2.3	16	3.8
Clivina fossor (Linnaeus, 1758)	8	2.8	5	0.6	7	0.9	0	0.0	4	0.9
Dyschirius (Bonelli, 1810)	6	2.1	10	1.3	17	2.2	1	2.3	5	1.2
Patrobus atrorufus (Ström, 1768)	0	0.0	7	0.9	2	0.3	0	0.0	0	0.0
Trechus secalis (Paykull, 1790)	7	2.4	24	3.1	11	1.4	1	2.3	7	1.7
Asaphidion pallipes (Duftschmid, 1812)	0	0.0	5	0.6	3	0.4	0	0.0	4	0.9
Bembidion lampros (Herbst, 1784)	1	0.3	13	1.7	58	7.4	0	0.0	25	5.9
Bembidion quadrimaculatum (Linnaeus, 1758)	0	0.0	1	0.1	1	0.1	0	0.0	1	0.2
Bembidion bruxellense (Wesmäel, 1835)	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0
Pterostichus cupreus (Linnaeus, 1758)	29	10.1	92	11.9	60	7.6	10	23.3	23	5.4
Pterostichus niger (Schaller, 1783)	18	6.3	57	7.4	55	7.0	2	4.7	38	9.0
Pterostichus sternuus (Panzer, 1779)	25	8.7	40	5.2	0	0.0	0	0.0	2	0.5
Pterostichus vulgaris (Illiger, 1798)	52	18.2	153	19.9	116	14.7	10	23.3	134	31.7
Pterostichus crenatus (Duftschmid, 1812)	3	1.0	3	0.4	1	0.1	1	2.3	0	0.0
Calathus melanocephalus (Linnaeus, 1758)	3	1.0	29	3.8	2	0.3	3	7.0	3	0.7
Calathus erratus (Sahlberg, 1827)	0	0.0	13	1.7	5	0.6	1	2.3	6	1.4
Synchus vivalis (Illiger, 1798)	0	0.0	9	1.2	3	0.4	0	0.0	1	0.2
Platynus obscuns (Paykull, 1790)	5	1.7	7	0.9	5	0.6	0	0.0	1	0.2
Platynus assimilis (Paykull, 1790)	1	0.3	7	0.9	5	0.6	0	0.0	3	0.7
Agonum sexpunctatum (Linnaeus, 1758)	0	0.0	4	0.5	6	0.8	1	2.3	0	0.0
Agonum mülleri (Herbst, 1784)	2	0.7	5	0.6	9	1.1	0	0.0	1	0.2
Agonum dorsale	1	0.3	10	1.3	3	0.4	1	2.3	3	0.7
Amara quenseli (Schönher, 1806)	0	0.0	7	0.9	0	0.0	0	0.0	0	0.0
Amara fulva (Müller, 1776)	0	0.0	0	0.0	34	4.3	0	0.0	1	0.2
Amara bifrons (Gyllenhal, 1810)	11	3.8	37	4.8	44	5.6	0	0.0	22	5.2
Amara ovata (Fabricius, 1792)	10	3.5	13	1.7	13	1.6	0	0.0	1	0.2
Amara apricaria (Paykull, 1790)	0	0.0	6	0.8	3	0.4	0	0.0	1	0.2
Amara consularis (Duftschmid, 1812)	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0
Amara similata (Gyllenhal, 1810)	3	1.0	1	0.1	26	3.3	0	0.0	0	0.0
Harpalus pubescens (Degeer, 1774)	54	18.9	124	16.1	238	30.2	8	18.6	96	22.7
Harpalus affinis (Schrank, 1781)	2	0.7	14	1.8	24	3.0	0	0.0	9	2.1
Harpalus spp.	0	0.0	12	1.6	3	0.4	0	0.0	3	0.7
Chlaenius nitidulus (Schrank, 1781)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2
Larvae	10	3.5	20	2.6	1	0.1	2	4.7	5	1.2
Total	287	100.0	770	100.0	790	100.0	43	100.0	423	100.0

(5 m broad). The pitfall traps were placed in the field in distances of 5 m from different field margins and also in field centre and in clear cut area (in all the places in three replicates). The trapping period lasted from 20 June to 25 July 2001 when the rape was harvested. During this period the traps were checked and material collected weekly. The collected material was identified in laboratory and the mean number of specimens from the species caught per trap was calculated.

RESULTS AND DISCUSSION

During a ten-year study, carried out on clear-cuttings in an intensively managed forest area (forest district of Räpina, Estonia), the rich carabid species composition was established. Specimens from more than 50 different taxa were found (Table 1). From true predators the specimens from genera *Carabus*, *Cicindela*, *Broscus*, *Trechus*, *Bembidion* and *Calathus* were presented. From the large car-

abids of genus *Carabus* 8 species were present. *C. arvensis* was the most numerous. The specimens of genus *Pterostichus* were more abundant. In general in Räpina clear-cuttings the carabids were not very numerous but taxonomic composition was diverse.

In 2001 in the winter rape field specimens from the 38 taxonomic groups were found. The species composition was various in different field parts depending on the field boundary (Table 2). More diverse taxonomic composition and higher activity densities were found in the field parts which bounded with diverse grass margin and winter wheat field and also in the clear cut area. Apparently all these locations were more suitable for carabids habitation. The number of specimens and species significantly decreased also in the direction of field centre. Only the number of large carabid *Carabus glabratus* was the highest in this region. The large carabids are able to migrate from margin to field centre more quickly than other carabids (THIELE 1977). Fewer specimens were also established in the rape field part which had forest border margin because this part was quite moist and plant cover between the forest and the rape field was pure and that was not offering good hibernation possibilities for carabids.

Acknowledgements

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Diagnostic and prognostic service in forestry of Croatia: pest and disease situation in Croatia in 2000

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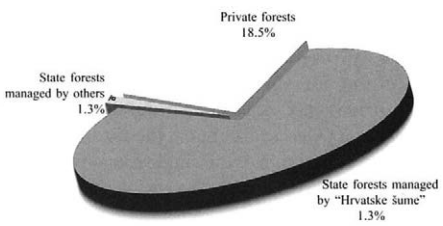
ABSTRACT: In the last 20 years (since 1980) Croatia has a well organised Diagnostic and Prognostic Service (DPS) for monitoring and forecasting outbreaks of forest insects and diseases. DPS has its headquarters in Forestry Research Institute in Jastrebarsko where all facilities (laboratories and necessary equipment) are situated.

THE ORGANIZATION OF DIAGNOSTIC AND PROGNOSTIC SERVICE (DPS)

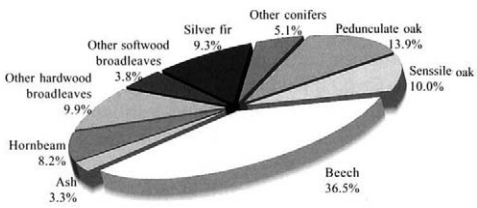
Continual observation

Foresters and specialists in the field of forest protection observe continually all stands which are managed by public enterprise "Hrvatske šume". Forests in Croatia are 80% state owned and 20% privately owned. All state owned forests are managed by "Hrvatske šume" and DPS is its service.

Every disease and insect outbreak is noted and immediately reported to the DPS and in December of each year the report is made. Specialists in the field of entomology and phytopathology from DPS, according to the needs, make field trips, asses damage, identify the disease or insect, give accurate and effective diagnosis and prognosis, give advice on protective measures and treatments.



Forests and forest land distribution by ownership



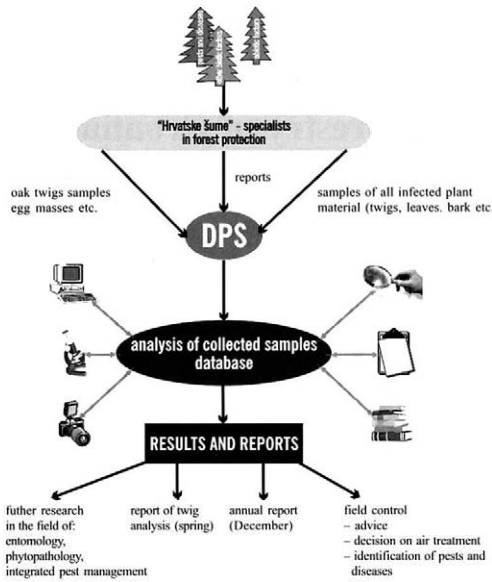
Tree species distribution

Monitoring of pests

The following insects are regularly monitored in Croatia:

1. *Lymantria dispar* – counting of egg masses
2. *Operophtera brumata, Erannis defoliaria* – glue rings
3. *Thaumetopoea pityocampa* – nest counting, cocoon counting
4. *Euproctis chrysorrhoea* – nest counting
5. *Ips typographus, Pityogenes chalcogaphus* – pheromone traps
6. *Tortrix viridana, Malacosoma neustria, Apethymus abdominalis, Operophtera brumata, Erannis defoliaria* and other defoliating insects that feed in early spring – branch sampling
7. *Stereonychus fraxini* – collecting of adults.

In December and January branch samples from oak forests are collected (according to special guidelines) and samples are, in laboratory conditions, monitored for occurrence of early defoliators which overwinter in buds and on oak twigs in egg stage. Fairly accurate, population densities (and damages) of early defoliators can be predicted and then closely monitored in the field and treated if necessary. Each spring a damage prognosis is given according to the results of branch analysis so that protection measures can be prepared in advance and the foresters in the field can act immediately. With the help of branch sampling the following insects are regularly monitored: *Tortrix viridana, Malacosoma neustria, Apethymus abdominalis, Operophtera brumata, Erannis defoliaria, Thaumetopoea processionea* and *Euproctis chrysorrhoea.*



Oak twigs sample

PEST AND DISEASE SITUATION IN CROATIA IN 2000

Plant diseases

The disease causing main problems in oak stands in Croatia is powdery mildew *Microsphaea alphitodes*. It attacks mature stands as well as oak seedlings, especially in warm and humid weather. It attacks young leaves emerging after heavy defoliation. In 2000, 6,150 ha in Croatia were attacked and 5,657 ha were treated with various fungicides.

Armillaria sp. is a disease present throughout Croatia and causing much concern in forests.

Sweet chestnut cancer (*Cryphonectria parasitica)* is also causing damage in natural stands of sweet chestnut and its attack has been registred on 1,450 ha. This is main factor in sweet chestnut decline in Croatia.

Other pathogens occurring in Croatian forests are: *Botrytis cinerea, Mycosphaerella pini, Cryptodiaporthe populea, Drepanopeziza punctiformis, Phaeocryptopus gaeumannii, Phomopsis conorum*. Where necessary, fungicides have been applied.

Insect pests

Most important defoliating insects

1. The most important harmful insects in Croatian forests are defoliators on oaks; each year they are causing major problems in oak forests. In the year 2000 those were defoliators from the family *Geometridae* (*Erannis defoliaria, Operophtera brumata* and others) which attacked 7,790 ha (heavy and very heavy defoliation) – treatment with insecticides was necessary on 3,784 ha. *Malacosoma neustria* attacked 4,250 ha and was treated on 3,974 ha. *Tortrix viridana* was more and more present in oak forests – in 2000, 1,633 ha were attacked. *Lymantria dispar* was considered to be main harmful oak defoliator but *Geometridae* and *Tortrix viridana* have taken its place. It has to be notified that all these defoliators come together in early and late spring, and make significant damage or total defoliation in oak forests. *Thaumetopoea processionea* attacked 278 ha. *Apethymus abdominalis* is present in oak stands every year in various population densities.

Strong attack of *Malocosoma neustria*

2. *Lymantria dispar* is regularly found in oak forests (in 2000 on 48,558 ha) but it does not cause significant damage (slight infestation) and no treatment was necessary. It has only caused total defoliation on the island of Cres on *Quercus ilex* but in the autumn of 2000 no egg masses were found or the single found were eaten by birds and other predators. In the spring of 2001 there was no outbreak.

3. The most important pest in Mediterranean pine forests is *Thaumetopoea pityocampa* which attacked 2,549 ha out of which 928 ha were treated.

4. In spruce stands *Ips typographus* and *Pityogenes chalcographus* are main harmful insects which are closely monitored and controlled with pheromone traps.

5. Oak acorn consumers include *Cucurli* sp., *Cydia amplana, Cydia splendana,* and gall wasps from the family *Cynipidae* attacking acorns and destroying acorn crop which was very abundant in 2000. Oak stands were treated from aeroplanes (450 ha) with insecticides.

6. Other insect pests occurring in Croatian forests are (where the outbreak made significant damage insecticides were applied): *Agelastica alni, Apethymus abdominalis,*

Argyresthia fundella, Balaninus sp., *Bytiscus populi, Chermes viridis, Coraebus fasciatus, Coleophora laricella, Cryptorhynchus lapathi, Euproctis chrysorrhoea, Evetria buoliana, Pityokteines curvidens, Pityokteines spinidens, Lygaeonematus abietinus, Paranthrene tabaniformis, Periclista lineolata, Phyllodecta vittelinae, Pineus strobi, Scolytus intricatus, Stereonychus fraxini, Thaumetopoea processionea, Tischeria ekebladella.*

Other biotic factors

Other biotic factors are rodents, weeds, game, mistletoes *Loranthus europaeus* and *Viscum album.*

Abiotic factors

The greatest damage was done by drought which was very intense and long lasting in 2000, and forests on shallow soils suffered mostly.

Decline of broadleaves and conifers which is a complex of several factors and is continually present in Croatian forests (especially oak and fir decline).

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Indices of site accessibility and preferences in investigations of pest distribution

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ABSTRACT: The method of site conditions evaluation for pests is described on the example of *Melolontha* sp. larvae distribution in the soils of two regions in Forest and Steppe zones. The calculations of site "availability" and "use" as well as selectivity and electivity indices are demonstrated. The conclusion is made that such approach allows to indicate the sites which are favorable for cockchafer larvae and unfavorable for forest growth.

Frequency and intensity of the forest pests outbreaks as well as the forest damage vary in different regions and even in the neighboring plots of the same stand. It can be explained by variety of microclimate indices which depend on site and stand structure as well as on host trees availability and preferences for given pest.

To optimize the survey and decision making, it is necessary to indicate the plots where pest density is the highest. The method of host trees "availability" and "use" evaluation was described by LECHOWICZ (1983). It was successfully used not only for host preference investigation for *Archips crataegana* Hb. (MESHKOVA 1992) but also for evaluation of other site and stand characteristics which are essential in the insects-defoliators distribution (MESHKOVA 2000). In fact in the case of accidental distribution, the number of insects in the different sites is proportional to number of plots with such site conditions. In the absence of electivity, insects colonize in higher degree those plots which number is higher. Therefore when we evaluate insects distribution we calculate "availability" of certain tree species as the relation of stem diameters sum of given host tree to the stem diameters sum for all hosts. When we evaluate the "availability" of plots with certain site conditions (or age, density etc.), we calculate the relation of the area occupied by plots with such conditions to the whole area of stands.

The "use" is calculated in the first case as the relation of insect density in the given host species to their average density in the stand. In the case of insect evaluation in the crown, the counts of larvae can be substituted by assessment of crown defoliation at the end of feeding period. It is suitable for two causes: on the one side visual assessment of defoliation allows to evaluate large number of trees without climbing or cutting branches. On the other side defoliation characterizes not only insect population but also hosts susceptibility to damage (MESHKOVA 1992). Like this the rate of different plots "use" was estimated as the relation of insect density in the plots with certain site or stand conditions to their mean density for all plots (MESHKOVA 2000).

Indices of electivity and selectivity are calculated after formulas (1) and (2) (LECHOWICZ 1983) and can be the measure of host or site preference.

$$E_i = \frac{(W_i - \frac{1}{ni})}{(W_i + \frac{1}{ni})} \quad (1)$$

where

$$W_i = \frac{\left(\frac{ri}{pi}\right)}{\sum_{i=1}^{m}\left(\frac{ri}{pi}\right)} \quad (2)$$

where: E_i – index of electivity to given parameter of site and stand
W_i – index of selectivity to given parameter of site and stand
n_i – number of plots with given parameter of site and stand
r_i – "use" of trees or plots with given parameter of site and stand
p_i – "availability" of plots with given parameter of site and stand
i – number of plots with given parameter of site and stand
m – total number of surveyed plots

Meaning of selectivity index W can vary from 0 to 1 and its interpretation depends on number of plots with given site or stand parameter. However electivity index E takes into account the number of plots with given site or stand parameters. It is zero when distribution is occasional, approaches to –1 when insects escape such conditions (or their survival is low) and approaches to +1 in preferred stands (LECHOWICZ 1983).

Here we present the example of this method application for estimation of *Melolontha* sp. larvae dissemination in the soil of the plots with different site conditions. After Ukrainian forest typology (POGREBNYAK 1955), site con-

ditions are characterized by combination of humidity and nutritive quality (so called "trofnost") indices. Levels of humidity are 0 (very dry), 1 (dry), 2 (fresh), 3 (moist), 4 (damp), 5 (wet). Levels of nutritive quality are A (sand), B (sandy loam), C (clay loam) and D (loam). According to this the typological net is formed which covers the whole diversity of site conditions. Table 1 shows the results of cockchafer larvae counts in Malin Forest Enterprise (Zhitomir region, Forest zone). The mean density was calculated as the larvae number per pit and the relative density was calculated as the per cent of pits with larvae presence.

One can see that the highest meanings of the both mean and relative density of larvae were registered in the sites A2, i.e., the most poor and dry lands in this region (Table 2). The lowest larvae density was registered in types B3 and C3. In the frame of the same humidity level the most poor lands were populated, and in the frame of the same nutrition quality the highest larvae population was estimated in the most dry sites.

At the same time, the analysis of site conditions distribution in the inspected area shows the considerable prevalence of B2 type (Table 2). Therefore the cockchafer female had to lay the eggs in such sites too, and the relative density of these sites was rather high as well as the "use" of the site. Calculation of electivity indices shows that the larvae escaped the moist sites ($E < 0$), preferred the fresh sites and the meaning of E decreased from poor (A) to rich (C) sites.

Table 1. Mean (larvae/1 m^2) and relative (% of pits with larvae presence) density of cockchafer larvae (Malin Forest Enterprise)

Mean density (total mean is 7.51 larvae/m^2)			Relative density (total mean is 77.4% of pits)		
Trofnost	Humidity 2	3	Trofnost	Humidity 2	3
A	12.2	–	A	86.67	–
B	7.2	1.73	B	79.59	54.55
C	5.0	1.6	C	75.0	55.56

Table 2. Calculation of electivity and selectivity indices for cockchafer larvae distribution (Malin and Izum Forest Enterprise)

Forest site type	Number of pits	Mean density (larvae/m^2)	Site "availability" (p)	Site "use" (r)	r/p	W	E
Malin Forest Enterprise							
A2	8	12.2	0.033	1.625	49.7	0.590	0.65
B2	168	7.20	0.822	0.959	1.2	0.014	0.40
B3	12	1.73	0.092	0.230	2.5	0.030	–0.47
C2	8	5	0.032	0.666	20.8	0.247	0.33
C3	4	1.6	0.021	0.213	10.1	0.120	–0.35
Mean weighted		7.51		sum	84.2		
Izum Forest Enterprise							
A1	86	3.88	0.429	1.385	3.2	0.03	0.37
B1	2	3.50	0.011	1.250	117.1	0.93	0.33
A2	79	2.07	0.394	0.740	1.9	0.02	0.08
B2	31	1.87	0.153	0.668	4.4	0.03	0.03
C2	3	0.00	0.013	0.000	0.0	0.00	–1.00
Mean weighted		2.8		sum	126.5		

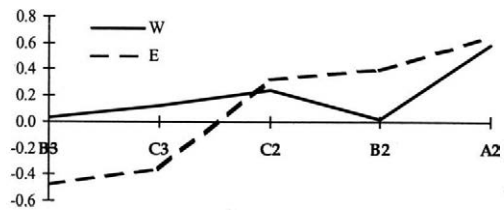

Fig. 1. Electivity and selectivity indices for cockchafer larvae distribution (Malin Forest Enterprise, Zhitomir region, Ukraine)

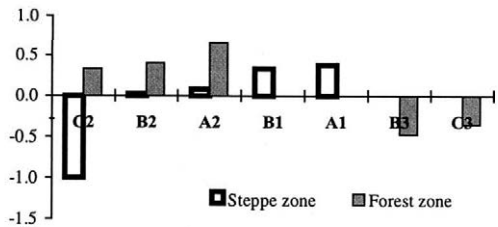

Fig. 2. Electivity indices for cockchafer larvae distribution for different natural zones of Ukraine

Graphic representation of cockchafer larvae distribution indices is the most demonstrative, when the data are sorted after index E (Fig.1).

The results of similar analysis for cockchafer larvae assessment in the Steppe zone (Izum Forest Enterprise, Kharkov region) are showed in the Table 2. Dry and poor sites (A1 and A2) predominate here, larvae density is the highest in the dry sites but is less than that one in the similar site conditions in forest zone. Nevertheless the threshold of danger is 0.5–3 larvae per 1 m^2 for Steppe zone and it is 3–10 for Forest zone (SKLAROVA et al. 1999). As one can see, index W does not allow to make any conclusion, it is rather high for B1 because the number of such plots is the lowest. At the same time, index E clearly shows the preferences of the most dry sites for cockchafer larvae (Fig. 2).

Graphical representation of electivity indices for cockchafer larvae distribution (Fig. 2) shows that in the both zones the pest prefers to populate sites A and B. It prefers to populate dry sites in the Steppe zone (A1, B1) and fresh sites (but not moist ones) in the Forest zone. In the frame of the similar level of humidity the pest prefers to populate more poor sites (A and B), so that it can serve the indicator of the sites which are not very favorable for forest growth.

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Some remarks about the testing of different pheromone baits and traps necessary and useful for the control of bark beetles *Ips typographus* (L.) and *Pityogenes chalcographus* (L.) in Romania

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ABSTRACT: The results of researches carried out in 1994–2000 show a good efficacy of pheromones Atratyp and Atrachalc produced in Romania by the Institute of Chemistry from Cluj-Napoca in comparison with Pheroprax produced in Germany. By tubular and barrier traps baited with these pheromones a lot of bark beetles *Ips typographus* and *Pityogenes chalcographus* were attracted. The captures of predators *Thanasimus formicarius* and *Nemosoma elongatum* were recorded as well.

In the researches carried out in 1994–2001 period some results concerning the testing of synthetic pheromones Atratyp and Atrachalc produced in Romania compared with Pheroprax and Chalcoprax produced in Germany were obtained. The data on the captures achieved by pheromone traps (Tubular, Winged-funnel and Theysohn type) show the evolution and variation of the insects flight.

MATERIAL AND METHOD

The data regarding experimental plots, year and period of observations, type of pheromone, type and number of pheromone traps used are included in Tables 1 and 2.

To compare the obtained results the index **Ia** representing the number of captured insects by one trap in one day was calculated.

The observations and collecting of captured insects by pheromone traps was made once or twice per week in the whole flight period.

RESULTS

THE ATTRACTION OF BARK BEETLES TO PHEROMONE TRAPS

The barrier type of traps (Winged-funnel and Theysohn) were move efficiently in the capturing of bark

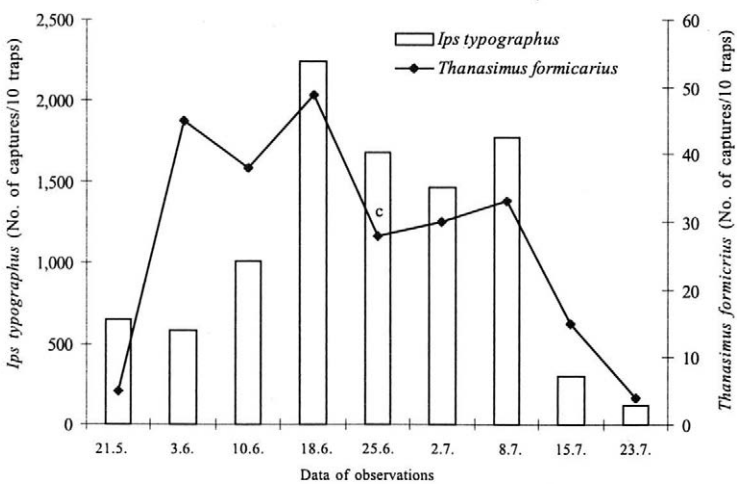

Fig. 1. The distribution of *Ips typographus* and *Thanasimus formicarius* captures by pheromone tubular traps, in flight period (Experimental plot Gârcin, Forest District Săcele, 1997)

Table 1. Intensity of attraction (Ia) to pheromone traps established for *Ips typographus*

Experimental area	Year	Type of trap	Type of pheromon	Number of traps	Observations period (number of days)	Ia (Number of captured/beetles day × trap)
Garcin	1997	Tubular	Atratyp 1	2	20. 5.–23. 7. (64)	12.6
(Forest District			Atratyp 2	2		9.2
Sacele)			Atratyp 3	2		15.7
			Atratyp 4	2		20.7
			Pheroprax	2		20.8
		Winged-funnel	Atratyp 1	1	10. 6.–23. 7. (43)	115.1
			Atratyp 2	1		114.4
			Atratyp 3	1		76.1
			Atratyp 4	1		139.1
			Pheroprax	1		79.1
	1998	Winged-funnel	Atratyp-98	5	21. 5.–22. 6. (33)	43.9
	1999	Tubular	Atratyp-99	4	28. 5.–14. 7. (47)	21.6
			Pheroprax	4	25. 5.–14. 7. (50)	43.1
		Winged-funnel	Atratyp-99	3	24. 5.–14. 7. (51)	124.3
			Pheroprax	3	19. 5.–14. 7. (56)	269.4
Tamina	2000	Tubular	Atratyp-00 I	3	3. 6.–20. 7. (49)	24.9
(Forest District			Atratyp-00 II	3		67.3
Brasov)			Pheroprax	3		38.9
		Theysohn	Atratyp-00 I	3	31. 5.–20. 7. (51)	106
			Atratyp-00 II	3		13.9
			Pheroprax	3		42.2
	2001	Tubular	Atratyp-01	4	17. 5.–10. 7. (44)	24.9
			Pheroprax	4	19. 6.– 6. 7. (17)	25.2
		Theysohn	Atratyp-01	4	17. 5.–29. 6. (36)	41.8
			Pheroprax	4	19. 6.–3. 7. (14)	28.8

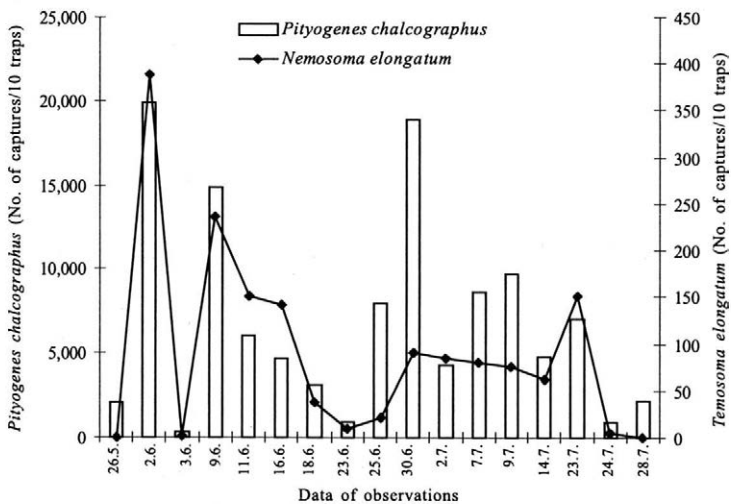

Fig. 2. The distribution of *Pityogenes chalcographus* and *Nemosoma elongatum* captures by pheromone barrier traps, in flight period (Experimental plot Gârcin, Forest District Săcele, 1998)

Table 2. Intensity of attraction (Ia) to pheromone traps established for *Pityogenes chalcographus*

Experimental area	Year	Type of trap	Type of pheromon	Number of traps	Observations period (number of days)	Ia (Number of captured/beetles day × trap)
Garcin	1994	Winged-funnel	Atrachalc-94	3	12. 5–9. 6. (29)	450.1
(Forest District			Chalcoprax	3	12. 5.–9. 6. (29)	586.1
Sacele)	1995		Atrachalc-95	3	17. 5–1. 8. (76)	22.6
			Chalcoprax	3	17. 5.–1. 8. (76)	613.5
	1998		Atrachalc-98	5	21. 5.–28. 7. (68)	105.0
	1999		Atrachalc-99	3	19. 5.–14. 7. (56)	276.5
Comandau	1994		Atrachalc-94	3	11. 5.–30. 8. (111)	35.1
(Forest District			Chalcoprax	3	11. 5.–30. 8. (111)	20.9
Comandau)	1995		Atrachalc-95	3	23. 5.–28. 6. (38)	3.9
			Chalcoprax	3	23. 5.–28. 6. (38)	24.7
Tamina	2000	Theysohn	Atrachalc-00	3	31. 5.–20. 7. (51)	8.3
(Forest District			Chalcoprax	2	31. 5.–20. 7. (51)	4.9
Brasov)	2001		Atrachalc-01	4	22.–26. 6.; 3.–6. 7. (7)	289.3
			Chalcoprax	4	19.–22. 6; 6.–10. 7. (7)	517.3

beetlees *Ips typographus* that tubular traps. Except year 1999, the field testing in 1997, 2000 and 2001 show the comparable captures obtained by traps baited with Atratyp and Pheroprax (Table 1).

The attraction of *Pityogenes chalcographus* to Chalcoprax and Atrachalc baits was various during the testing carried out in 1994–2001 period. The formula of attractive substance produced in Romania and tested in 1994 and 2000 years was the most efficient. The results are comparable with those obtained with Chalcoprax (Table 2).

THE VARIATION OF CAPTURES IN FLIGHT PERIOD

The captures of bark beetles *I. typographus* and *P. chalcographus* during the flight period as well as the captures of their predators *Thanasimus formicarius* and *Nemosoma elongatum* are presented in Figs. 1 and 2. Following the variation of captures the evolution of flight – i.e. the first flight and the flight of sister generation, is distinguished. The flight of predators was parallel whith the flight of pests, but with much lower intensity.

CONCLUSIONS

1. The barrier type of traps (Winged-funnel and Theysohn) are more efficient in the capturing of *I. typographus* beetles than Tubular traps.

2. The field testing carried on in years 1994, 1997, 2000 and 2001 emphasised good efficacy of pheromone baits Atratyp and Atrachalc produced in Romania in comparison with Pheroprax and Chalcoprax produced in Germany.

3. The curve of *I. typographus* and *P. chalcographus* populations level is parallel with the curve of their predator *Thanasimus formicarius* and *Nemosoma elongatum*, as a result of relation host – predator.

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Sanitary state of resinous stands from Romania and the protection measures applied in the 1990–2000 period

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ABSTRACT: The sanitary state of conifer stands and protection measures yearly applied in Romania between 1990 and 2000 are presented. The pest populations' level in resinous stands was reflected by the quantity of infested wood and the number of standing trees attacked by trunk insects from wind-damaged areas. After the natural calamity produced by wind and snow on the 5th November, 1995 in Eastern Carpathians in Romania, the greatest infestations by bark and wood boring insects on standing or fallen trees have been registered.

The main pests which affect the health state of the resinous forests and plantations in Romania are the following: *Ips typographus, Ips amitinus, Pityogenes chalcographus, Polygraphus poligraphus, Dendroctonus micans, Pityokteines curvidens, Pissodes harcyniae, Pissodes piceae, Pissodes pini, Tomicus piniperda, Tomicus minor, Ips acuminatus, Ips sexdentatus, Trypodendron lineatum, Urocerus gigas, Sirex juvencus, Monochamus sartor, Monochamus sutor, Tetropium castaneum* in stands and *Hylobius abietis, Hylastes ater, Hylastes cunicularius* in plantations.

The fluctuations of the pest populations level are in correlation with periodical calamities caused by wind or snow.

Data regarding the quantities of broken/fallen and infested wood material, the infested standing trees and the protections measures applied yearly in the forest were acquired from the statistics and forecast of the pests.

In this paper the situation of natural calamities in 1990–2000 period and the evolution in this time of the pests populations level is presented. In forest the populations level is reflected by quantities of infested wood material and number of standing trees attacked by trunk insects.

The highest natural calamity (as volume of fallen trees) took place in 1995 (Fig. 1). As a result of this calamity, the highest population level of bark and wood boring insects was registered in the following years. This level was reflected by the proportion of wood material infested in 1996–1998 and a lot of standing trees attacked especially in 1999–2000.

Difficult situation regarding the sanitary state of coniferous stands determined the following protection measures: installation of the pheromone traps, installation of the classical trap trees, installation of the chemically treated and baited (with pheromone) trap trees, debarking of the wood material (Fig. 2).

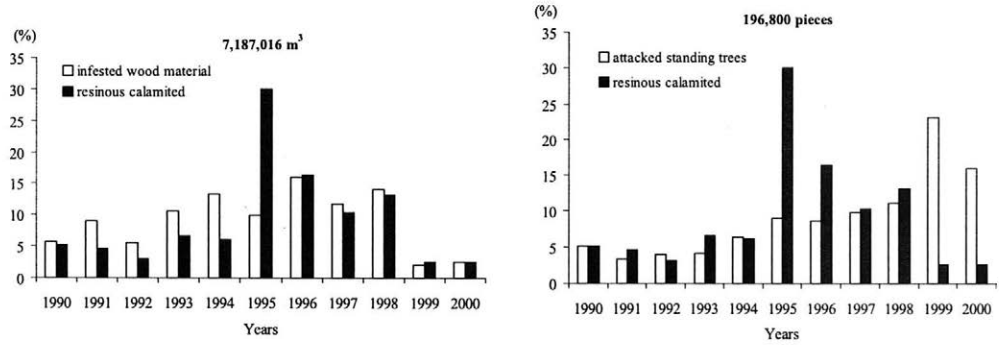

Fig. 1. The situation regarding the resinous stands calamited by wind and snow and the damages produced by bark and wood-boring insects

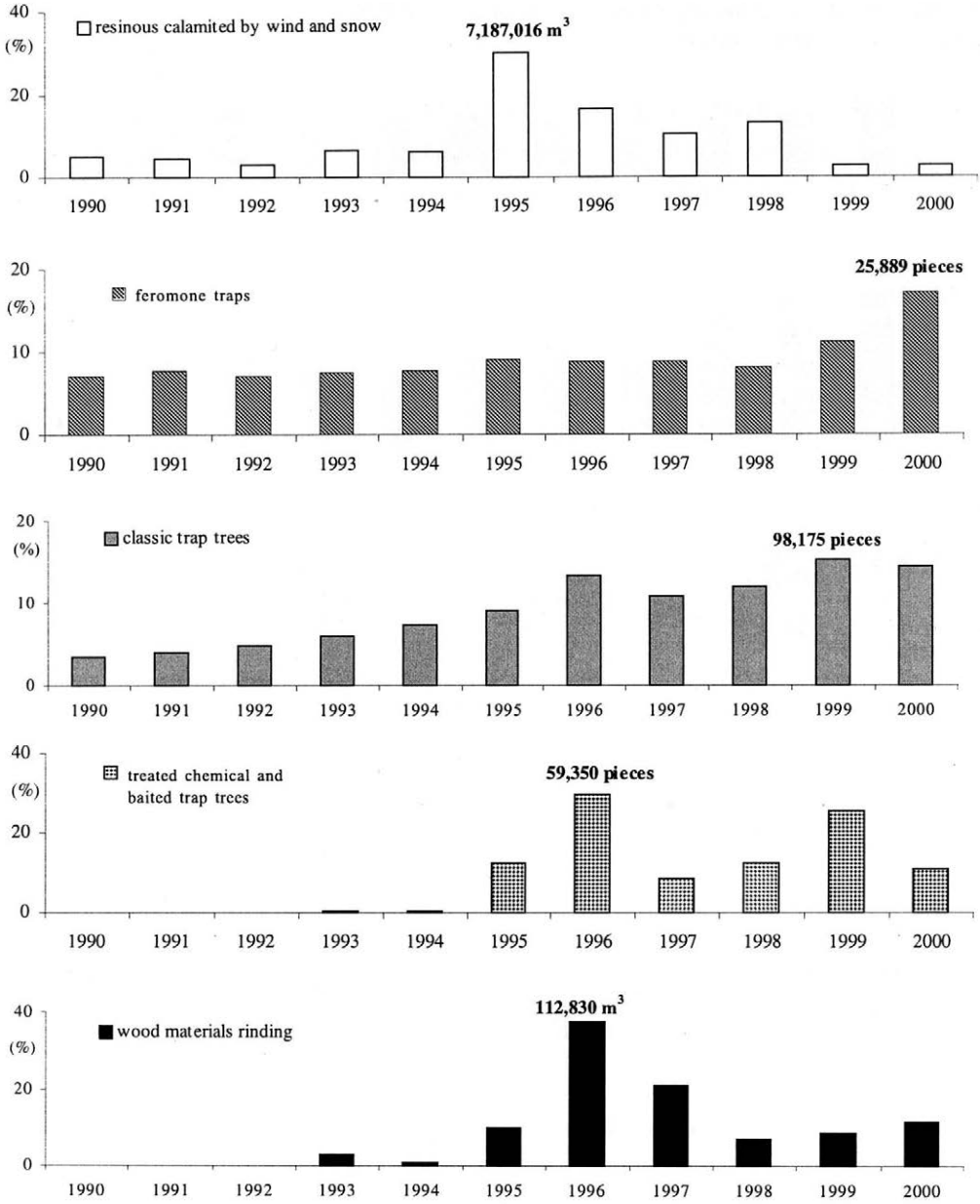

Fig. 2. The situation regarding the resinous stands calamited by wind and snow and the protection measures applied in 1990–2000 period

Regarding the sanitary state of plantations, the surface reforested yearly in 1990–2000 period and the surface infested by pests did not vary significantly from year to year (Fig. 3). The protection measures consisted in installation of toxic bark traps and treatment by sinking of the young plants before plantation. These actions were intensified in 1997–2000 when an increase of the pest populations level was registered.

In conclusion, the protection measures applied yearly in resinous stands and in plantations were efficient. The level of bark beetle populations and of plantation pests showed an obvious decrease in 2000 and especially in 2001.

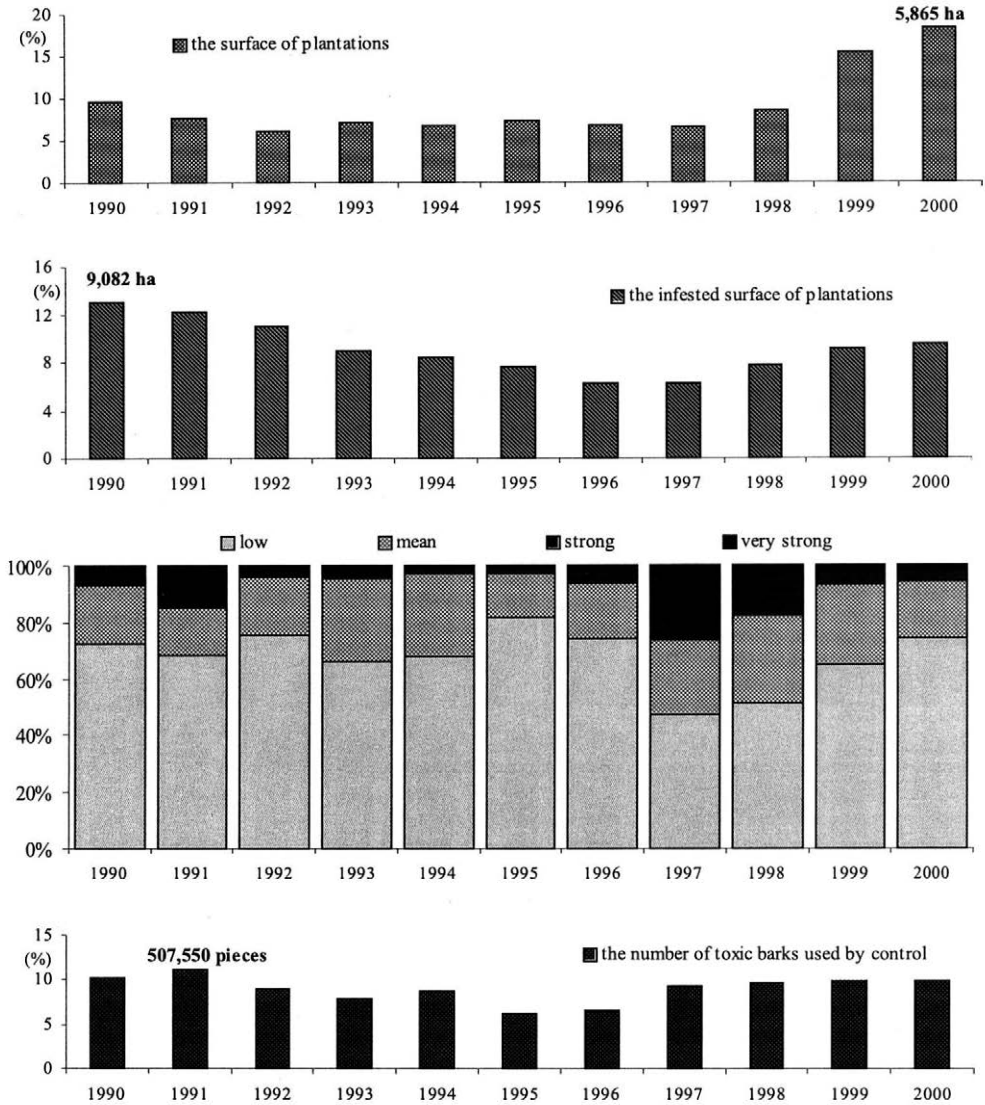

Fig. 3. The evidence of resinous plantations from Romania damaged by *Hylobius abietis* and the measures of control applied in 1990–2000 period

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Spatial patterns of the distribution of trees infected by *Ips typographus* (L.) (Coleoptera, Scolytidae) in the National Park "Sächsische Schweiz" from 1996 to 2000

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ABSTRACT: The attack dynamic of the spruce bark beetle (*Ips typographus* [L.]) shows a wide variability. An analysis of the spatial pattern of the attack locations with a Geographical Information System (GIS) was the aim of the investigation. The research area was the National Park (NP) "Sächsische Schweiz" near Dresden, Germany. Long-term documentation make detailed investigations to the attack dynamics of the spruce bark beetle possible. Different information were used for instance inventory-data, registered spots of attacks on standing trees and results from pheromone-trap systems. Relations between stand structure typs (portion and the suitability of the host trees) and the attack on standing trees were shown. The distances from attacks in a year (n) to nearest attacks in the year before (n–1) were calculated with GIS. Different distances in the years 1997–2000 were discussed in relation to the population dynamic and the effectivity of prophylactic protection measures in single stands.

WORKING HYPOTHESIS

The attack dynamic of the spruce bark beetle (*Ips typographus* [L.]) shows a wide variability. This is influenced mostly by weather conditions. During the latency, the attacks concentrate on lying trees (by windthrow or snowbreak). Spots of attacks on standing susceptible trees occur with an increasing population density. Areal attacks of vital spruces occurs during the gradation. The alterations in the host selection criteria and the spatial patterns of the attack locations could be analysed with a Geographical Information System (GIS).

METHODS

RESEARCH AREA

The forest-sandstone-area of the National Park (NP) "Sächsische Schweiz" near Dresden, Germany has been used for wood production for a long time. In the examined eastern part of the NP, the spruce usually dominates in

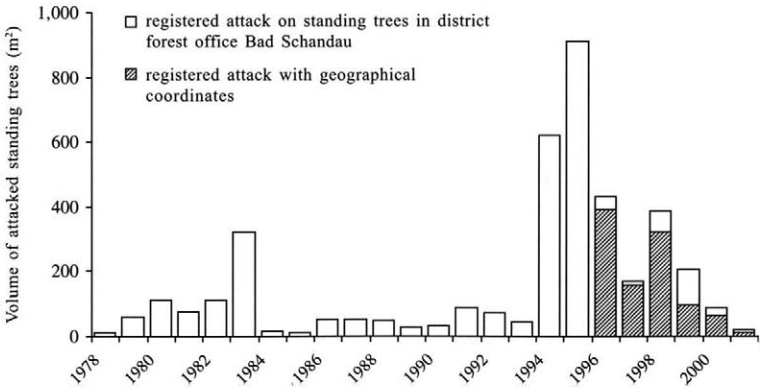

Fig. 1. Volume (m³) of infested trees 1978–2001

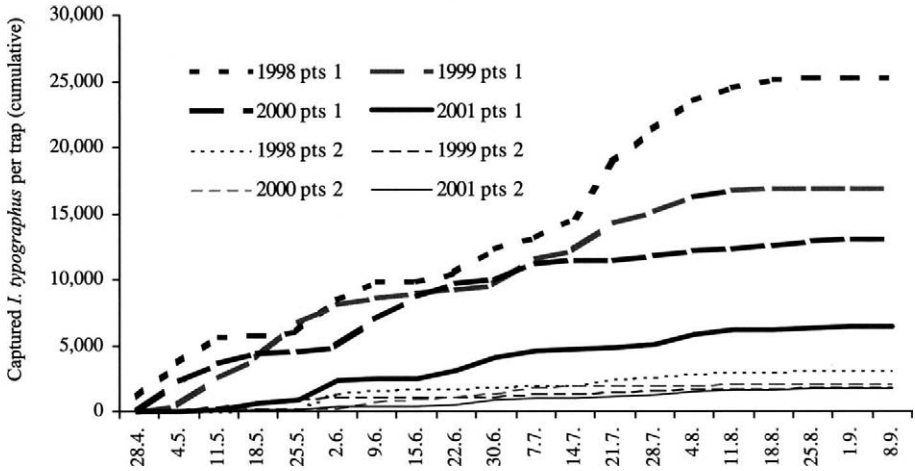

Fig. 2. Number of bark beetles captured in 3 pheromone trap groups in 1998–2001

pure stands over 60 years (55.5%). Such forest structures characterise a potential attack-endangering for the spruce bark beetle. However catastrophic outbreaks did not appear in the past (Fig. 1). Essential reasons therefore are the diversity of the local site types and stand structures in small areas and the absence of stronger windthrow- and snowbreak damages. According to the aim of the NP no measures are carried out against the spruce bark beetle in the main protection zone (1,300 ha). In the area with silvicultural activity, the integrated pest management concept without the application of insecticides is used (GRUNWALD 1999). Long-term documen-tation makes detailed investigations on the attack dynamics of the spruce bark beetle possible. The attack development and the flight activity of the beetles in the observation period indicate a retro-gradation with some short interruptions (Figs. 1 and 2).

USED DATA

Various kinds of information were used for the investigation, such as:

- inventory-data of a permanent spot check (psc) (deadline 1. 1. 96, in a 141.4 × 141.4 m grids) to characterise the attack-endangering (STRÖDE 1998),
- inventory-data of the forest management planning (deadline 1. 1. 98),

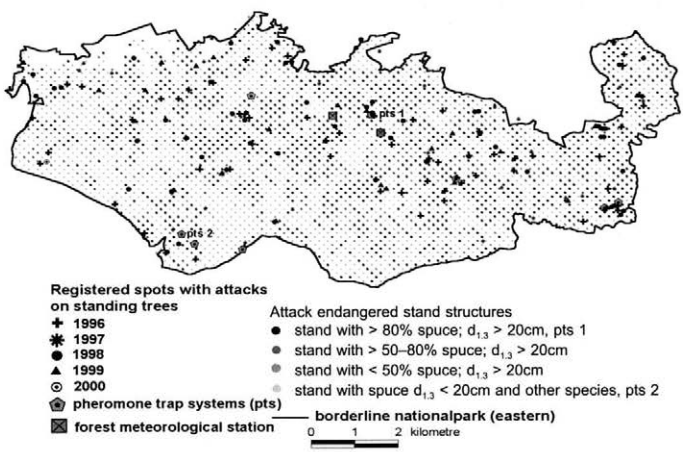

Fig. 3. Research area with structure data

Table 1. Types of stands with attacks on standing trees 1998–2000

Stand structure type (sst)	Distribution of the attacks in sst			Portion of the sst in the research area (all ages) (%)
	1998 n = 79 (%)	1999 n = 29 (%)	2000 n = 29 (%)	
Spruce stands type with < 20% admixed tree species	73.4	86.2	69.0	32.4
Spruce stands type with ≥ 20% needle tree species	15.1	10.4	20.7	20.3
Spruce stand type with ≥ 20% broadleaved tree species	7.6	3.4	6.9	11.4
Other stand types with ≥ 20% needle tree species	3.8	0	3.4	17.3

– registered spots of attacks on standing trees by the forest district office* as well as the NP*, since 1996 with geographical parameters,
– linkage of the single-data* by a Geographical Information System (GIS) and ArcView®,
– pheromone trap systems (pts) consist of Theysohn® – traps with Pheroprax®– ampoules like the use in forest practise*.

Fig. 3 is a map from the research area with important data.

RESULTS

The questions: "Where and how long do the spruce bark beetles fly?" are very important for the analysis of the spatial patterns. The attack on standing trees in relation to the forest structure was analysed at first. Table 1 shows the results.

70–86% of the attacks were concentrated on 32% of the research area in the stands, with dominating spruce (portion over 80%). Spruce stands with an admixture of at least 20% of other conifer species were attacked in accordance with their area share. The attack frequency was lower when the area share of broadleaf admixtures in spruce stands was at least 20%. In stands, with other tree species dominating, the attacks on the single admixed spruces could be observed rarely.

The suitability of a stand is also characterised by the portion of suitable host trees (spruce, diameter at breast height > 20 cm). Figure 4 shows the results concerning this parameter.

For 60–70% of the spots of attacks, the neighbour stand structure (described with the next psc-point, middle distance: 50–80 m), was characterised by a high share of spruces with attack-suitable dimension (diameter at breast height > 20 cm) during the whole observation period. Stands (psc-points) without or with a small portion(< 50%) of suitable host trees were neighboured with spots of attacks rarer then expected accidental distribution would have been.

The distances from attacks in a year (n) to nearest attacks in the year before (n–1) were calculated with GIS. The results for the period 1997–2000 are shown in Fig. 5.

In the years 1997–2000 spots of attacks occurred in average distance of 580 m from a next attack of the year before. In comparison to 1997 attacks doubled by the development of a second beetle generation in 1998. The longer distances (770 m) indicate a resettlement of susceptible stands independent from attacks in the year before. The retrograde attack through the development of only one generation in 1999 (Fig. 2) occurred in the minimal distance of 430 m on average. A narrow spatial relationship can be assumed with attacks from the year before.

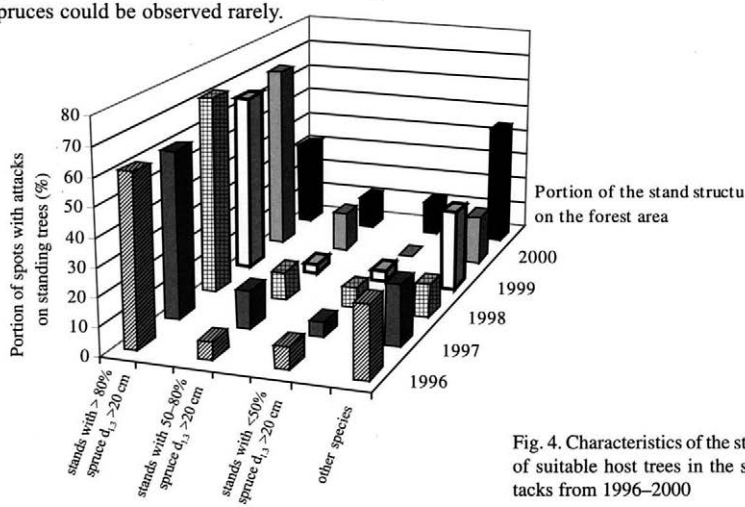

Fig. 4. Characteristics of the stand types on the basis of the share of suitable host trees in the surrounding of the spots with attacks from 1996–2000

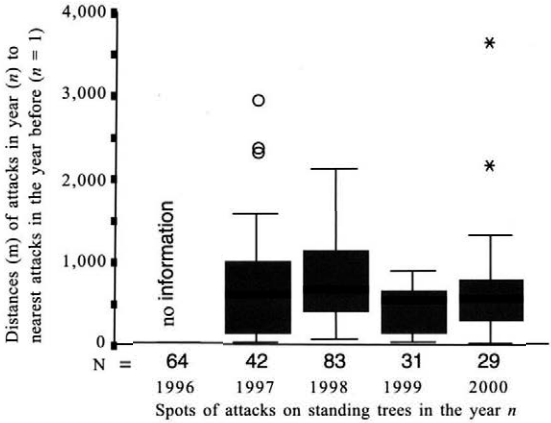

Fig. 5. Calculated distances between spots with infested standing trees in 1997 until 2000 to nearest attacks in the year before

Table 2. Classification of the distances between current and the respective nearest spot of attacks on standing trees in the years before

Year	Number of analysed spots of attacks	Portion of spots of attacks with a distance to the nearest spot of attacks from the year before in the steps (%)					Summarised (%)	
		≤ 100 m	> 100–250 m	> 250–500 m	> 500–1,000 m	> 1,000 m	≤ 500 m	> 500 m
1997	42	1.9	21.4	7.1	35.7	23.8	40.4	59.5
1998	83	7.2	13.2	10.8	34.9	33.7	31.2	68.6
1999	30	23.3	10.0	13.3	53.3	0.0	46.6	53.3
2000	29	13.8	10.3	13.8	44.8	17.2	37.9	62.0

The frequency of the distances in steps are listed in Table 2.

WICHMANN and RAVN (2001) showed that new attacks develop less than 650 m from an old attack, and 80% of the new attacks are less than 250 m from an old attack. In the NP only 20–33% of the new attacks occurred until 250 m from an old attack.

Wide distances between current attacks and attacks from the year before show the limits to stop an attack expansion by use of prophylactic protection measures in single stands. During the retrogradation and probably during the development of the first beetle generation such measures are effective because of the short distances and the low spread-tendency of the beetles.

CONCLUSION

A Geographical Information System makes possible to analyse area and point data with parameters characterising susceptibility as well as the attack dynamics of the spruce bark beetle. Well known contexts of the attack dynamics are quantitatively describable and confirm previous experiences on the effectiveness of protection measures.

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*The authors thank the foresters of the forest district office "Bad Schandau" and the rangers of the NP for the data preparation and the enforced data collection and Mrs. LORENZ of the LAF for the Arcview® evaluations.

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The catch of the larch bark beetle *Ips cembrae* (Heer) with pheromone traps in Slovenia

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ABSTRACT: Only a few localities of the larch bark beetle *Ips cembrae* (Coleoptera, Scolytidae) have been known in Slovenia until recently. The search for new localities of the *I. cembrae* in the alpine and sub alpine region of the country from 1994 to 1996 was based on the data of the presence of larch in individual forest sections. Beetles were collected from larch logs, trap trunks, cutting remains, attacked standing trees and standard black Theysohn traps, baited with the synthetical pheromone Cemprax®. The new localities (51 in total) prove that *I. cembrae* inhabits the entire region of the natural larch range in Slovenia. Field response of bark beetles to the pheromone Cemprax® was studied on the Peca Mountain, where twenty pairs of standard black Theysohn traps (baited/non-baited) were used. In the period from May 27th to September 21st, 24 different bark beetle species were caught. Six species (*Hylastes cunicularius, Pityogenes chalcographus, Ips cembrae, Dryocoetes autographus, Ips typographus* and *Ips acuminatus*) represented more than 98% of the total catch. A relatively small number of captured *I. cembrae* individuals ($n = 630$) can be explained by high altitude and low larch bark beetle population density. The three *Ips* species were attracted to traps by the pheromone Cemprax®. It seems that Cemprax® has no effect on the catch of *H. cunicularius* and *D. autographus*.

The larch bark beetle *Ips cembrae* (Coleoptera, Scolytidae) inhabits in the natural range of the European larch (*Larix decidua* Mill.) mainly felled trees, unpeeled logwood and occasionally weak standing trees (gallery – Fig. 1). A stronger attack has not been registered in Slovenia yet and only a few localities of its occurrence have been known until recently.

NEW LOCALITIES OF *IPS CEMBRAE* IN SLOVENIA

It has been assumed that, due to a high proportion of larch in the forests of the northern Slovenia, the species occurs in the major part of the alpine and sub alpine zoogeographical region of the country. The search for localities of the *I. cembrae* was based on the data on the presence of larch in individual forest sections. Beetles were collected from larch logs, trap trunks, cutting remains and attacked standing trees. Part of new localities (41%) were found by means of standard black slot Theysohn traps, baited with the synthetical aggregation pheromone Cemprax® produced by Cyanamid Agrar. Beetles were collected periodically from 1994 to 1996.

I. cembrae was found in 51 localities in 26 UTM quadrants in total (Fig. 2). The species was found for the first time in the Julian Alps. The new localities also include the

Fig. 1. Longitudinal star-like gallery system of the larch bark beetle *Ips cembrae*

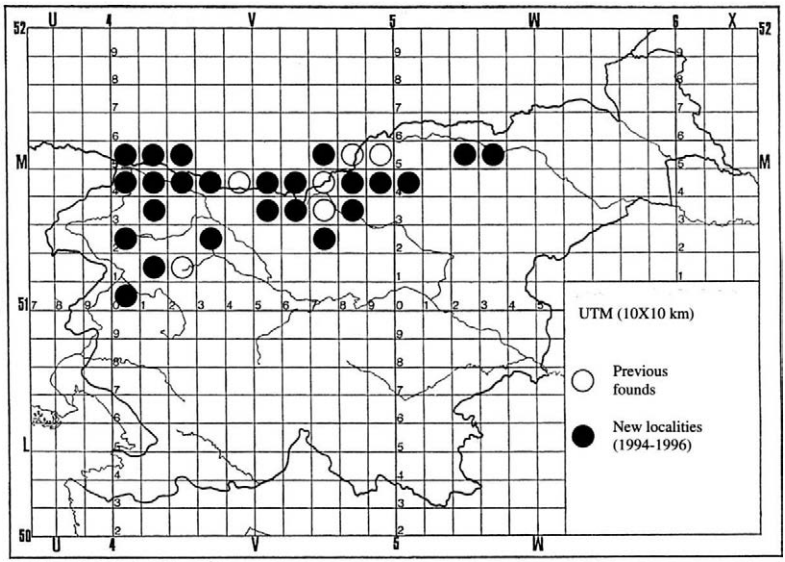

Fig. 2. Distribution of *Ips cembrae* in Slovenia

most southern, the most eastern and the most western ones in Slovenia. Most of them are situated at altitudes of over 1,000 m. The new localities support the hypothesis that *I. cembrae* inhabits the entire region of the natural larch range in Slovenia, that is, it is present in the Karavanke range, the Julian Alps and the Kamnik Alps. Some localities are also situated outside the natural larch range (the Pohorje, Kal) and confirm some older finds held in museum collections.

Table 1. Captured bark beetle species in Cemprax® baited and unbaited traps, host tree species and total of captured specimens

Species	Supposed main hosts on the site	*n*
Hylastes cunicularius Erichson	*Picea abies*	2,067
Pityogenes chalcographus (Linné)	*P. abies*	1,087
Ips cembrae (Heer)	*Larix decidua*	630
Dryocoetes autographus (Ratzeburg)	*P. abies, Pinus sylvestris*	427
Ips typographus (Linné)	*P. abies*	234
Ips acuminatus (Gyllenhal)	*P. sylvestris*	122
Polygraphus poligraphus (Linné)	*P. abies*	18
Xyloterus lineatus (Olivier)	*P. abies*	12
Phthorophloeus spinulosus Rey	*P. abies*	9
Crypturgus hispidulus Thomson	*P. abies, P. sylvestris, L. decidua*	7
Pityophthorus pityographus (Ratzeburg)	*P. abies*	5
Orthotomicus laricis (Fabricius)	*P. sylvestris*	4
Hylurgops glabratus (Zetterstedt)	*P. abies*	2
Xylocleptes bispinus (Duftschmidt)	*Clematis vitalba*	2
Cryphalus intermedius Ferrari	*L. decidua, P. sylvestris*	2
Pityogenes bidentatus (Herbst)	*P. sylvestris*	2
Ips amitinus (Eichhoff)	*P. abies*	2
Crypturgus cinereus (Herbst)	*P. sylvestris, P. abies*	1
Dryocoetes alni (Georg)	*Alnus* spp., *Corylus avellana*	1
Cryphalus abietis (Ratzeburg)	*P. abies, P. sylvestris*	1
Cryphalus saltuarius Weise	*P. abies*	1
Pityogenes quadridens (Hartig)	*P. sylvestris, P. abies, L. decidua*	1
Pityokteines spinidens (Reitter)	*Abies alba*	1
Ips sexdentatus (Boerner)	*P. sylvestris*	1

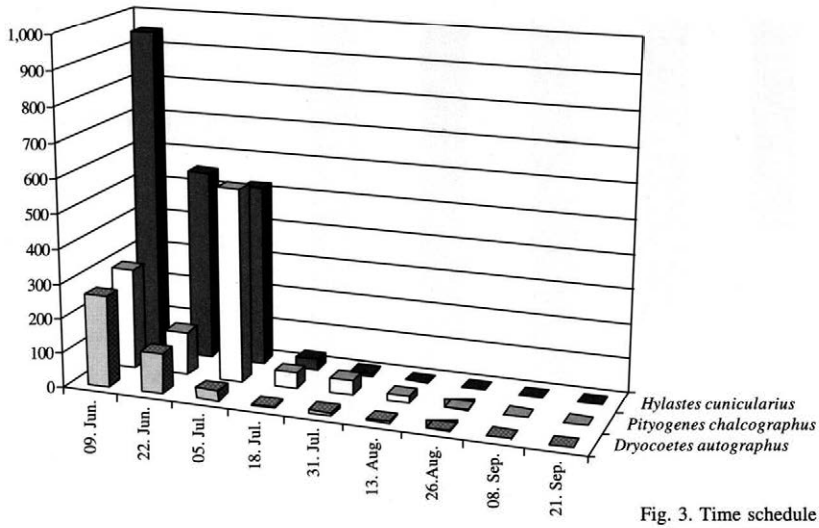

Fig. 3. Time schedule of the catch of *Hylastes cunicularius*, *Pityogenes chalcographus* and *Dryocoetes autographus*

FIELD RESPONSE OF BARK BEETLES TO THE PHEROMONE CEMPRAX®

The experiment took place on the Peca Mountain (Karavanke, northern Slovenia, UTM VM 85), from May 27th to September 21st 1994, at five selected study sites at altitudes from 1,020 to 1,360 m. Two main vegetation associations, *Adenostilo alliarie-Piceetum* and *Abieti-Fagetum dinaricum*, were found in the research area. The average wood stock was 356 m^3/ha with the following tree species composition: *Picea abies* 72%, *Larix decidua* 15%, *Pinus sylvestris* 7%, *Acer pseudoplatanus* 4% and *Fagus sylvatica* 2%. Twenty pairs of standard black slot Theysohn traps were used. For each pair, only one trap was baited with the aggregation pheromone Cemprax®, and the other was a control trap. The pairs of traps were set at a distance of 5 m. Beetles were collected every 13 days. New pheromone dispensers were added only once, on July 18th.

In total, 24 different bark beetle species were caught (Table 1). The first six species in the table account for more than 98% of the total catch. A relatively small number of captured eight spined larch beetles ($n = 630$) can be explained by high altitude and stable forest stands with low larch bark beetle population density. Over 71% of all *Hylastes cunicularius* specimen were caught on one study site only.

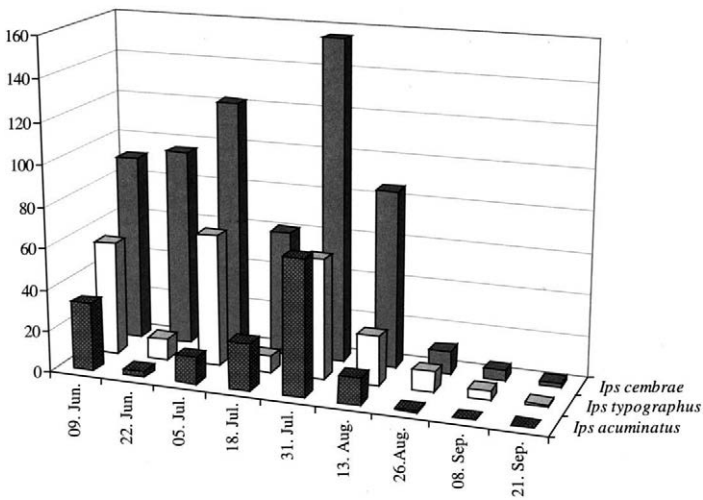

Fig. 4. Time schedule of the catch of *Ips cembrae*, *I. typographus* and *I. acuminatus*

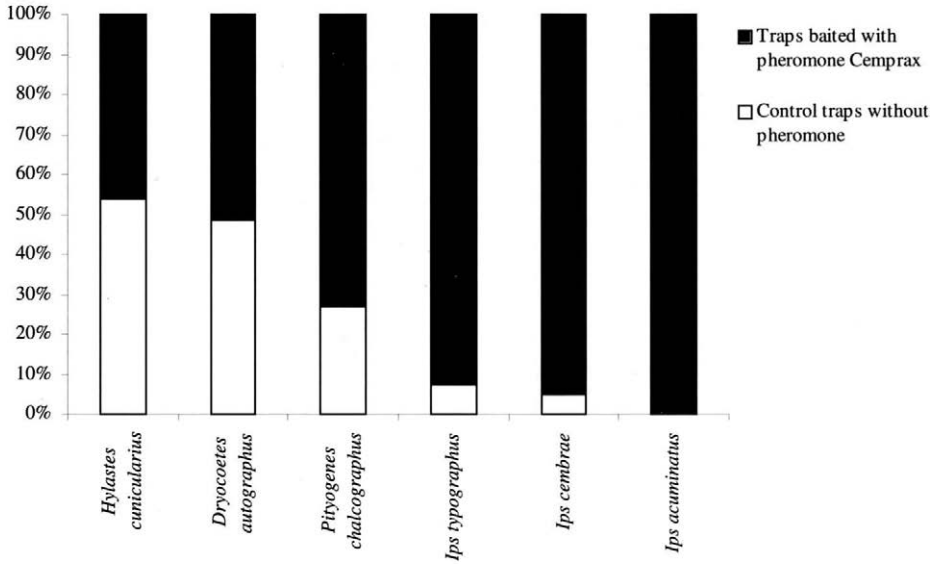

Fig. 5. Proportion of the catch in pheromone-baited traps and in control traps

Fig. 3 suggests we probably came across the culmination of swarming of this species in late May/early June. The application of the second pheromone bait increased the catch of *Ips cembrae, I. typographus* and *I. acuminatus* considerably (Fig. 4).

Ips cembrae, I. typographus and *I. acuminatus* were attracted to traps by the pheromone Cemprax® (Fig. 5). It seems, however, that Cemprax® has no effect on the catch of *H. cunicularius* and *Dryocoetes autographus*.

Acknowledgements

The author is grateful to: the Slovenian Forest Service for their assistance in the search for bark beetles and for the use of their databases, MPlus enterprise for supplying pheromone samples, and Mr. SAVO BRELIH for his assistance in the determination of beetles.

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Monitoring *Ips typographus* (L.) (Col.: Scolytidae) using GIS

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ABSTRACT: A model for monitoring the development of the spruce bark beetle *Ips typographus* (L.), supported by Geographic Information Systems (GIS), is presented. Various figures describe elements, functional scheme and output of the model.

We present a model for monitoring the development of the spruce bark beetle *Ips typographus* (L.) supported by Geographic Information Systems (GIS). Based on correlations between climatic (air temperature, solar irradiation), topographic (altitude, exposition, slope, and illumination) and forest stand related parameters (stand density, stand age) a topoclimatic model of the study area is developed. Consequently the calculation of air and cambial temperature for any location of the investigated site is facilitated by measuring air temperature and solar irradiation at a reference station. Considering parameters of bark beetle eco-physiology the model allows to predict the status of brood development in the field.

Within the scope of modelling GIS is used for data processing and visualisation. Topographic and stand related parameters, derived from a Digital Elevation Model (DEM)

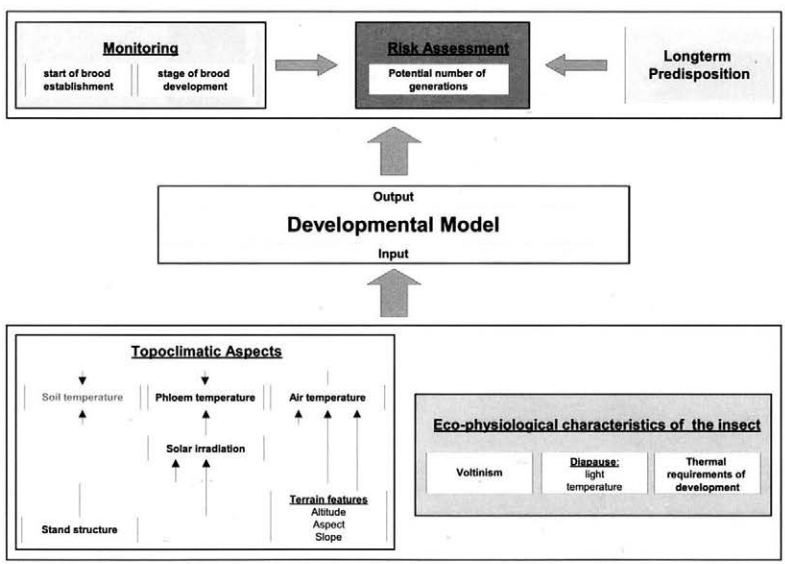


Fig. 1. Elements and output of the 'developmental model'

Basic input elements of 'developmental model' are topoclimatic aspects of the study area and eco-physiological characteristics of the bark beetle population (swarming activity, developmental times and thresholds of different stadia, type of voltinism, induction and termination of diapause)

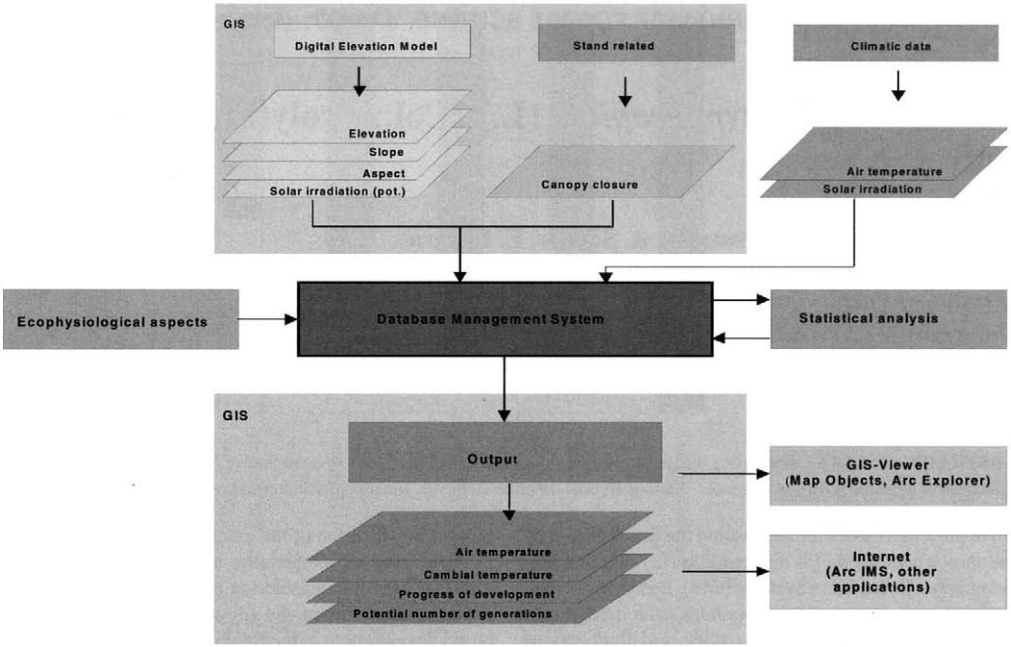


Fig. 2. Functional scheme of the model

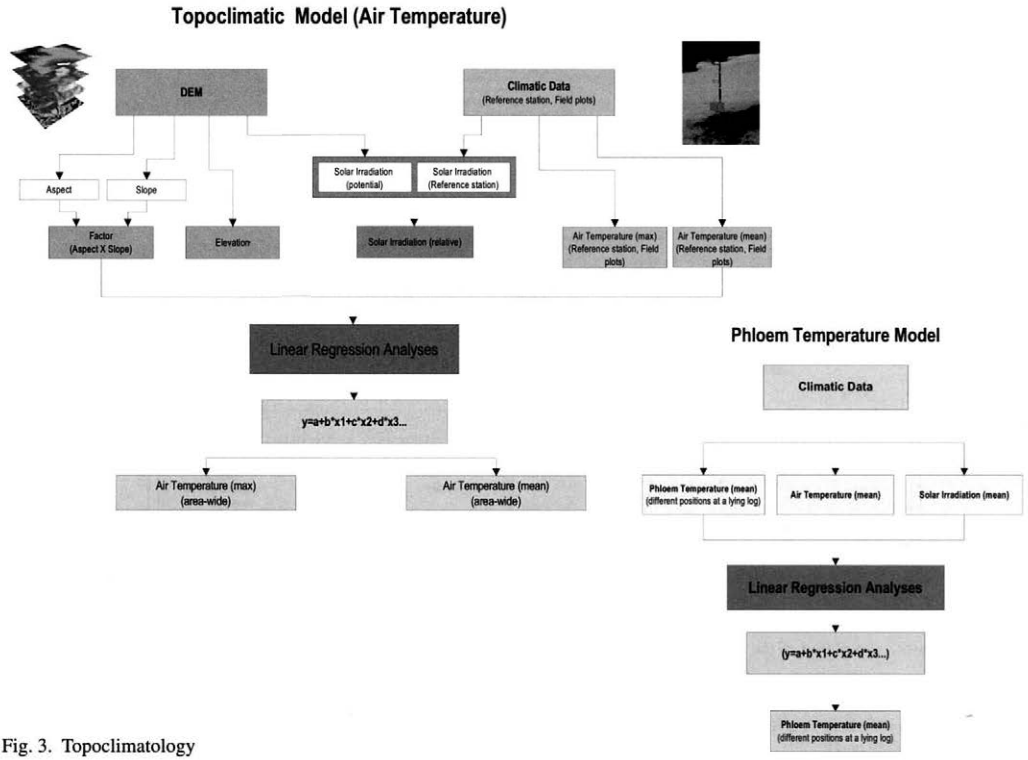
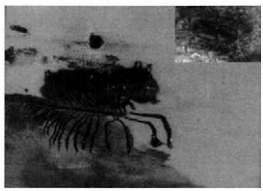
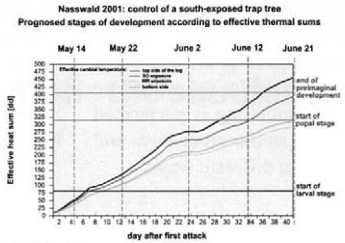


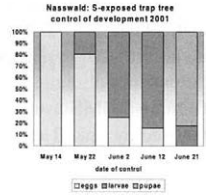
Fig. 3. Topoclimatology

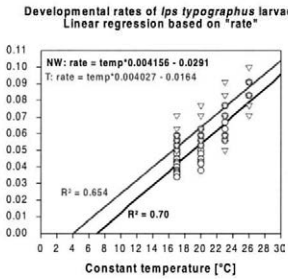


Sandwich rearing technique

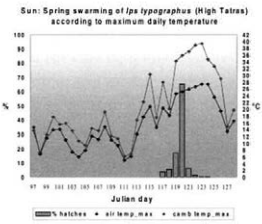


Verification

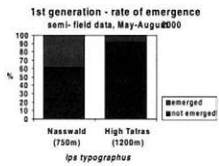




Calculation of thermal value



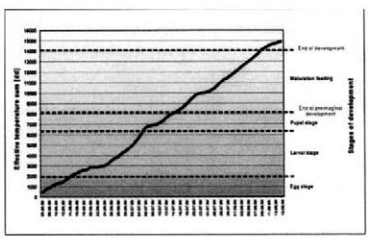
Spring swarming

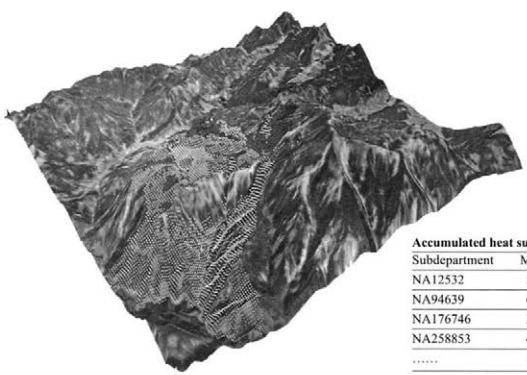


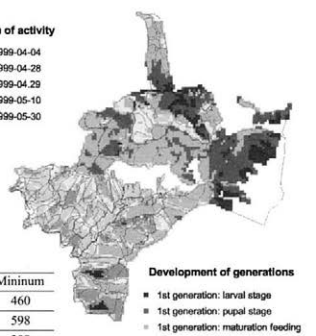
Type of voltinism

Fig. 4. Eco-physiology

Monitoring and assessing potentials of bark beetle development needs profound information on eco-physiology. Of major interest is the characterisation of studied populations regarding voltinism, diapause, spring swarming and their thermal requirements for development







Accumulated heat sums (2000-07-17)

Subdepartment	Mean	Maximum	Minimum
NA12532	523	585	460
NA94639	660	723	598
NA176746	370	433	308
NA258853	483	545	420
.....	.....	.....	.....
.....	.....	.....	.....

Fig. 5. Model output

The visualisation of the results may be realised in various ways. Using standardised interfaces, data are transferred and presented as tables, graphs or attributes in GIS in a cartographic way. Data may be visualised by means of Internet Mapping Systems in the Internet and will be easily accessible for practical use

and digital forest maps are exported to a Database Management System (DBMS). The relationships needed for the models can be analysed and validated by a linked statistical package. The results of multivariate regression analysis are used to derive input variables for generating different topoclimatic models. Modelling is performed within the DBMS using system specific procedures and visualised by linked applications in different ways.

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Level of mycorrhizal infection: the standard method

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ABSTRACT: The contribution describes the standard method for fine root analyses which has been used since 1993 in the studies of mycorrhizal infection of forest trees. This non-destructive method enables relatively fast evaluation of root systems and thus to compare different stands.

The growth conditions and health state of trees as dominant fraction of forest ecosystems are reflected in the quality and quantity of their root network. New, less invasive and simple standard methods are necessary for a clear evaluation of root systems. These methods enable us to compare different stands as well as to study year round root dynamics and long-term changes caused by climate fluctuation and by anthropic influence.

In this poster presentation we describe the standard method for fine root analyses which has been used since 1993 in our studies of correlations between quality of root and crown systems (Fellner, Pešková 1995). Similar protocol is also adopted for root analysis of seedling mycorrhizal infection. In this case, however, the whole root system is tested.

SAMPLING STRATEGY

The fine root distribution is concentrated in the depth of 8–30 cm, mainly close to litter and humus horizons. Marks et al. (1967) and Alexander (1985) calculated the optimum volume for borehole samples. The diameter about 4 cm is enough when only roots less than 2 mm are significant. Sample size used in different studies fluctuate from 1.2 to 10 cm of diameter, and sampling depth from 7.5 to 90 cm. Larger samples can contain more representative composition, but the labor costs of root preparation and analyses grow significantly. We use the cylinder soil probe with 6 cm of diameter and a height of 15 cm. This seems to be the optimum between sample size and acceptable time for root evaluation. Five samples are taken from each study plot in order to prevent accidental deviations. They are scattered not randomly, but regularly in the distance of 1 m from single select trees.

PREPARATION OF ROOT SAMPLES AND GENERAL EVALUATION

From each probe all roots were separated manually, then all remaining soil was washed out. All roots were classi-

Fig. 1. Cylindrical probe with saw rim used for root sampling

Fig. 2. Sampling

Fig. 3. Oak study plots

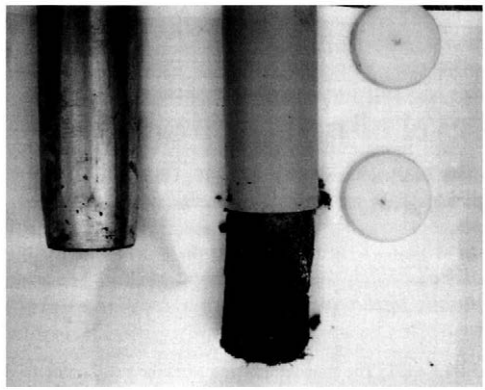

Fig. 4. Fresh soil sample is kept in the inner plastic tube

fied into four root classes according to root diameters, and for further analyses only thinnest roots (to 1 mm of diameter) were stored in the fixation solution (glutaraldehyd). The root dry matter and their average length was measured for all four classes.

LEVEL OF MYCORRHIZAL INFECTION

The main factors analyzed were absolute and relative numbers of active and non-active mycorrhizal tips. Mycorrhizae were evaluated within the root fraction under 1 mm. We applied the modified method of JAKUCS et al. (1986) using 20 root sections of 5 cm of length. The level of mycorrhizal infection was evaluated using two parameters: density and percentage of mycorrhizal tips. The density of active and non-active mycorrhizae was counted as an average value of the number of mycorrhizal tips connected with 1 cm of a root. The percentage proportion of mycorrhizae was calculated as a ratio of active and non-active mycorrhizal tips (VOGT et al. 1983; CAISOVÁ 1994).

CONCLUSIONS

Despite the fact that data from individual probes can reveal a relatively large variability, the total values are repeatable and they reliably reflect the parameters tested. This non-destructive method enables relatively fast evaluation of root system of trees in forests.

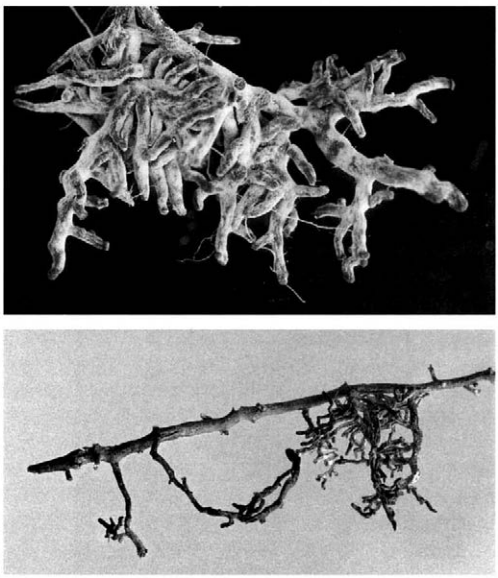

Fig. 5. Root with mycorrhizal infection

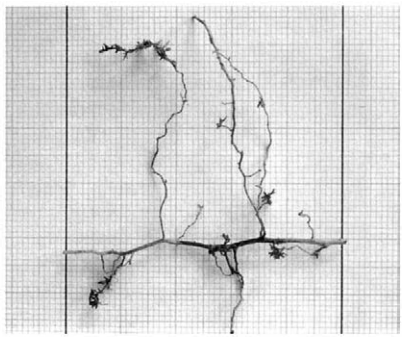

Fig. 6. Root segment (5 cm, < 1 mm of diam.) evaluated under microscope (magnification 20×)

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The six-toothed bark beetle *Ips sexdentatus* (Boerner, 1767) (Coleoptera: Scolytidae) in the fire site Kojnik

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ABSTRACT: The presented research furthers the knowledge of insects attacking the Austrian pine (*Pinus nigra*) one of which is the six toothed bark beetle (*Ips sexdentatus*). There were no recorded large-scale outbreaks of this rare species in Slovenia. Our research shows, that although the beetle was found in the fire-site Kojnik, it is not the primary pest. The beetle's bionomy and ecology were investigated as well as the hypothesis that *I. sexdentatus* overwinters in the ground. Tests with the sloth flight barrier trap, encapsulated with the pheromone Pheroprax (which is used for attracting *Ips typographus*), showed, that the same pheromone can be successfully used for attracting *I. sexdentatus*.

WORKING METHODS

Determination of research plots
Collecting of insects
Setting up the traps (type Theysohn, pheromone Pheroprax)
Analysis of soil samples to determine *I. sexdentatus* overwintering sites
Measuring bark thickness of sampling trees
Determination of collected species

RESULTS TABLES

Table 1. Breast-height diameter and bark thickness of sampling trees, height of attack and size of six-toothed bark beetle population

		Tree number															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	SUM
I.	d	25	22	12	27	23	32	8	28	11	8	10	9	10	14	13	
	dl	6.4	13.1	5.2	12.8	13.3	14.8	9.6	16.1	4.6	6.5	9.7	–	13.2	11.4	–	
	hn	20	20	–	20	20	20	–	20	–	–	–	–	4	20	–	
	N	1	1	–	6	–	25	–	–	–	–	–	–	–	1,217	–	1,250
	A	0.6	0.7	–	3.7	–	14.7	–	–	–	–	–	–	–	1,352.2	–	
II.	d	13	23	28	9	8	11	10	21	11	15	14	12	16	11	12	
	dl	13.7	12.0	17.1	12.0	7.0	11.0	8.9	8.9	14.9	11.5	–	11.6	–	8.2	–	
	hn	11	20	20	–	–	15	–	20	19	8	–	17	–	20	–	
	N	–	–	3	–	–	–	–	–	–	–	–	–	–	369	–	372
	A	–	–	1.6	–	–	–	–	–	–	–	–	–	–	527.1	–	
III.	d	12	15	16	22	6	14	10	27	12	11	10	11	12	10	12	
	dl	11.2	11.8	8.5	13.0	6.1	10.4	15.2	17.0	11.8	12.0	–	14.4	–	8.8	–	
	hn	11	20	10	20	–	12	3	20	16	6	–	3	–	20	–	
	N	–	5	–	–	–	–	–	4	–	–	–	–	–	93	–	102
	A	–	5.6	–	–	–	–	–		–	–	–	–	–	132.9	–	

I.: First debarking (16. 9. 1999); II.: Second debarking (1. 10. 1999); III.: Third debarking (16. 10. 1999)
d: Breast-height diameter (cm); dl: Bark thickness (mm), hn: height of attack
N: Number of *Ips sexdentatus* specimens; A: Number of *Ips sexdentatus* specimens per m of sampling tree bark

Table 2. Number of specimen of *Ips sexdentatus* catched in traps from 16. 9. till 16. 10. 1999

Location	Total	First catch			Second catch		
		total	TWF	TWOF	total	TWF	TWOF
1	150	121	94	27	29	25	4
2	31	–	–	–	31	22	9
3	144	123	113	10	21	19	2
4	173	162	143	19	11	9	2
5	86	80	80	..	6	6	–
Total	584	486	430	56	98	81	17

TWF: Trap with pheromon bait
TWOF: Trap without pheromon bait

Table 3. Number of overwintering specimens of *Ips sexdentatus* in root collar and in soil

	Plot									
Location			1	2	3		4		5	6
Root collar	147	61	0	0	19	70.4	128	59.8	0	0
First square	83	34.4	0	0	8	29.6	75	35	0	0
Second square	11	4.6	0	0	0	0	11	5.2	0	0
Third square	0	0	0	0	0	0	0	0	0	0
Fourth square	0	0	0	0	0	0	0	0	0	0
Total	241	100	0	0	27	100	214	100	0	0

SUMMARY

The aim of our research was to investigate some less known facts about the six-toothed bark beetle population (*I. sexdentatus*). This rare and, in Slovenia, under-researched species was found in the fire-site Kojnik (in south-west Slovenia). In 1998, a forest fire destroyed or seriously damaged about 46 ha of pine stands which established conditions suitable for nesting and further propagation of the species.

Our investigation was carried out through field observations and measurements. The sampling frame was the intersection of the damaged and undamaged part of the pine stand. Within this intersection we chose 45 trees of various diameters for sampling. All the sample trees were debarked up to the height of two meters.

Individuals of the *I. sexdentatus* were present on 10 trees. On 22 other trees it was possible to observe only their gallery systems. At the intersection the species thus attacked 71% of all sampled trees. Up to 1,217 beetles were found on a single tree. Despite this rather high number, we found no indications of beetles attacking healthy and vital trees. The six-toothed bark beetle may, therefore, not be considered, to be a primary pest.

In the bionomy of the six-toothed bark beetle little is known about its overwintering. For the spruce bark beetle (*Ips typographus*) it is known that it overwinters in the ground. To verify if the six-toothed bark beetle overwinters in the ground, we established 6 ground research plots. In 2 of these we found specimens. The highest abundance was 3 individuals/100 cm^2. Our hypothesis that *I. sexdentatus* spends the winter season in the ground may therefore be considered correct.

The six-toothed bark beetle's gallery systems and the bark itself are home to many and diverse predators that reduce its population. The most important predators come from families such as Histeridae, Tenebrionidae and Cleridae (Coleoptera). The species *Thanasimus formicarius* was the most frequently found on sampling trees. Other species seem to be less significant in regulating the bark beetle's populations, some of them may be even harmless, due to their belated development (species from the family Staphylinidae and Elateridae).

Further, we investigated if the sloth flight barrier trap, encapsulated with the synthetic pheromone Pheroprax (type Theysohn, also used for attracting *I. typographus*) can be used for reducing the six-toothed bark beetle population outbreaks. Since it was possible to catch in 30 days (in the period between 16th September 1999 and 16th October 1999) 584 specimens with this trap with an average of 64 individuals/trap, we thus consider the pheromone method efficient.

In case that the six-toothed bark beetle's abundance would grow and the bark-beetle would become the primary pest, we recommend to employ the same measures as used for the spruce barkbeetle. However, precautionary measures such as regular field inspections, strict sanitary actions, regular timber felling, skidding and transportation, and immediate improving of sanitary conditions, are imperative. In so doing, the bionomy of the species must be considered.

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Monitoring of phytosanitary situation in the Tellerman forest (South forest-steppe of European Russia) over the period of 1983–1999

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One of our research objectives at the Tellerman forest station (the Voronezh province) in 1983–1999 was to monitor the oak stands of different types and ages.

The monitoring included the following stages:

I. Reconnaissance observations of oak stands in the Tellerman forest (38,000 ha). Observations were performed four times during this period (1983, 1986, 1997, 1999) on the surface area of 2,000 ha in Tellerman forest, 2,000 ha in the adjacent Gribanov forest (1998), partially in Lobanov fo-rest (1983, 1990) and Khoper reserve. In the course of the observations we noted the general phytosanitary situation, the condition of trees by visual estimation of crowns, trunks, and the incidence of diseases. In case of need, model trees were felled and the samples of wood were taken for mycological analysis.

II. Detailed annual observations of 10–14 permanent observation plots (POPs) with a total tree quantity above 1,000. Here we estimated the condition of each tree by a six grade system: 1 – apparently healthy, with no visible signs of damage or disease, dense green crown and no more then 10% of dry branches; 2 – slightly or moderatelly weak with a thin crown and a dry branch proportion within 25%; 3 – severely weak with quite a sparse crown and up to 50% of dry branches; 4 – a declining tree, with a thin crown, yellow foliage and dry branches up to 75%; 5 – recently dried standing tree, with a preservation of dry leaves or small twigs; 6 – old dried standing tree without leaves and small twigs, possibly with an exfoliated bark.

These grades (or categories of state) were given on the basis of 25 parameters of the tree state, which included the condition of crown, of trunk, the presence or absence of faults, insect damage and disease signs (fruit bodies etc.).

III. Periodical observation of old-aged oak stands. They were started in 1993 year in two large blocks (about 30 ha each). The first is a forest reserve, with the exclusion of any management; the second is a memorial stand (natural monument), where the forest control measures were permitted. All the trees (880) in these areas were marked and mapped, and in the first block fallen dead trees were estimated too.

Our observations of the Tellerman forest were started in 1983, at the end of the last wave of oak decline (1976–1982), initiated by dry years succession and severe insect defoliations (OSIPOV et al. 1989; SELOCHNIK 1999, 2000), and we could control only the consequences of this event. So in 1983 many forest areas were severely weakened, with sparse crowns, slight green foliage, and a group, curtain and focus oak decline. Over two following years the oak condition improved markedly. Since 1985 no foci of fresh oak decline were noticed in any areas under observation. At present we can see only some severely cluttered up areas, first of all in old-aged stands, where sanitary measures were not conducted.

The condition of oak stands in the Lobanov forest and Khoper reserve was quite satisfactory, without signs of fresh oak decline. In Gribanov forest we noticed foci of old dried standing trees after an oak defoliation by *Lymantria dispar* in 1990–1991.

Observations on the POPs revealed the general trends of tree conditions (Fig. 1) in all oak forest types (upland, flood-plain and solonetz stands) and ages (60–250 years) over 16 years (1983–1998). Here we can see the predominance of the second grade trees during all the observation period as a consequence of past oak declines. However the histogram shows an increase in the numbers of first grade trees and a decrease in the poor grades. It was also shown that after last wave of oak decline in the Tellerman forest, the restoration process started. First of all it was promoted by more humid period at the end 1980s and early 1990s, and secondly by the absence of severe defoliation in the upland oak stands. In the flood-plain oak stands, in spite of annual defoliation by the early-spring complex of leaf-eating insects, oak trees are recovering due to secondary foliage and new crown development from water sprouts.

In this period oak decline affected only individual trees in dense stands and was within the limits of natural mortality.

Apart from the general trends, we have demonstrated the curves of tree distribution in the grades of condition

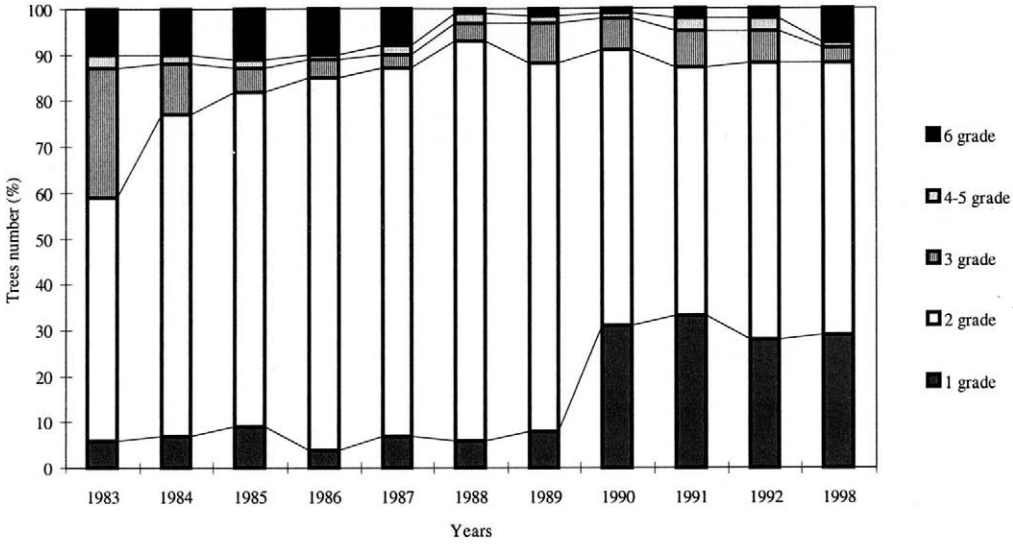

Fig. 1. General oak tree distribution into 6 grades of condition in all permanent observation plots (POPs) of the Tellerman forest for the period 1983–1998

and calculated a mean-weighed grade for each POP during this period. In Fig. 2 such curve for the POP in the 80-year upland oak stand in 1983 had two "humps" (for grades 2 and 3 represented by 40% and 50%, respectively). There was none apparently healthy tree (grade 1) and a few trees of pure grades of state which means the end of the drying process. The mean-weighed grade here was 2.86. In 1985, the tree distribution curve had one-peak, with a predomination of grade 2 trees, and only 3.3% of grade 3 trees. The mean grade was 2.36. In 1998 this curve was similar to that in 1985, but an increase in grade-1-tree numbers up to 20.4% was noted. There were no considerable other alterations for 14 years and mean grade was 2.0. According to some Russian authors (MOZOLEVSKAYA et al. 1984), the stands with mean grades over 2.5 are regarded as weakened. So, at the POP in 1983 our stand was severely weakened, in 1985 – less weak, and in 1998 – nearly normal (healthy).

Among the fungal pathogens in the observed oak stands, wood-destroying fungi were predominated. Such fungi as *Inonotus dryophilus*, *Fomes robustus* were noted in 60–100-year old oak stands, and they were of low occur-

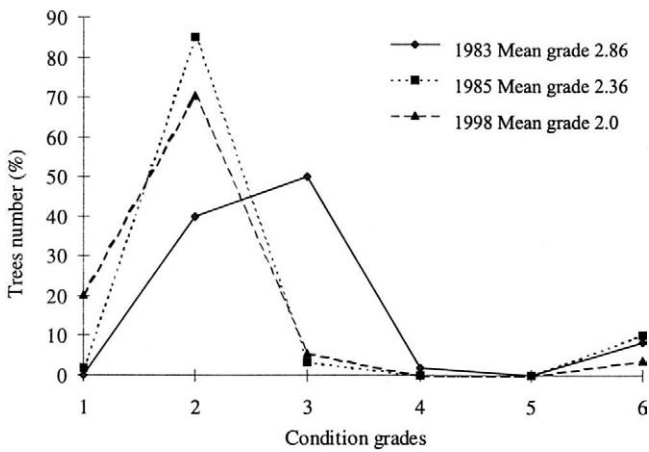

Fig. 2. Tree distribution pattern in grades of condition (1–6) for the POP in the 80-year upland oak stand in different years

rence (2–3%). Other *Basidiomycetes* were distributed first of all in old-age stands, where their infestation could reach 20–30%. On living trees, there were *Fistulina hepatica*, *Inonotus dryadeus*, *Laetiporus sulphureus* (the latter can also colonise dead trees and stumps) and occasionally *Fomes fomentarius*. On the dead fallen trees and stumps *F. fomentarius*, *Ganoderma applanatum* and *Daedalea quercina* were most common; *Fomes pinicola*, *Inonotus squamosus*, *Pleurotus dryinus*, *Pholiota squarrosa* etc. were occasionally noted on dead trees and stumps.

The *Armillaria* complex has a particular position among wood-destroying fungi, as it is more distributed in oak stands of all types and ages. We established that in the forest-steppe region this complex was dangerous to trees severely weakened by climatic constraints, defoliations by insects-phyllophages etc. in the last stage of oak decline (SELOCHNIK, KONDRASHOVA 1991; SELOCHNIK 1998, 1999, 2000). Based on evidence by European and Russian scientists (KORHONEN 1978; RADZIEVSKAYA 1989; GUILLAUMIN et al. 1985; LUISI, LERARIO 1997, and other), on morphologic signs and ecological properties, we believe that we deal in this case with more than one species. It is most likely that in forest-steppe region *Armillaria gallica* occurs more often as a weak pathogen, infesting those oak trees that are under stress by abiotic, biotic and anthropogenic factors.

Among oak diseases, induced by fungi-micromycetes, we consider that oak mildew and tracheomycosis to be more important. However our investigations showed that oak mildew is only one factor of oak weakening within the chain of events bringing to oak decline (SELOCHNIK et al. 1994; SELOCHNIK, ROMANOVSKY 2000), and this position coincides fully with the opinion by many Russian authors (NAUMENKO 1950; LESOVSKY, MARTYSHECHKINA 1985; SHIRNINA 1987, and many others).

In connection with tracheomycosis (caused by *Ophiostoma* species and their anamorphs) oak decline observed in the oak stands affected individual trees only; there were no foci of the disease, and under favourable conditions for oak (that occur in the Tellerman forest during the last decades) these pathogens can exist in oak wood as endophytic fungi (SELOCHNIK 1998, 2000).

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Ips typographus (L.) as a biological indicator in the Eastern Carpathians (Ukraine)

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ABSTRACT: The general patterns of *Ips typographus* (L.) in Ukrainian Carpathians are presented and the main opinions concerning its role as a biological indicator of the disturbances in the functioning of forest ecosystems are discussed.

Drastic natural calamities (floods, landslides, disastrous snowfall, storms, windfalls, tornado, fires) in recent years (June 1997–March 2001) covered vast territory of Ukraine and caused the damage of forest plantations on considerable areas. In the Carpathians *Ips typographus* (L.) still remains especially dangerous for the spruce (SLOBODYAN 1998, 1999).

Describing the bark beetle *I. typographus* it must be noted that its activity increases depending on slope exposition, especially on the southern slopes where its density increases with the altitude (up to 1,000–1,100 m above sea level) and slope steepness.

In our opinion the increase of insects activity in the mountains is chiefly connected with global warming up caused by greenhouse effect. According to the data of hydrometeorological institute under the conditions of the Carpathians especially winters have became warmer (on the average by 5°C). Absolute minimum and absolute maximum temperatures as a whole have not undergone any change, but the amplitude of their fluctuations has considerably increased, which caused a disastrous flood in March, 2001 (the precipitation registered during March amounted to 113 mm) in the Transcarpathians. Warm winters in the Carpathians in recent years have not only favoured *I. typographus* adaptation, but to a large extent have enabled the continuation of the development cycle of its summer–autumn generation and formation of imago stage on slight slopes in early spring period.

Mention should also be made that in the mountains the basic mass of bark-boring insects is concentrated in the stand periphery – directly along the woodland border. As the distance into the depth of the woodland increases, the insects concentration sharply decreases. Peculiar signs characterize attack capability of the insect population in their propagation period. According to our data the most intense *I. typographus* attacks are quite often observed on the northern (shady) side of absolutely healthy trees. The main attack is often dealt on the portion of the trunk just below the beginning of the crown. The formation of attacking mass of the insects depends not only on the main direction of winds and can take place not only at the expense of their migration from the neighbouring woodland plots, but also due to their transference from the depth of the plantation to its periphery.

As a biological indicator, *I. typographus* can distinctly show the change in microclimatic conditions (increase in lighting and temperature parameters), disturbance of physiological processes of the spruce, decline of stand health and its drying up. Taking into consideration the above said it is necessary, in further forest management policy, to get rid, under certain conditions, of the stereotypes (traditional) of forestry practice based on the strict sticking to the peculiar principles of vertical level. Contrary to vertical level practice, the system of forest protective measures of spruce forests on the southern slopes must include buffer zones composed of mixed beech-spruce-fir stands, characteristic in particular for virgin forests of the upper timber line in the Carpathians. At that intermittent belt (across the slopes), the alternation of pure spruce and mixed beech, spruce and other species plantations is possible. At that, the width of spruce belts can extend from top to bottom.

The so called geo-chemical centres in the mountains, or upper areas of watershed, must be covered with mixed plantations certainly excluding sub-alpine area where they cannot exist.

CONCLUSIONS

I. typographus populations in Ukrainian Carpathians are characterized by considerable quantity and fluctuations, which is caused by extreme susceptibility of spruce stands to mass pest propagation.

Between the main causes of mass bark beetles' propagation there are windthrowns and root rots, which considerably disturb the sustainable development of spruce ecosystems.

As a biological indicator, *I. typographus* can distinctly show the change in microclimatic conditions (increase in lighting and temperature parameters), disturbance of physiological processes of the spruce, collapse of stand health and its drying up.

Solving of *I. typographus* problem requires the complex approach with participation of different interested European countries and permanent monitoring.

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Distribution and infection biology of *Flammulina velutipes* (Curt.: Fr.) Sing.

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ABSTRACT: *Flammulina velutipes* (Curt.: Fr.) Sing. is the widely spread fungus in forests and forest-plantations of Ukraine. It grows in various forest types. The study of population structure of separate species of fungi is very important by way of research of infection biology of xylogenous basidiomycetes, protective mechanisms of a plant and the increases of its resistance to diseases. The determination of the factors of sexual compatibility from every fruit body or mycelial formation (if such capability exists) and estimation of kindred of individuals of one species is given of such capability. For this purpose a research of the genetic status of *F. velutipes* fruit bodies developing in different regions of Ukraine and on different hosts plants, was conducted. The results of crossing of 21 fruit bodies testers of *F. velutipes* are presented. The experiments enabled the recognition of kindred *F. velutipes* strains collected in the territory of Ukraine and revealed the presence of strain VV5, which has shown intersterility concerning others investigated strains. The possibility of the existence of intersterility groups of this fungus in Ukraine is supposed.

Flammulina velutipes (Curt.: Fr.) Sing. is the widely spread fungus in forests and forest-plantations of Ukraine. It grows in various forest types. It is a wood-rotting agaric appearing during the colder part of the year on leaving, slightly decayed stumps or trunks of various deciduous trees. *F. velutipes* is frequently met especially on aspen, poplar and willow. It is fruiting by the large close groups. This fungus is also named winter mushroom because it forms the fruit bodies in September and October, and in southern and south-east regions till in December (PSURTSEVA 1987). *F. velutipes* is a good edible mushroom.

F. velutipes has already been reported as a parasite. However, very limited information is available on its epidemiology and virulence. Our research is aimed at better understanding of the impact and infection biology of this agent.

The study of population structure of separate fungi species is very important by way of research of infection biology of xylogenous basidiomycetes, protective mechanisms of plant and the increase of its resistance to diseases. The determination of the factors of sexual compatibility from every fruit body or mycelial formation (if such capability exists) and estimation of kindred of individuals from one species is given by such capability. Numerous publications describe the distribution of wood-degrading basidiomycetes' clones in a substratum (HOLMER et al. 1994; RIZZO, BLANCHETTE 1995; HATTORI et al. 1996). The knowledge of population structure, not only helps us to understand the biology of fungi and trace their evolutionary history, but also can provide a base for hypotheses about their future.

MATERIALS AND METHODS

The fruit bodies of *F. velutipes* were collected by us in various regions of Ukraine on various substratum (Table 1). There were cases of fruit bodies' detection in January–February during warm winters, at positive temperatures.

The fungus well develops in culture and is suitable for manipulations with obtaining of spores. It is very important, as there are definite limitations concerning the usage of other signs (for example, dark lines in the wood) as criterion of separation of individuals of a fungus in a natural population.

Fruit bodies were collected in separate cellophane knapsack and further utilized for the determination of the incompatibility factors.

For this purpose 15 monosporous cultures were received from every fruit body on the potato-glucose medium with agar. Distribution of monosporous cultures of each fruit body in four groups with the different incompatibility factors was determined in Petri-dishes with the medium of same consistence, by mating of monosporous culture in all possible combinations between themselves (for example – A1B1, A2B2, A1B2 and A2B1, according to tetrapolar system of compatibility). The formation of

dikaryon, which morphologically differed from monokaryotic culture by presence of clamp connections on mycelium, means the successful mating between monosporous cultures. The four monosporous cultures with different incompatibility factors, which served as testers for further mating were taken from every basidiocarp. Just such mating between testers from different fruit bodies revealed the allelic constitution of every fruit body on the substratum.

Due to the necessity of simultaneous isolation of monosporous isolates in culture and the high risk of loss of a part of cultures, the great quantity of fruit bodies was needed. However timely obtaining of cultures from cap tissue of a fungus and the capacity of fungus to generate the basidiocarps in laboratory created favourable conditions for the analysis of population structure of the fungus. Fruit bodies of *F. velutipes* were grew in conical flasks on 250 ml with using a humid husks of sunflower as substratum.

RESULTS AND DISCUSSION

The results of crossing of monosporous cultures of fruit body strain RT1 among themselves are submitted in Fig. 1. The testers culture (till four for every strain) were managed to be selected due to experiments of crossing among monosporous cultures.

The results of crossing of testers from different fruit bodies are presented in Tables 2–4.

Almost all strains were crossed among themselves, except the strain VV5 from acacia, which was completely intersterile to all strains (alleles of compatibility are designated, as $A^*_1B^*_1$ $A^*_2B^*_2$). In the other strains of *F. velutipes,* alleles 35 A and 31 B were detected, and some strains had identical A or B alleles (for example strains SK1 and SK2 had allele B23).

The fruit bodies of investigated *F. velutipes* strains were collected at different years, on various substratum, at various stages of development, in various climatic conditions and in various seasons, therefore differed morphologically. The strains demonstrated similarity among themselves in pure culture.

Thus, the experiments of crossing enabled the recognition of kindred of *F. velutipes* strains collected in the territory of Ukraine and demonstrated the presence of the strain VV5, which shows intersterility concerning others investigated strains. The study on fruiting of monosporous cultures among various strains has revealed some differences in quantitative attributes of fruiting in culture at strain VV5 (SUKHOMLYN 1999).

The detection of intersterility strain assumes a possibility of the existence of intersterility groups at this fungus.

Table 1. Strains of *Flammulina velutipes* which we used at experiment

No.	Strain	Location, year	Substratum	Collector
1	RT1	Lutsk, 1992	*Acer campestre*	Sukhomlyn M.
2	LK3	Lutsk, 1993	*Populus nigra*	Sukhomlyn M.
3	KL2	Donetsk, 1993	*Acer campestre*	Sukhomlyn M.
4	KL3	Donetsk, 1993	*Acer campestre*	Sukhomlyn M.
5	VV12	Lviv, 1995	*Acer tataricum*	Sukhomlyn M.
6	D8	Donetsk, 1995	Stamp *A. tataricum*	Sukhomlyn M.
7	PN	Rahiv, 1993	*Populus tremula*	Sukhomlyn M.
8	OR	Volnovaha, Donetsk region, 1994	*Juglans*	Drmchenko S.
9	Don1	Donetsk, 1994	*Acer campestre*	Drmchenko S.
10	Don3	Donetsk, 1994	*Acer campestre*	Drmchenko S.
11	Don4	Donetsk, 1994	*Populus pyramidalis*	Drmchenko S.
12	VV5	Donetsk, 1994	*Acacia*	Drmchenko S.
13	VV4	Donetsk, 1995	*Populus pyramidalis*	Vdovichenko V.
14	ON	Lyuboml, Volynsk region, 1995	*Populus alba*	Sukhomlyn M.
15	SK1	Kovel, Volynsk region, 1996	*Populus nigra*	Sukhomlyn M.
16	SK2	Kovel, Volynsk region, 1996	*Populus nigra*	Sukhomlyn M.
17	LS	Makarevichi, Volynsk region, 1996	*Populus tremula*	Sukhomlyn M.
18	KN1	Kaniv, Cherkaski region, 1997	*Juglans*	Sukhomlyn M.
19	KM2	Kaniv, Cherkaski region, 1997	*Salix daphnoides*	Sukhomlyn M.
20	KT8	Krasni Liman, Lugansk region, 1997	*Acer platanoides*	Sukhomlyn M.
21	HT4	Krasni Liman, Lugansk region, 1997	*Populus tremula*	Sukhomlyn M.

Table 2. Results of testers crossing of different strains of *F. velutipes* from *Acer, Acacia* and *Juglans* (between themselves)

Strains	Testers	Alleles	Strains RT1	D8	VV12	KT8	KL2	KL3	Don1	Don3	VV5	KN1	OR
			1 6 9 7	2 8 6 12	7 9 11 5	8 5 3 12	1 10 6 8	1 5 4 7	4 12 3 9	8 2 6 13	3 6 5 9	5 3 6 10	6 5 12 2
RT1	1	A_1B_1	− − + −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	6	A_1B_2	− − − +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	9	A_2B_2	+ − − −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	7	A_2B_1	− + − −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
D8	2	A_3B_3		− − + −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	8	A_3B_4		− − − +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	6	A_4B_4		+ − − −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	12	A_4B_3		− + − −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
VV12	7	A_5B_5			− − + −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	9	A_5B_6			− − − +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	11	A_6B_6			+ − − −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	5	A_6B_5			− + − − -	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
KT8	3	A_7B_7				− − − +	+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	5	A_7B_8					+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	3	A_8B_8					+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	12	A_8B_7					+ + + +	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
KL2	1	A_9B_9					− − + −	+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	10	A_9B_{10}						+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	6	$A_{10}B_{10}$						+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	8	$A_{10}B_9$						+ + + +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
KL3	1	$A_{11}B_9$						− − + −	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	5	$A_{11}B_{10}$						− − − +	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	4	$A_{12}B_{10}$						+ − − −	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
	7	$A_{12}B_9$						− + − −	+ + + +	+ + + +	− − − −	+ + + +	+ + + +
Don1	4	$A_{13}B_{11}$							− − + −	− − + −	− − − −	+ + + +	+ + + +
	12	$A_{13}B_{12}$							− − − +	+ − − +	− − − −	+ + + +	+ + + +
	3	$A_{14}B_{12}$							+ − − −	+ − − −	− − − −	+ + + +	+ + + +
	9	$A_{14}B_{11}$							− + − − −	− + − −	− − − -	+ + + +	+ + + +
Don3	8	A_5B_{11}								− − + −	− − − −	+ + + +	+ + + +
	2	$A_{15}B_{12}$								− − − +	− − − −	+ + + +	+ + + +
	6	$A_{14}B_{12}$								+ − − −	− − − −	+ + + +	+ + + +
	13	$A_{14}B_{11}$								− + − − −	− − − −	+ + + +	+ + + +
VV5	3	$A^*_1B^*_1$									− − + −	− − − −	− − − −
	6	$A^*_1B^*_2$									− − − +	− − − −	− − − −
	5	$A^*_2B^*_2$									+ − − −	− − − −	− − − −
	9	$A^*_2B^*_1$									− + − − − − − −		− − − −
KN1	5	A_6B_{13}										− − + −	+ + + +
	3	$A_{16}B_{14}$										− − − +	+ + + +
	6	$A_{17}B_{14}$										+ − − −	+ + + +
	10	$A_{17}B_{13}$										− + − − −	+ + + +
OR	6	A_8B_{15}											− − + −
	5	$A_{18}B_{16}$											− − − +
	12	$A_{19}B_{16}$											+ − − −
	2	$A_{19}B_{15}$											+ − − −

+ with clamp connections; − without clamp connections

Table 3. Results of testers crossing of different strains of *F. velutipes* from *Acer*, *Acacia* and *Juglans* with strains from *Populus* and *Salix*

Strains	Testers	Alleles	RT1	D8	VV12	KT8	KL2	KL3	Strains Don1	Don3	VV5	KN1	OR
			1 6 9 7	2 8 6 12	7 9 11 5	3 7 8 17	1 10 6 8	1 5 4 7	4 12 3 9	8 2 6 13	3 6 5 9	5 3 6 10	6 5 12 2
VV4	4	$A_{20}B_{17}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	5	$A_{20}B_{18}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	13	$A_{21}B_{18}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	7	$A_{21}B_{17}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
Don4	1	$A_{15}B_{11}$	++++	++++	++++	++++	++++	++++	-++-	--+-	----	++++	++++
	9	$A_{15}B_{12}$	++++	++++	++++	++++	++++	++++	+--+	---+	----	++++	++++
	5	$A_{22}B_{12}$	++++	++++	++++	++++	++++	++++	+--+	+--+	----	++++	++++
	6	$A_{22}B_{11}$	++++	++++	++++	++++	++++	++++	-++-	-++-	----	++++	++++
LK3	11	$A_{23}B_{19}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	1	$A_{23}B_{20}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	8	$A_{24}B_{20}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	6	$A_{24}B_{19}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
ON	1	$A_{25}B_{21}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	7	$A_{25}B_{22}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	10	$A_{26}B_{22}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	11	$A_{26}B_{21}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
SK1	10	$A_{27}B_{23}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	4	$A_{27}B_{24}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	6	$A_{28}B_{24}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	9	$A_{28}B_{23}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
SK2	1	$A_{27}B_{23}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	5	$A_{27}B_{25}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	13	$A_{29}B_{25}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	6	$A_{29}B_{23}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
HT4	7	$A_{30}B_{26}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	11	$A_{30}B_{27}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	9	$A_{31}B_{27}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	12	$A_{31}B_{26}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
PN	1	$A_{32}B_{10}$	++++	++++	++++	++++	+--+	+--+	++++	++++	----	++++	++++
	8	$A_{32}B_{28}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	2	$A_{33}B_{28}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	13	$A_{33}B_{10}$	++++	++++	++++	++++	+--+	+--+	++++	++++	----	++++	++++
LS	1	$A_{28}B_{29}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	6	$A_{28}B_{24}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	10	$A_{34}B_{24}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	9	$A_{34}B_{29}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
KN2	2	$A_{35}B_{30}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	5	$A_{35}B_{31}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	15	$A_{30}B_{31}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++
	17	$A_{30}B_{30}$	++++	++++	++++	++++	++++	++++	++++	++++	----	++++	++++

+ with clamp connections; – without clamp connections

Table 4. Results of testers crossing of different strains of *F. velutipes* from *Populus* and *Salix* (between themselves)

Strains	Testers	Alleles	VV4	Don4	LK3	ON	Strain SK1	SK2	HT4	PN	LS	KN2
			4 5 13 7	1 9 5 6	11 1 8 6	1 7 10 11	10 4 6 9	1 5 13 6	7 119 12	1 8 2 13	1 6 10 9	2 5 15 17
VV4	4	$A_{20}B_{17}$	− − + −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	5	$A_{20}B_{18}$	− − − +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	13	$A_{21}B_{18}$	+ − − −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	7	$A_{21}B_{17}$	− + − −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
Don4	1	$A_{15}B_{11}$		− − + −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	9	$A_{15}B_{12}$		− − − +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	5	$A_{22}B_{12}$		+ − − −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	6	$A_{22}B_{11}$		− + − −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
LK3	11	$A_{23}B_{19}$			− − + −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	1	$A_{23}B_{20}$			− − − +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	8	$A_{24}B_{20}$			+ − − −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	6	$A_{24}B_{19}$			− + − −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
ON	1	$A_{25}B_{21}$				− − + −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	7	$A_{25}B_{22}$				− − − +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	10	$A_{26}B_{22}$				+ − − −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
	11	$A_{26}B_{21}$				− + − −	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
SK1	10	$A_{27}B_{23}$					− − + −	− − + −	+ + + +	+ + + +	+ + + +	+ + + +
	4	$A_{27}B_{24}$					− − − +	− − + +	+ + + +	+ + + +	+ − − +	+ + + +
	6	$A_{28}B_{24}$					+ − − −	+ + + +	+ + + +	+ + + +	− − − +	+ + + +
	9	$A_{28}B_{23}$					− + − −	− + + −	+ + + +	+ + + +	− − + +	+ + + +
SK2	1	$A_{27}B_{23}$						− − + −	+ + + +	+ + + +	+ + + +	+ + + +
	5	$A_{27}B_{25}$						− − − +	+ + + +	+ + + +	+ + + +	+ + + +
	13	$A_{29}B_{25}$						+ − − −	+ + + +	+ + + +	+ + + +	+ + + +
	6	$A_{29}B_{23}$						− + − −	+ + + +	+ + + +	+ + + +	+ + + +
HT4	7	$A_{30}B_{26}$							− − + −	+ + + +	+ + + +	+ + − −
	11	$A_{30}B_{27}$							− − − +	+ + + +	+ + + +	+ + − −
	9	$A_{31}B_{27}$							+ − − −	+ + + +	+ + + +	+ + + +
	12	$A_{31}B_{26}$							− + − −	+ + + +	+ + + +	+ + + +
PN	1	$A_{32}B_{10}$								− − + −	+ + + +	+ + + +
	8	$A_{32}B_{28}$								− − − +	+ + + +	+ + + +
	2	$A_{33}B_{28}$								+ − − -	+ + + +	+ + + +
	13	$A_{33}B_{10}$								+ + + +	+ + + +	+ + + +
LS	1	$A_{28}B_{29}$									− − + −	+ + + +
	6	$A_{28}B_{24}$									− − − +	+ + + +
	10	$A_{34}B_{24}$									+ − − -	+ + + +
	9	$A_{34}B_{29}$									− + − −	+ + + +
KN2	2	$A_{35}B_{30}$										− − + −
	5	$A_{35}B_{31}$										− − − +
	15	$A_{30}B_{31}$										+ − − -
	17	$A_{30}B_{30}$										− + − -

\+ with clamp connections; − without clamp connections

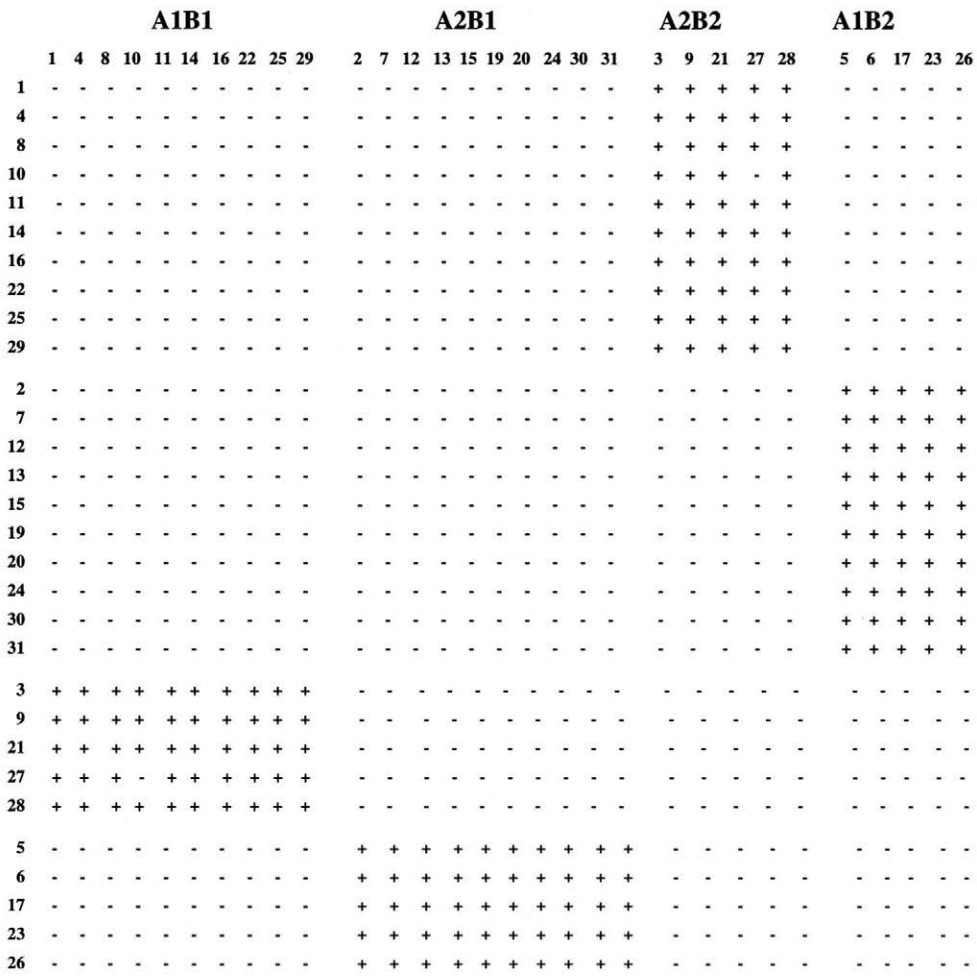

Fig 1. Distribution of incompatibility factors between monokarions of fruit body of *F. velutipes* strain RT1 (A and B – incompatibility factors; 1–31 – numbers of monokarions)

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The usage of NPV in the biological control of *Lymantria dispar* (L.) and *Euproctis chrysorrhoea* (L.) in Romania

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We started using baculoviruses as a biological insecticide in 1998, when the biopreparation based on NPV, named INF-ld was homologated in Romania. After several aerial spray programs we come to the conclusion that this way of using does not meet the optimal requirements both technically and economically. The application of this biopreparation as a water suspension from the ground with the help of manual sprayers gave the best results.

MATERIAL AND METHODS

We tested the sequential method in which only several egg masses or nests of caterpillars are sprayed (3–5%).

The transmission of NPV, from beginning to end of generalization of the infection, was made by direct contagion of the caterpillars and by the virus handling by the biotic and abiotic propagation vectors.

For gypsy moth (*Lymantria dispar* L.) we used manual sprayers to spray the egg masses and we made the treatment in bands: 5 m treated bands alternating with untreated bands wide of 50 m. The treatments were made at the beginning of the hatching of the caterpillars.

For browntail moth (*Euproctis chrysorrhoea* L.) we worked in the following way:

Variant 1. We sprayed the nests on the trees with pomp similar to a Kalimax machine on a given scheme (25 × 50 m).

Variant 2. We cut several caterpillar nests, immersed them for 3–5 seconds in a virus biopreparation suspension and then hung them up on the trees uniformly distributed on the area (25–30 nests per ha). The treatments had been made in March before the caterpillars left the nests.

RESULTS AND DISCUSSION

In 4 years of research (1998–2001) we treated with a virus biopreparation INF-ld 30 infestation spots of *L. dispar* in all stages of gradation. These were found on oak,

Fig. 1. The marking of the treatment bands by circular painting of the trees with lime

Fig. 2. The spraying of the egg masses with the manual sprayer

Fig. 3. A pomp similar to the Kalimax machine

Fig. 4. The spraying of the browntail moth nests

Fig. 5. The immersion of a browntail moth nest in INF-Id suspension

Fig. 6. Browntail moth nest treated by immersion and hung up on a branch of an oak

Fig. 7. Gypsy moth caterpillars in agony, with clear symptoms of viral disease

Fig. 8. Gypsy moth caterpillars dead due to the viral epizooty

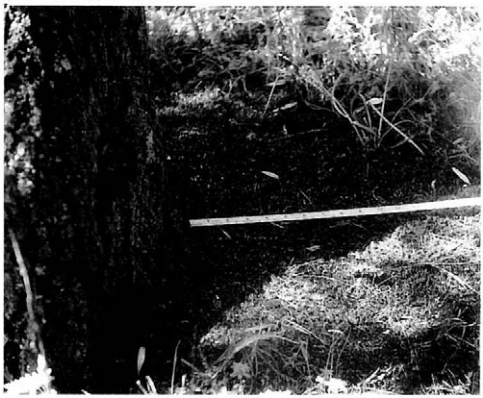

Fig. 9. Browntail moth caterpillars dead because of the viral infection, in the field

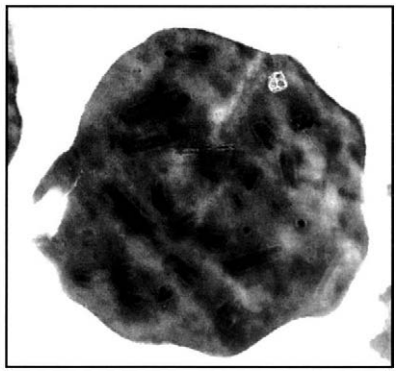

Fig. 10. Nucleopolyhedrosis virus in adipose tissue of browntail moth caterpillar in the treated area (ultrafine section in capside seeing at the electronic microscope)

Table 1. The results of the application of treatment with the viral biopreparation INF-ld in Romania

Moth and trees species	Stage of gradation	Number of spots treated	The degree of (%) contagion of the caterpillars in the year of treatment	The method identification of the contagion	Reinfestation in the next year after the treatment
Gypsy moth	*Lymantria dispar* L.				
Oaks	I	3	92.3 (83–100)		No
	II	2	96.7 (92–100)	Examinations with the electronic microscope	No
	III	15	99.8 (97–100)		No
	IV	7	100		No
Poplar, willows	III	3	92.7 (91–99)		No
					No
Browntail moth	*Euproctis chrysorrhoea* L.				
Oaks Variant 1	III	3	66.2 (39–85)	Examinations with the electronic microscope	Not yet known
Variant 2	III	3	75.6 (52–85)		

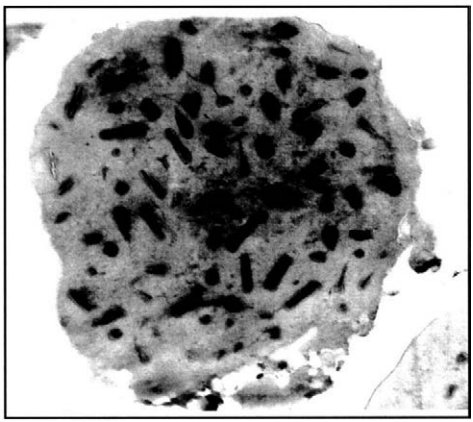

Fig. 11. Nucleopolyhedrosis virus in adipose tissue of gypsy moth caterpillar in the treated area (ultrafine section in capside seeing at the electronic microscope)

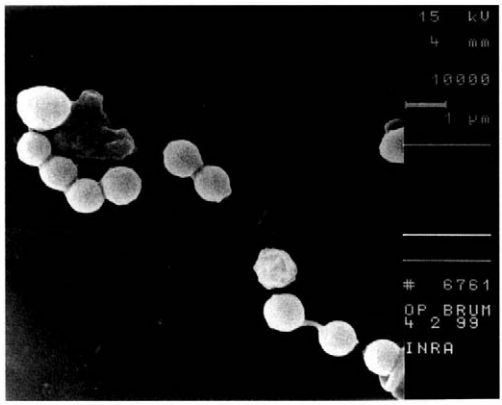

Fig. 12. Nucleopolyhedrosis virus in the biopreparation INF-ld (at the stereoscopic microscope)

poplar and silky willow woods ranged in 8 districts of Romania. For *E. chrysorrhoea* we treated 3 oak woods with infestation spots in 2001.

The viral epizooties released in all the treated focuses of *L. dispar* and *E. chrysorrhoea*. The defoliations were diminished under the admissible limits. In all biological samples nucleopolyhedrosis virus was identified.

CONCLUSIONS

- The gradation stopped in all gypsy moth infested stands, with INF-ld treatments.
- The low contact probability and the lack of some propagation vectors can explain the lower proportion of contaminated caterpillars in the early stages of the gypsy moth gradation.
- For the browntail moth infestation spots, our observations are still going on because we have made treatments during 2001.
- The probability of direct contact for browntail moth is lower than for gypsy moth.
- For browntail moth control, the method of treatment by nests immersing is more effective than the spraying.

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Outbreaks of *Bupalus piniaria* (L.) (Lepidoptera, Geometridae) and *Pissodes piniphilus* (Herbst) (Coleoptera, Curculionidae) in Estonia

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ABSTRACT: The pine looper moth, *Bupalus piniaria*, is one of the main pests of Scots pine, *Pinus sylvestris* L. It is a common species which occurs permanently also in Estonia, but its abundance varies considerably among different regions and years. However, outbreaks resulting in the complete defoliation of pine stands have taken place quite rarely here. Only five remarkable outbreaks of *Bupalus piniaria* were registered during the last century, mostly from the same regions of the northern and south-eastern parts of the country. The damaged area has expanded considerably during recent decades. The trees previously defoliated by the pine looper were often attacked by the pine-top weevil, *Pissodes piniphilus*, and by the bark beetles *Tomicus piniperda* and *T. minor*. Outbreaks of *Pissodes piniphilus* are usually associated also with the root-rot diseases caused by *Heterobasidion annosum* and *Armillaria* spp. An overview is given of the damages by the pine looper moth and the pine-top weevil in pine forests of Estonia.

The pine looper moth, *Bupalus piniaria* (L.) (Lepidoptera, Geometridae), is one of the main pests of Scots pine (DAJOZ 2000). Infestations by this defoliating moth are numerous in Central Europe, while it causes damage only rarely in the northern part of its range.

According to faunistic data, the pine looper is a common species which occurs permanently also in Estonia (JÜRIVETE et al. 2000). It can be a dominating species in some field catches in coniferous and mixed forests, but its abundance varies considerably among different regions and years. However, the outbreaks resulting in the complete defoliation of pine stands, have taken place quite rarely here. Only five remarkable outbreaks of *B. piniaria* have been registered during the last century, mostly from the same regions of the northern and south-eastern parts of the country (MIHKELSON 1986, 1998). The aim of this paper was to give an overview of the damages caused by two insect pests, the pine looper moth, *B. piniaria*, and the pine-top weevil, *Pissodes piniphilus*, in pine forests of Estonia.

OUTBREAKS OF *BUPALUS PINIARIA*

The first known outbreak of *B. piniaria* was registered from the Anija forest district, northern Estonia, in 1910–1912; about 15 hectares of pine forest were destroyed as a result of damage (DANIEL 1928). Another outbreak was registered in 1918 when 74 hectares of pine forest, damaged by the pine looper, were felled in Mädaoidu, Halliku forest district, Tartu county (DANIEL 1928).

The third documented outbreak of *B. piniaria* in Estonia occurred in the same region as the first one. It started in Kiiu forest, Anija forest district, in 1925. According to DANIEL (1935), 172.5 hectares of pine forest were damaged in Kiiu forest in 1925–1927; a large number of defoliated trees died. In 1927–1928, a defoliation of 150 hectares of pine stands was reported from the Anija forest district (DANIEL 1928). In the following years, the pine looper moth spread also to the neighbouring forest districts of Kolga, Rummu and Sagadi and reached to the coast of the Finnish Gulf. The outbreak of *B. piniaria* in northern Estonia lasted until 1930, the total area of damaged pine forests being 270 hectares (DANIEL 1935). In the same period, an outbreak of the pine looper occurred also at Vastseliina, southern Estonia, which led to the clearcutting of 30 hectares of damaged pine stands in 1930–1932 (MIHKELSON 1986).

During the following 50 years, there was registered no serious damage caused by the pine looper moth in Estonia. At the beginning of the 1980s, prominent outbreaks of *B. piniaria* were reported from the same regions as fifty years earlier. In the Vastseliina forest district, southern Estonia, the forest area damaged by the pine looper was about 150 ha in 1980–1981; 47 ha of severely dam-

aged pine forest were cut (MIHKELSON 1986; VAASK 1991). A relatively large-scale damage was caused by the pine looper in northern Estonia in 1980–1982. In the forest districts of Käsmu, Sagadi and Palmse on the territory of the Lahemaa National Park, 952 hectares of pine stands were damaged, but only 4 hectares of stands died and were removed by felling (KALVIK 1985). The outbreak of the pest was stopped by the aerial spraying of damaged forest with permethrin in July 1983.

Ten years later, in 1990–1992, the largest known outbreak of *B. piniaria* occurred in southern Estonia. About 4,000 hectares of pine forests were damaged in Orava, Vastseliina and Värska forest districts as well as in the vicinity of Obinitsa and Saatse villages; 30 hectares of damaged forest were felled (VAASK 1991; KALJULA 1992). In the Käsmu forest, northern Estonia, the area defoliated by the pine looper was only 36 hectares in 1992–1993 (PILT 1994).

Although the damaged area has expanded considerably during recent decades, the area of dead or severely damaged pine stands, designated for clearcutting, has remained rather limited and stable. If no pest control measures had been used, much more damage would have occurred during the last outbreaks (MIHKELSON 1998).

The following control measures have been used against *B. piniaria* during the last two outbreaks in Estonia (KALVIK 1985; KALJULA 1992):

- aerial spraying with permethrin (*Ambush*) from a plane, 900 ha in Käsmu and Sagadi, northern Estonia, July 1983;
- surface treatment of damaged stands with microbiological preparations (*Dendrobacillin, Biotoxibacillin*) based on the bacterium *Bacillus thuringiensis*, using a tractor sprayer, 500 ha in Orava and Vastseliina, southern Estonia, August 1991;
- aerial spraying with the hormone preparation *Dimilin* from a helicopter, 330 ha in Orava and Vastseliina, southern Estonia, and 40 ha in Sagadi, northern Estonia, August 1992.

FACTORS DETERMINING THE ABUNDANCE AND DISTRIBUTION OF *BUPALUS PINIARIA*

Site conditions. Outbreaks of *B. piniaria* are often associated with particular site conditions. In Estonia, outbreaks have occurred only in dry and fresh pine forests on sandy soils (boreal heath forests). By the beginning of the 1980s the pine looper moth had quite clearly become a stenotope species in North Estonia – 81.6% of all damaged stands were of the *Cladina* site type, 14.6% of the *Vaccinium* site type and 3.8% pine stands were of other site types (MIHKELSON 1986, 1998). In 1991–1993, pine stands of the *Vaccinium* site type in south-eastern Estonia suffered most severely; in the Orava forest district 62.8% of all damaged stands were of the *Vaccinium* site type, whereas only 20.7% of the *Cladina* site type and 16.5% of other types of pine stands were damaged.

Weather conditions. In the northern part of the range, weather conditions are the most important factors influencing the population dynamics of *B. piniaria*. The life history of this species is quite well known. The adults emerge in late May or in June, the oviposition period lasts from June to July, and the eggs take about three weeks to hatch. Larval growth is slow, taking about four months – the feeding period of the larvae lasts from July until late October. During this period, particularly at the end of the season, weather conditions constitute the main limiting factor for the population growth of *B. piniaria* in the northern part of its range. Only in the case of a long and warm autumn can the larvae finish their development and pupate successfully, which lays a basis for possible outbreaks in the following years. Although such good weather in October is not very common in Estonia, the general trend of climate warming is undoubtedly favourable for the pine looper moth.

Pupal parasitoids. In 1992–1993, the pupal parasitoids of the pine looper moth were studied in northern and south-eastern Estonia (ÕUNAP 1996). Altogether, 14 species of parasitoids and two species of hyperparasitoids were reared from pupae of *B. piniaria*. The mortality of the pupae due to parasitoids was quite high – in the Orava forest district, 57.5% of all pupae were destroyed. The most abundant species among the parasitoids were *Blondelia nigripes* (Fll.) (Diptera, Tachinidae), *Heteropelma calcator* Wesm. and *Erigorgus biguttatus* Grav. (Hymenoptera, Ichneumonidae).

CONSEQUENCES OF DEFOLIATION

A single year's defoliation rarely kills the tree, but two successive years of defoliation are already invariably fatal for the tree. Often, however, trees are sufficiently weakened following a single defoliation to succumb to secondary attacks by bark- and wood-boring insects such as *Tomicus piniperda* and *T. minor* as well as *P. piniphilus*. Attacks of secondary pests present a major threat to pine trees stressed temporarily by defoliation.

The bark beetles *T. piniperda* and *T. minor* are common species everywhere in pine forest. Observations have indicated that the pine-top weevil, *P. piniphilus*, occurs also frequently in pine stands defoliated previously by *B. piniaria* in southern and northern Estonia.

OUTBREAKS OF *PISSODES PINIPHILUS*

The damage caused by *P. piniphilus* in pine stands in southern Estonia and northern Latvia are known from the end of the 19th century (KNERSCH 1901; KOHH 1939). In the vicinity of Taheva, Valga and Valka (partly the territory of present Latvia), 370 hectares of pine stands were destroyed by the pine-top weevil (KOHH 1939). A small-scale damaged area (7.4 ha) was registered from Koorküla, southern Estonia, in 1913 (KOHH 1939).

In the 1930s, about 3,600 hectares of pine stands, mainly in southern Estonia (Ahja, Erastvere), were damaged by *P. piniphilus*; 55,000 cubic metres of timber were cut in the damaged areas (KOHH 1939). At the same time (1932–1937), only 85 hectares of damaged pine forest were regis-

tered from the Sagadi forest district, northern Estonia (KOHH 1939).

In 1971–1972, an outbreak of the pine-top weevil occurred almost in the same region of southern Estonia, in the Räpina forest district (RIIS 1975). At the beginning of the 1990s, thousands of hectares of pine stands were infested by *P. piniphilus* in southern Estonia (LUIK 1993, 1994).

Outbreaks of *P. piniphilus* are usually associated also with root-rot diseases caused by the fungi *Heterobasidion annosum* and *Armillaria* spp. According to data from the Centre of Forest Protection and Silviculture, 680–700 ha of pine stands damaged by root-rot diseases as well as by the pine-top weevil were registered in 1998–1999 (ASI et al. 2000).

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Current status and trends of pine defoliators in Poland

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ABSTRACT: The importance of insect pests (nun moth *Lymantria monacha* L., pine beauty moth *Panolis flammea* Den. et Schiff., pine moth *Dendrolimus pini* L., pine looper *Bupalus piniarius* L.) of Scots pine stands in Poland in the last two decades was characterized. The total area of their occurrence was about 10.6 mil ha and they were controlled on ca 7.7 mil ha of forests.

In the last two decades (1981–2000) the most important insect pests of Scots pine stands in Poland were: nun moth (*Lymantria monacha* L.), pine beauty moth (*Panolis flammea* Den. et Schiff.), pine moth (*Dendrolimus pini* L.), pine looper (*Bupalus piniarius* L.) and some species of sawflies (*Diprionidae*) (Fig. 1). The total area of their occurrence was about 10.61 mill ha and they on ca 7.81 mil ha of forests. In 2001 nun moth, pine beauty and pine moth were controlled (Fig. 2).

The greatest threat was due to the nun moth. This serious pest occurred on 7,75 million ha of forests and it was controlled on 6.31 mil ha (Fig. 3). The last outbreak of nun moth started in 1997 in the North-western Poland. In subsequent years this pest has extended its territory to the east and south of Poland. In 2001 the nun moth threatened pine forests mainly in the South-western Poland. Local outbreaks of this pest has arisen in the eastern part of the country. In 2000 and 2001 the threat was similar. At present the outbreak of nun moth in Poland is at the developing stage.

In the discussed period the pine beauty moth occurred on the area of 874,000 ha and was controlled on 409,000 ha. The present outbreak started in 1998 in the North-western Poland (Fig. 4). In 2000 this pest threatened forests in the same part of country. In 2001 symptoms of an outbreak decline were observed. In 2000 and 2001 the total area of the pine beauty moth control was 64,000 ha and above 70,000 ha respectively. Low threat from this pest in the last two years was related to the use of the chemical control and unfavourable climatic conditions in spring and summer 2001.

Pine moth occurred on 250,000 ha and was controlled on 183,000 ha of forests from 1981 to 2000 (Fig. 5). Its outbreaks arose mainly in the Western and South-eastern Poland. Actually the outbreak of this pest develops in the western part of the country. The chemical control was performed on 11,500 ha in 2000 and on 22,400 ha in 2001. The threat due to the pine moth may increase in the next year.

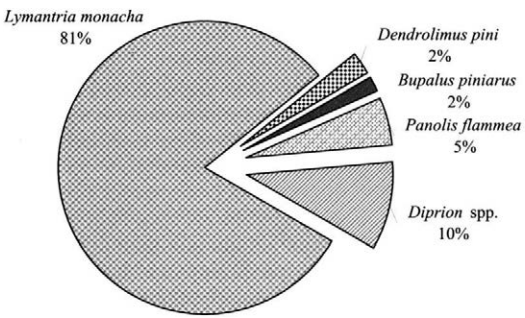

Fig. 1. Contribution in proportions of control area of pine defoliators (1981–2000)

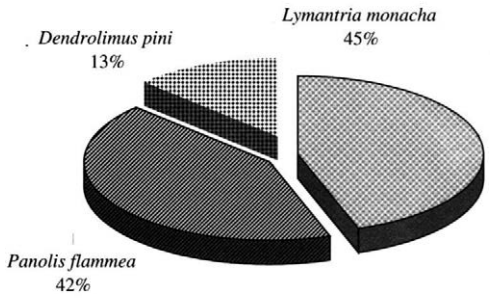

Fig. 2. Contribution in proportions of control area of pine defoliators in 2001

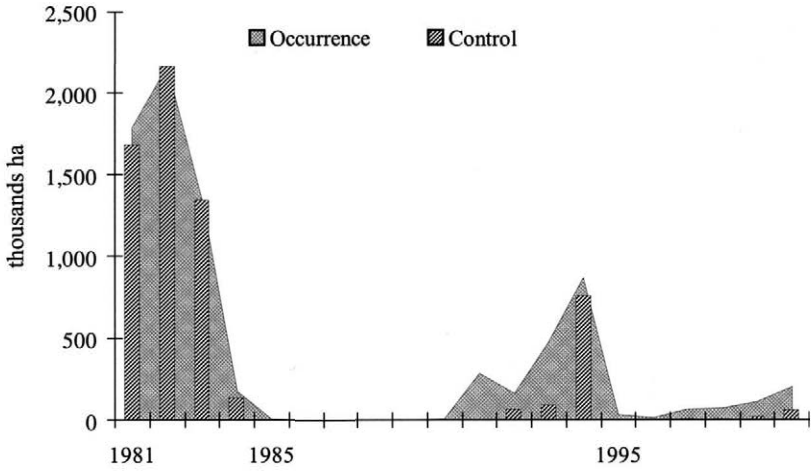

Fig. 3. Occurrence and control of *Lymantria monacha* in 1981–2000

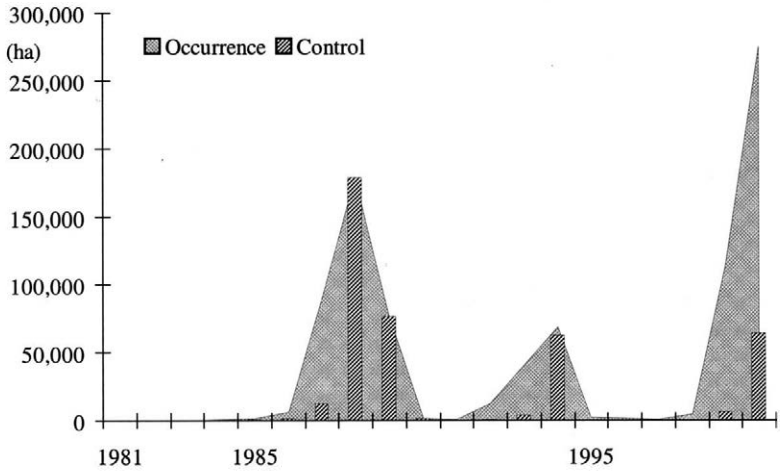

Fig. 4. Occurrence and control of *Panolis flammea* in 1981–2000

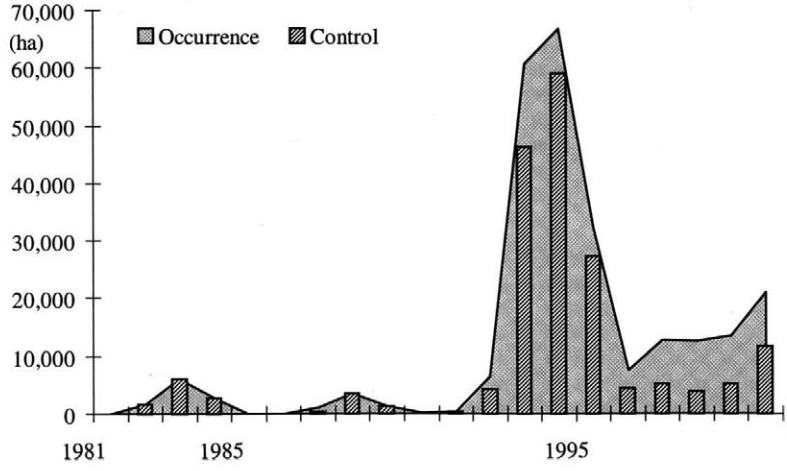

Fig. 5. Occurrence and control of *Dendrolimus pini* in 1981–2000

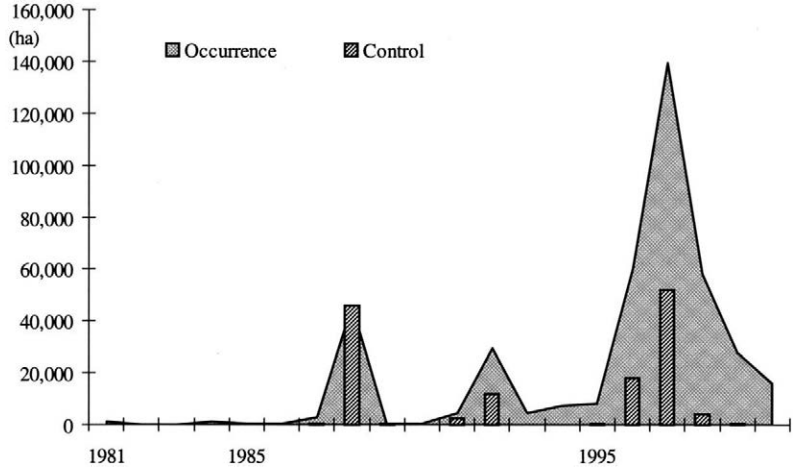

Fig. 6. Occurrence and control of *Bupalus piniarus* in 1981–2000

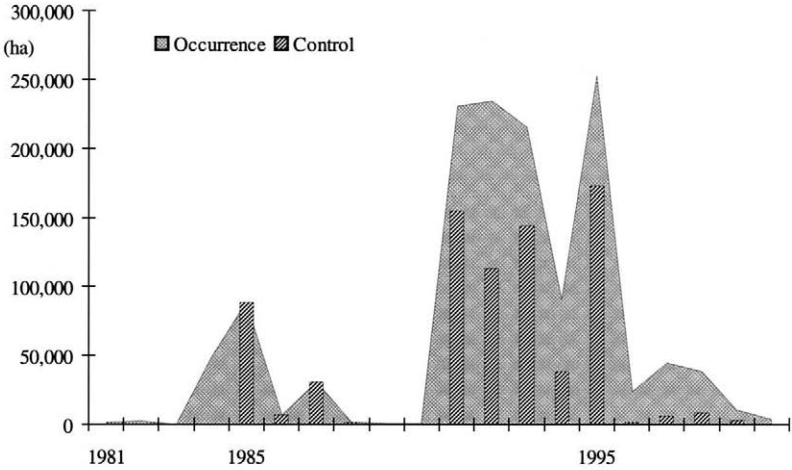

Fig. 7. Occurrence and control of *Diprion* spp. in 1981–2000

The pine looper infested 408,000 ha of forests and was chemically controlled on 136,000 ha in the last two decades (Fig. 6). In this period the greatest threat from the pest was noted in 1997. At that time the total area of its occurrence was over 52,000 ha. In the current year, there is no hazard from pine looper in Polish forests.

The total area of sawflies' occurrence in 1981–2000 was 1.33 mill ha whereas the area of control was 771,000 ha (Fig. 7). Large outbreak of these pests took place in 1991–1999. Since that time their populations have been at low density levels.

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2nd International Workshop "The Ore Mountains 2000: Die-back of Norway Spruce and Birch – Current Knowledge and Perspectives"

In spite of the fact that air pollution is progressively decreasing at the end of 80ies, new damage of spruce and birch stands has been observed since winter 1995/96. The damage seems to be caused by a combination of anthropogenic and abiotic/biotic factors. While spruce has been regenerating gradually since 1997, birch stands still continuously decline. Also symptoms of so called "New type of forest decline", spread in most of Central and Western Europe in eighties, have appeared in the ridge region of the western part of the Ore Mountains.

In September 2000, the 2nd International Workshop "The Ore Mountains 2000: Die-back of Norway Spruce and Birch – Current Knowledge and Perspectives" was organized by the Forestry and Game Management Research Institute of Jíloviště-Strnady, and the Technical University of Essen, closely cooperating within the Ore Mts. region. The workshop took place in September 18–22, 2000 in Kovářská, the Ore Mountains, it was supported by the Ministry of Agriculture and Ministry of Environment. Technical support was provided by Forests of the Czech Republic.

In total 30 participants took part in the workshop, from Germany (7), Slovenia (4), Slovakia (2), USA (1) and the Czech Republic (16), interested to present their research results and practical experience in presentations and posters.

Before the meeting there was an excursion, prepared in cooperation with the Regional Inspectorate of Forests of the Czech Republic, Karlovy Vary and Teplice. The excursion route was focused on important problems of the Ore Mts. First there was a short visit in Přísečnice dam, with a practical demonstration of good spruce stand regeneration after devastating winter 1995/96. Than the region of Klínovec (Maut, Meluzina) was visited, with several stops aimed with demonstration of damaged transitory birch stands, of different level of damage and regeneration. The last part of the excursion was dedicated to yellowing of the spruce stands in forest district Horní Blatná, i.e. new symptoms of forest damage. Spruce stands of different age, and different level of damage (color changes) were demonstrated. The participants were also informed about the activity of the Forest of the Czech Republic on mitigation of the damage.

The meeting was focused on following topics: Phytopathology – biotic agents, Ecophysiology, Forest restoration and applied forestry.

After an official opening of the session and an introductory lecture on specific natural conditions and air pollution development within the Ore Mts. region (Dr. LOMSKÝ), the section Phytopathology – biotic agents was open. In frame of this section there were three presentations. Introductory lecture on the impact of the root pathogens on spruce, alder and oak was presented by Prof. OSSWALD from Germany. Other two presentations were dedicated to the occurrence of bark beetles, and the structure of phytopatogens and fungi pathogents within the region of Ore Mts.

In the ecophysiological section 6 presentations and 4 posters were prepared. Two introductory contributions were presented by Prof. PFANZ a Prof. MATYSSEK. The contributions were focused on the SO_2 impact and acid deposition on the stands within the OM region, and on birch sensitivity to ozone and its impact on physiological processes and changes in anatomical structure. Following presentations were dedicated to genetic, chemical, biochemical and histological aspects of damage to the spruce and birch stands in the Ore Mts.

In the section Forest restoration and applied forestry there was 10 presentations and 2 posters. The section was open by the introductory presentations by Ing. ŠRÁMEK a Dr. EISENHAUER, bringing a complex information on the damage of the spruce and birch stands in nineties, both at the Czech and German side of the Ore Mts.

Following presentations were dealing with the problem of an introduction of other ameliorative species, health state of the spruce and birch stands, changes in nutrition of the damaged stands, state of soil and its degradation, ameliorative measures and tending measures in the transitory stands.

There was an interesting discussion in different sections, and, thanks to the German colleagues, also very useful exchange of practical experience, and the measures used in the German part of the Ore Mts., to mitigate the damage after winter 1995/96, and the damage of transitory stands.

Following conclusion has been agreed by all the participants:

- *In the view of current problems within the Ore Mts. forests, we cannot prove that even significantly lowered air pollution level will not cause health damage in forests stands in the future. The spruce damage in 1996, birch decline after spring 1997, and yellowing of spruce in 1999 and 2000 are connected with direct or background influence of air pollution (SO_2, NO_x, O_3, acid deposition).*
- *The young spruce stands in the eastern part of the Ore Mts., damaged in winter 1995–96, exhibit certain regeneration up to now. It can be explained both by favourable weather conditions in the last two years, and lower SO_2 load (no accumulating).*
- *It is recommended to prove how high the air concentration of SO_2 can rise in case of long-term inversion under current level of air pollution production, and what could be thus its influence on the forest stands.*
- *The yellowing of spruce stands in the western part of Ore Mts. reveals the same symptoms as the "Neuartige Waldschäden" in the Fichtelgebrge and the Bayerische Wald, which started fifteen to twenty years ago. It is directly connected with magnesium deficiency, but the exact underlying mechanism of nutrient imbalances is not clear yet.*
- *In the regularly limed forests of the Saxonian part of Ore Mts. there are no yellowing symptoms.*
- *Dolomite liming and fertilising based on soil analyses of the damaged stands can improve the cations balance in forest soils and trees, and it may temporarily avoid large-scale forest decline. More detailed research about causal influences is needed for definite solution of the problem.*
- *To obtain information on the kinetics and progress of damage symptoms, the reliable surveying of the damage development would be of importance.*
- *Further it is recommended to analyse the uptake pathways of nutrients (analyses of soil environment, roots, root pathogens, mycorrhizae), the effect of current level of nitrogen deposition which can cause dilution effect of cations by an enhanced growth of trees and leaching effect of acid deposition for both soil and foliage.*
- *From the silvicultural point of view it is recommended to enhance the forest ecological stability and nutrient cycling by changing the spatial structure, appropriate soil treatment, introducing of ecologically suitable deciduous tree species, and use of natural regeneration in genetically suitable stands.*
- *The die-back of birch observed both in the Czech and Saxonian parts of the Ore Mts. was initiated by the course of meteorological factors in spring 1997, concentration of damage at wet sites is of importance.*
- *There is a strong evidence, that the symptoms could be explained by damaged root system. The stands damaged did not stabilised, their further development can be hardly predicted.* Betula pubescens *and* Betula carpattica *exhibit much better health state than* Betula pendula *which grows there outside of its ecological range.*
- *It is recommended to examine the cause of root damage, mycorrhiza and the role of secondary pathogens. Furthermore, the risk of ozone impact in the Ore Mts. is to be examined, which will be of increasing importance for the broadleaved species within the mountain areas.*
- *From the silvicultural point of view, it is recommended not to use* Betula pendula *in elevated locations, which are not its natural area. There is significant risk for this species especially when the trees of unknown provenance are used. Suitable provenances of* Betula pubescens *and* Betula carpattica *can be used. In the stands, variety of species should be used to enhance forest stability, succession ability and bio-diversity.*
- *It is strongly recommended to keep the state of game at the level not disturbing stabilisation process of the forest ecosystems.*

For the organisers: Bohumír Lomský, Hardy Pfanz and Vít Šrámek

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An introduction to the development of tree and forest damage by air pollution in the Ore Mts.

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ABSTRACT: To understand current situation in the Ore Mts. it is necessary to look back on the history of the damage development. When describing the damages to forest stands in the Ore Mts. caused by air pollution, many other factors playing an important role in their development, has to be considered. It is mainly geological, geo-morphological and soil conditions within the Ore Mts. region. Also the temperature and precipitation conditions are specific. Antropogenic activities, both in the past and today, affecting the species composition, are also of importance. The development of air pollution damage, complex of stressing factors, triggering mechanisms of the damage, and the impact on forest management are described. Political changes at the end of eighties have affected significantly the development of economical activities within the region. Nevertheless the sulphur proportion in the complex of stress factors was decreased significantly due to lowering of the industrial production and de-sulphurisation of the big emission sources, new stresses, connected with the new mechanisms and symptoms of damage of both surviving old stands and new transitory stands, can be observed.

Keywords: natural condition; geo-morphology; geology; pedology; climate; air pollution damage; complex of sress factors

From the viewpoint of forestry and ecology the impact of air pollution had an extremely devastating effect on forests within the Ore Mts range. For more then fifty years extremely high levels of SO_2 (but also other pollutants like HF and ozone) directly affected tree and forest health at the plateau region (mainly spruces and birch). Damage was on one side permanently observed throughout the years, but it was sometimes synchronized by abiotic factors like frost. To understand better the causal reasons and the current situation of forest health status, it is necessary to summarize shortly the history of air pollution within the Ore Mts. Besides the pollution development, also the natural biotic and abiotic conditions will be mentioned, that played a decisive role in the development of forest.

NATURAL CONDITIONS

Geomorphology. The Ore Mts. form a border massif between northern Czech Republic and Eastern Germany with an area of around 15,000 ha; stretching in NE-SW direction, they cover an oval area of about 130 km in length, with a width of only 6–19 km at the Czech (southern) side. The massif was formed by rolling uplands inclining towards NW, forming a mean height between 700–1,000 m a.s.l. To the SE a steep fault-slope falls to the basins at the Ore Mts. piedmont. The foot of the slope is about 300–350 m above sea level; near the western, Most basin, the height is about 450 m a.s.l. The Ore Mts. can be divided into three parts (south-western, central, north-eastern; DEMEK 1965), differing in relief and altitude.

The Klínovec area, of an average altitude about 1,000 m, is located in the south-western part. The highest spots are Klínovec – 1,243 m, Špičák – 1,115 m, and Fichtelberg – 1,214 m on the German side. The Jindřichovice plateau is also situated in this SW-part of the mountains. It is lower and more flat (about 700 m), divided from the region around Klínovec by steep slopes of about 100 m depth (Děpoltovice – Nejdek), additionally dissected by the deep valleys of two (Rotava and Svatava) rivers. The central part of the Ore Mts. reaches an altitude of about 750–900 m a.s.l. The plateau had been broken by tectonic forces into smaller parts, which were subsequently lifted along the fault lines to different heights. The north-eastern part of the Ore Mts. in surroundings of Habartice and Větrov is the lowest, the height in the east of Krásný Les being 640 m a.s.l. The main slope is steep and cut with short, deep valleys. In relation to air pollution it is appropriate to split the area in two main parts: the plateau, of relatively smooth terrain, and the rough fault-slope.

Geology. The Ore Mts. are a part of the Czech massif crystalline region. The whole region has a very rich geology of rather favorable chemical composition. The mountains are built up of mostly crystalline schist and granite. They can be divided into several parts differing in geology. From SW-NE the following geology is published:

a) Kraslice Upland consisting of phyllitic slate, phyllite, and mica schist;
b) Nejdek Upland consisting of granite;
c) Jáchymov Upland with the Klínovec mountain group, and the connected Vejprty upland (most variable in

terms of geology) consisting of phyllite, mica schist, and various kinds of gneiss. There are effusions of basalt rocks (most frequently nefelinite);

d) The north-eastern half, composed mostly of various types of gneiss.

Peat bogs are rather common at the plateau.

Pedology. The rocks of the Ore Mts. (except of basaltoides) are poor in calcium, magnesium, and phosphorus. Even potassium, abundant in the rocks, is only slowly released and of short supply and availability for plants. Granite, quartz porphyrite, orthogneiss, and mica schist form very poor soils. The soils on top of paragneiss and phyllite are of more favorable chemistry. Various soils are formed: (i) light sandy soils formed by granite, (ii) clay loam to heavier sandy soils above gneiss and mica schist, and (iii) usually sandy loam, formed from phyllite. Due to rain the finer fraction of gneiss, mica schist and phyllite is washed out and deposited in convex terrain formations.

The natural soil development was affected by silviculture, due to the changes of a naturally more rich tree species composition in favor of a pure spruce monoculture. Additionally, soils were strongly affected by air pollution. Chronic emissions of SO_2 and NO_x caused a gradual acidification of soils. Acidification was followed by leaching of cationic minerals from the soils, and liberation of heavy metals within the rooting depth of the trees. The increase in the heavy metal content of the soils was further enhanced by the fall-out of heavy metal-rich dusts (Cd, Pb).

Climate. The long-term average of the annual mean temperature is 5.5°C; depending on altitude, the average year temperatures range from 2.7 to 6.6 °C. Long-term year precipitation is 890 mm (ranging from 740 to 1,150 mm; KUBELKA 1992; PLÍVA, ŽLÁBEK 1986). The top plateau of the Ore Mts. is classified as mildly cool; the Klínovec area as a cold mountain area; the adjacent slopes are classified as mildly warm, humid and the upland area and mountain edges as a mildly warm and mildly humid (HMÚ 1958).

Temperature inversions can be observed at the plateau in terrain depressions and closed valleys. Inversions occur during sunny weather; the cool air flows downhill, forming a persistent cool air lake at the bottom of the valleys; the lighter, warmer air is thereby being forced upward. Typical inversion sites are the wetlands and peat bogs at the plateau. Besides inversion localities where the cold air layer (frost lake) ranges from several decimeters to several meters, also inversion layers of several hundred meters are typical for this region. Such situations are quite common in winter (under the conditions of stabile anticyclones).

With a gradual slope at the German side of the Ore Mts. (leading to the plateau at 800 m a.s.l.) the massif sharply drops to the Czech basin at about 250–300 m a.s.l. This geo-morphological configuration is rather decisive for air turbulation. The air flows, enriched in solid and gaseous aerosols, meet the colder flows coming from the north and north-west, and forming extended areas of fog and mist. Due to the terrain configuration the characteristic fog may be observed throughout the year at the altitude of 600–800 m a.s.l. On average there are more then fifty foggy days per year, and cloudy days persist for more than 70% of the year.

In the NE part of the Ore Mts. winds from N to NW are prevailing (HEGER 1957). At the southern, Czech side, the W and NW winds mostly occur in the basin (Tušimice). During the winter period, however, the role of south-eastern and southern winds increases (FIALA 1999).

The mountain spruce stands are slowing down the winds. It is obvious that the vast deforestation was of significant impact on the wind velocity in this region. Windbreaks are most dangerous in normal forest practice. At the vast air pollution calamity clear-cuts, mostly the new cultures and the young stands were endangered. They were, and still are, damaged mechanically in winter by rime and ice formation. Moreover, the danger of wind-driven frost-desiccation is increased, causing a deleterious transpiration of buds and twigs (and evergreen needles) at the break of spring. This water loss is unavoidable, and due to the still frozen top layer of the soil, the plant cannot compensate it.

DEVELOPMENT OF AIR POLLUTION DAMAGE

At the beginning of the 12th century the border region between Germany and the Czech Republic was covered by continuous forests. In the 12th and 13th centuries the exploitation of the forest stands had started, connected to the development of mining activities. Mines and iron works needed big amounts of wood, both for constructions and charcoal production. Since the second half of the 15th century the colonization of the area increased with the mining activities being highest during the middle of the 16th. Silver and tin mining was prevailing, but also lead, copper and iron were exploited; many mining towns were established during that period. This was of extreme importance for the forest health status. Forests were completely devastated in many parts (Přísečnice) and there was also the risk of an insufficient wood supply for the mines. At the end of the 17th century the activity of iron mills was increased, resulting in exploitation of the nobility forest at the Klášterec region. The felled areas have been were regenerated by sowing and planting, which was done using mainly Norway spruce. The increased demand for wood had increased the prices, and, as a consequence, the cheaper brown coal was used. The development of industry was directly connected with dramatically increased brown coal-mining activities. Burning of sulfur-rich brown coal lead to incredibly high sulfur emissions, which then started to affect the health status of forest stands within the region.

PERIOD BEFORE 2nd WORLD WAR

Within the region of NW-Bohemia the air pollution and its impact on the forest stands was to be seen already at the end of the last century. The characteristics of tree damage, however, were different to those observed after the 2nd World War. In 1880 brown coal production was

about 6 millions tons. In 1920–1940 the production ranged from 13 to 17 millions tons, most of which was exported to other regions. Burning of brown coal was not the only pollution source. Various emissions from burning spoil heaps were also important. Burning spoil heaps were proven to be the main cause of tree damage within the regions of Kyselka, Duchcov and Most. Also stands growing at the foothills and mainly consisting of deciduous trees were affected. The pollution was exported with warm air flows even to higher elevations which were covered by mountain spruce stands. These stands were affected also by emissions from bigger distances (regions of intensive coal mining in Saxonia and the Ruhr basin).

PERIOD OF 1947–1965

Only in 1947 the brown coal production reached a similar level as it had before the war. During that time an intensive damage of forest stands was observed, resulted from long-term pollution with high doses of sulfur dioxide enhanced by extreme climatic conditions during the winter of 1946/47. The regional distribution of damaged stands corresponded to the existence of the local emission sources coming from Jiřetín towards Nová Ves v Horách.

In the fifties several brown coal-driven power plants at the Chomutov region were installed, directly situated at the southern foothills of the Ore Mts. Although the emission of SO_2 was still rather low, it was obvious that the pollution would affect the main ridge of the Ore Mts. due to the common situations of climatic inversions and their concentrating effect on air pollutants.

During this period damage symptoms of spruce that were clearly caused by SO_2 were observed locally. The first calamity felling of spruce was registered in 1963 (near Janov and Dubí); in this context there was a gradation of bark beetles. To regenerate the stands, classical forestry technologies and positive tending was used; birch and ash were used as transitory tree species. Norway spruce, beech, larch, and other tree species typical for the region were planted.

PERIOD OF 1966–1977

Beginning of sixties was characterised not only by an increased area of damaged stands but also by significantly more intensive damage of both older spruce stands and young plantations. Total disintegration of damaged spruce stands was so fast that the under planting by beech was not a solution. Also the target species composition had to be re-considered, same as still applied intensity of calamity felling. Norway spruce was excluded from stand regeneration in the region strongly affected by pollution and other tree species were recommended. Besides spruce also birch and ash were accepted as a target tree species.

In transitory stands some exotic species, mainly Blue spruce (*Picea pungens*), were used. Wood production was substituted by preference of non-productive forest functions (water and soil protection etc.).

At the beginning of spring 1977 an intensive damage – reddening of needles was observed both at spruce and pine at a vast region ranging from Labe-river to Klínovec. Less intensive damage was observed also in the stands west from Klínovec. The damage was most probably result of sharp temperature breaks at the end of March 1977. Mostly stands weaken by long-term air pollution load were affected. Also the SO_2 concentrations were high enough in that time to call acute damage. Increased mortality resulted in significant increase of calamity felling.

PERIOD OF 1978–1987

Repeatedly unfavorable weather conditions at the break of 1978–1979 meant a tragedy for the stands. In this period there were again several inversion situations combined with high concentrations of pollutants (e.g. 850–1,400 μg SO_2/m^3 per h). The impact was much more serious than in the previous years. A vast area of spruce stands of all age categories was completely destroyed. About 60% of spruce in that area (nearly 12,100 ha; timber supply 1.880 mil. m^3) had died and were subsequently felled. The whole region from Sněžník to Klínovec was affected. However, even during that time the stands west of Klínovec were not affected.

In general this period can be characterized as a culmination in stand damage with increasing areas of clear-cuts, a total collapse of spruce stands at the plateau region. In parallel, the regeneration of transitory species was intensified. Since 1985, the silvicultural activities using heavy machinery were stopped and small-range regeneration started to be applied again.

PERIOD OF 1988–1991

The eighties meant a certain stabilization of the spruce stands, which were thought to be "partly adapted" to increased SO_2 concentrations, although some damage was still observed locally. Mainly in the western part of the Ore Mts. at individual trees or group of trees symptoms of the so-called "new forest decline" (yellowing of older needle age classes) were observed. The symptoms were most probably caused by long-term effect of acid rain on soils disturbing the stand nutrition by nutrient leaching. Some changes in the nutritional status were even observed in broad-leaved species. The regeneration of the affected area with so-called transitory species was practically finished in the eastern part of the Ore Mts. Furthermore, a decisive part of the damaged stands had already been felled. Tending and transforming of the stands was the main target. This period can be characterized as an intermezzo of (preliminary) optimism.

PERIOD OF THE NINETIES

In the second half of the seventies and at the beginning of eighties the air pollution in the Ore Mts. by sulphur oxides culminated. A reduction of the industrial production within the Ore Mts. basin and the trials to de-sulfurise the main pollution sources (power plants in Tušimice, Prunéřov, Počerady) resulted in slightly lower emissions

(KUBELKA et al. 1992). The data of the measuring stations situated in the most loaded part of the Ore Mts. (Přebuz, Měděnec, Šebestián, Cínovec) confirmed this trend of decreasing SO_2 concentrations in the air. At the same time also the deposition of protons and sulfur compounds was decreased (LOCHMAN 1996; LOCHMAN, ŠEBKOVÁ 1998). Since 1986 the deposition of H-ions ranging of 2.5–6 kg /ha per year was reduced; today they do not exceed 0.3 kg/ha per year. The fall-out of sulfate in the spruce stands reached values of 570 kg/ha per year. After felling of the stands also the deposition of sulfates was decreased. Since 1988 the fall-out of sulfates reached high concentrations ranging from 50 to 100 kg/ha.year.

But with the emissions of SO_2 being decreased, the role of other air pollutants within the Ore Mts. region had increased. Mainly fluorine was of importance (LOMSKÝ, PASUTHOVÁ 1996), originating not only from the power plants within the basin (Tušimice, Prunéřov, Počerady, Ledvice), but also from the glass and china factories (Klášterec, Dubí, etc.). Furthermore, the development of the road traffic increased the concentrations of nitrogen oxides in the air. These oxides are chemical precursors of ozone, which started to affect the forest stands in the top parts of the Ore Mts. But also the petrochemical industry within the region still remained a source of organic solute emissions. Besides, it was also confirmed (winter 1993/94, 95/96) that under the special meteorological conditions of this region, even low SO_2 concentrations in the air can accumulate, causing a severe acidification stress to the trees.

THE NEW SITUATION – COMPLEX STRESS FACTORS

Paralleling the events in the forties and seventies, a sudden reddening of recent-years spruce needles was observed during the winter of 1993 to 1994. In November 1993 an acute damage of the assimilation organs was shown to be a combination of several stress factors, with an increased SO_2 concentration playing the decisive role amongst them. During inversion caused by a south-eastern wind and a sudden sharp temperature drop, the SO_2 emissions had increased. With several short interruptions it lasted nearly 1.5 months in November and December 1993. Half-hourly SO_2 concentrations exceeded 3,000 µg per m^3, and daily concentrations were above 400 µg/m^3 (LOMSKÝ, ŠRÁMEK 1999). Individual trees or groups of trees were damaged, mainly at the stand margins, within the FA Klášterec and Janov. Mostly the youngest needle age class was affected. The vitality of the spruce buds was nearly unaffected. Nevertheless, the stands regenerated well during the next year.

Another severe damage of the spruce stands was then observed during the winter 1995/96 and in the spring 1996. Reddening and mechanical damage of the spruce needles was to be seen at 700 a.s.l.; the damage increased with increasing altitude. Serious damages were observed in the top parts of the Ore Mts., from Kovářská to Načetín. Analysis showed that the damage of the assimilation organs of spruce stands was influenced by combination of different factors (LOMSKÝ et al. 1996).

As in previous years, there had been an inversion situation (daily SO_2 concentrations reaching 190 µg/m^3, half-hour concentration exceeding 400 µg/m^3, maximum concentrations reaching even 2,542 µg/m^3) over a prolonged period. At the plateau the situation was lasting from the end of November 1995 to the end of January 1996. Hard rime during the inversion exacerbated the situation. The most serious damage to the forest stands was found in December and January. During that period south-easterly winds were prevailing, transporting pollutants directly from the sources within the Ore Mts. basin to the mountain plateau. An increased pollution load in this part of the Ore Mts. was proved by high concentrations of the sulfur and fluorine in the needles (LOMSKÝ et al. 1996).

The content of sulfur and fluorine in needles after winter 1995/96 significantly exceeded the values found in 1993/94. The average fluorine contents in needles of the young spruce stands had reached the threshold values of 7–11 µg per g and also the contents of sulfur were significantly increased (TESAŘ et al. 1982). Compared to the situation in winter 1996/97, the sulfur contents were only slightly increased, and the content of fluorine was similar to previous winters (5 µg/g). Similar trend was observed with other needle year classes. In 1998 and 1999 the sulfur contents were only slightly increased and the fluorine contents stayed rather low. This sort of damage was observed at more then 12,000 ha of spruce stands. The area and extend of damage and declining stands was registered by the Institute for Forest Management (ÚHÚL). Declining stands of an age up to fifty years amounted to 1,250 ha, and stands older than fifty years were about 360 ha (ÚHÚL 1996).

The development of the damage to spruce stands was different. Older stands, strongly affected during winter 1995/96, were declining in 1998. Regeneration of the spruce stands moderately or slightly damaged was better then supposed; regeneration was according to the age and level of damage. By that time the stand defoliation and height increment had reached the state before the damage.

In spring 1997 first symptoms of extended damage to birch stands at the plateau of the Ore Mts. were registered. About 3,000 ha of the birch stands were affected. Damage was caused again by a synergetic impact of several stressing factors (inversion, temperature breaks, frost); a direct influence of air pollution could not be proven (ŠRÁMEK, LOMSKÝ 1998). Sharp temperature changes at the break of spring were most probably the triggering factor.

The damage of the birch stands had continued also in 1998. The stands were deteriorated gradually. The stands being only slightly affected (up to 30% defoliation) stayed at a constant level of damage. In the middle of 1998 about 4,960 ha of the total 7,000 ha at the top plateau were damaged. To compare to the situation in 1997, the total extend of damaged birch stands had increased to 68%. After three years the damaged area was about 5,428 ha (14.4% were weakened stands, 30.8% weakened and damaged stands, and 46.8% strongly damaged). The most damaged

stands consisted of 20 years-old trees growing at wet and peat bog sides and gleic soils at 900 m a.s.l. (ŠRÁMEK 1999).

In spring 1999, 500 ha of spruce stands were damaged in the western part of the Ore Mts. (Horní Blatná, Kraslice, Kladská). In parallel to needle chlorosis, needle desiccation was observed. The symptoms were similar to the "new type of forest decline" caused usually by effects of a long-term impact of acidic air pollutants on soils, thus indirectly influencing the nutritional status of the trees. In this part of Ore Mts. there are the poorest soils (Nejdek granite region), and some degradation of the soil can already be observed. Deterioration of the soil quality is probably caused by acidification of the upper soil horizons and leaching of nutrients from the sorption complexes. In the spruce stands a critical depletion of basic nutrients, mainly of Mg and Ca, was found.

The nutrient contents in the leaves were rather low (N, Ca, P, Zn), or at physiological threshold values (Mg). Nutrient deficiency resulted in a discoloration and dysfunction of the assimilation organs. The content of S and F was found to be rather low, hinting to an indirect effect of air pollutants.

CONCLUSIONS

In spite of significant reduction of SO_2 emissions within the Ore Mts. basin, there is still the danger of a high pollution load (cumulating in inversion situation) during extreme weather conditions. Besides the direct impact of air pollution during "acute" stress situations, the forest stands in the Ore Mts. are weakened by the long-term air pollution impact. Such weakened stands are additionally affected by other pollutants like fluorine, nitrogen oxides, ozone, heavy metals, acidic depositions. Long-term deposition on forest soils will affect soil pH and stand nutrition. A newly developing decline in birch also clearly demonstrates that even the trees, formerly being thought too be rather tolerant species, can be heavily affected. The causal decline mechanism in birch is not yet fully understood. This "new damage" needs detailed and continuous research. The presentations of the workshop are dedicated to this type of damage and the problem of forest development within the Ore Mts. region in general.

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How sensitive is birch to ozone? Responses in structure and function

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ABSTRACT: Although *Betula pendula* and *B. pubescens*, the tree species of birch in Europe, cover large and ecologically diverse areas of distribution, evidence about limiting ozone (O_3) impact in terms of unambiguous cause-effect relationships is scarce, regarding growth under actual site conditions. Similar to other tree species, considerations about risks imposed by chronic exposure to elevated O_3 levels must largely rely on principles of O_3 action as known for young trees grown under controlled chamber conditions. Such principles are well documented for birch, concerning physiological processes and structural differentiation at the cell, organ and whole-plant level, and interactions are highlighted between O_3 impact and effects of different light, water and nutrient availabilities. Although the resulting O_3 responses can be scaled consistently across the internal levels of tree functioning, evidence is rather poor for upscaling to old and tall trees and their specific habitats. Taking into account the ecophysiology of birch, hypotheses about this latter kind of upscaling are proposed, being aware, however, of the demand for experimental validation in the field. A means for approaching this validation are experimental 'free-air' O_3 fumigations which have been conducted extensively in northern Europe on juvenile birch plants. Findings of this approach are summarized and compared with O_3 responses of birch plants at central-European or sub-Mediterranean sites. Overall, it is concluded that birch is sensitive to chronic O_3 stress, although the extent of stress response can strongly be governed by the genetical constitution and other environmental influences. 'Free-air' O_3 fumigations must be extended to natural habitats and tree age beyond the juvenile stage in order to achieve a process-based and quantitative risk assessment of ecological relevance for the long-term performance of birch trees and forests under chronic O_3 impact.

Keywords: *Betula pendula; Betula pubescens;* ozone; sensitivity; scaling; ecophysiology

THE TREE SPECIES OF BIRCH IN EUROPE AND THE RISK OF OZONE EXPOSURE

Birch is a species-rich genus with about 40 species being spread across the northern hemisphere (BARTELS 1993). Many of them displaying a shrub-like growth habit, *Betula pendula* and *B. pubescens* can develop into trees of more than 30 m in height, but rarely grow older than 120 years (SCHÜTT et al. 1992). Although these two species represent the only trees of the genus birch which are autochthonous to Europe, both of them cover large natural areas of distribution, expanding from France and Great Britain in the west to far beyond the Ural mountains in the east (MEUSEL et al. 1992), and from low to high elevations of about 2,000 m a.s.l. in the Alps. Both species reach northern Scandinavia, where *B. pubescens* can form the boreal timberline, however, it is *B. pendula* which clearly extends into the Mediterranean region, namely Italy and the Balkans. The expansion to southern Europe may reflect the higher drought tolerance of *B. pendula*, although both birches are water-demanding, with *B. pubescens* – the so-called 'swamp birch' – typically occupying the rather wet sites (ELLENBERG 1996). Both species have a compact root system, i.e. they may be shallow-rooted but can extensively expand their horizontal roots underneath the soil surface. The soils are typically acidic and poor in nutrition, and the modest requirements for soil quality in combination with high demands for light characterize both birches as distinct pioneer species. This conclusion is supported by high growth rates as based on an indeterminate or 'free' growth pattern, i.e. the longitudinal shoot growth and leaf formation can continue throughout the growing season. Nevertheless, due to the high light demand both trees are weak competitors and,

Dedicated with appreciation to Prof. Dr. H. SANDERMANN's jr. 60th anniversary.

thus, restricted to poor sites which include cold habitats at high latitude and altitude.

Given the wide and ecologically diverse distribution of the two birch species across Europe, their areas of distribution have been affected almost in total, during the 20th century, by distinct increases in the tropospheric ozone (O_3) concentration to above pre-industrial levels (FOWLER et al. 1999). Since 1870, in Central Europe the mean O_3 exposure has increased in rural regions by a factor of 2 to about 6 at high elevations of the Alps, and peak concentrations can distinctly exceed 100 nl/l in urban areas (STOCKWELL et al. 1997; MATYSSEK et al. 1997). Upward trends in O_3 levels were reported to persist in the upper troposphere (STAEHELIN, SCHMID 1991). Continued increases have been found also in the British Islands (DOLLARD et al. 1995), and in northern Europe high O_3 episodes are observed as early as during spring (SKÄRBY, KARLSSON 1996). These primarily occur downwind of industrialized areas, perhaps being enriched by long-distance advection from the central and western parts of Europe or, also, by incursions of stratospheric ozone (DAVIES, SCHUEPBACH 1994). High O_3 concentrations were reported from eastern Europe (Poland, Ukraine) and discussed as causes of leaf injury in sensitive species (BYTNEROWICZ et al. 1993; BLUM et al. 1997). The situation is rather specific in southern Europe, where interactions between the orography of the Mediterranean Basin, macro-climatic gradients in atmospheric pressure between the Atlantic Ocean and the Asian continent, high exhausts of O_3 precursors and intense insolation can lead to local, meso-scale air circulation systems which accumulate ozone to rather high levels (MILLAN et al. 1997; SANZ, MILLAN 1998). The combination of Mediterranean climate and excessive air pollution along with the peculiarity of high summer precipitation as occurring at the southern edge of the Alps appears to be particularly conducive to O_3 injury in the local vegetation (SKELLY et al. 1999). Attempts of modeling the environmental constraint posed by ozone across Europe (HETTELINGH et al. 1996, 1997) suggest the entire geographic ranges of both birch species to be at risk by adverse O_3 effects (MATYSSEK, INNES 1999). One needs to be aware, however, that current threshold definitions of O_3 impairment are rather vague with respect to trees (e.g. *'Critical Level for Ozone'* concept defined as AOT40 which is the *'accumulated exposure over a threshold of 40 nl/l'*; cf. FOWLER et al. 1999; FUHRER, ACHERMANN 1999; VANDERHEYDEN et al. 2001).

Similar to other tree species, also in the case of birch considerations about risks that may arise from chronic exposure to elevated O_3 levels must largely rely on studies with young trees grown under controlled experimental conditions (e.g. in exposure chambers: MATYSSEK, INNES 1999; SKÄRBY et al. 1998; KOLB et al. 1997). This is due to a prevalent lack of rigorously demonstrated cause-effect relationships by ozone under actual site conditions, given the logistic limitations of ecophysiological field work on tall trees beyond the juvenile stage. The following account will first address, therefore, principles of O_3 action in birch as observed in studies on young trees under controlled exposure conditions. This account will be extended then to the issue on how the sensitivity of *B. pendula* and *B. pubescens* may be modified by physiological interactions between O_3 stress and effects of variable nutrient and water supply or light conditions. Findings will be integrated from studies which have documented O_3 responses in young birch trees as growing in the 'open air', i.e. under actual site conditions. Given this evidence, it will be hypothesized to which extent findings from young birch plants may be 'scaled' to mature trees in the field. A perspective will be proposed on how to overcome the deficits in knowledge about the O_3 tolerance of ageing trees as growing in their actual habitats. On the grounds of the available evidence, a conclusion will be drawn about the sensitivity of the two European tree species of birch to chronic O_3 stress.

PRINCIPLES OF OZONE ACTION IN BIRCH

There is evidence that ozone after passage through the stomata rapidly decomposes into secondary, oxidative derivatives which themselves can be injurious to the metabolism and structure of leaves so that the concentration of ozone approaches zero in the intercellular space of the leaf mesophyll (LAISK et al. 1989). The decay of ozone into reactive derivatives, unless having already been happened during the diffusive influx process, largely occurs in the mesophyll apoplast which contains antioxidants like ascorbate that form the 'front line' in oxidant defense (POLLE 1995). To the extent ozone or its derivatives reach the plasmalemma, they may link to receptors that can initiate 'oxidative burst' reactions (ELSTNER et al. 1996; PELLINEN et al. 1999) and 'programmed cell death' (KANGASJÄRVI et al. 1995), leading to local necroses as a means against spreading injury. Such latter defenses are mediated at the gene level through molecular signal chains including the oxidative O_3 derivatives, ethylene formation as well as salicylic or jasmonic acid (SANDERMANN 2000). As ozone hardly reaches the chloroplasts (URBACH et al. 1989), molecular signaling is also suggested to induce the decline of chloroplasts (loss of pigments and rubisco activity; SANDERMANN 1996; PÄÄKKÖNEN et al. 1998). The mechanistic nature of the receptors and signal chains has only partly been unraveled to date, however, it appears that primary defense against ozone is rather similar, at the cellular level, to responses elicited by biotic agents (SANDERMANN et al. 1997; LANGEBARTELS et al. 1997; SANDERMANN 2000). It can be concluded that the primary response mechanisms to ozone in birch are consistent with findings in other woody and herbaceous plants (PELLINEN et al. 1999).

In leaves of *Betula pendula*, chronic O_3 impact in fact increased the level of apoplastic ascorbate, and together with the pool of dehydroascorbate, the overall defense capacity appeared to be raised (POLLE et al. 2000). Other constituents involved in oxidant scavenging like glu-

tathione, glutathione reductase and peroxidase tended to be activated as well in the apoplast. Also in the symplast, levels of ascorbate and glutathione were enhanced, although this response depended on nutrition (see below). Effects of the primary O_3 impact on the mesophyll were also reflected in the cell walls facing the intercellular space by droplet-like protrusions (at the outer cell wall surface) which appeared as 'unetchable exudates' under low-temperature scanning electron microscopy (= LTSEM: MATYSSEK et al. 1991; GÜNTHARDT-GOERG et al. 1993). Combinations of different microscopic techniques have revealed these protrusions to mainly consist of calcium pectate and to be distinguishable, by chemical composition and appearance, from structural changes as induced by other kinds of stress (GÜNTHARDT-GOERG et al. 1997). As oxidative stress may increase the cytosolic calcium level (LOCK, PRICE 1994), 'trapping' of calcium in cell walls by incorporation into pectate may function as a kind of detoxifying mechanism and apparently spreads from the sub-stomatal cavities, the sites of O_3 uptake, into the intercellular space. Given such primary effects of ozone, other changes in the plant can be regarded as secondary responses to O_3 stress. For example, the overall width of cell walls tended to be increased under O_3 stress, being accompanied by increases in the leaf mass/area ratio (LMA) and stomatal density, but reduced leaf size (GÜNTHARDT-GOERG et al. 1993). The cellular extension growth appears to be inhibited by ozone which may render membranes leaky to water loss and lower the turgor during the process of leaf differentiation (HEATH, TAYLOR 1997; cf. MATYSSEK et al. 1988). Loss of cell fluid also seems to be the cause of advancing O_3 injury, when shrinkage in volume leads to cell collapse, by this enhancing the intercellular space as long as the epidermal cell layer stays intact.

The structural changes affected the gas exchange of the birch leaves: The photosynthetic performance declined as a consequence of the collapsing mesophyll cells (MATYSSEK et al. 1991). This was preceded by a reduced rubisco activity (SAURER et al. 1995) and paralleled by a lowered, effective quantum yield of photosystem II (F/m' of PS II) but increased non-photochemical quenching (NPQ, SHAVNIN et al. 1999), whereas the optimal quantum yield of PS II, Fv/Fm, tended to be rather stable (MAURER et al. 1997). Both the photosynthetic capacity of CO_2 fixation and carboxylation efficiency declined dramatically so that the CO_2 concentration in the intercellular space of the mesophyll increased. This latter change may have been the stimulus for some degree of stomatal closure which overrode the effect of the increased stomatal density on leaf transpiration, and the stomatal narrowing was microscopically confirmed by LTSEM (MATYSSEK et al. 1991). The partial stomatal closure could not prevent, however, a decline in the water-use efficiency of photosynthesis (WUE). Macroscopically, the leaf-internal decline was accompanied by discoloration, progressing from chlorotic stippling through a stage of 'bronzing' of the entire leaf lamina into the formation of large brownish necroses (MATYSSEK et al. 1990).

Structural changes probably also affected the translocation of assimilates in the birch leaves, given the disruption of symplastic pathways due to the progressive cell collapse. Also phloem loading appeared to be disturbed as indicated by starch accumulation along leaf veins (MATYSSEK et al. 1992; GÜNTHARDT-GOERG et al. 1993). This accumulation tended to be paralleled by increased levels of sucrose, glucose and fructose, while reduction of sucrose phosphate synthase activity and stimulation of sucrose synthase and invertase reflected favored degradation of sucrose rather than synthesis (LANDOLT et al. 1997; EINIG et al. 1997). The metabolic status resembled an end-product inhibition of photosynthesis in the leaves, induced by reduced assimilate export, with the carbon flow being switched from sucrose synthesis to glycolytic and anaplerotic processes feeding the detoxification and repair of O_3 injury. This view is supported by enhanced respiratory activity and stimulation of the CO_2-binding PEP-carboxylase enzyme (PEPC, MAURER et al. 1997; LANDOLT et al. 1997), enhancing the carbon pool of the citric cycle (cf. WISKICH, DRY 1985). It was the low ^{13}C discrimination of PEPC rather than a limited CO_2 uptake through the stomata that caused the increase of ^{13}C in the biomass of O_3-exposed birch trees (Fig. 1(A), SAURER et al. 1995; cf. FARQUHAR et al. 1989), given the decline in

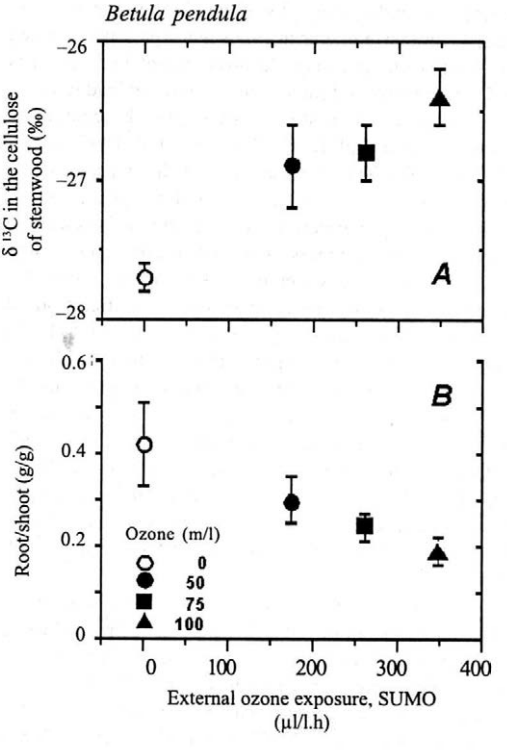

Fig. 1. ^{13}C in the cellulose of stem wood (A), and root/shoot biomass ratio (B) of *Betula pendula* as related to the external O_3 exposure (i.e. the SUM0 dose) experienced throughout the growing season (means ± standard deviation); after data from MATYSSEK et al. (1992) and SAURER et al. (1995)

WUE despite partial stomatal closure (MATYSSEK et al. 1992). The linear relationship between ^{13}C and external O_3 exposure indicates a constant ratio of the latter to the physiologically effective O_3 influx into the leaves and a proportional metabolic response to the accumulating O_3 impact on the mesophyll.

Given the increased demand for detoxification and repair processes and the inhibited assimilate translocation from the leaves, the development of the non-green organs must be expected to be limited under O_3 stress. The organ limited most is the root system so that the root/shoot biomass ratio (R/S) declined – again, in a linear relation to the external O_3 exposure (Fig. 1B). Increment in stem length was less limited than radial stem growth, and stems developed a similar number of nodes and leaves along their axes irrespective of O_3 stress (MAURER 1995) so that changes in biomass partitioning by ozone do not appear to merely reflect retarded ontogeny (MATYSSEK et al. 1998; cf. WALTERS et al. 1993). Limitation in radial stem growth was accompanied by structural decline in the cortex and phloem tissue (GÜNTHARDT-GOERG et al. 1993; POLLE et al. 2000). Ozone exposure also suppressed lateral branching so that this effect on the annual whole-plant biomass production can be quantified along with those of reductions in leaf size and photosynthesis, and of premature leaf loss at the lower stem parts (Fig. 2). These oldest leaves on axes which result from indeterminate growth experience the highest O_3 exposure (i.e. external O_3 dose) and are shed first, and their loss may limit the increments of the lower stem and the root (DICKSON, ISEBRANDS 1991) in addition to the inhibited translocation of assimilates. The efficiency of the whole-plant production as based on the foliage area formed during the growing season may be reduced by up to 60% (MATYSSEK et al. 1992), and the biomass production again tends to decline in a linear way with the increasing O_3 exposure.

OTHER FACTORS AS MODIFIERS OF THE OZONE RESPONSE IN BIRCH

Pursuing an ecophysiological perspective, the action of ozone must not be regarded as separated from other environmental impacts which altogether determine the sensitivity to stress (MOONEY et al. 1991; SKÄRBY et al. 1998). It is commonly agreed upon that high irradiance can increase the injurious potential of elevated O_3 levels (HEATH, TAYLOR 1997), as the antioxidative capacity which is inherently required to cope with the oxidant release during photosynthesis may be exceeded by additional oxidative stress. This kind of detoxification immanently depends, however, on the energy supply from photosynthesis (SCHUPP, RENNENBERG 1988; MENSER 1964) so that the question arises about the toxicity of ozone under light limitation. There is evidence that low-light conditions can raise the sensitivity to ozone (KOLB et al. 1997; MATYSSEK et al. 1995a), and such observations have been made also in birch (MATYSSEK et al. 1995b; GÜNTHARDT-GOERG et al. 1997). The same O_3 exposure at night, including dawn and dusk, not only fa-

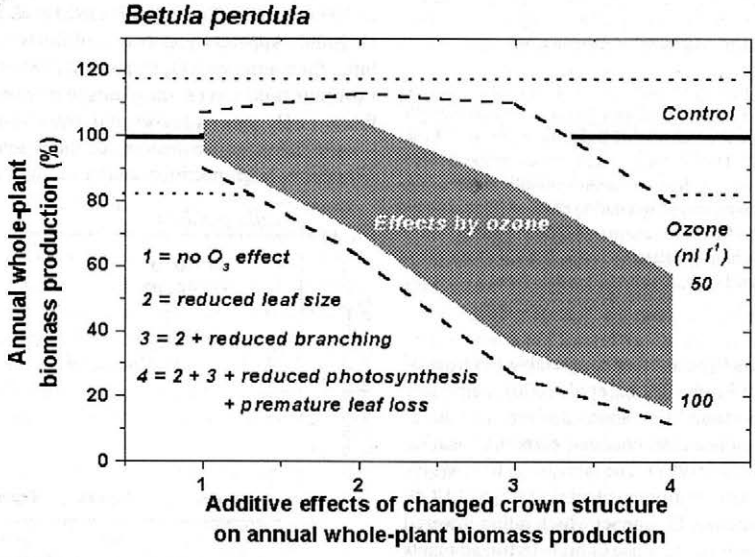

Fig. 2. Additive effects of O_3-induced changes in crown structure on the annual whole-plant biomass production of *Betula pendula*: Influence of persisting O_3 levels between 50 and 100 nl/l (dark area, standard deviation given as dashed lines) relative to control plants in O_3-free air (drawn bold line, standard deviation given as dotted lines; biomass production of the control set as 100%). Steps 1 through 4 represent the O_3-caused consequences of reduced leaf size (2), plus inhibited formation of lateral branches (3), plus premature leaf loss in combination with photosynthetic decline (4) for the proportional decline in biomass production (redrawn from MATYSSEK et al. 1992)

vored leaf discoloration, but also led to more distinct declines in the whole-plant production and in the stem weight/length and root/shoot ratios (R/S) than during the daylight hours, and 24 h exposure resulted in additive effects of the declines under low and high-light conditions. Stomata were open at night, assuring O_3 influx, although the stomatal conductance was about 50 % only of the level under high irradiance. Given the lowered O_3 influx at night, plants were more sensitive to ozone in the absence of light (cf. KOLB, MATYSSEK 2001). Contrasting with the common view of stomatal closure in the dark, stomata have the potential of staying open at night (TOBIESSEN 1982), and there are a number of conditions (e.g. chronic O_3 impact itself) that may be conducive to such a stomatal behavior (MATYSSEK, INNES 1999). It is an open issue, though, if the light-demanding character of birch predisposes to high O_3 sensitivity under light limitation (KOLB, MATYSSEK 2001).

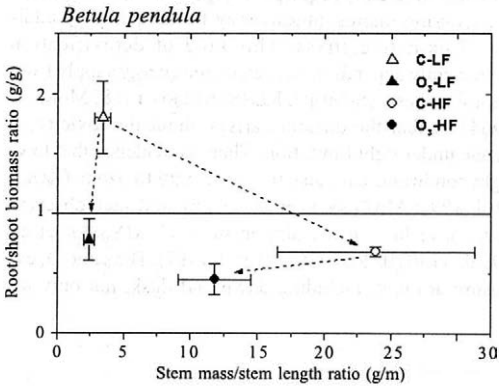

Fig. 3. Changes in whole-plant carbon allocation as expressed by the root/shoot biomass ratio in relation to the stem mass/length ratio of *Betula pendula* at the end of the growing season; Low and high-nutritional plants (triangles and circles, respectively) were exposed either to O_3-free air (open symbols) or to an O_3 regime of 40 nl/l at night, and 90 nl/l during daytime (closed symbols; means ± standard deviation). Abbreviations: LF = low-fertilized, HF = high-fertilized, C = O_3-free air ('control'), O_3 = 40/90 nl/l night/day O_3 regime (after data from MAURER, MATYSSEK 1997)

Nutrition appears to be another appreciable modifier of the O_3 response of birch (POLLE et al. 2000), being less reflected by proportional O_3-caused declines of whole-plant production rather than changed carbon allocation (MAURER, MATYSSEK 1997). The increase in R/S, as typically observed in low-nutritional plants (STITT, SCHULZE 1994), was prevented by O_3 impact which rather lowered this ratio to levels similar to those of high-fertilized plants (Fig. 3), although differential effects of nutrition on O_3-induced declines in the stem weight/length ratio were less pronounced. High nutrition had minor effects only on the O_3 response of R/S. The change in whole-plant allocation apparently related to the indeterminate growth pattern of the birch shoots which promoted, at high nutrition, extension growth and leaf formation throughout almost the entire growing season, whereas low nutrition made these increments cease early in the season. By this, low-nutritional plants were required to maintain their lower number of leaves, even if O_3-injured, whereas the oldest and, therefore, O_3-injured leaves at the basal stem parts of high-nutritional plants tended to be prematurely shed. As a consequence, the proportion of injured leaves in the foliage area along stems stayed below 50% by early September (Fig. 4), and this percentage was even lowered, when taking into account the largely intact foliage of the extensive branch formation at high nutrition. Foliage injury approached 100% only by early October. At low nutrition (and in the absence of branching), O_3-caused injury affected more than 50% of the foliage throughout most of the growing season and reached 100 % already during early September (Fig. 4). The maintenance of a persistently high proportion of injured foliage apparently represented both an enhanced demand for assimilates as reflected by high respiratory carbon loss in the whole-tree carbon balance (MAURER, MATYSSEK 1997) and an aggravating impact of disrupted assimilate translocation on the below-ground carbon allocation (cf. RENNENBERG et al. 1996). Given these constraints, the WUE of the whole-plant biomass production was low in low-nutritional plants under chronic O_3 exposure, even though partial stomatal closure occurred in response to ozone under low nutrient supply (MAURER et al. 1997).

It were the O_3-exposed leaves of the low-nutritional plants that showed, in most distinct ways, the changes in carbon metabolism (starch, sugars) mentioned above, including increases in ^{13}C and defense capacity (SAURER et al. 1995; LANDOLT et al. 1997; EINIG et al. 1997; POLLE et al. 2000). Apparently, nutrition offers two 'strategies' to birch for coping with O_3 stress (MATYSSEK et al. 1997b): Low nutrition 'forces' the plants to rely on the photosynthesis of O_3-injured leaves and, thus, to maintain them – with drastic consequences for the whole-plant carbon allocation. High nutrition enables a high leaf formation

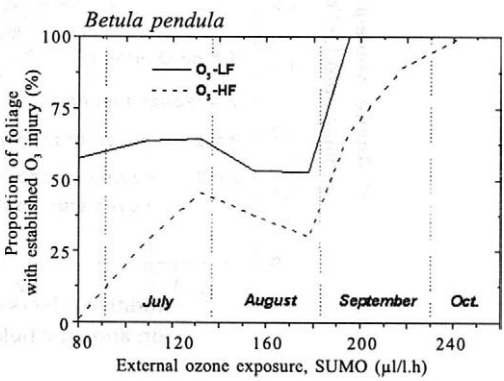

Fig. 4. Proportion of foliage with established O_3 injury in the whole-plant foliage area of low or high-nutritional birch plants (*Betula pendula*) during the seasonal course (and in parallel to the accumulating external O_3 exposure, i.e. the SUM0 dose); treatments and abbreviations as given in Fig. 3 (after data from MAURER, MATYSSEK 1997)

rate so that the need for maintaining O_3-injured leaves and their effects on the whole-plant carbon balance are diminished. The extent to which these 'strategies' substantiate strongly determines the sensitivity of specific plant parameters under consideration and may explain the high variability found in tree responses to ozone (POLLE et al. 2000; MATYSSEK et al. 1995a). Variable nutrient availability may be a common situation for pioneers like the two birch species in question which can occupy edaphically disturbed sites of high nutrient availability, but which do also tolerate poor soils so that resulting O_3 responses in the field may be rather inconsistent. In another study by PÄÄKKÖNEN et al. (1995), high nutrition tended to decrease, in *Betula pendula*, O_3 injury and premature loss of leaves, although the nutritional status was mainly determined by nitrogen supply. It needs to be examined, to what extent the quality of nutrition (nitrogen *vs.* balanced nutrient supply) may as well modify the responsiveness to ozone (MATYSSEK et al. 1995a).

Also soil water supply can be variable in the habitats of the two birch species, and in particular the sandy and drier sites of *Betula pendula* may tend to develop moisture deficits, although this tree species is water-demanding. Findings disagree, however, as to whether drought may necessarily prevent O_3 injury through stomatal closure, or if chronic O_3 exposure may render stomatal regulation imprecise through mechanical or biochemical changes in the stomatal apparatus (WIESER, HAVRANEK 1993; GÖTZ 1996; HEATH, TAYLOR 1997; MAIER-MAERCKER 1998), by this increasing risks of impairment by both O_3 uptake and poorly controlled water loss. In *Betula pendula*, effects of drought and O_3 stress appeared to be additive in reducing leaf number, foliage area and starch formation in the mesophyll cells, but increasing epidermal cell wall width and tannin-like depositions in the vacuoles, both being regarded as defense reactions (PÄÄKKÖNEN et al. 1998a). Drought counteracted O_3 effects on leaf differentiation by decreasing the stomatal density, however, both stresses lowered the stomatal widths. Nevertheless, drought was beneficial only in slightly reducing the O_3-caused leaf discoloration, although the latter was related to the gene induction of stress proteins (PÄÄKKÖNEN et al. 1998b). Only severe drought appeared to protect from O_3 impact, whereas mild soil moisture deficit rather was conducive to O_3 injury (PÄÄKKÖNEN et al. 1998c). It was concluded that drought/ozone interactions were rather complex in birch so that generalizations were not readily achievable.

Part of the complexity in birch response appeared to result from a high variation in the O_3 sensitivity between genotypes, and this conclusion substantiated both for *Betula pendula* and *B. pubescens* (PÄÄKKÖNEN et al. 1997). O_3 tolerance was associated with compact leaf structure and, remarkably, increased stomatal density, whereas sensitive genotypes were characterized by ultrastructural decline of chloroplasts. Individuals with low capacity of leaf formation had high proportions of O_3-injured foliage, which resembled findings on the O_3 response of low-nutritional birch plants (MAURER, MATYSSEK 1997). It seems that the indeterminate growth pattern and the degree of its expression, either mediated through the genetical constitution or environmental influences, pre-determines the responsiveness of birch to ozone. It is also evident that the genetical variability in concert with the environmental scenario can initiate a broad spectrum of gradually differing stress responses in the two birch species so that the resulting range in sensitivity can easily differ from presumptions on the responsiveness to ozone (VANDERHEYDEN et al. 2001; MATYSSEK, INNES 1999; SKÄRBY et al. 1998).

EVIDENCE OF OZONE RESPONSES IN BIRCH UNDER PREVAILING FIELD CONDITIONS

Most findings, addressed so far, on responses of birch to ozone were based on investigations conducted in exposure chambers (which represents a situation similar to the state of knowledge about other tree species in Europe; MATYSSEK, INNES 1999). However, some of the addressed data, namely most of those provided by PÄÄKKÖNEN and co-workers, have in fact been elaborated by using the 'free-air' fumigation approach in the field. This methodology offers the advantage of preventing plant enclosure in containments and, by this, avoiding potential artifacts by micro-climatic bias (MUSSELMAN, HALE 1997). Hence, the ecological significance of such O_3 exposure studies is increased, and the prevailing ambient O_3 regime can serve as a 'control' of experimentally enhanced O_3 treatments (HÄBERLE et al. 1999). Although being more 'site-relevant', basic findings obtained from experimental 'free-air' exposure of birch were rather consistent with those from chamber studies (PÄÄKKÖNEN et al. 1993, 1997): Elevated O_3 levels reduced, in sensitive genotypes of birch, the height growth and foliage mass, promoted leaf discoloration and induced partial stomatal closure, but increased the stomatal density of leaves differentiating under O_3 impact. Ultra-structural decline occurred in the chloroplasts, and as observed elsewhere (GÜNTHARDT-GOERG et al. 1993; MATYSSEK et al. 1998), leaves formed by indeterminate growth in mid-summer were more sensitive to ozone than those which had flushed during spring. By comparing birch clones from different parts of Finland for O_3 sensitivity in response to 'free-air' fumigation, it was concluded that risks by O_3 impact may be highest in the southern, coastal region of the country (PÄÄKKÖNEN et al. 1997). 'Carry-over' effects were studied in birch during years succeeding experimental 'free-air' O_3 exposures, revealing persisting reductions in shoot and root biomass along with inhibited bud development, leaf growth and branching as well as decreases in photosynthesis and stomatal conductance (PÄÄKKÖNEN et al. 1999; OKSANEN, SALEEM 1999). Based on these experiments and silvicultural data of *Betula pendula* plantations, modeling attempts were made to estimate yield loss in timber production as caused by chronic O_3 exposure during rotation periods (KÄRENLAMPI 1999). Although the model was parametrized, in part, with data from young birch plants, minor declines in

photosynthesis turned out to lower timber yield by about 10 to 20 % by the end of the rotation, whereas assumptions of a favored carbon allocation into the O_3-exposed leaves tended to counteract loss in production (cf. MOONEY, WINNER 1991).

Also in Central Europe, O_3 injury of birch leaves was identified in the open field, when plants grown under the ambient O_3 regime prevailing outside were compared with individuals exposed to controlled O_3 treatments inside exposure chambers (GÜNTHARDT-GOERG et al. 1998). The same kind of stippling occurred, when leaves of both sets of plants had experienced similar O_3 exposure. The southern edge of the Alps mediates between Central Europe and the Mediterranean region in displaying typically high precipitation of the insubric climate during the summer months, but being characterized also by high insolation and elevated O_3 regimes which are advected from the industrialized Milan area in northern Italy (WUNDERLI, GEHRIG 1990; STAFFELBACH et al. 1997; MATYSSEK, INNES 1999). The resulting high water availability during periods of high irradiance and O_3 impact may be rather conducive to an O_3-induced impairment of the vegetation in this sub-Mediterranean region. In fact, a survey conducted in this region, in the canton of Ticino (southern Switzerland), revealed a number of autochthonous and introduced species, comprising both herbaceous and woody plants, that exhibited symptoms of leaf injury (stippling, discoloration; SKELLY et al. 1999) which had previously been described to be indicative of O_3 impact (SKELLY et al. 1987). *Betula pendula* belonged, in this survey, to the array of symptomatic plants. Offsprings of symptomatic plants were grown, in a second step, in exposure chambers and submitted to either ambient O_3 regimes or treatments of reduced O_3 levels (filtered air). In offsprings of sensitive plants, same leaf symptoms were reproduced under the ambient O_3 fumigation regimes as found in the open field (VANDERHEYDEN et al. 2001). Symptoms were consistent with known responses to enhanced O_3 levels, and were delayed in filtered-air treatments of reduced O_3 levels (SKELLY et al. 1999). Also *Betula pendula* behaved in this way, with the leaf symptoms being consistent with those found in central and northern Europe (VANDERHEYDEN et al. 2001). In this approach, which fulfilled the *Koch's postulates* in linking, in a rigorous way, leaf symptoms occurring in the field to ozone as the causing agent, birch appeared to be less O_3-sensitive relative to other woody species, in particular to the introduced *Prunus serotina* (cf. MATYSSEK et al. 1997a). One needs to be aware, however, that ranking of O_3 sensitivity across species is questionable, given – as pointed out above – the strong influences of genotypic constitution and accompanying site factors on the O_3 responses of trees.

HYPOTHESES ON THE OZONE RESPONSE OF AGEING BIRCH TREES AND PERSPECTIVES OF VALIDATION

The current knowledge about the impact of ozone on birch is mainly based on studies of juvenile plants, including the evidence from 'free-air' O_3 fumigations (see above). Concerning this early ontogenetic stage, principles in structural and functional response patterns to ozone have largely been understood, as *Betula pendula* is one of the plants that has been examined rather profoundly for its sensitivity to ozone. Basically, two pathways of O_3 action exist which both eventually result in changed carbon allocation (Fig. 5): One through injurious alterations, progressing from disruption of photosynthesis and assimilate translocation to premature leaf loss and productive decline, and the other one counteracting, through defense mechanisms, the risk of O_3 injury. This latter pathway tends to maintain production, relying on energy and substrate-demanding repair and detoxifica-

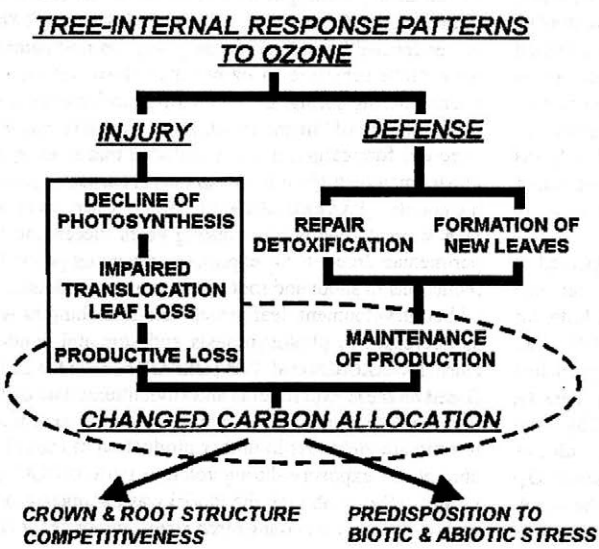

Fig. 5. Pathways of O_3 action in birch (see text for details)

tion processes and/or an enhanced capacity of growing new, initially intact leaves (WOLFENDEN, MANSFIELD 1991). The changed carbon allocation can be reflected in modifications of tissue morphology and above- and below-ground growth patterns, while associated changes in productivity and respiratory or transpiratory costs may lower the water-use efficiency of growth. The available evidence allows for 'scaling' processes involved in these pathways across the tree-internal levels of cells, organs and the whole plant (KOLB, MATYSSEK 2001).

What about extending, however, 'scaling' to tree age beyond the juvenile stage, or to growth under the actual site conditions of forests or plantations? Clearly, information on O_3 sensitivity is missing for such latter scenarios (MATYSSEK, INNES 1999; KOLB 2001), and birch is no exception in this respect. Hence, it may be concluded only that the principles of O_3 action known to date may be of some relevance also for ageing trees under given stand conditions, even though modifications are rather likely. The fact that O_3-caused alterations in whole-plant allocation may change root and shoot architecture, e.g. reduce bud formation and branching, inherently has consequences for competitiveness (Fig. 5), considering the occupation of canopy or soil space and its exploitation for resources as the basic means of competitive interaction between plants (KÜPPERS 1994; BAZZAZ 1997). The competitiveness of light-demanding pioneers like birch trees may be vulnerable, in particular, through allometric changes in growth. Weakening through shading (also along crown-internal light gradients) may be exacerbated through chronic exposure to elevated O_3 levels, as light limitation appears to be conducive to O_3 injury in birch (see above). Gradients of O_3 regimes should be considered across the fairly open canopies of birch stands, given the observation that O_3 levels may be appreciably high even within rather closed canopies of shade-tolerant beech (BAUMGARTEN et al. 2000). Light limitation may be meaningful also at sites of persistently high O_3 impact throughout diurnal courses like in rural areas or at high elevation (WIESER, HAVRANEK 2001; MATYSSEK et al. 1997a; LEFOHN, JONES 1986). O_3 impact at night may be relevant, in particular, in the high-altitudinal habitats of *Betula pubescens*. It is uncertain, however, if high O_3 sensitivity under low-light conditions is inherently linked to high light demands of a tree species (KOLB 2001; TJOELKER et al. 1993).

High nutrient availability of disturbed sites can favor pioneers like birch, and it may be the indeterminate shoot growth that profits most from such conditions. A high rate of longitudinal shoot growth and leaf formation may sustain competitiveness and counterbalance productive loss by ozone, as the new leaves are initially intact in terms of photosynthesis and lose productivity only after having experienced prolonged O_3 exposure (cf. TJOELKER, LUXMOORE 1991). Nevertheless, the biomass production may be reduced, if the older injured leaves are prematurely shed. As trees grow in size, however, the proportion of leaves formed through indeterminate growth typically decreases relative to the older foliage of the spring flush, and by this, the 'advantage' of stress compensation through new leaf formation is diminished (KOLB et al. 1997; KOLB 2001). Thus, ageing birch trees may become similar to individuals of low nutrition as the latter limits indeterminate shoot growth and represents a constraint for maintaining the existing foliage, even if O_3-injured (KOLB, MATYSSEK 2001). Under such conditions, birch tends to resemble species with determinate shoot growth, and readjustment of whole-plant allocation for coping with O_3 stress may be crucial for survival (MAURER, MATYSSEK 1997). In this respect, responsiveness in allocation may be more meaningful in ecological terms than the maintenance of high productivity, although associated changes in the allometric relationships may distinctly affect competitiveness. Overall, it may be the low rather than high-nutritional sites which typically represent habitats of *Betula pendula* and *B. pubescens*, comprising poor sandy and wet bog soils. Chronic O_3-caused limitation of root growth may weaken birch at such sites, losing below-ground competitiveness and becoming susceptible to nutritional deficiencies (cf. MATYSSEK et al. 1993).

Low-nutritional and shallow soils may be variable also in moisture so that limitation of the horizontal roots extending near the soil surface may impose another risk. Although the effects of water supply on the O_3 sensitivity of birch was rather ambiguous, there are indications that stomatal regulation, depending on water availability, may mediate the susceptibility to O_3 stress also in birch (PÄÄKKÖNEN et al. 1998). Water relations may determine, however, the O_3 sensitivity of ageing birch trees in an additional way that links, as found in other species, the stomatal conductance to the dimensions of the stem and crown: As the frictional resistance of the water flux increases with the length of the transport pathway through the tree, and gravitational constraints on the water flux gain importance with tree height, the stomatal pores tend to narrow (YODER et al. 1994; BAUERLE et al. 1999). Interrelationships of this kind represent the majority of findings on the water relations in ageing trees (KOLB 2001). Consequently, the O_3 influx into the leaves may be lowered as well so that old rather than young trees may be 'shielded' against O_3 impact. Also, lower metabolic activity may render old trees less susceptible to oxidative stress (LAURENCE et al. 1994). However, stomatal narrowing also limits the carbon gain (WARING, SILVESTER 1993; HUBBARD et al. 1999) so that the assimilate pool may be diminished in old trees for feeding repair and detoxification processes – and the O_3 sensitivity may be high. The situation may exacerbate in old trees, if raised O_3-driven respiration costs lower the carbon pool required for maintaining the standing biomass (cf. WARING, SCHLESINGER 1985).

This latter issue again relates to O_3-caused alterations in allocation which may create conflicts also with the carbon demands for other stress defenses (Fig. 5), namely, of biotic impacts by pathogens and phytophagous insects (HERMS, MATTSON 1992; LERDAU, GERSHENZON 1997). Such tradeoffs in resource partitioning mirror tree fitness

(BAZZAZ 1997) and appear to form the basis of O_3-induced predispositions to biotic stress which are assumed (rather than the chronic O_3 exposure itself) to eventually lead to tree mortality and to diminish genotypic diversity (MILLER et al. 1997). In this context, interactions exist between O_3 impact, parasite resistance and mycorrhization, as limitation of the latter by O_3 exposure of the tree (ERICSSON et al. 1996) can lead to a lowered metabolic defense capacity and favor parasite attack (GEHRING et al. 1997; LANGEBARTELS et al. 1997). Besides these peculiar relationships, attention needs to be directed, in general, to the aspect of mycorrhization and its effects on interactions between nutrition, water availability and the O_3 sensitivity of trees (cf. ANDERSEN, SCAGEL 1997). Potential effects of reduced assimilate pools under O_3 stress on the frost hardiness appear to deserve attention also in birch of high-altitude sites (cf. SKÄRBY et al. 1998).

The hypotheses posed above about the O_3 sensitivity of ageing trees under stand conditions need to be validated, in a rigorous way, at given field sites. The appropriate methodology for achieving this aim is the 'free-air' fumigation technique which allows exposure to elevated O_3 levels without micro-climatic bias, and the use of the unchanged O_3 regime at the site as a 'control' (MUSSELMAN, HALE 1997; HÄBERLE et al. 1999). Although this approach has been used in several investigations, it either has been operated with gases other than ozone, or if ozone was applied, then mainly juvenile trees or only discrete crown parts have been fumigated (KARNOSKY et al. 2001). This technique definitely needs to be extended to the experimental O_3 exposure of tall trees under given site conditions, and this postulate also holds true for trees of *Betula pendula* and *B. pubescens* in order to quantify the risks imposed by chronic O_3 stress in an ecologically meaningful context.

CONCLUSIONS

Viewing the evidence available to date, birch must be regarded as sensitive to O_3 impact as nowadays prevailing at many sites across Europe, and a few field studies did prove ozone as an agent that can cause injury to birch leaves. Findings are mainly based on extensive investigations of *Betula pendula*, but there is evidence of similar susceptibility to ozone in *B. pubescens*. Subtle responses in structural differentiation and metabolism have been unraveled in birch to experimental O_3 regimes of relevance for the chronic O_3 stress that nowadays prevails in the field, although most evidence is restricted to juvenile trees grown under controlled chamber conditions. As for other tree species, validation of response mechanisms is required in the field as the pre-requisite of a quantitative risk assessment of chronic O_3 stress, and risks may substantiate in tree fitness, *via* changes in resource allocation, growth pattern, competitiveness and capacity in stress defense, even in the absence of macroscopic injury. A means for achieving the required validation is the 'free-air' O_3 fumigation technique, in particular, if extended to use on ageing and tall trees under stand conditions. One needs to keep in mind, though, that also in the two tree species of birch native to Europe, responsiveness to ozone may vary across wide ranges of genetic disposition and interactions with environmental influences. Assessments of O_3 risks in trees are gaining in relevance with respect to global change effects, as chronic O_3 impact will stay high (along with enhanced N deposition and increasing CO_2 concentration) during the decades to come (FOWLER et al. 1999) and may mitigate the carbon sink strength of forest ecosystems (SAXE et al. 1998; CEULEMANS et al. 1999). Thus, chronic O_3 regimes above the pre-industrial level as found in many forested areas have become and will remain one of the crucial components in global change scenarios.

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Epicuticular waxes at Norway spruce (*Picea abies* [L.] Karst.) characterize the extent of air pollution

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ABSTRACT: Changes in structures and amount of epicuticular waxes on spruce (*Picea abies* [L.] Karst.) needles have been followed in immission regions and in regions without air pollution during the last three years. After an unfavourable winter season 1995/96 in the Ore Mts., due to high immission load and unfavourable climatic conditions, there was a considerable destruction of epicuticular waxes on spruce needles and total amount of waxes decreased. The changes in epicuticular waxes are followed in three regions of this immission region in higher altitudes, with the first and the second needle year-class. In the past two years a lesser destruction of epicuticular waxes has been monitored and also their total amount was on increase. In the whole region of the Ore Mts. a lowered air pollution load has been monitored during the last two years which resulted in lesser damage to assimilatory tissues, compared to previous years. But not even in the lowest altitudes of this region the measured values of quantity and structure of epicuticular waxes reach those from the regions without air pollution. The damages to epicuticular waxes in the Ore Mts. increase with growing altitude. The amount of immission load in this region is still higher than it should correspond to ideal growth conditions for Norway spruce.

Keywords: spruce; epicuticular waxes; air pollution; degradation; structure; needle

In the period from the end of eighties to the first half of nineties, due to technical desulphurization of the big air pollution sources, health state of forest stands in the Ore Mts. improved and the immission load of stands decreased. The health state of spruce stands considerably improved. But after a long-lasted winter period 1995/96 in the Ore Mts. their state again grew worse. A combination of stress factors – unfavourable dispersion conditions, immissions, frost and rime caused dieback of large area of Norway spruce stands. This state manifested itself at the most in regions of altitudes above 600 m. The whole assimilative apparatus of the spruce was largely damaged due to the air pollution stress. The dieback of trees continued until the year of 1997. With regard to the fact that in the whole Czech Republic the state of life environment improved in the last two years, also the damages to the assimilative apparatus of the spruce in the Ore Mts. decreased. Production activity of forest ecosystems depends on a balance of the whole complex of physiological processes which influence the creation of biomass. And with regard to the changed chemical environment, surrounding the needles, the conifers have predispositions to several biotic and abiotic stressors. The needles are directly exposed to the immission stress and that is why it can be expected that they will prove, as the first, the damage caused by the air pollution (Trimbacher, Weiss 1999). If the assimilative tissues are damaged by the immissions, at first the malfunctions and later on also morphological deviations occur. It is well known that the ongoing physiological processes are reflected in the leaf morphology to a considerable extent. Plant epidermis with the cuticle and waxes suffer from the action of immisions, it is an interface between the plant and the environment, and in such a way it is constantly exposed to natural and anthropogenous effects (Eglinton, Hamilton 1967; Cutler et al. 1982). By Juniper and Cox (1973) it is called the first line of plant defense, at the same time it is also damaged by the immissions as the first.

Erosion of the epicuticular layer, blockage of stomata by amorphous wax and damage to cuticle lead to considerable changes in water balance, in the exchange of gases, in photosynthesis and in resistance against infections (Turunen, Huttunen 1990; Grill et al. 1989). The cuticle features also influence to a considerable extent the deposition and subsequent behaviour of pesticides, growth regulators, leave nutrients and other chemical components (Ylimaritino et al. 1994).

The aim of this study was to compare the structure and amount of epicuticular waxes after three years when the immission load decreased and state of Norway spruce stands improved in the Ore Mts.

MATERIAL AND METHODS

Samples for the comparative study have been taken after the winter period 1996/97 and in the fall 1999 in the region of the Ore Mts., in forest districts Litvínov, Janov and Klášterec from young-growth stands (age 18–20 years), always two branches in the direction of prevailing wind flow, from the fifth whorl, at two to three trees. Sample trees from the middle part of the stand which characterized the state of the whole stand best were chosen in all observed regions. At the same time the sampling was carried out in a region with minimum immission load and in region without air pollution (The Drahanská Upland – Němčice in altitude of 620 m, The Brdy Upland – Praha in altitude of 862 m). In the Ore Mts. stands in altitudes from 600 to 900 m were followed.

The study has been carried out at the first and second needle-year classes. Changes in structure of epicuticular waxes were analyzed in fresh state by means of a scanning electron microscope (SEM) Tesla BS 300 with magnification of 1,500×. Fifty needles in each needle – year class were taken for structuralanalysis, 122 needles from each branch in observed needle – year classes were taken for quantitative analysis.Quantitative analyses of the epicuticular waxes were carried out according to methods of MOSSELEY (1983) and GUNTHARDT et al. (1994).

Description of localities. The Ore Mts. mean annual air temperature 5.5°C, total annual precipitation 887 mm, mean annual SO_2 concentration exceeded 50 μg/m^3. The Brdy Upland (altitude 862 m): mean annual air temperature 5.4°C, total annual precipitation 827 mm, mean annual SO_2 concentration 10.9 μg/m^3. The Drahanská Upland (Němčice – altitude 620 m): mean annual air temperature 6.8°C, total annual precipitation 640 mm, mean annual SO_2 concentration 11.0 μg/m^3.

The climatic data for the Ore Mts. were provided by the meteorological station Měděnec, which is located in the same altitude as observed regions. At control regions the climate data were measured directly in the observed stands.

RESULTS AND DISCUSSION

The study showed considerable differences in the structure and quantity of epicuticular waxes in the years under investigation, differing in the air pollution load in the Ore Mts. The use of the structure of epicuticular waxes as an indicator of air pollution is based on the observation of wax structures by means of SEM. Undamaged spruce needle is covered on its surface with a filamentous wax structure, which is particularly evident in the region of stomata (Fig. 1). The wax structure in the figure is undamaged characterizing the situation in the region free of air pollution (Fig. 2). This state is kept by the needles in the given region until the third year of life. There is also a partial degradation of epicuticular waxes due to aging of needles, but this is strongly increased by the influence of immissions; in regions with a strong immission load the destruction is five times quicker (MAKELA, HUTTUNEN 1987; TUOMISTO 1988; BEDNÁŘOVÁ 1999, 2000).

The degradation of epicuticular waxes is manifested as a fusion of wax filaments and leads to an amorphous appearance of waxes (Fig. 3). On this picture the situation at the strongly damaged needles in the Litvínov forest district in winter period 1996/97 is documented. Fig. 4 shows an improvement in the state of the epicuticular waxes in the year 1999 in the same stand of Norway spruce when compared with the year 1996/97 (Fig. 3). Compared to the control sampling from regions with a minimum immission load there are still visible negative changes in the structure of epicuticular waxes. Also evident is a lesser amount of waxes on the surface of needles (the waxes are deposited at the most in the surrounding of the stoma), but in spite of it there is visible a very positive change in state of the assimilative apparatus on Norway spruce stands from the Litvínov forest district, compared to the year 1996/97.

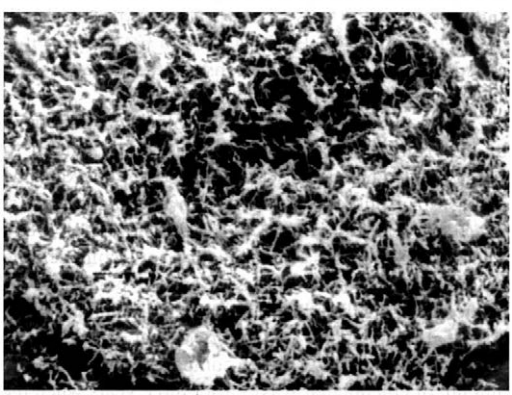

Fig. 1. Undisturbed structure of epicuticular waxes in spruce (*Picea abies* [L.] Karst.) in the region free of air pollution – the Brdy Upland, winter 1999; alt. 862 m

Fig. 2. Disturbed structure of epicuticular waxes in spruce (*Picea abies* [L.] Karst.) in the air polluted region – Litvínov, winter 1996–97; alt. 800 m

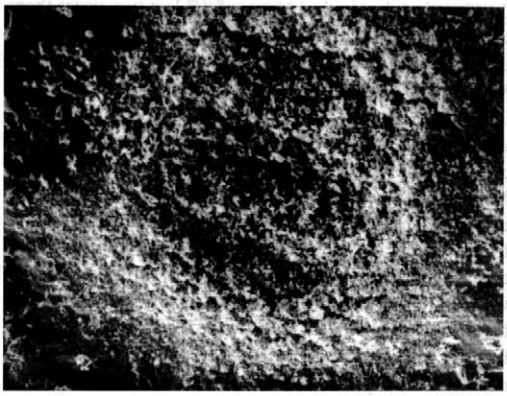

Fig. 3. Epicuticular waxes – moderately damaged. Litvínov, winter 1999; alt. 800 m

Fig. 4. Disturbed structure of epicuticular waxes in spruce (*Picea abies* [L.] Karst.) in the air polluted region – Klášterec, winter 1996-97; alt. 780 m

Fig. 5. Epicuticular waxes – moderately damaged. Klášterec, winter 1999; alt. 780 m

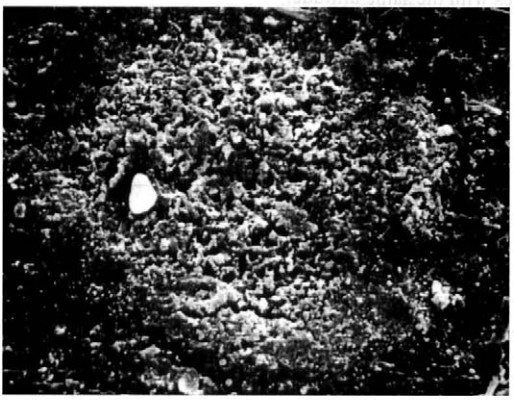

Fig. 6. Disturbed structure of epicuticular waxes in spruce (*Picea abies* [L.] Karst.) in the air polluted region – Janov, winter 1996–97; alt. 795 m

A lesser destruction of epicuticular waxes was observed in the mentioned year in the forest district Klášterec (Fig. 5). The waxes are eroded as well, and fissures on the cuticula appear. A considerable shrinkage of waxes appeared in the surrounding of stomata. Fig. 6 reveals the situation on the same stand in the year 1999. The epicuticular waxes are being still damaged but already in a lesser extent, and on the needle surface there is a greater quantity of epicuticular waxes. They partially maintain already a filamentous structure. It was the forest district Janov where the destruction of epicuticular waxes was the least. Compared to the controle from the region without immissions, we can see a damage to the filamentous structure and a thinner wax coat on needles; but in the year 1996/97 waxes from this region were eroded least (Fig. 7). An evident state improvement of the epicuticular waxes occurred in 1999 (Fig. 8). The rate of epicuticular wax erosion correlates with the level of air pollution (TU-

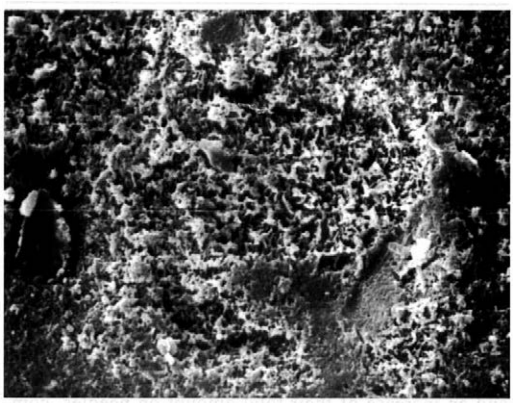

Fig. 7. Epicuticular waxes – moderately damaged. Janov, winter 1999; alt. 795 m

RUNNEN, HUTTUNEN 1988; TURUNEN et al. 1995; TUOMISTO 1988). These authors mention in their papers that the degree of wax erosion is directly related to the level of air pollution being based on the comparison of regions with different pollution load. The hypothesis has been also proved in the presented study. Epicuticular waxes from the region free of air pollution load (Brdy) did not show any destruction as compared with samples at the same altitude from a region with heavy air pollution load.

Quantitative analyses of epicuticular waxes. Destruction of epicuticular waxes is also accompanied by diminishing the wax layers and thus by decrease in the total amount of waxes on needles (GÜNTHARDT et al. 1994). The amount of epicuticular waxes was in harmony with the degree of structure damages in the followed localities of our study. The total amount of epicuticular waxes on spruce needles (*Picea abies* [L.] Karst.) in the Ore Mts. decreased with increasing altitude (Table 1). In regions without air pollution higher values of epicuticular waxes on the Norway spruce needles were reached even on places with the same altitude.

Table 1. The quantity of epicuticullar waxes in spruce (*Picea abies* [L.] Karst.), Ore Mts., year 1996/97

Place of sampling	Altitude (m)	Needle year-class	% DM weight of needles
Litvínov	800	1	1.44–1.52
Litvínov	800	2	1.38–1.42
Klášterec	780	1	1.44–1.53
Klášterec	780	2	1.40–1.41
Janov	795	1	1.58–1.61
Janov	795	2	1.44–1.45

Table 2. The quantity of epicuticular waxes in spruce (*Picea abies* [L.] Karst.), Ore Mts. and regions free of air pollution, year 1999

Place of sampling	Altitude (m)	Needle year-class	% DM weight of needles
Litvínov	800	1	1.78–1.79
Litvínov	800	2	1.49–1.50
Klášterec	780	1	1.70
Klášterec	780	2	1.50
Janov	795	1	1.72–1.83
Janov	795	2	1.50
Němčice	620	1	1.96
Němčice	620	2	1.80
The Brdy Upland	862	1	1.96
The Brdy Upland	862	2	1.80

On the all followed localities of the Ore Mts. there can be seen a decrease in destruction of epicuticular waxes and an increase of their total amount on needles, compared to the year of 1996/97 (Table 2). The greatest positive change occurs in higher altitudes, which confirms the situation that in the course of the last two years there was a decrease of air pollution load in this region and that the epicuticular waxes react to a change very sensitively. More than 32% of the region under study were under the load of 40 $\mu g/m^3$ of SO_2 in the year 1995. In 1996, due to wrong dispersion conditions, the immission load increased to the value of 50 $\mu g.m^3$ of SO_2 on 37% of the Ore Mts. area, which resulted to a considerable damage of epicuticular waxes and to a dieback of many hectares of forest stands. In the following years the SO_2 immissions decrease. In the year 1998 20.58% of the area under study were under the load of 30 $\mu g.m^3$ of SO_2. When comparing the results with samples taken in the region with minimum load we can see, that none of the Ore Mts. localities reaches the state of epicuticular waxes from regions free of air pollution.The immission situation and growth conditions in the Ore Mts. are still not quite optimal for Norway spruce and the stands are exposed to a stress which manifests itself also on health condition of the stands. MAKELA and HUTTUNEN (1987) report that in case the needles are long-term exposed to an average SO_2 concentration higher than 20 $\mu g/m^3$, filaments degradation of epicuticular waxes occurs and their amount decreases.

CONCLUSIONS

A considerable damage to the assimilatory apparatus of Norway spruce (*Picea abies* [L.] Karst.) occurred in the Ore Mts. immission region after a long-lasting winter period with unfavourable dispersion conditions in 1996. Compared to the regions without air pollution load, the epicuticular waxes were considerably damaged and there was also their loss. The most extensive damages to epicuticular waxes were monitored in the forest district Litvínov, the lowest in the forest district Janov. On all the forest districts the damages increased with increasing altitudes of stands. The air pollution load on the whole territory of the Czech Republic decreased in the last two years, which manifested itself positively on the health state of Norway spruce in the Ore Mts. From the investigation in 1999 there is a conclusion that there was a lesser destruction of epicuticular waxes and that their amount increased compared to the year of 1996/97. But in spite of the fact the structures of epicuticular waxes and their quantity do not reach the values of samples from regions without air pollution load. The stands of Norway spruce in higher altitudes in regions with a long-term immission load are more damaged, compared to the stands from the same altitudes with a background air pollution load. The most severe damages to the structure of epicuticular waxes and their shrinkage occur during the winter period, when unfavourable dispersion conditions prevail and the harmful substances accumulate in needles. The Ore Mts. still belong among the endangered regions, because the rate of immission load is still higher than it would correspond to the ideal growth conditions for Norway spruce; this anthropogenous factor is often accompanied by the unfavourable climatic conditions.

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Biochemical, histochemical, structural and reflectance markers of damage in Norway spruce from the Krušné hory Mts. used for interpretation of remote sensing data

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ABSTRACT: This paper introduces a NASA project on the development of new remote sensing methods for monitoring Norway spruce forest health, specifically on separation of initial damage classes (DC0 and DC1) of forest decline. Such methods could markedly reduce labor costs and lead to accurate large-scale monitoring of forest health. Also included are field and laboratory analyses designed to provide reliable ground truth support of the ASAS hyperspectral sensor used. Research was conducted in August 1997 and 1998, and data obtained included pigment concentrations, anatomical and histochemical data and spectral reflectance.

Keywords: hyperspectral data; lignin; needle structure; phenolics; photosynthetic pigments; *Picea abies* (L.) Karst.; remote sensing; spectral reflectance

The forest decline phenomenon in the Krušné hory Mts. has been described since the early 1950s and is attributed to the combination of severe atmospheric pollution and climatic conditions (MATERNA 1997). The Krušné hory trends southwest-to-northeast, along a gradient of atmospheric deposition which leads from heavy (to the east) to light (to the west) related to the distance from pollution sources. Nearly all spruce forests on the Krušné hory Mts. plateau are damaged and symptoms range from the presence of chlorosis or needle yellowing and needle loss to the death of whole trees (BAUR et al. 1998). Damage of forests in the Krušné hory Mts. started in the late 1950s based on the assessment of foliar loss and needle chlorosis and necrosis. Such visual assessment is time-demanding and labor-consuming but reasonably precise. However, it may be observer-biased, and this approach does not allow detection of the early previsual stages of damage to conifers.

Previsual stages of damage are recognizable first at the metabolic level, then at the anatomical level and finally are expressed by visible, morphological changes. The amount of photosynthetic pigments in conifers is known to be dependent on many environmental factors such as nutrient deficiencies, particularly those of magnesium (SOLBERG et al. 1998), phosphorus (BOUMA, DOWLING 1982), and nitrogen (PUECH, MEHNE-JAKOBS 1997). Atmospheric pollutants can also have effects on the concentration of photosynthetic pigments (ROCK et al. 1988) although contrary results are reported (SHAN et al. 1995; KRONFUß et al. 1998).

Other studies have focused on metabolic and structural markers of early damage, including the altered anatomical structure of needles (VOGELMANN, ROCK 1988; MOSS et al. 1998) and accumulation of phenolic compounds (ZOBEL, NIGHSWANDER 1991). Such potential markers of non-visible damage in conifers require detailed laboratory analyses, and are conducted on a limited amount of needle tissue.

Remote sensing methods have the potential to provide low-cost, long-term and large-scale monitoring of forest health. They are based on the analysis of the spectral reflectance properties of vegetation, related to the amount, anatomical structure and chemical composition of the vegetation (ROCK et al. 1986; MCLELLAN et al. 1991; MARTIN, ABER 1994). Forest assessment methods, based largely on foliar loss and canopy discoloration conducted in the field, allow recognition of five categories or levels of forest decline in Norway spruce stands. When using multispectral remote sensing satellite data (Landsat TM), only three damage categories of Norway spruce stands (healthy, moderately damaged, and dead/dying) may be recognized (LAMBERT et al. 1995). New hyperspec-

tral remote sensing methods under development may allow detection of initial levels of damage at the stand level.

The present NASA project was designed by Dr. Barrett N. Rock and his Czech collaborators, primarily Dr. Jana Albrechtová. The aim of the project was to correlate *in situ* and airborne hyperspectral datasets with field and laboratory assessments of tree damage. Structural, histochemical and biochemical parameters were characterized in order to determine what previsual needle changes, i.e. markers of early damage, could be used for the best identification of actual tree health. Hyperspectral remote sensing methods were developed as a source of accurate estimates of forest health, including the separation of initial damage classes (DC0 and DC1) and the reliable estimates of content of potential markers of damage.

MATERIAL AND METHODS

In August, 1997 and 1998 53 sites were established in Norway spruce (*Picea abies* [L.] Karst.) forests to asses forest health. They were located in the Krušné hory Mts. along increasing gradient of documented atmospheric pollution (Přebuz, Boží Dar, Kovářská). All these sites were located in approximately 60-year-old forests at similar elevation (about 900 m above sea level) and aspect. The climatic conditions of all sites were similar, but they differed greatly in the exposure to atmospheric pollution and the level of damage. Levels of damage were assessed using methodology established for color infrared photography and forest field surveys (HILDEBRANDT, GROSS 1992). This includes five different degrees of damage (DC0, healthy to DC4, dead) which differ slightly from classification commonly used in the Czech Republic. Sunlit branches from the middle third of the functional crown of five representative trees per site (in total 265 trees) were sampled for analyses. First, second, and third year needles were collected directly at the site, treated according to each analysis and transported to the laboratory. A total of 48 sites were sampled for pigment content and anatomical analyses of needles. For more detailed biochemical investigation, four sites representing different degrees of damage were chosen from within the 53 sites.

Common forestry measurements were used to describe the composition, structure and vitality status of vegetation at selected plots. They included measurements of tree diameter at breast height (using DBH tape), tree height (using clinometer), stand density (using Basal Area Factor 10 prism), canopy closure (using spherical densiometer) and assessment of natural regeneration (number and age class of seedlings in randomly placed 1 m^2 plots). The damage classes of single trees was evaluated based on the percentage defoliation, described in the series of standardized photographs (MÜLLER, STIERLIN 1990) and presence of chlorosis and necrosis (ENTCHEVA et al. 1996). Each sampling site was ascribed a damage value based on the average of damage for the five representative trees.

For anatomical analysis, paraffin-embedded cross sections of needles were prepared according to JOHANSEN (1940) using safranin and fast green differential stains. Proportional amounts of cellular features were determined by image analysis. Hand and cryo-sections of fresh needles were used mostly for the histochemical detection. Presence of phenolic compounds was determined using Fast Blue BB Salt (O'BRIEN, MCCULLY 1981). The Vanillin-HCl test (GARDNER 1975) was used to identify condensed tannins, while the Hoepfner-Vorsatz test (REEVE 1951) and Neu's reaction (VALETTE et al. 1998) were used to provide more information about the chemical composition of the phenolics. Lignin was detected with phloroglucinol-HCl (NĚMEC 1962).

The concentrations of chlorophyll *a* and *b* and the total amount of carotenoids were determined spectrophotometrically. Needles were placed in dimethylformamide and left in the dark at 8°C for 5 days until bleached (PORRA et al. 1989). The absorbance of extracts was then measured at 480, 647 and 664 nm using Unicam Helios α spectrophotometer. The amount of chlorophylls and carotenoids was then calculated according to WELLBURN (1994). Total lignin content was determined spectroscopically after thioglycolysis and dissolution in NaOH (LANGE et al. 1995).

Spectral reflectance measurements of age classes of branch segments and needles were acquired with a portable GER 2600 spectroradiometer. This instrument was used for the scanning of whole branch annual segments. Additionally, the Near-Infrared (NIR) Spectrometer laboratory instrument was used to obtain reflectance features used for further predictions of lignin, nitrogen and cellulose concentrations in needles (ENTCHEVA 2000). Airborne hypespectral data were acquired for the 53 sites using the Advanced Solid-state Array Spectroradiometer (ASAS) developed at the NASA Goddard Space Flight Center (IRONS et al. 1991). The spectral range of ASAS covers 410–1,032 nm in 62 spectral bands. It was flown on an Antonov AN-2 single engine biplane at 2,500 m above terrain, producing an approximately 820 m swath width, with a 1.5 m by 2.0 m nominal spatial resolution. For this study only nadir data were acquired. Air-borne hyperspectral data were calibrated using bright and dark targets on the ground and spectrally characterized at the time of overflight. Overflight occurred on August 17 and September 1, 1998.

RESULTS AND DISCUSSION

The Material and Methods indicate the full range of analyses made as part of this project. Only selected results will be presented below.

Photosynthetic pigment concentrations varied with both age and damage (Fig. 1). The total concentrations of chlorophylls, the concentrations of chlorophyll $a + b$, and the total concentrations of carotenoids were age-dependent. The total concentration of chlorophyll $a + b$ reached values from 2–4 mg/g dw. Some authors report total Chl $a+b$ content to be 3–4 mg/g dw for healthy Norway spruce (WEIKERT et al. 1989), while the others (WEDLER et al.

1995) report total Chl content much lower about 1 mg/g. Our result support the view that a good physiological state characterized trees in 1997 and 1998. The ratio of chlorophyll *a* to *b* (Fig. 1) was significantly higher for more damaged trees in 1997 than in 1998. The ratios in third-year needles in 1998 were not dependent on a degree of tree damage. Also the ratio of chlorophylls *a* to *b* showed age-dependence, with the first-year needles lower than older needles in 1997. We observed differences in sensitivity of chlorophyll *b* to conditions in the Krušné hory Mts. to be similar to KONEČNÁ et al. (1989). The increase of the ratio in 1998 when compared to 1997 could indicate a worsening condition of needle photosynthetic apparatus in 1998.

A continuing analysis of anatomical structure indicates a correlation of differences in mesophyll cellular conditions with increased levels of damage for the trees supplying the needles. We observed an increase in the amount of intracellular space in mesophyll of needles from more damaged trees (Fig. 2A,B), similar to the type of mesophyll degradation observed in red spruce (*Picea rubens*) needles damaged by exposure to low pH cloud events (MOSS et al. 1998). Similar findings were also reported by KUKKOLA et al. (1997), who found a decrease in intercellular space volume of pine needles with increasing distance from a source of pollution. The occurrence of intercellular spaces is normal in healthy spruce mesophyll tissue (Fig. 2A), and represents an extension of sub-stomatal cavities which facilitate gas exchange across mesophyll cell wall surfaces. In the previous study (MOSS et al. 1998), degradation of the mesophyll cells lining the sub-stomatal cavities occurred within days of needle exposure to a single acidified (pH = 2.6) cloud event. Since similar low pH cloud events are known to occur in the Krušné hory Mts., such an event may explain the increase in the amount of intercellular space seen in needles from heavily-damaged trees (Fig. 2B). In addition to the cellular degradation, increases in intracellular air space were seen with increased plasmolysis (many of the cells with dark-staining contents seen in Fig. 2B) and the loss of cellular contents (collapsed mesophyll cells noted with stars in Fig. 2B). When needles were physically injured or wounded, a compact tissue of small, densely-packed cells developed and healed the wound (Fig. 2C,D) instead of cellular degradation described above (Fig. 2B). These densely-packed wound-response cells (Fig. 2C,D) were filled with phenolic compounds, similar to the dark-staining contents of mesophyll cells from damaged trees (Fig. 2B). We observed an increasing frequency of deposition of such phenolic compounds in mesophyll cells of increasingly damaged needles (Fig. 2B), as well as with wounded needles which occurred more often for damaged trees (Fig. 2C,D). The cause of the wounding is not known.

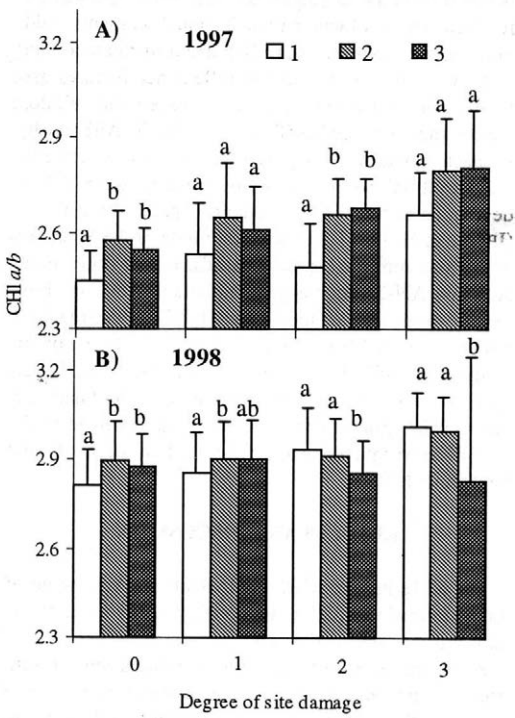

Fig. 1. The ratio of chlorophylls *a* to *b* (Chl *a/b*) of first- (1), second- (2), and third-year (3) needles of Norway spruce collected from sites of different damage class in August 1997 (A) and 1998 (B). Bars represent SD, $n = 265$. Different letters in graph show significant differences ($P = 0.01$)

Histochemical and biochemical analyses showed statistically significant ($P < 0.01$) higher average amounts of lignin for healthy trees than for damaged trees (Fig. 3). Based on spectral analysis with NIR System, estimates of percentage of lignin and cellulose in dry and ground needles of Norway spruce were also significantly ($P < 0.00001$) lower in needles from more damaged trees (Fig. 4). Although it is generally accepted that increased cell wall lignification is a non-specific reaction of plants to stresses (LEWIS, YAMAMOTO 1990), data similar to ours have been reported by MAIER-MAERCKER and KOCH (1986), who found partially delignified cell walls in guard cells of Norway spruce after exposure to SO_2. PFANZ and OPPMANN (1991) assumed that sulfite (the product of detoxification of SO_2) competitively inhibited peroxides involved in lignification. The high SO_2 levels associated with the heavily damaged sites could result in decreased amounts of lignin in affected tissues. More details are given in SOUKUPOVÁ et al. (2000). However, it should be mentioned that lignin prediction such as the one presented in Fig. 4 is in fact, affected by the concentration of other phenolic compounds, as was demonstrated in another part of this study because differentiation among lignin and phenolic concentration based only on the spectral data is very problematic if not impossible and that these compounds can only be assessed as the total. The lignin content using both approaches (biochemical as well as spectral) yielded similar results.

Laboratory-based spectral reflectance measurements (GER 2600) were also used to characterize previsual chang-

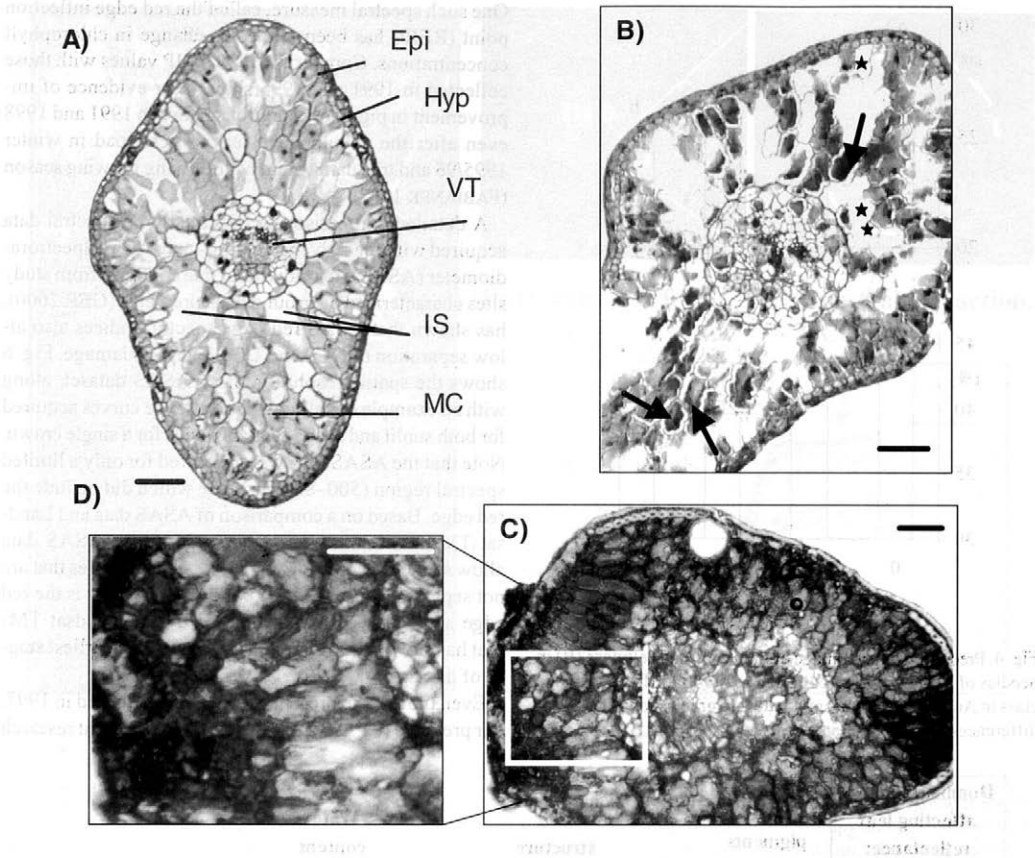

Fig. 2. Cross-sections of needles of Norway spruce, light microscopy, bright field, stainting: A, B – safranin and fast green; C, D – fast blue BB. Bar represents 100 µm. **A**) healthy needle. Light grey color indicates low accumulation of phenolics in mesophyll cells; Epi – epidermis, Hyp – hypodermis, VT – vascular tissue in central cylinder, IS – intercellular spaces associated with normally occurring sub-stomatal cavities, MC – mesophyll cells. **B**) damaged needle with increased proportion of intercellular spaces. Stars correspond to collapsed mesophyll cells. Arrows point to dark-staining mesophyll cells with high content of phenolics. **C**) injured needle with healed wound on left. Dark grey to black cellular contents correspond to heavy accumulation of phenolic compounds. **D**) detail of injured region of a needle in C)

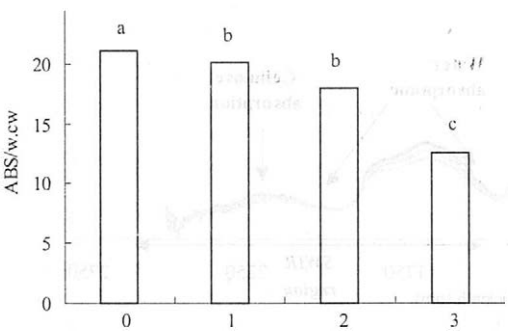

Fig. 3. Lignin content of needles evaluated using thioglycolic acid extraction collected at sites of different damage class in August 1998. Different letters in graph show significant differences ($P = 0.01$) in the lignin content. w.cw – weight of cell walls, ABS – absorbance at 225 nm, $n = 15$

es leading to needle loss. Different reflectance peaks or absorption features correspond to the content of different chemical compounds (Fig. 5). Even though the overall shape of curves is similar for vegetation, the absolute values, local minima and maxima, wavelength position of inflection points, etc. differ and are diagnostic for species type, foliar age-class and damage class. For example, spectral curves of different needles age classes were lower for older needles (Fig. 5), perhaps due to longer exposure to effects of environmental conditions. These spectral data can be used for developing spectral indexes which correlate with different physiological or structural parameters and plant physiological state (stress and water indices). Red edge (approximately 680–750 nm) spectral indices were shown in this study to have the highest sensitivity to separating DC0 and DC1 damage classes. The red edge spectral indexes also correlate well with all levels of damage exhibited along the Krušné hory Mts. One such

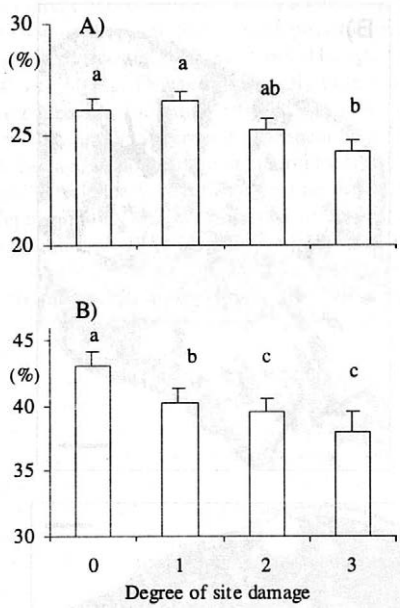

Fig. 4. Prediction of percentage of lignin (A) and cellulose (B) in needles of Norway spruce collected at sites of different damage class in August 1998. Different letters in graph show significant differences ($P \leq 0.05$). Bars represent SD, $n = 15$

One such spectral measure, called the red edge inflection point (REIP) has been related to change in chlorophyll concentrations. Comparing 1998 REIP values with those collected in 1991 and 1995 show clear evidence of improvement in pigment conditions between 1991 and 1998 even after the documented heavy stress load in winter 1995/96 and tree damage in the following growing season (FABIÁNEK 1997).

A detailed comparison of airborne hyperspectral data acquired with the Advanced Solid-state Array Spectroradiometer (ASAS), for individual tree canopies from study sites characterized by ground measurements (GER 2600), has shown that ASAS red edge spectral indices also allow separation of DC0 and DC1 levels of damage. Fig. 6 shows the spatial resolution of an ASAS dataset, along with an example of calibrated reflectance curves acquired for both sunlit and shaded ASAS pixels for a single crown. Note that the ASAS data were acquired for only a limited spectral region (500–850 nm), one which did include the red edge. Based on a comparison of ASAS data and Landsat TM data for the Krušné hory Mts., the ASAS data allow separation of DC0 and DC1 damage classes that are not separable with TM data. As noted above, it is the red edge spectral region (not imaged by the Landsat TM) that has shown the greatest sensitivity to the earliest stages of damage.

Even though the present NASA project started in 1997, our previous (e.g., ARDO et al. 1997) and present research

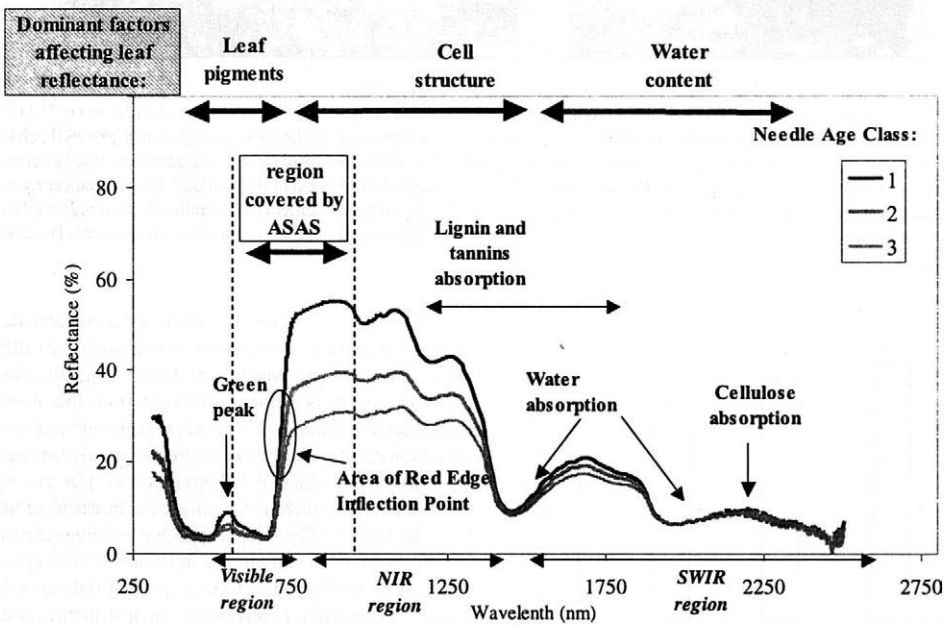

Fig. 5. Reflectance curves produced using the GER 2600 field spectrometer. The curves represent average reflectance values for 1st, 2nd, and 3rd year age classes of needles of Norway spruce collected at selected study sites in the Krušné hory Mts. These data were collected during the 1998 field season. Spectral regions are marked which are dominantly affected by leaf structural or physiological factors. Peaks marked in the graph correlate with content of chemical compounds (NIR – Near Infrared; SWIR – Short Wave Infrared)

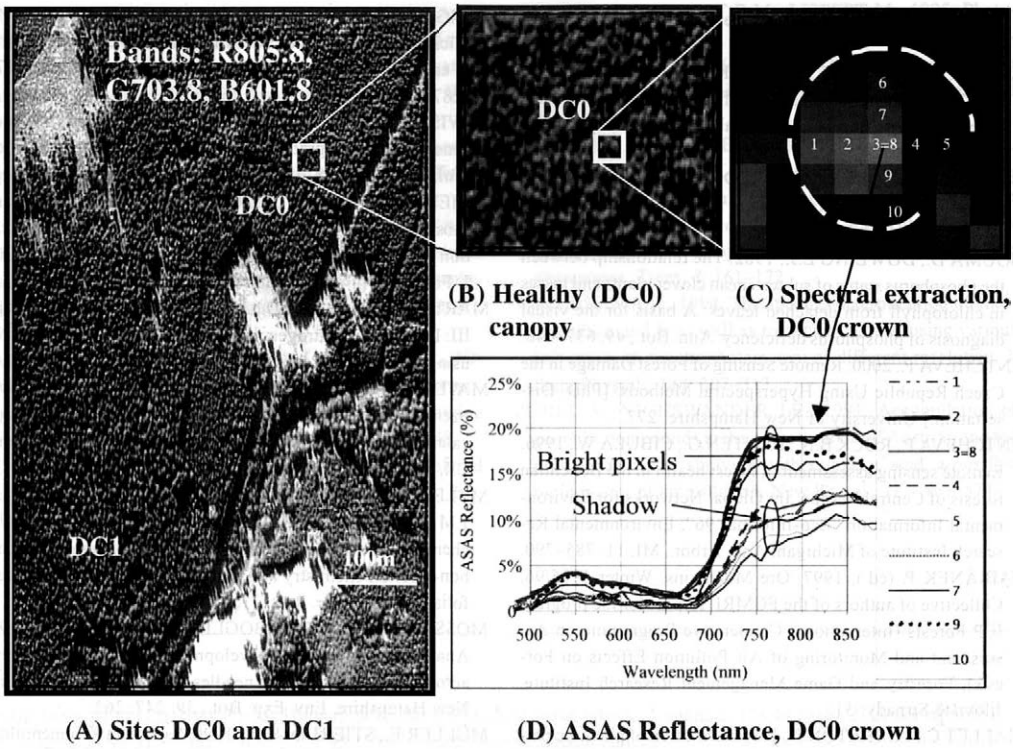

Fig. 6. Extraction of reflectance spectra for Norway spruce canopies from individual tree crowns. Note the fine spatial resolution (1.5m pixels) provided by the ASAS sensor (A and B). The presence of heavy shadow within the canopy and tree crowns of the healthy and heavily damaged stands provide an opportunity to compare spectral curves from both sunlit and shadowed portions of each crown (C and D). D) ASAS reflectance data from a single DC0 tree crown, showing differences in amplitude due to shadowing and similarities in wavelength position of red edge features (680–750 nm) independent of shadow effects. Once normalized, the wavelength position of red edge portions of the 9 spectral curves are identical (not shown)

covered a much longer period of time. For the time period from 1991–1998 we provide evidence that forest health conditions were improving, based on spectral properties, pigment content, foliar chemistry and anatomy. We do note, however, that the Chl *a*/*b* data suggest that data from 1998 represented a worse photosynthetic condition than was seen in 1997. Perhaps this change between 1997 and 1998 was a precursor to the worsening conditions (massive needle yellowing) seen currently in the Krušné hory Mts. following the winter of 1998/99.

The results obtained in the present study support the view that airborne hyperspectral data provide improved damage discrimination when compared with broad-band multispectral data such as Landsat TM. The project focused on scaling up laboratory and field measurements to remote sensing of such measurements. Such scaling from microscope to macroscope (remote sensing) is one of the foci of forest science promising to lower labor cost in monitoring of forest health and also to supply scientists dealing with large-scale modeling of climate with more extensive and precise data on forest health and associated carbon sequestration. The launch of the NASA EO-1 satellite, with hyperspectral capabilities similar to ASAS, provides an opportunity to conduct such studies from orbit.

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Amino acids content in leaves of birch in the eastern part of the Ore Mts.

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ABSTRACT: In the area of the eastern Ore Mts., the total amino acid content was determined in birch leaves within stands of the II. age class (Klášterec and Janov transects) and within stands of the I., II. and III. age classes (Litvínov transect). Assessments were performed regards the transect and elevation (both only in the II. age class), in the Litvínov transect also regards the age class. For assessments of potential air-pollution impact, *Q* index and *So/N* molar index were used. It was revealed that there were amino acid content differences between the transects. The content of amino acids did not suggest any disturbation of their metabolism. In spite of that, the differences could be explained by different air-pollution load.

Keywords: birch (*Betula pendula* Roth); leaves; amino acids; Ore Mts.

Contents of amino acids could show on conditions of plants. The content of amino acids is associated with impact of stress. Stress may stop synthesis of proteins and increase content of free amino acids. It can also change pattern of amino acids, mainly concentration of proline is increasing (LARCHER 1988). There are more studies about contents of free amino acids (ZEDLER et al. 1986; EDFAST et al. 1990; ERICSSON et al. 1993; HUHN, SCHULZ 1996) and their seasonal changes, or impact of fertilisation. Contents of free and protein bound amino acids in birch (*Betula pubescens* Ehrh.) were investigated in Finland in relationship with growth of *Epirrita autumnata* (Borkh.) larvae (SUOMELA et al. 1995).

The contribution is aimed at assessing the total amino acid content in birch leaves within stands of the eastern Ore Mts. area. The factors under study are the elevation (a.s.l.) within the transects, in the Litvínov transect then moreover the stand age class, *Q* index (weight ratio between organic – *So* and inorganic *Sa* sulphur fractions) and *So/N* index (molar ratio between organic sulphur fraction and nitrogen content). These indices can be considered to be indicators of air-pollution load.

MATERIALS AND METHODS

In the north-west part of the Czech Republic in the Krušné hory Mts. (Ore Mts.) three altitude transects were established. Klášterec – KLA (ca. 50°23' N, 13°02' E), Janov – JAN (ca. 50°32' N, 13°24' E), all from 500 m to 900 m a.s.l. and Litvínov – LIT (ca. 50°38' N, 13°37' E) from 600 m to 900 m a.s.l. (cf. Fig. 1 in HRDLIČKA, KULA 2001; cf. also HRDLIČKA, KULA 1998). Origin choice of these transects was based on immission load decreasing from west (KLA) to east (LIT). These transects covers representatively the whole eastern Ore Mts. area.

Samples (23 stands and 69 sample trees) of control branches were taken at each transect level (for KLA and JAN 500–900 m a.s.l., for LIT 600–900 m a.s.l.; the height gradient of 100 m) from the upper, released and lighted parts of the birch crown from three permanent sample trees in the stands of age class II (21–40 years), by transect LIT in the stands of age class I (0–20 years) and age class III (41–60 years) too. Leaves stored in paper bags were dried at 80°C for 8 hours, and then were milled. This material was used for all analyses. The content of inorganic sulphur was determined as sulphate by isotachophoretic method (HRDLIČKA 1994). The contents of amino acids were determined after hydrolysis or oxidative hydrolysis (methionin and cystein) by ion-exchange chromatography using an automatic aminoacid analyser AAA T339 (Mikrotechna Prague) with Na-citrate buffers and ninhydrine post-column detection (LIŠKA, KRÁČMAR 1998). The content of total sulphur (*St*) and content of nitrogen (*N*) were determined previously (HRDLIČKA, KULA 1998). Content of organic form of sulphur (*So*) is difference between content of total and inorganic sulphur (*Sa*). We also calculated two ratios: index *Q* (it represents ratio between *So/Sa*) and index *So/N* (molar basis).

The obtained values of element and amino acid contents and calculated ratios were processed by statistical methods using the UNISTAT program. The calculated mean values were completed with the estimation of a confidence interval ($\alpha = 0.05$). For the evaluation of differences between data of transects or data of level of altitudes by individual transects the classical model analysis of variance was applied using multiple comparison by Tukey (UNISTAT 1995).

RESULTS

AIR-POLLUTION IMPACT

The air-pollution load was assessed by Q index (So/Sa) and So/N molar index. The Q index values were classified by the method used for spruce (GASCH et al. 1990; HRDLIČKA 1994, 1996). The index total value (1.28 ± 0.10) for the whole study area corresponds to the class of weak impact. In the transects, the air-pollution load rose from east to west: Litvínov transect of weak impact class (Q = 1.70 ± 0.15), Janov transect of weak and medium impact class (1.24 ± 0.09) and Klášterec transect of medium impact class (0.92 ± 0.11). In the Klášterec transect, several individual trees were already heavily affected (Q values ranged 0.80–0.51). The So/N molar index values ranged 0.014–0.031 with the total mean value of 0.0229 ± 0.0006. In the individual transects, the following values were ascertained: Litvínov 0.0231 ± 0.0007; Janov 0.0214 ± 0.0013; Klášterec 0.0245 ± 0.0011. They are lower values than those reported in the literature (0.025–0.035; DIJKSHOORN, VAN WIJK 1967). In the stands under study, there is thus a mild insufficiency of sulphur organic fraction as compared with nitrogen.

AMINO ACIDS CONTENT REGARDS THE TRANSECT

The sample trees were selected in individual transects according to the elevation. The data obtained represent the total amino acid contents, free and bonded in proteins, in birch leaves. The list of the amino acid content values (including the confidence intervals for $\alpha = 0.05$) and proportions (%) in individual transects (and for the Litvínov transect also for the age classes) are presented in Table 1. The values are grouped according to amino acids biosynthesis pathways.

The highest amino acid amount in the II. age class stands was found in the Litvínov transect, the lowest one in the Klášterec transect. This is true for most of content amino acids determined and for the total amino acids content (the sum of all determined amino acids) in the respective transect. Lysine content in the Klášterec transect is clearly lower (6.262 mg/g) as compared with the respective values in the other transects (Janov 8.746 mg/g, Litvínov 8.647 mg/g). Isoleucine and tyrosine contents are the highest in the Janov transect and the lowest ones in the Klášterec transect. In the case of valine, a higher value is in the Litvínov transect (8.556 mg/g), lower values are in the Klášterec (7.065 mg/g) and Janov (6.934 mg/g) transects. Methionine content is higher in the Klášterec transect (2.290 mg/g), in the Janov and Litvínov transects, it is comparable (proportional values already indicate the trend of decreasing content from the Klášterec transect to the Litvínov transect – see Table 1). A wholly clear decrease trend can be seen in cysteine, when in the Klášterec transect, the content is 2.225 mg/g, in the Janov transect 2.187 mg/g and in the Litvínov transect only 1.411 mg per g. When we examine the sum of sulphur-containing amino acids, we find that this sum is also dropping down from the Klášterec transect (4.515 mg/g) through the Janov transect (4.220 mg/g) to the Litvínov transect (3.521 mg/g).

Regards the stand age influence on amino acid content (examined in the Litvínov transect), no significant differences or trends were found between individual age classes. Only in sulphur-containing amino acid cysteine, the content value in the III. age class was higher (1.787 mg/g) as compared with lower and respective values in the II. (1.411 mg/g) and I. (1.385 mg/g) age classes.

When we examine the content quantitative order of individual amino acids, then in all transects, the highest was glutamic acid content followed by aspartic acid and leucine (it was approximately a third of the total amino

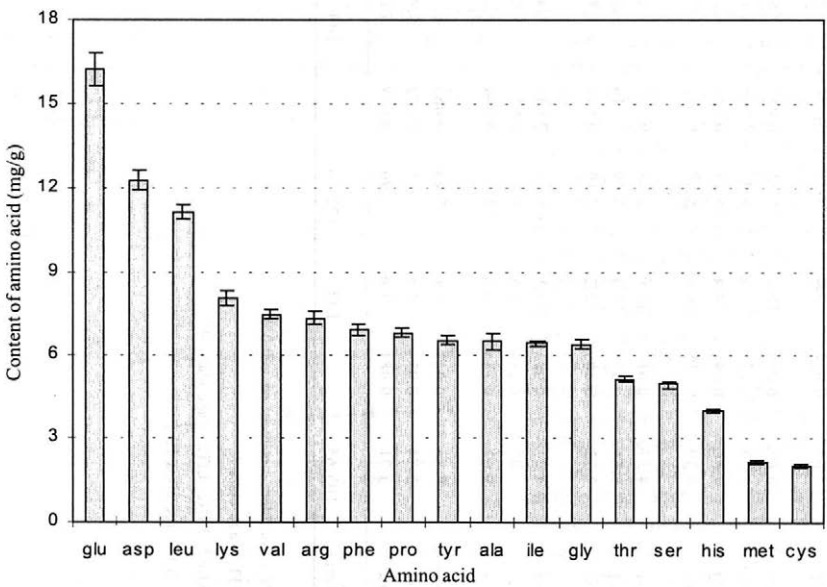

Fig. 1. Content of amino acids in the Ore Mts. (descending order)

Table 1. Content of amino acids (mg/g) and proportion ak/total (%)

	KLA2			JAN2			LIT1			LIT2			LIT3		
AK	average	IS	%	average	IS	%	average	IS	%	average	IS	%	average	IS	%
glu	13.41	0.100	12.9	15.98	0.045	13.0	19.36	0.579	15.1	19.87	1.218	14.5	18.50	0.612	13.85
lys	6.26	0.080	6.0	8.75	0.038	7.1	8.85	0.581	6.9	8.65	0.425	6.3	7.90	0.148	5.9
pro	5.98	0.058	5.8	7.17	0.031	5.8	7.10	0.337	5.5	7.48	0.447	5.5	7.44	0.270	5.6
arg	5.84	0.032	5.6	7.79	0.042	6.3	8.30	0.175	6.5	8.73	0.448	6.4	8.26	0.200	6.2
asp	10.37	0.044	10.0	11.84	0.052	9.6	13.64	0.442	10.6	14.95	0.574	10.9	14.00	0.422	10.5
met	2.29	0.022	2.2	2.03	0.006	1.7	2.58	0.033	2.0	2.11	0.331	1.5	2.74	0.179	2.1
thr	4.56	0.044	4.4	5.27	0.023	4.3	5.32	0.276	4.2	5.85	0.311	4.3	5.74	0.196	4.3
ile	6.30	0.028	6.1	6.80	0.032	5.5	5.94	0.152	4.6	6.29	0.343	4.6	6.74	0.168	5.0
ser	4.17	0.017	4.0	5.37	0.026	4.4	5.04	0.345	3.9	5.51	0.415	4.0	5.37	0.278	4.0
gly	5.64	0.054	5.4	6.19	0.014	5.0	6.99	0.182	5.4	7.60	0.312	5.6	7.49	0.143	5.6
cys	2.23	0.009	2.2	2.19	0.011	1.8	1.39	0.051	1.1	1.41	0.059	1.0	1.79	0.054	1.3
ala	4.61	0.021	4.5	6.68	0.021	5.4	7.70	0.220	6.0	8.64	0.359	6.3	8.24	0.197	6.2
val	7.07	0.154	6.8	6.93	0.021	5.6	7.72	0.166	6.0	8.56	0.367	6.3	8.39	0.201	6.3
leu	9.62	0.135	9.3	11.32	0.054	9.2	11.02	0.284	8.6	11.98	0.534	8.8	12.27	0.217	9.2
phe	5.84	0.043	5.6	7.45	0.060	6.1	6.97	0.294	5.4	7.73	0.445	5.7	7.78	0.209	5.8
tyr	5.74	0.031	5.5	7.23	0.039	5.9	6.07	0.331	4.7	6.89	0.390	5.0	6.43	0.226	4.8
his	3.71	0.081	3.6	3.90	0.009	3.2	4.52	0.206	3.5	4.48	0.142	3.3	4.54	0.117	3.4
Total	103.65		100	122.90		100	128.47		100	136.71		100	133.62		100

IS – confidence interval ($\alpha = 0.05$)

LIT1– age class I.

KLA2, JAN2, LIT2 – age class II.

LIT3 – age class III.

acid content within the transect). Within the Litvínov transect, no differences were found between individual age classes, the proportional content of these three amino acids was at the level of 34%. The order of the other amino acids in individual transects differed slightly. The differences found, however, are insignificant. Three amino acids with the lowest contents are in all transects histidine (about 3%), methionine (2.2–1.5%) and finally cysteine (2.2–1.0%). In the Litvínov transect, cysteine content is absolutely and also relatively the lowest as compared with the other transects (Table 1).

AMINO ACIDS CONTENT IN THE STUDY AREA

Similarity of amino acid proportions in individual transects enables to assess ratios among amino acids examined within the whole eastern Ore Mts. area (Fig. 1). The highest and different are the contents of glutamic acid (16.23 ± 0.58 mg/g) and aspartic acid (12.26 ± 0.36 mg/g), leucine (11.12 ± 0.26 mg/g) and lysine (8.06 ± 0.25 mg/g). Amino acid contents, from valine to glycine, are balanced ranging 7.5–6.4 mg/g. Threonine and serine contents are lower, being approximately at the level of 5 mg/g. Histidine content (4.01 ± 0.07 mg/g) differs further. The lowest are sulphur-containing amino acid contents of methionine and cysteine at the level of 2 mg/g.

REGRESSION ANALYSIS

Examined were regression relationships in the total amino acid content (*sak*) within individual transects, to the elevation and then within the whole eastern Ore Mts. area to nitrogen content and *Q* index values.

Change of the total amino acid content (age class II.) affected by the transect elevation is illustrated in Fig. 2. While in the case of the Klášterec and Janov transects a linear increase trend in the total amino acid content occurs with increasing elevation, in the Litvínov transect the values found variable. At the same time, values are increasing from east to west through the transects (except for the Litvínov transect, where the value for the elevation of 800 m a.s.l. drops down below the value level

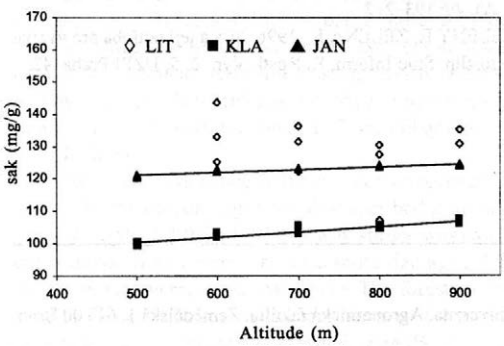

Fig. 2. Content of amino acids in relation to transect and altitude (age class II; parameters of regression model in text)

in the Janov transect). Estimation of parameters in regression model for the Klášterec transect is given by the equation: $sak = 0.0156 \times NM + 92.6370$, with the determination index of 89.59%. For the Janov transect then by the equation: $sak = 0.0083 \times NM + 117.0930$, with the determination coefficient of 89.33%. Both these models are highly significant.

Regards nitrogen content (for detailed data on nitrogen content and respective conclusions see HRDLIČKA, KULA 1998) within the eastern Ore Mts. area, the trend of increasing total amino acid content with increasing nitrogen content was found. The respective highly significant regression model can be expressed with estimated parameters by the regression equation: $sak = 3.5966 \times N$, with the determination coefficient of 47.41%.

The total amino acid content also depends on the *Q* index (index data are not presented in detail). For the eastern Ore Mts. area, the highly significant model with estimated parameters was found, namely the regression equation: $sak = 26.891 \times Q + 86.567$, with the determination coefficient of 59.39%.

DISCUSSION

The amino acids with the highest content are glutamic and aspartic acids and leucine, the proportion of which in the total amino acid content is ca. 32–35%. High proportions of glutamic and aspartic acids are related with their central role in amino acid metabolism. They are also nitrogen transport form in plants (LARCHER 1988). Their high content (related to the other amino acids) proves that amino acid metabolism is not disturbed.

The least represented are, on the contrary, the sulphur-containing amino acids methionine and cysteine. Their percentage differs between individual transects, the lowest is in the Litvínov transect where methionine constitutes 1.54% and cysteine does 1.03%, the highest is in the Klášterec transect (methionine 2.21%, cysteine 2.15%). The increased amount of sulphur-containing amino acids in the Klášterec transect is related with higher air-pollution concentrations (in particular of sulphur oxides) in this area (see HADAŠ 1999; KULA, HRDLIČKA 1996). With this, also increased amount of total sulphur (HRDLIČKA, KULA 1998) and the *Q* index lowest value (approximately equivalent content of both sulphur forms) corresponds in this transect. It seems that under suitable conditions, even moderate sulphur excess can be transferred to sulphur-containing amino acids (thus to *So*). However, this opinion cannot be considered to be definitive. The literature data report certain constant of *So* content and sulphur excess deposition was transferred in to inorganic form (DIJKSHOORN, VAN WIJK 1967; ZELENÝ, ZELENÁ 1996). At the same time, we can see in the regression model $sak = f(Q)$ that with increasing *Q* also the total amino acid content increases. In other words, excess input of sulphur compounds is changed in trees into sulphate form; it reduces the *Q* value and suppresses amino acid biosynthesis or proteosynthesis.

The relationship between the total amino acid content and nitrogen content, expressed by regression model, corresponds to nitrogen importance as the amino acid component. Regards only the close significant dependence (determination coefficient of 47.41%), the model suggests non-negligible nitrogen proportion (and its compounds) in substances derived from amino acids, and contained in birch leaves.

We compared the amino acid contents found by us with the data reported by SUOMELA et al. (1995). In both studies, the highest content of glutamic acid was found. The lowest contents were found for sulphur-containing amino acids. Proline content (designated as plant stress indicator – LARCHER 1988) is comparable for both regions. A marked difference between both studies is a low proportion of aspartic acid in the study by the Finnish authors. Its proportion is only 4.96% (10.17% found by us), which shifts this acid approximately to the glycine content level in the Ore Mts. Sulphur-containing amino acid content in the Ore Mts. region is distinctly higher. This comparison confirms our opinions: 1. in the eastern Ore Mts. area, the amino acid metabolism is not disturbed; 2. higher inputs of sulphur compounds mean a relatively increased content of sulphur-containing amino acids.

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The analysis of photosynthetic pigments, ascorbic acid and macronutrients – a tool for evaluation of the effect of air pollution in Norway spruce (*Picea abies* [L.] Karst.)

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ABSTRACT: Photosynthetic pigments, ascorbic acid and major macronutrients were studied in Norway spruce needles as stress indicators. Analyses were carried out on ten selected forest plots in the Zasavje in Central Slovenia, an area highly polluted by thermal power plant. The same investigations were carried out also at the high plateau Pokljuka, an area with relatively clean air, situated at the NE part of the Triglav National Park in the Julian Alps. The analyses of biochemical parameters of the spruce needles showed great impact of air pollutants from thermal power plant in the Zasavje district (high total sulphur content, disturbed mineral nutrition, low content of chlorophylls and disturbed composition and age pattern of photosynthetic pigments). Analyses of the same parameters in the Norway spruce needles from the Pokljuka profile showed rather natural situation, e.g. altitude depended pattern with small disturbance detected at the lowest sampling site which could be ascribed to air pollutants from the nearby and more remote pollution sources. The results of study confirmed the role of analysed parameters as vitality indicators in forest decline studies.

Keywords: Norway spruce; air pollution; biochemical needle vitality parameters; macronutrients; photosynthetic pigments; ascorbic acid

Zasavje is situated in the centre of the Posavsko hribovje, on the very South East outskirts of the Savinjske Alps. The major source of air pollution in the Zasavje is the Trbovlje Thermal Power Station. Its beginnings go back to the year 1893, and the power plant has been operated since 1968 as the TET II with the capacity of 125 MW. In sixties half-hour concentration of sulphur dioxide in the most exposed areas reached even 20,000 μg/m^3 (PARADIŽ 1972) and average year concentration of sulphur dioxide reached 740 μg/m^3 (HOČEVAR et al. 1986). A 360 m high smoke stack, which was constructed in 1976, was supposed to be a solution to the valleys of the Zasavje. Since that time mean annual concentrations of sulphur dioxide measured in the Zasavje have been fallen near by 40 μg/m^3. But high hourly concentrations of sulphur dioxide in the surrounding of TET are still quite common (Table 3).

In 1988 only 1.8% of beech in the Zasavje was healthy. About 84% of total damages could be ascribed to air pollution (ŠOLAR 1989). In 1991 Norway spruce was twice, and common beech even ten times more damaged than the Slovenian average (ŠOLAR 1991). The forests in the Zasavje area are still among the most damaged in Slovenia which has been recently confirmed again (BATIČ et al. 1999a; VIDERGAR-GORJUP, BATIČ 1999).

The Triglav National Park is situated in the western part of Slovenia, in the Julian Alps. Apart from minor air pollution sources at the extreme NE part of the park there are no major local air pollution sources in the area (BATIČ et al. 1999a) and input of pollutants relays mostly on transboundary sources.

Different abiotic and biotic condition of forest sites as well as different physiological conditions of trees and differences in genotype can influence the assessing of air pollution using the Norway spruce as an indicator organism. Climate data and measurements of air pollutants are necessary to draw conclusions about their impact on the growth and development of needles. Needles are affected not only by pollutants but also by high summer temperatures, droughts and by cold and ample precipitation immediately before sampling. Effects of air pollutants, drought, attack of pathogens and other abiotic stresses can lead to disturbances in tree metabolism such as enhanced free radical formation, disturbances in mineral nutrition, changed growth etc. and great care must be paid to avoid the confusion in using biochemical indicators of air pollution (TAUSZ, GRILL 1995).

Macronutrients, photosynthetic pigments and ascorbic acid are often used as stress indicators for early diagnosis of disturbances in forest trees (AMUNDSON et al. 1992; ALSCHER, CUMMING 1990; LANGE et al. 1987; KÖST-

NER et al. 1990; LUCAS et al. 1993; SIEFERMANN-HARMS 1994; TAUSZ, GRILL 1995; TAUSZ et al. 1996). Ascorbic acid content is a good indicator of oxidative stress in needles. Its content in non-polluted areas increases with altitude, with the intensity of oxidative stress (FOYER et al. 1997) and is decreased by very high SO_2 pollution. Plants are taking up sulphur through roots or via stomata. At excessive supply it accumulates in needles or leaves. Total sulphur content in needles is used as indicator of SO_2 impact on forest trees. Combination of analyses of different stress physiological parameters in forest trees with air pollution measurements, analyses of mineral nutrition of forest trees and use of some other sensitive bioindicators provide a more complete explanation of the process of forest decline (BATIČ et al. 1999b).

MATERIALS AND METHODS

Spruce trees were sampled in autumn 1995 at ten sampling sites in the Zasavje (Javor, Ravenska, Ostenk, Jelenca, Retje, Marno, Kovk, Gore, Dobovec and Ključevca) and at three sites at the Pokljuka high plateau in the Julian Alps. Both investigated areas are on predominantly calcareous bedrocks, typical for the South Alps where brown soils (eutric cambisols) and rendzinas (rendzic leptosols) are the most common soils types. Exceptions are sites Ostenk, Marno and Jelenca in Zasavje region with distric cambisols, developed on schists, sandstone and conglomerate. At each of the sites, three vital, apparently healthy, about 60 to 80 years old spruce trees with well lit upper parts of the crown were chosen. From each tree one branch from the seventh whorl was cut off, covered with black foil and left overnight in a cool place. Later on the needles were separated into age classes, frozen in liquid nitrogen, lyophilised, pulverised and stored in a deep freezer until further processing. All pigment extraction procedures were performed in dim light and at low temperatures. The Spectra-Physic HPLC system with an UV-vis Spectra Focus detector was used for the analyses of ascorbic acid, (TAUZS et al. 1996) and photosynthetic pigments, chlorophyll *a*, chlorophyll *b*, zeaxanthin, lutein, α-carotene, β-carotene (PFEIFHOFER 1989). Lichrosorb RP-8 (250 × 4,6 mm i.d., 5 μm particle diameter) column with Lichrosorb RP-8 (7.5 × 4.6 mm i.d., 5 μm particle diameter) precolumn was used for ascorbic acid analysis and Spherisorb ODS-2 (250 × 4.6 mm i.d., 5 μm particle diameter) column with Spherisorb ODS-2 (7.5 × 4.6 mm i.d., 5 μm particle diameter) was used for pigment analysis.

Needles for macronutrients analysis were dried on the air, pulverised and homogenised. Total sulphur content of the current year and of the one year old needles was determined by a Sulmhomat 12 ADG. The content of nitrogen was measured by the modified Kjeldahl method with the Vadopest – 5 device. The content of phosphorus was defined by the molybdenum blue colorimetric method with spectrophotometer, the content of potassium by a flame photometer, and the content of calcium and magnesium by atomic absorption spectrometry.

Limit values for the evaluation of the damage on the trees due to the impact of sulphur dioxide are presented by the IUFRO classification modified by KALAN et al. (1995) in Table 1. Common sulphur content class in current-year needles and in one year old needles is determined on the base of the sum of sulphur content class of both groups (Table 2). In the first class there are the needles with small content of sulphur, indicating small concentrations of sulphur in the air. Also in the 2nd class the damage due to the sulphur dioxide impact is not expected. The 3rd class comprises the trees from the areas where sulphur dioxide can cause damage on the trees and the 4th class the trees with frequent injury caused by sulphur dioxide.

Table 1. Limit values for classification of sulphur content (as determined with Sulmhomat 12-ADG) in the current year needles and in the one year old needles (KALAN et al. 1995)

	Sulphur content (%)	
Class	Current year needles	One year old needles
1	< 0.097	< 0.114
2	0.098–0.123	0.115–0.149
3	0.124–0.158	0.150–0.192
4	> 0.158	> 0.192

Table 2. Determination of the common sulphur content class (current year needles and one year old needles) (KALAN et al. 1995)

Common sulphur content class	Sum of current year needle sulphur content class and one year old needle sulphur content class
1	2
2	3 and 4
3	5 and 6
4	7 and 8

RESULTS

Measurements of air pollutants from the operational monitoring system run by the Thermal Power Plant Trbovlje are presented in Table 3. There are no permanent air pollutant measuring stations at high plateau Pokljuka.

Only few sites are the same, e.g. Kovk, Dobovec and Ravenska vas as for Norway spruce needle sampling. Measured maximum concentrations of sulphur dioxide are very high at all three sites because they are situated at the plateau close to the chimney, and due to wind direction there are under direct influence of chimney gasses. Sites Zagorje, Trbovlje and Hrastnik are in the bottom of the side valleys of river Sava, still with very polluted air but protected from the directs emmission from the high chimney due to their shelter location. The site Kum is the most distant to thermal power plant, situated at an altitude of 1,200 m, not any more directly influenced by the high chimney.

Table 3. Mean annual conc. (Mean) and highest hourly conc. (Max.) of SO_2 in mg/m³ measured in the Zasavje in the period from 1992 to 1996 (PLANINŠEK 1997)

Site and altitude	SO_2 concentration (mg/m³)									
	1992		1993		1994		1995		1996	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Zagorje, 250 m	71	1,701	60	1,000	48	716	41	606	34	605
Trbovlje, 290 m	69	1,456	71	943	49	765	48	797	37	785
Hrastnik, 300 m	62	1,430	51	638	32	663	29	844	24	1,162
Kovk, 590 m	73	2,084	59	1,309	70	1,917	58	1,630	35	1,622
Dobovec, 790 m	30	2,507	50	3,613	29	2,429	36	4,308	41	6,021
Kum, 1,220 m	17	530	13	539	11	776	13	2,324	18	1,114
Ravenska, 480 m	56	1,412	34	869	34	1,103	50	1,111	51	1,078

Table 4. Average content of macronutrients in spruce needles of a current year from the Zasavje (values below limit values in bold) and limit values for determination of nutrition stress in Norway spruce (SIMONČIČ 1997)

Sampling site and altitude	Average content of macronutrients in current year needles (mg/g dry weight)				
	N	P	K	Ca	Mg
Javor, 1,078 m	14.0	**1.260**	5.054	3.923	**0.983**
Jelenca, 750 m	13.2	**0.850**	7.745	4.398	1.156
Ključevca, 1,070 m	14.4	1.573	**3.075**	6.474	1.155
Gore, 880 m	13.5	**1.032**	4.561	6.276	**1.037**
Kovk, 590 m	14.3	1.546	6.292	**1.061**	**1.061**
Dobovec, 790 m	12.4	**1.061**	6.340	4.620	**1.006**
Marno, 390 m	12.5	**1.128**	7.519	6.357	**0.997**
Ostenk, 390 m	14.8	**1.206**	7.681	3.665	**0.784**
Ravenska, 480 m	11.7	**1.163**	6.736	8.600	1.324
Retje, 490m	13.3	1.473	7.810	5.349	**0.756**
Limit value	9.0–20.0	1.300	4.200	3.600	1.100

Table 5. Average content of macronutrients in spruce needles of a current year from the Pokljuka (values below limit values in bold) and limit values for determination nutrition stress in Norway spruce (SIMONČIČ 1997)

Sampling site and altitude	Average content of macronutrients in current year needles (mg/g dry weight)					
	N	P	K	Ca	Mg	S
Mokri log, 950 m	11.6	**1.025**	4.829	3.860	**0.793**	0.980
Goreljek, 1,240 m	12.2	**1.055**	5.704	7.029	**0.875**	1.003
V Razorih, 1,575 m	12.2	**1.017**	6.059	5.771	**0.731**	0.945
Limit value	9.0–20.0	1.300	4.200	3.600	1.100	

The contents of the main measured macronutrients in Norway spruce needles from 10 sites from Zasavje area and three sites from Triglav National Park are presented in Tables 4 and 5.

A deficiency of at least one nutrient was found in the needles from all sampling sites. Phosphorus and magnesium were the most often deficient due to predominantly limestone bedrock where soil circumstances impair uptake of these two elements. Only two sites in the Zasavje area are limited by other elements, the site Kovk in calcium content and the site Ključevca in potassium.

Total sulphur content was very high in all samples from the Zasavje region (Table 6) and low in the Triglav National Park. The majority of sites in the Zasavje region belongs to sulphur content class 4 or 3. These sites can be classified as polluted by sulphur dioxide and damage to trees can be attributed to the harmful effects of sulphur compounds. In 1995 the highest content of sulphur was determined in samples collected at Kovk, Dobovec and Ravenska. Needles sampled at Jelenca and Ključevca were the least polluted with sulphur. Also in 1988, 1990 and 1991 needles of spruce trees from Kovk,

Dobovec and Ravenska were classified in the 4th class of sulphur content (trees with frequent sulphur damage). In the samples from the Pokljuka plateau the sulphur content is low and needles could be classified in sulphur classes 1 and 2, meaning more or less natural background values.

The decrease in the chlorophyll content was determined predominantly in three years old, at Kovk and partly at Ostenk even in two years old needles (Fig. 1a). At Ključevca and partially also at Marno, at Gore and Jelenca the total content of chlorophyll in one year old needles was lower than 1.5 mg/g. Chlorophyll content in needles sampled in Triglav National Park (sites in the Pokljuka plateau) showed natural age depended pattern (Fig 1b), but needles from sites at lower elevations (Mokri log, Goreljek) had less pigments than needles from higher

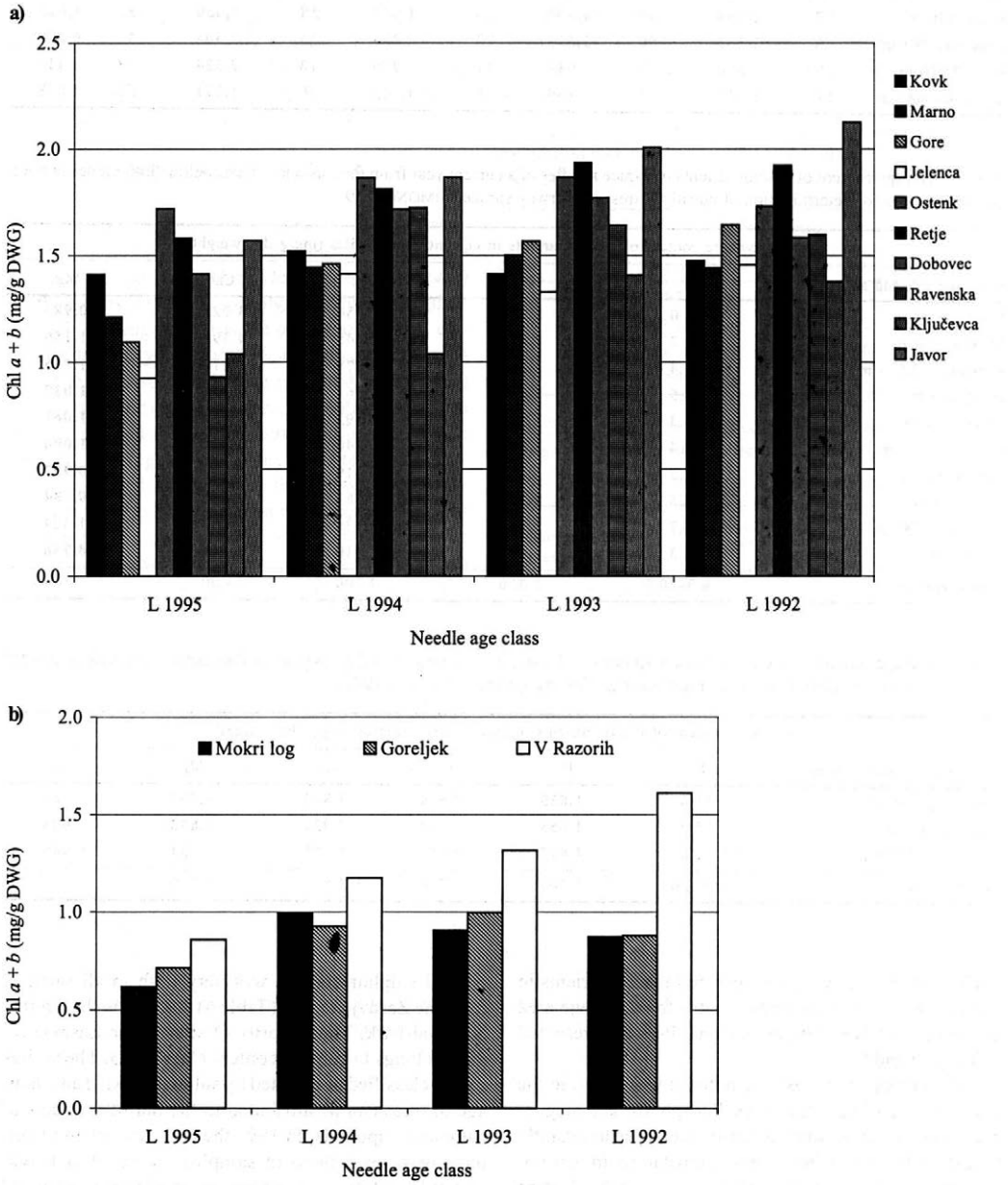

Fig. 1. Chlorophyll content (mg/g) in four needle age classes (L 1992, L 1993, L 1994, L 1995) of Norway spruce needles (*Picea abies* [L.] Karst.) sampled at ten sites in the Zasavje (a) and at three sites on the Pokljuka (b)

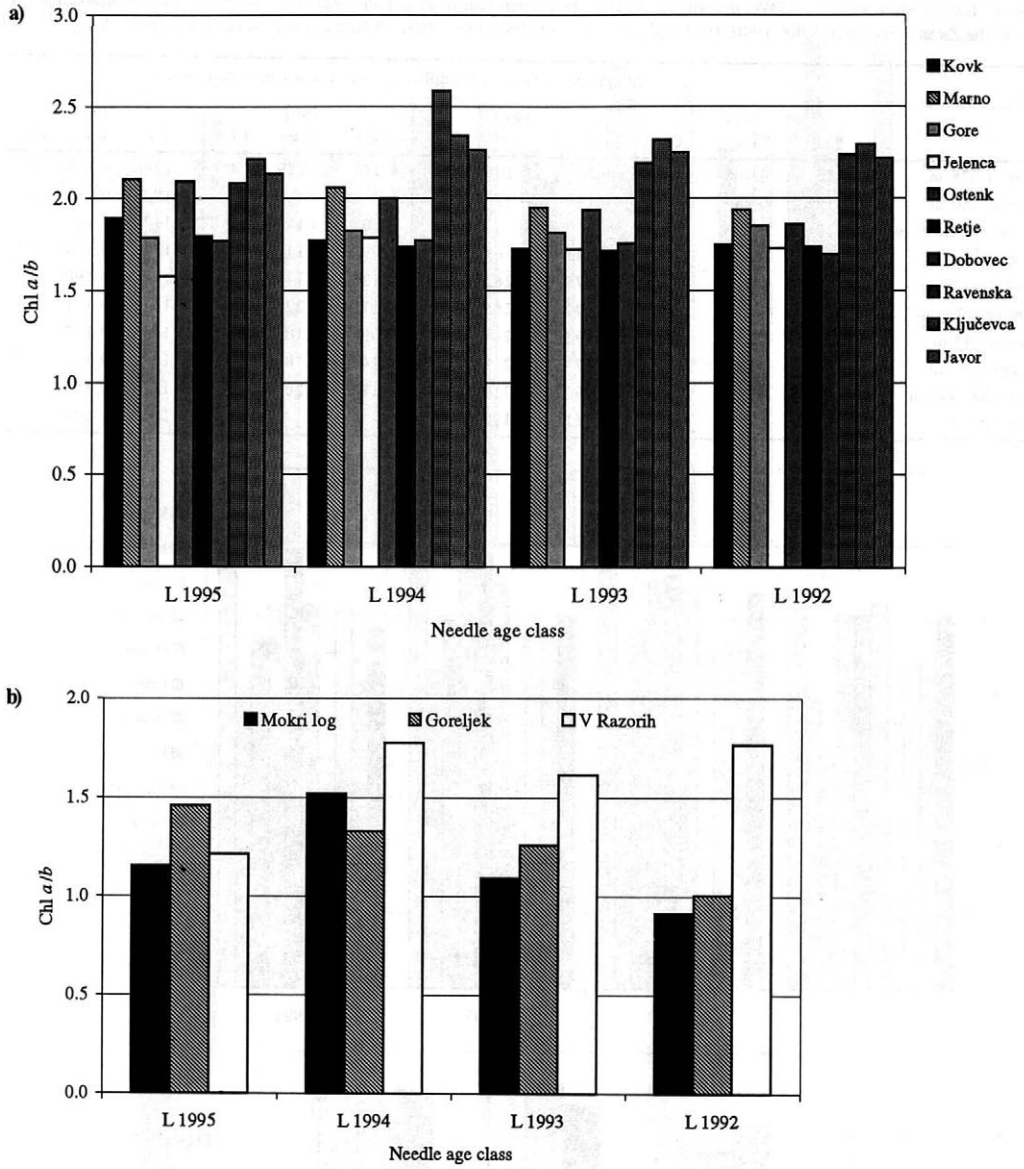

Fig. 2. Ratio of the chlorophyll a/b in four needle age classes (L 1992, L 1993, L 1994, L 1995) of Norway spruce needles (*Picea abies* [L.] Karst.) sampled at ten sites in the Zasavje (a) and at three sites on the Pokljuka (b)

elevations. The ratio between the two chlorophylls was below 2 at Kovk, Gore, Jelenca, Ostenk, Retje and Dobovec and slightly higher at Ključevca, Javor and partially in Ravenska (Fig. 2a) and premature degradation of chlorophyll took place at sites such as Kovk, Dobovec and Ravenska, all very close to the chimney of thermal power plant. At sites on the Pokljuka plateau (Fig. 2b) the ratio chlorophyll *a*/chlorophyll *b* decreased at both sites on lower elevations (Mokri log, Goreljek).

The content of carotenoids in spruce needles sampled in the Zasavje was between 0.064 mg/g (exceptionally 0.009 mg/g) and 0.150 mg/g (Fig. 3a). The content of carotenoids in needles from the Pokljuka plateau (Fig. 3b) showed natural age and altitude depended pattern.

The content of zeaxanthine was quite high at Retje, Dobovec and Javor sites and low at Jelenca and Ključevca (Fig. 4a) in the Zasavje region. Absolute values of this pigment were slightly higher in needles from the Pokljuka plateau (Fig. 4b).

Ascorbic acid content was found to be high in the needles of spruce growing at the Gore sampling site and low in the needles sampled at Ostenk, Retje and Dobovec

Table 6. Total sulphur content (% DW) in spruce needles of the current year (0 y) and one year (1 y) old spruce needles sampled at ten sites in the Zasavje region in 1988, 1990, 1991 and 1995 (ŠOLAR 1989, 1991, 1992) with the common sulphur content classes (Cl)

Site and altitude	Total sulphur content and sulphur content classes in spruce needles											
	1988			1990			1991			1995		
	0 y	1 y	Cl	0 y	1 y	Cl	0 y	1 y	Cl	0 y	1 y	Cl
Javor, 1,078 m	0.131	0.144	4	0.153	0.166	4	0.153	0.189	4	0.124	0.123	3
Jelenca, 750 m	0.126	0.143	3	0.142	0.175	4	–	–	–	0.107	0.110	2
Ključevca, 1,070 m	0.125	0.143	3	–	–	–	0.102	0.188	2	0.113	0.119	2
Gore, 880 m	0.118	0.133	3	0.142	0.164	4	0.099	0.115	2	0.131	0.124	3
Kovk, 590 m	0.147	0.208	4	0.175	0.262	4	0.138	0.176	4	0.164	0.190	4
Dobovec, 790 m	0.154	0.182	4	0.200	0.255	4	0.178	0.226	4	0.165	0.161	4
Marno, 390 m	0.183	0.232	4	0.192	0.241	4	0.095	0.101	2	0.153	0.187	3
Ostenk, 390 m	0.155	0.202	4	0.175	0.219	4	0.145	0.183	4	0.143	0.152	3
Ravenska, 480 m	0.162	0.206	4	0.190	0.219	4	0.181	0.200	4	0.172	0.150	4
Retje, 490 m	0.158	0.202	4	0.161	0.192	4	–	–	–	0.130	0.144	3

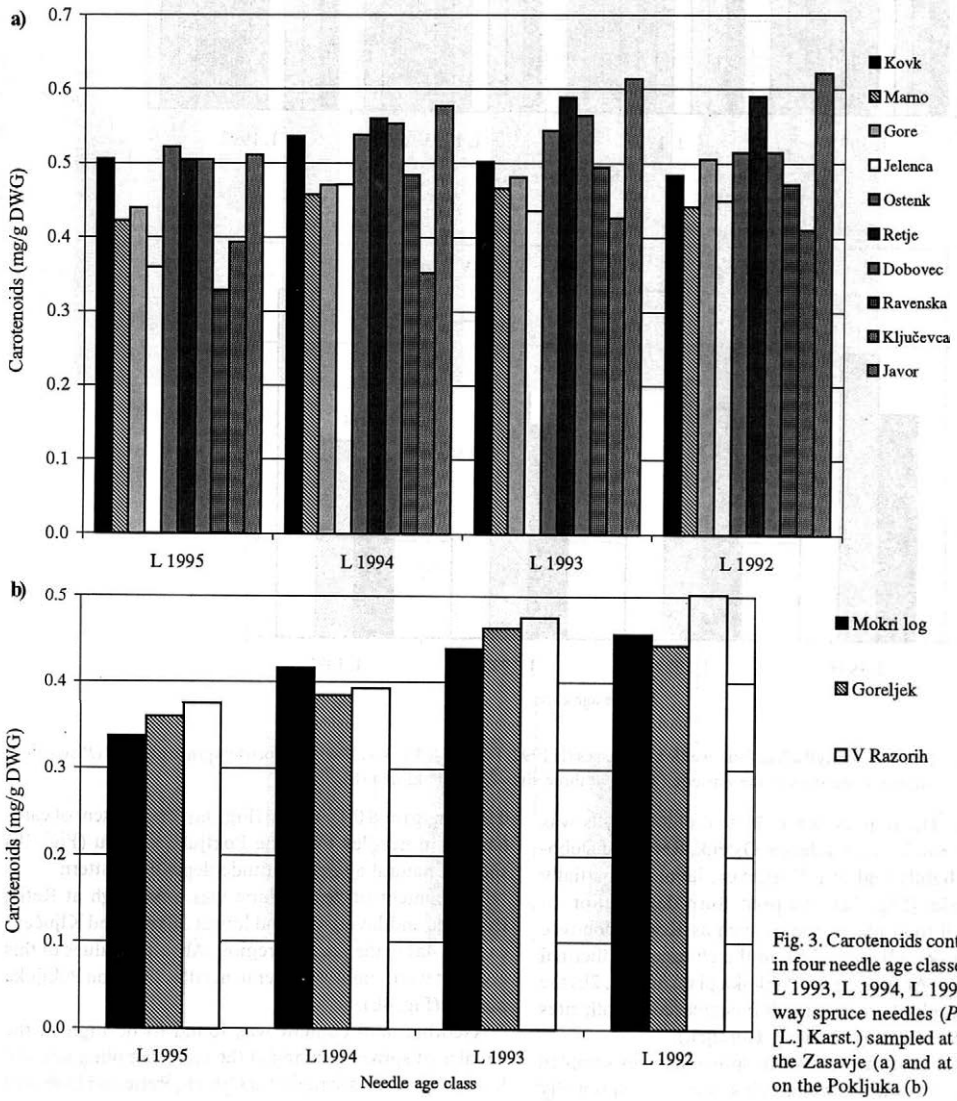

Fig. 3. Carotenoids content (mg/g) in four needle age classes (L 1992, L 1993, L 1994, L 1995) of Norway spruce needles (*Picea abies* [L.] Karst.) sampled at ten sites in the Zasavje (a) and at three sites on the Pokljuka (b)

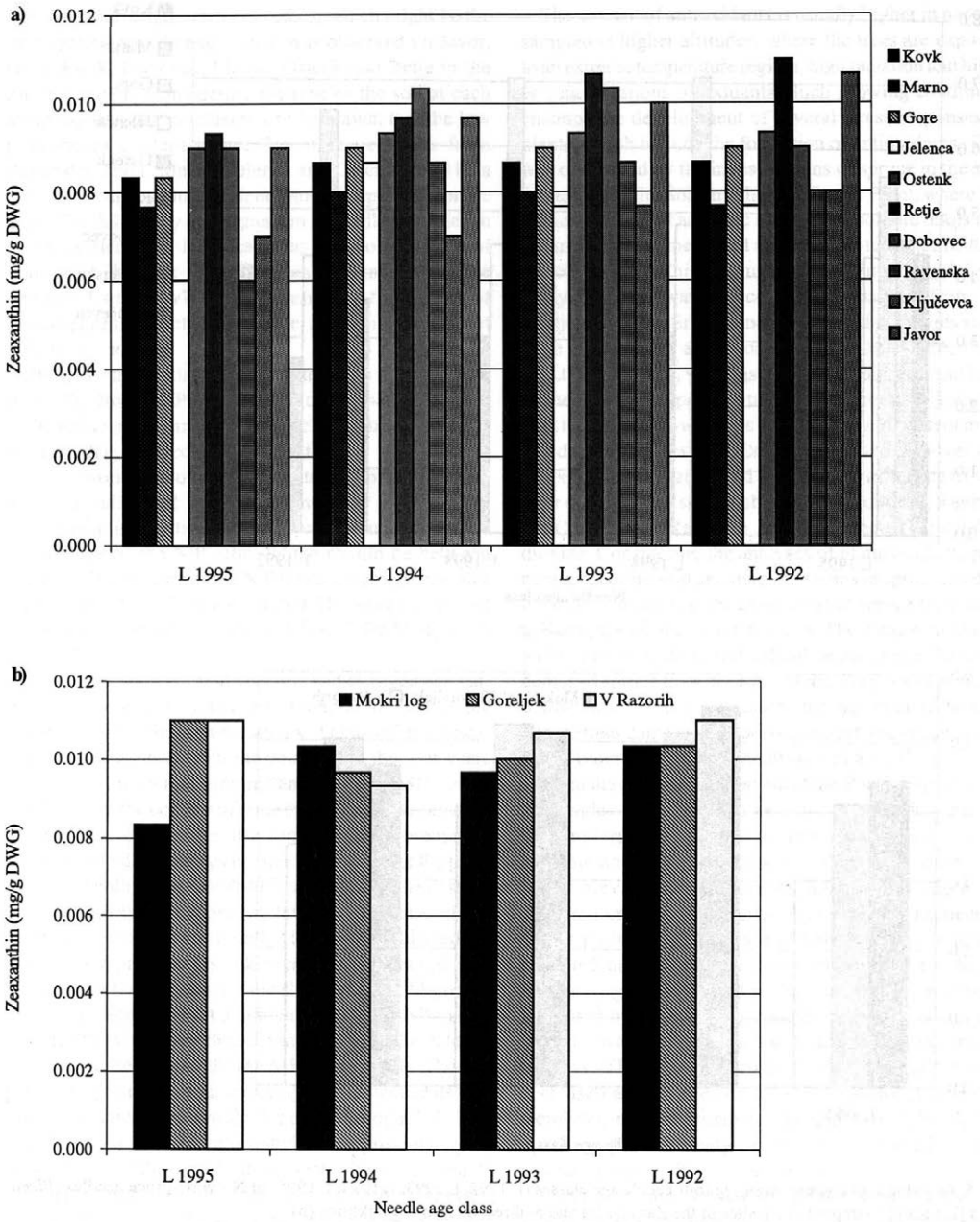

Fig. 4. Zeaxanthine content (mg/g) in four needle age classes (L 1992, L 1993, L 1994, L 1995) of Norway spruce needles (*Picea abies* [L.] Karst.) sampled at ten sites in the Zasavje (a) and at three sites on the Pokljuka (b)

(Fig. 5a) in the Zasavje area. Needles from the relatively clean air area from the Pokljuka plateau show quite different situation in relation to this antioxidant. Slightly polluted sites at lower elevation (Mokri log and Goreljek) show an increase of ascorbic acid content in comparison with the site at the timber line (V Razorih) (Fig. 5b).

DISCUSSION

Climate data and air pollutants measurements in the Zasavje area lead us to conclusions that the growth and development of one and two year old needles were affected not only by pollutants but also by high summer tem-

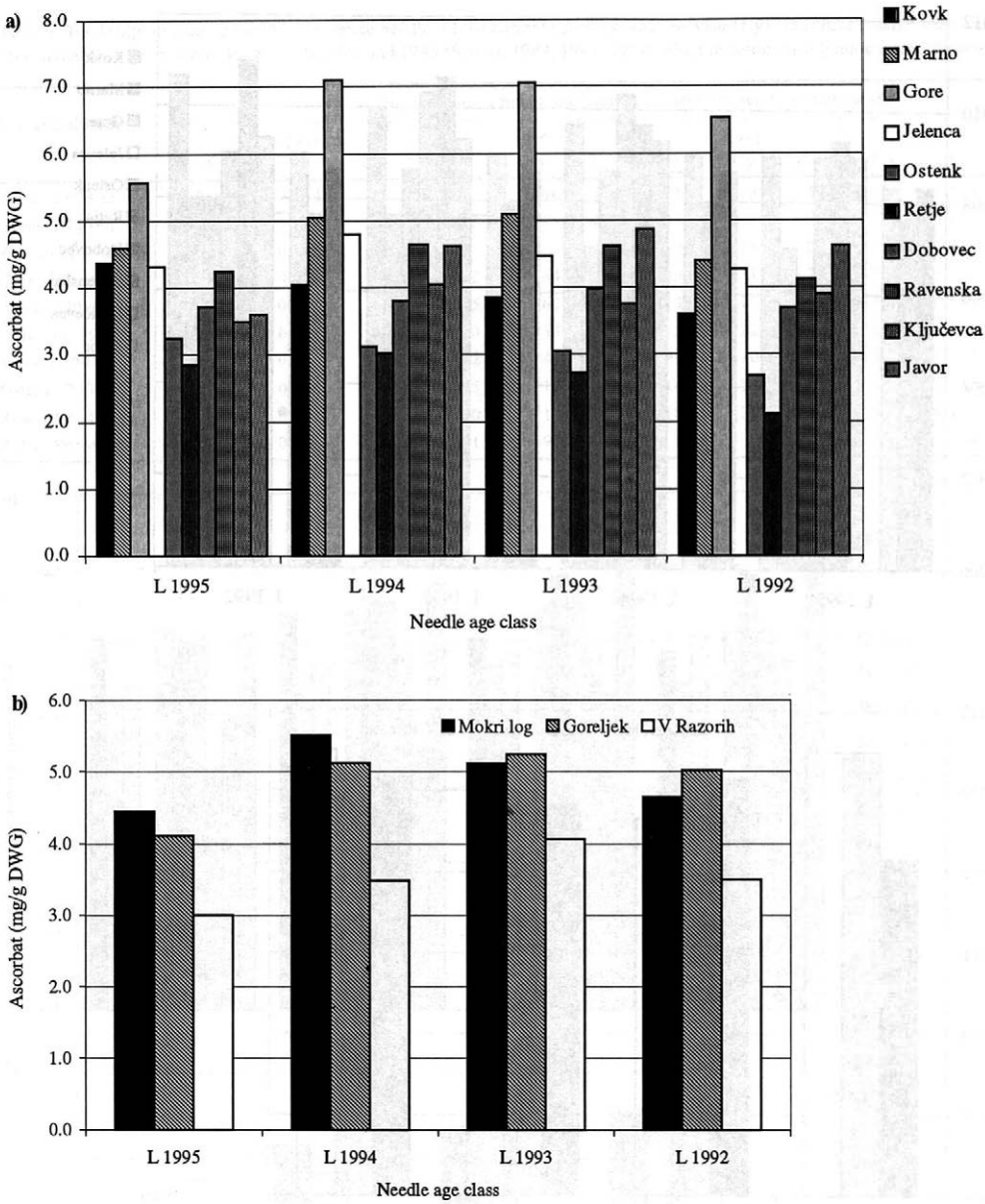

Fig. 5. Ascorbic acid content (mg/g) in four needle age classes (L 1992, L 1993, L 1994, L 1995) of Norway spruce needles (*Picea abies* [L.] Karst.) sampled at ten sites in the Zasavje (a) and at three sites on the Pokljuka (b)

peratures in 1994 and by cold and ample precipitation immediately before sampling. Comparatively low pH was determined in the precipitation in years 1994 and 1995 on Kovk and Dobovec (data not shown). According to the sulphur dioxide data (Table 3) the site Kum is an area least polluted with sulphur dioxide and Kovk, Dobovec and Ravenska are the most polluted areas in the Zasavje region. The highest hourly concentration of sulphur dioxide usually occurs at Dobovec. There are no permanent measuring stations of air pollutants at high plateau Pokljuka but from the short term measurement, carried out during a case study (GOMIŠČEK et al. 1997) we can conclude that area is much cleaner than Zasavje area.

Almost all sites showed low content of P and Mg. Partly this can be ascribed as the effect of predominantly limestone bedrock where phosphorus uptake is impaired and antagonism between calcium and magnesium takes place making supply with magnesium nonoptimal.

The lack of magnesium in needles, which might be the first symptom of damaged tree, was observed on Javor, Gore, Kovk, Dobovec, Marno, Ostenk and Retje in the Zasavje region. Considering the type of the soil at each sampling site, the conclusion can be drawn, that the low phosphorus content in needles of spruce trees from Ravenska, Javor, Marno, Jelenca and Ostenk could be a consequence of an insufficient mineral supply of spruce trees. The deficiency of magnesium in needles sampled in Marno, Ostenk and Retje can also be a consequence of poor soil. The lack of calcium and magnesium in the needles from Kovk was presumably the result of disturbances in metabolism due to the influences of pollution.

Phosphorus and magnesium content was deficient also in needles from the Pokljuka. This can be better ascribed to the influence of limestone bedrock and subalpine environment than to effects of air pollution.

In the estimation of nutrition status of spruce the ratio between individual nutrients in needles is important. A harmonious nutrition state of spruce can be indicated on the base of the N/P ratio, which should be between 6 and 12. In our samples the N/P relation was unfavourable for trees growing at Gore and Jelenca. The ratios of the other macronutrients should be: N/K: 1–3, N/C: 2–20, N/Mg: 8–30 (SIMONČIČ 1997).

The chlorophyll content was low and changed age pattern of chlorophyll content was found at all sites in the Zasavje region. The concentrations of chlorophyll in needles should increase from the youngest to the four years old needles in normal circumstances (ANDERSEN et al. 1991). When the content of chlorophyll decreases already in three years old needles, this can be a sign of premature ageing due to disturbances in mineral nutrition or the presence of air pollutants (KOSTNER et al. 1990). In the Zasavje region (with the exception of Javor), a decrease in the chlorophyll content was found in three years old needles, at Kovk and partly at Ostenk even in two years old needles (Fig. 1a). At Ključevca and slightly less at Marno, at Gore and Jelenca the total content of chlorophyll in one year needles was lower than 1.5 mg/g, which characterises damaged trees (SIEFERMANN-HARMS 1994). The impact of air pollution in Zasavje region is indicated also by low ratio between chlorophyll *a* and chlorophyll *b*. The ratio between the two chlorophylls is approximately 2, which indicates the air pollution effect, where chlorophyll *a* degrades more rapidly than chlorophyll *b*. A slightly higher ratio appeared only at the spruce trees on Javor, Ključevca and partly in Ravenska. The situation with chlorophyll contents in one year needles over 1.5 mg/g, little ascorbic acid, a lot of α-carotene and some lutein, which should indicate that the stress is controllable (RIBARIČ-LASNIK 1996), was found on Dobovec, Retje and Ostenk. Low content of carotenoids and the small concentration of chlorophyll indicate a particularly strong oxidation stress on Gore, whereas at site Ključevca the lack of potassium could explain low vitality of trees, indicated by pigment analyses (FABIAN-GALAN 1972).

The content of antioxidants is usually higher in needles sampled at higher altitudes, where the trees are exposed to an extreme temperature regime, high radiation and higher concentrations of oxidants. Such growing conditions enhance the development of several stress responses in plants, which include the formation of antioxidants. This was confirmed by the investigations of spruce in the surroundings of the Šoštanj Thermal Power Plant, where the highest content of ascorbic acid, water-soluble thiols and β-carotene were measured at higher altitudes (RIBARIČ-LASNIK 1996). This findings are also supported by our analyses of Norway spruce needles analyses from the Pokljuka plateau. Small concentrations of pollutants stimulate synthesis of antioxidants (MELHORN 1986; OSSWALD et al. 1987), whereas long term pollution and high concentrations of pollutants caused decrease of ascorbic acid in needles. Low values of ascorbic acid content measured in the needles from Ostenk, Retje and Dobovec can be explained by strong and long lasting influence of sulphur dioxide. The sites such as Kovk, Dobovec, Ravenska, Ostenk, and Retje are strongly affected by sulphur dioxide. Considering the analyses of photosynthetic pigments, ascorbic acid and macronutrients in spruce needles we can conclude that the most stressed spruce trees were at Kovk, at Dobovec and Ravenska. The damage at Marno and Jelenca is medium and difficult to determine. The least damaged spruce trees are from Javor. They are exposed to oxidative stress above all due to the elevation of the site. Spruce trees damage at Ključevca and at Gore is higher due to unfavourable growth condition and altitude.

From the analyses carried out at the Pokljuka plateau in the Triglav National Park we can conclude that there is more or less normal situation. There is slight increase of ascorbic acid and a decrease in chlorophyll at sites on lower elevation, what can be ascribed to slight air pollution impact at these sites, very probably influenced by air pollution in the valley. This is opposite to the expected natural altitude depended values, e.g. being higher at greater altitudes. But air pollution effect, measured by total sulphur content in needles is still too small to overcome the reaction ability of Norway spruce needles. The ratio chlorophyll *a*/chlorophyll *b* also decreased at both sites on lower elevations (Mokri log, Goreljek), indicating premature degradation of chlorophyll *a*, taking place already in one year old needles, and indicating again effects of air pollutants.

From the data presented in this study it can be concluded that the used biochemical and physiological parameters are good tools for interpretation of stress effects in forest decline studies. The bigger the set of analysed parameters is, the stronger is their explanation power in relation to vitality (defoliation, growth, propagation).

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Content of micro- and extraneous elements in leaves of birch

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ABSTRACT: The content of microelements (Mn, Zn and Cu) and extraneous elements (Pb, Cd and Al) were determined in leaves of birch growing in the region of the eastern Ore Mts. and Děčín Sandstone Upland. They were assessed in relationship to the transect (Klášterec, Janov, Litvínov and Sněžník), to the elevation above sea level, age class of stand and nutrition of trees. Except for the zinc content, contents of other elements in birch leaves were different in individual transects. Differences were also found at the transect different elevations, but without any regular dependence. The content decrease trend at higher elevations of the eastern Ore Mts. transects was observed in Mn, Cd and partly also in Al. In the Sněžník transect, the content in birch leaves was increasing in older stands in all elements except for Mn. Regarding the criteria for element content as nutrient, Mn and Zn contents were optimal/higher, that of Cu was insufficient. In the extraneous elements assessed from the viewpoint of potential negative effects, Pb and Al contents were at the natural background level, that of Cu was common up to excessive.

Keywords: birch (*Betula pendula* Roth); leaves; microelements; extraneous elements; Ore Mts.

The birch is the most important substitute tree-species of the Ore Mts. and Děčín Sandstone Upland after spruce stands died out. Since 1986, its resistance to biotic, abiotic and anthropogenic affects has been investigated (KULA 1997; KULA et al. 1999). A complex leaf analysis examining the content of nutrient and extraneous elements in this region has been carried out since 1995 (HRDLIČKA, KULA 1998; HRDLIČKA, KULA 2001). Parallelly, assessed is the amino acid content in birch leaves as a potential stress indicator or as non-physiological load in the tree-species (KULA et al. 2000), and investigated are soil (VAVŘÍČEK 1999) and air-pollution (HADAŠ 1999) conditions in the area of research interest. The results of these partial examinations and hitherto preliminary complex conclusions point out the complex project to be purposeful.

The present contribution is aimed at assessing the actual content of nutrient microelements (Mn, Zn, Cu) and extraneous elements (Pb, Cd, Al) in birch leaves using repeated samplings in 1998 (under suspected heavy air-pollution impact at the period end) and assessments of the nutrition state in birch stands in dependence on the elevation above sea level, stand age and transect situation. On such way, registered was the initial state for the next monitoring of the birch response to expected positive changes (reduction) of the air-pollution load in the eastern Ore Mts. region (transects of Klášterec, Janov and Litvínov) or in the Děčín Sandstone Upland (Sněžník transect).

MATERIALS AND METHODS

In the north-west part of the Czech Republic in the Krušné hory Mts. (Ore Mts.) and the Děčín Sandstone Highland, four altitude transects were established: Klášterec – KLA (ca. 50°23' N, 13°02' E), Janov – JAN (ca. 50°32' N, 13°24' E) and Litvínov – LIT (ca. 50°38' N, 13°37' E), all from 500 m to 900 m a.s.l., and further Sněžník – SNE (ca. 50°52' N, 14°03' E), only from 500 m to 700 m a.s.l. (see Fig. 1 in HRDLIČKA, KULA 2001; see also HRDLIČKA, KULA 1998). Original choice of the transects was based on immission load decreasing from west (KLA) to east (SNE).

The actual mean values of element content: total for Mn (WARREN et al. 1990; EKOLA 1998), in an extract in HNO_3 ($c = 2$ mol/l) for Zn, Pb and Cd (ANDERSSON 1975) and exchangeable Al (SOKOLOV 1939; EKOLA 1998) in the A soil horizon for particular transects are presented in Table 1 (only stands age class II; content of Cu not determined).

Samples (53 stands and 159 sample trees) of control branches were taken (the end of August 1998) at each transect level (the height gradient of 100 m) from the upper, released and insulated parts of the birch crown from three permanent sample trees in the age class I (1–20 years), II (21–40 years) and III (41–60 years) stand. Leaves stored in paper bags were dried at 80°C for 8 hours. Some dried leaves were ashed in a muffle furnace at 200°C for 2

Table 1. Content of elements (in μg/g) and pH value (KCl) in soils, horizon A, stands age class II

Transect	pH	Mn	Zn	Pb	Cd	Al
KLA	2.90	193	6.6	30	0.12	4374
JAN	2.93	94	10.8	43	0.11	6318
LIT	2.97	829	17.4	47	0.10	4698
SNE	3.04	12	3.4	26	0.10	2430

hours and 450°C for 12 hours for metal analyses. Mineral residues were extracted with warm HCl ($c = 1$ mol/l). Manganese, zinc, copper, lead, cadmium, and aluminium were determined by atomic absorption spectrophotometry using the AAS 30 (Carl Zeiss, Jena, Germany) spectrometer.

The obtained values of micro- and extraneous contents were processed by statistical methods using the UNISTAT program. The calculated mean values were completed with the estimation of a confidence interval ($\alpha = 0.05$). For the evaluation of differences between differently classified data, the classical model analysis of variance was applied using multiple comparison by Tukey (UNISTAT 1995).

RESULTS

The data obtained (content of elements) are largely heterogeneous between individual transects. Within each transect, element contents varied between stands of different age classes and at different elevations. Under this aspect, the results were assessed in the present study. The element contents in individual transects are presented in Table 2, according to the transects, stand age classes and elevations then in Figs. 1 and 2. The limit values for element assessments are presented in Tables 3 and 4. In the microelements (Mn, Zn, Cu), the limit values correspond to normal nutrition and growth rate. In the extraneous elements (Pb, Cd, Al), concerned is the exceeding over common contents, which is tolerable and thus not endangering the tree-species growth rate. For deducing these limit values, compare, e.g., HRDLIČKA and KULA (1998).

MICROELEMENTS

Manganese is the element, the content of which differed markedly between the transects. In the Litvínov and Klášterec transects, the values of its content were distinctly higher versus the Janov and Sněžník transects (Table 2). In particular, a high Mn level (6,783 μg/g) was found in the Litvínov transect at the elevation of 500 m a.s.l. (stand of the III. age class). In the transects of the eastern Ore Mts., Mn contents were lower at the elevations of 800 and 900 m a.s.l. (Fig. 1). This suggests that this element content is declining with the increasing elevation of stands. The stand age does not affect Mn content, its values in individual transects varied differently (Fig. 2). Regarding the CC3 class limits (100 μg/g), they were thus markedly higher (cf. Table 3). This is also evident from Figs. 1 and 2 (limits are not registered).

The zinc content was independent on the transect, no significant differences were found between the transects (Table 2). At individual elevations of the transects (Fig. 1), the content varied differently, significant differences were found only in the Janov transect. In the eastern Ore Mts., Zn content also varied differently with the stand age, but differences were not significant (Fig. 2). In the Sněžník transect, zinc content was increasing with the stand age. Similarly to manganese also in zinc, the CC3 class limit values (50 μg/g) were surpassed, zinc content was optimal/higher (cf. Table 3). This is also shown by Figs. 1 and 2 (limits are not registered again).

Table 2. Element contents (μg/g) in birch leaves (mean values ± confidence interval, $\alpha = 0.05$; data were pooled and classified by transects (TRA); TRA/number of analyses – KLA/78, JAN/84, LIT/84, SNE/72; [x]letters indicate significant differences between marked TRA – only first character)

TRA	Mn	Zn	Cu	Pb	Cd	Al
KLA	1803 ± 210^{SJ}	187 ± 11	5.07 ± 0.17^{J}	1.55 ± 0.05^{LJ}	0.30 ± 0.03^{LS}	74 ± 1^{L}
JAN	942 ± 165^{LK}	179 ± 14	4.65 ± 0.16^{KS}	1.38 ± 0.06^{KS}	0.26 ± 0.03^{LS}	78 ± 2^{L}
LIT	2234 ± 377^{SJ}	183 ± 9	4.89 ± 0.25^{S}	1.39 ± 0.07^{KS}	0.38 ± 0.03^{SKJ}	93 ± 2^{SKJ}
SNE	586 ± 107^{LK}	193 ± 14	5.29 ± 0.14^{LJ}	1.53 ± 0.06^{LJ}	0.20 ± 0.02^{LKJ}	77 ± 3^{L}

Table 3. Classes of microelement content in birch leaves (μg/g)

Content class	Mn	Zn	Cu
CC1	< 30	< 15	< 6
CC2	30–100	15–50	6–12
CC3	> 100	> 50	> 12

Content class: CC1 – insufficient, CC2 – sufficient, CC3 – optimum/higher

Table 4. Classes of extraneous element content in birch leaves (μg/g)

Content class	Pb	Cd	Al
EC1	< 2	< 0.1	< 103
EC2	2–10	0.1–0.2	103–120
EC3	> 10	> 0.2	> 120

Content class: EC1 – background, EC2 – common, EC3 – excessive

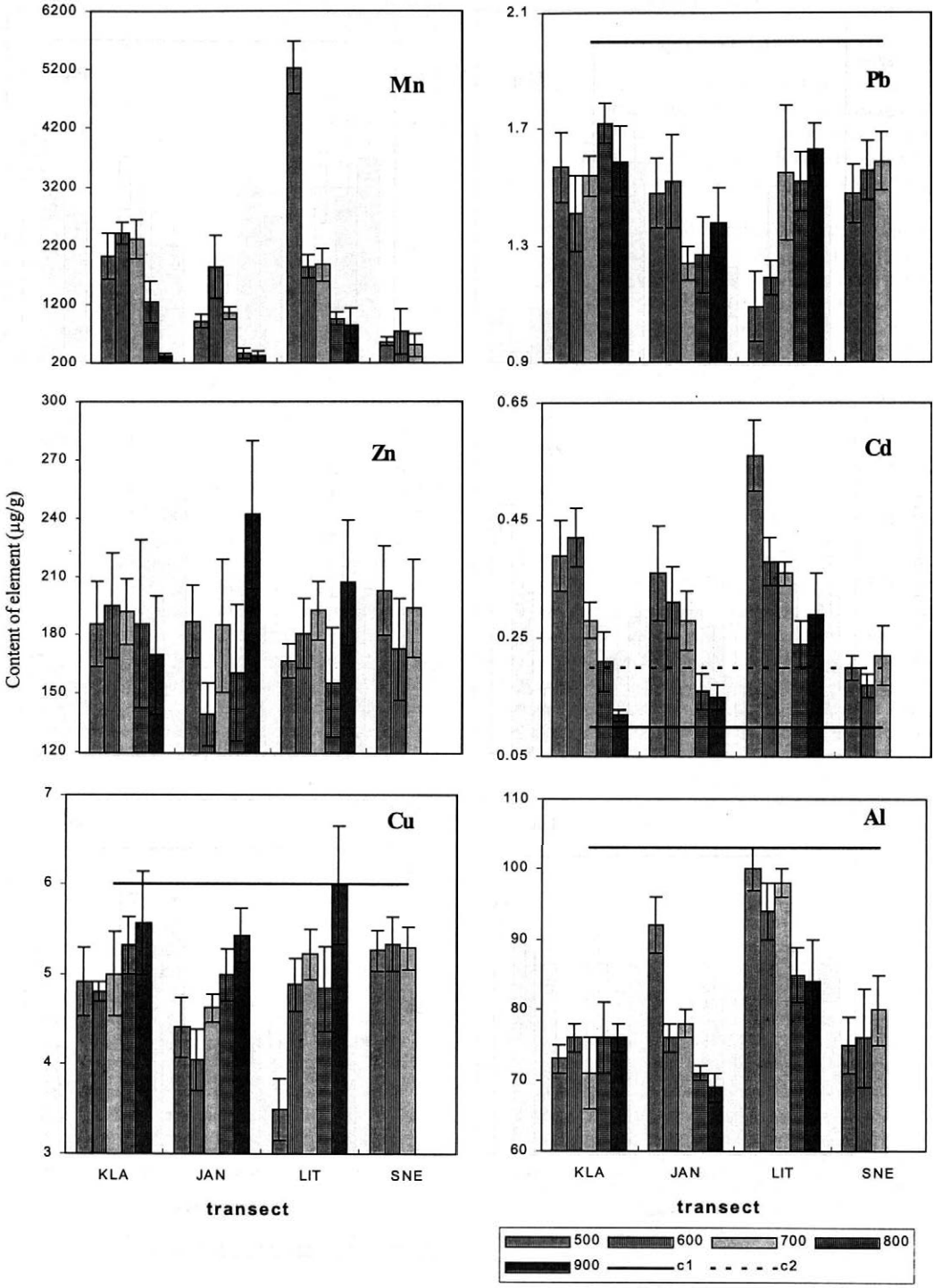

Fig. 1. Content of elements (µg/g) in relation to transects (KLA – Klášterec, JAN – Janov, LIT – Litvínov, SNE – Sněžník) and altitude (mean values ± confidence interval, $\alpha = 0.05$; c1: lower class limit of sufficient/common content, c2: upper limit of sufficient/common content, see Tables 3, 4)

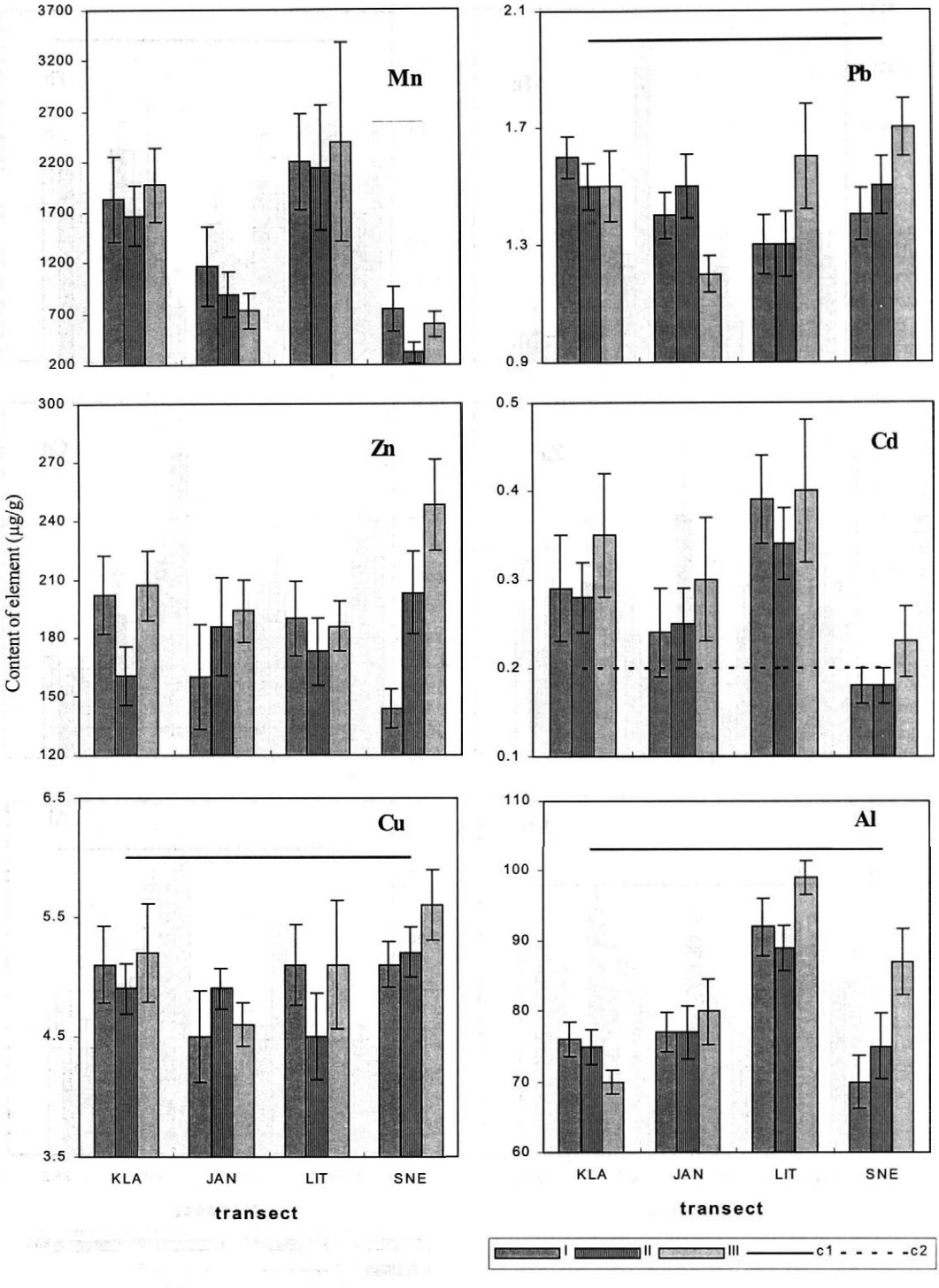

Fig. 2. Content of elements (µg/g) in relation to transects (KLA – Klášterec, JAN – Janov, LIT – Litvínov, SNE – Sněžník) and stand age (mean values ± confidence interval, $\alpha = 0.05$; c1: lower class limit of sufficient/common content, c2: upper limit of sufficient/common content, see Tables 3, 4)

The copper content varied between individual transects. The lowest content was in the Janov transect, the highest one in the Sněžník transect (Table 2). All these contents, however, were insufficient in relationship to the nutrition (cf. Table 3). At individual elevations of the transects in the eastern Ore Mts. the value increasing trend with increasing elevation was observed. In the Klášterec and Litvínov transects, the value for 900 m a.s.l. lies only at the limit of the CC1/CC2 classes (Fig. 1, Table 3). In the Sněžník transect, the copper content was not changed by the elevation. In individual age classes of stands in the eastern Ore Mts., Cu content varied, in the Sněžník transect, an increase trend with the stand age is suggested. All values of Cu content are insufficient (Fig. 2, Table 3).

EXTRANEOUS ELEMENTS

The lead content was different between the transect pairs of KLA and SNE (higher values) and LIT and JAN (Table 2). At the transect individual elevations, the lead content varied. General trends, however, cannot be found. Similarly, the lead content according to the stand age does not indicate general trends. In the Litvínov and Sněžník transects, somewhat higher lead content was observed in the oldest stands (Fig. 2). All values found in Pb content belongs to the EC1 class, thus the background level is concerned (cf. Table 4).

The cadmium content was the highest in the Litvínov transect and the lowest in the Sněžník transect. In the Klášterec and Janov transects, Cd contents were coincident but differed from the other transects (Table 2). Only the Sněžník transect values lie on the boundary of the EC2/EC3 classes, the other values belong to the EC3 class. Cd content is thus excessive (cf. Table 4). In the eastern Ore Mts. transects, Cd content decline was observed with the stand elevation increasing (Fig. 1). At higher elevations of the Klášterec and Janov transects, Cd content occurred within the EC2 class, thus within the class of common content (Fig. 1, Table 4). In the Sněžník transect, Cd content varied around the boundary of the EC2/EC3 classes (Fig. 1). Regarding the stand age, the values of Cd content in the Klášterec, Janov and Sněžník transects show increasing trend in the third age class (Fig. 2). Cd level was, however, excessive, in the Sněžník transect younger stands then common (Fig. 2, Table 4).

The aluminium content in the Litvínov transect was higher versus the other transects (Table 2). In the Janov and Litvínov transects, Al content declining trend with the stand increasing elevation is suggested, in the Sněžník transect this trend is reverse (Fig. 1). Similarly, we can see reverse trends in Al content changes with the stand age (Fig. 2). Whereas in the Klášterec transect, the decline is in accordance with the age increase, in the other transects (especially in Sněžník), we can see the content increasing trend, first of all, in the III. age class. All values of the aluminium content belong to the EC1 classification class, therefore, to the background (cf. Table 4).

DISCUSSION

MICROELEMENTS

The microelements contents found in birch leaves enable to make conclusions from two aspects. On the one hand, they indicate the nutrition level in birch stands, and on the other hand, the potential excess can show microelement non-natural inputs. They can be inputs both from the soil and atmosphere.

The copper content in birch leaves of the stands under study was predominantly (90% of all values) lower than 6 μg/g, thus in the CC1 classification class of insufficient content. The lowest values were at the level of 3.5 μg/g and less (minimum value of 2.5 μg/g) at the lowest elevations of the Janov and Litvínov transects. These contents will correspond with the opinion by other authors on the normal values of Cu content in plants (2–20 μg/g – MARKERT 1992; 4–12 μg/g – DMUCHOWSKI, BYTNEROWICZ 1995; 2.5–25 μg/g – ALLEN et al. 1974). Cu content can be thus considered to be moderately insufficient. A similar state was ascertained, e.g., in the Moravian-Silesian Beskids during investigations on spruce nutrition, where content of Cu only 2–4 μg/g was found in spruce needles (HRDLIČKA 1997). This is confirmed by the opinion (e.g., DMUCHOWSKI, BYTNEROWICZ 1995) that forest tree foliage does not accumulate copper. As well, it is likely that copper compounds come to roots, where they are accumulated. In the case of need, they are transported to leaves (WEST 1979).

The manganese content in all stands exceeded the limit of 100 mg/g, it was thus in the class of the optimum up to excessive content (CC3). As such, it exceeded in all stands the level of 4,000 μg/g (with maximum of 6,783 μg/g in the III. age class stand) in the Litvínov transect at the elevation of 500 m a.s.l. These high values can be caused by increased manganese content in the soil. This is suggested by the results of soil analyses (Table 1). Very high values for the elevation of 500 m a.s.l. in the Litvínov transect correspond to the Mn content found at A horizon (3,250 μg/g). Obtaining of Mn from the soil is supported by a low value of pH (MENGEL, KIRBY 1978). Birches growing in acid soils contained in their leaves up to 7,000 μg/g manganese (KITAO et al. 1997). Therefore, birch is probably the tree-sort with increased tolerance to Mn accumulation in leaves. Our results confirm this tolerance. That indicates that the limit value of 100 μg/g corresponds only to the upper limit of the sufficient content. Unknown is the level of tolerated content, thus the lower limit of toxic content. That will probably depend on many factors, such as, e.g., soil pH, macroelement content in the soil and leaves (first of all of Ca and Mg, their uptake is inhibited by Mn excess; BERGMANN 1988; MARSCHNER 1995). The toxic limit will be probably individual for separate stands and site conditions. We are of opinion that this limit could range 7,000–10,000 μg/g.

The zinc content in all stands exceeded the limit of 50 μg/g, it was thus in the optimum up to the excessive

content class (CC3). This limit deduced according to the data by BERGMANN (1988) (cf. HRDLIČKA, KULA 1998) appears to be low. DMUCHOWSKI and BYTNEROWICZ (1995), on the basis of the literature data, report the range of 10–100 μg/g as normal zinc content. Higher contents than 400 μg/g are designated by these authors to be phytotoxic. They also report that the content higher than 100 μg/g indicates pollution inputs. Regarding those data, the contents found by us can be divided as follows: 4% of values less than 100 μg/g and 3% of values more than 300 μg/g. The Zn maximum value found was 340 μg/g in the Sněžník transect (500 m a.s.l., III age class). Zn content can be thus designated to be increased but not toxic.

EXTRANEOUS ELEMENTS

The extraneous elements content in birch leaves indicates their non-natural input. This input can be caused either primarily by direct air-pollution impacts with extraneous element compounds, or secondarily through elements released from acid soils.

The cadmium content in birch stands ranged, according to Table 4, within the excessive content class (EC3). Below the lower limit of this class, 35% of the measured values occurred. The literature presents also other content limit considered to be common or normal in stands not loaded by air-pollution. DMUCHOWSKI and BYTNEROWICZ (1995), on the basis of the literature data, even report the range of 0.05–0.5 μg/g. This limit exceeds 8% of Cd values found by us. Therefore, also according to other opinions on assessments of Cd content in birch leaves, we come to the conclusion on its excessive content in the stands under study. The results have shown that, in the eastern Ore Mts., Cd content declines with the increasing elevation. This induces the conclusion that the cadmium amount increased in stands is probably of air-pollution origin from the sources of the Ore Mts. basin. Interesting is the finding that the correlation between Cd and Mn contents is highly close (the highly significant correlation coefficient of 0.7275). This can be judged also subjectively comparing these metal contents in stand leaves at elevations in individual transects (Fig. 1). Especially, this is evident in the Litvínov transect at the elevation of 500 m a.s.l., where both these elements had their highest values.

The lead content in stands was predominantly in the natural background class (EC1). Only 2% of contents exceeded the class limit value. The highest content was ascertained in the Litvínov transect (2.5 μg/g) at the elevation of 700 m a.s.l. in the stand of the III. age class. In this element, there is rather a coincidence. ALLEN et al. (1974) report as the normal level the value of up to 3 μg/g. The content values at the level of natural background and their independence on the elevation indicate the absence of significant air-pollution impacts with lead compounds within the area of the stands under study in the eastern Ore Mts. and Děčín Sandstone Upland.

The aluminium content was in the class of natural background (EC1) stands. Its upper limit exceeds 3% of values, but the highest value is only 109 μg/g (the Sněžník transect, 500 m a.s.l., III. age class). The Al maximum contents range just at the EC1 class limit (103 μg/g). Forest tree-species grow in relatively acid soils with a greater content of free Al^{3+} ions and are adapted sufficiently to these conditions (GÖRANSSON, ELDHUSET 1991). This is true also for birch. Al amounts found in birch leaves can be designated as natural ones. Content changes at individual elevations can be associated with different pH in the soil environment (Table 1) and, therefore, with the amount of free, available aluminium.

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Chemical composition of deciduous and coniferous vegetation, mosses and humus as environmental indicator in Slovakia

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ABSTRACT: Concentrations of Al, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, N, Na, Ni, Pb, Rb, S, Sr, V and Zn in the foliage of five species (*Pinus sylvestris* L., *Picea abies* Karst., *Abies alba* Mill., *Fagus sylvatica* L., *Quercus* sp.), three mosses (*Pleurozium schreberi, Hylocomium splendens* and *Dicranum* sp.) and humus from 3,063 plots are completed with their contents related to the limit values and composition of individual particles in stomata of leaves. In comparison 1991/94 for mosses reduced concentrations of Cd, Pb and Zn as well as increased concentrations of Cr, Cu, Fe and Ni were found.

Keywords: air pollution; foliage; humus; mosses

Prolonged effects of high concentrations of various pollutants have resulted in large-scale dying not only of conifers but also deciduous trees. The above-described conditions are not limited to the vicinity of pollution sources but have spread throughout Slovakia's territory long ago. Huge quantities of pollutants from abroad are also deposited in the Slovak territory, mainly from Poland, and Czech Republic from where they are carried by prevailing northerly, north westerly and westerly winds. Furthermore, it must be taken into account that Slovakia has a rugged topography. The highest altitudes reach 2,632 m and the tree limit (incl. dwarfed pine) 1,800 m. 85% of forest exhibited symptoms of damage (Green report 1995).

The earth's crust may be regarded as a natural reservoir of all chemical elements in the biosphere. 8 from a total of 88 natural elements make up more than 99 % of the earth's crust weight. Oxygen accounts for 46.4% of the crust, Si 28.15%, Al 8.23%, Fe 5.63%, Ca 4.15%, Na 2.36%, Mg 2.33% and K 2.09%. Oxygen is the only non metallic element among the eight most abundant elements in the earth's crust. All the other 80 elements combined make up less than 1%. Water is the main fraction of live organisms as they contain on average 85–90% of it. Dried bodies of plants are dominated by carbon (44.5%), oxygen (42.5%), hydrogen (6.5%), nitrogen (2.5%), phosphorus (0.2%), sulphur (0.3%), alkali metals and alkali-earth metals.

In contrast to the earth's crust, organisms are composed mostly of non metallic. Thanks to their increased contents in vegetation, nine elements are referred to as macro-elements. Elements whose concentrations in plants are lower but still are crucial for their life are called microelements. These comprise Cl (2,000 mg/kg), Si (1,000 mg/kg), Mn (200 mg/kg), Na (150 mg/kg), Fe (150 mg/kg), Zn (50 mg/kg), B (40 mg/kg), Cu (10 mg/kg), Cr (1.5 mg/kg), Mo (0.5 mg/kg), and Co (0.2 mg/kg). Both macro- and microelements are indispensable to growth and normal life of vegetation, and can be replaced by no other element. Therefore they are referred to as essential (MAŇKOVSKÁ 1996).

Concentrations of 26 elements (Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, F, Fe, Hg, K, Li, Mg, Mn, N, Na, Ni, Pb, S, Se, Sr, Rb, V, Zn) in the foliage, in forest tree species foliage stomata, differences in the content of elements in industrial areas, 2 national parks, military area, and heavy metal concentrations in the mosses (the difference 1991/94) and cover humus are presented.

MATERIAL AND METHODS

The foliage, mosses and cover humus were taken on monitoring plots from 3,063 plots, in accordance with the international methodology (ICP 1994). The samples were not washed before analysis. The samples were taken by monitoring specialists in August 1994, and mosses also in August 1991. The samples of foliage, mosses and cover humus were analysed for the concentration of following 26 variables in the laboratories of Dionýz Štúr Institute of Geology in Bratislava, Slovak Republic. The accuracy of the analytical data published in paper was verified and tested by 109 separate laboratories (HUNTER1994). The foliage of forest tree species was treated on surface by JEOL Ionsputtering. The foliage was evaluated by scanning microscope JEOL 400 A and X-ray analyser LINK 10000. The particles deposited in the stomata of foliage (external content) were assessed as to their morphology and EDX spectra (MAŇKOVSKÁ 1996). External presence

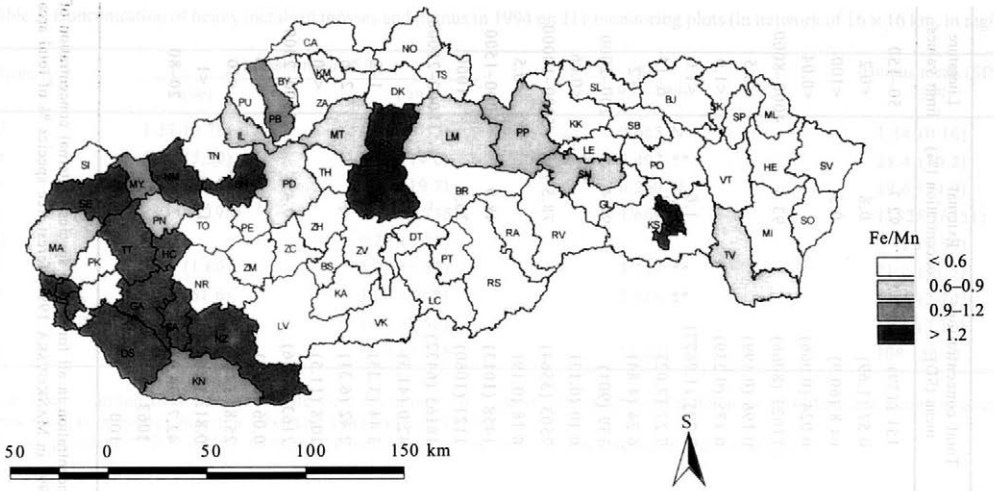

Fig. 1. Ratio Fe/Mn in the foliage of forest tree species for districts (limit value 0.5)

of individual elements on the stomata of foliage was evaluated separately. The samples were evaluated by common statistical methods.

RESULTS AND DISCUSSION

Total concentrations of the elements (mg/kg) studied in the foliage (*P. abies, P. sylvestris, A. alba, F. sylvatica* and *Quercus* sp.), external element concentration (in %) in the stomata of foliage and literature values are given in Table 1. Total content of heavy metals in mosses (*Pleurozium schreberi, Hylocomium splendens* and *Dicranum* sp.), statistical comparison (1991/94), and cover humus is given in Table 2. The assessment of heavy metals content in cover humus is problematic. The majority of literature data takes into account on the accumulation of elements in humus, and it is expressed for an area (kg/ha per year, or kg/m^2). It always depends on mass of humus. On 111 PMP the mass of humus for 1 ha varied form 0.3 kg/m^2 for broadleaves to 14 kg/m^2 for conifers. Forests cover about 20,000 km^2, what is approximately 41% of Slovakia's territory. Conifers make up 42.7% of all Slovak forests (spruce 26.8%, pine 7.7%, fir 5%, larch 1.9%, dwarf pine 1.0% and others 0.1%) and deciduous trees 56 % (beech 29.1%, oak 11.3% others 16 %) – Green report (1995).

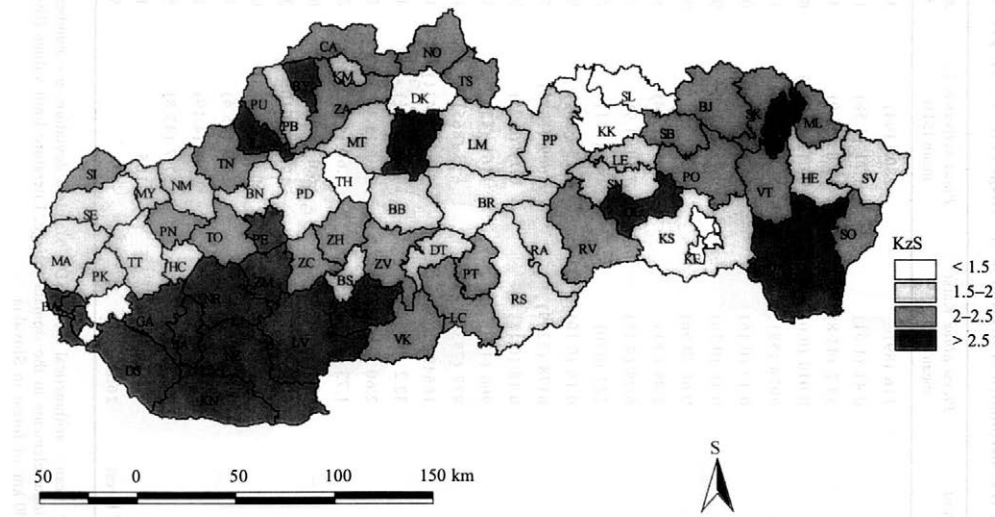

Fig. 2. Loading of foliage of forest tree species by sulphur for districts (limit for S 1,500 mg/kg = 1.5 KzS)

Table 1. Concentration of elements in the foliage of forest tree species on 3,063 monitoring plots (in network of 4 × 4 km, in mg/kg)

Element	*Picea abies* Karst. mean (SD)	*Pinus sylvestris* L. mean (SD)	*Abies alba* L. mean (SD)	*Fagus sylvatica* L. mean (SD)	*Quercus* sp. mean (SD)	Total concentrations mean (SD)	External concentration (%)	Literature limit values
Al	116 (89)	280 (194)	366 (181)	119 (84)	92 (53)	151 (139)	92.7	50–150
As	0.41 (1.51)	1.21 (3.58)	1.15 (2.61)	0.68 (1.44)	0.44 (1.11)	0.57 (1.69)	0.8	<0.2
Ba	53.2 (43.8)	15.8 (25.9)	35.6 (23.9)	100 (83.8)	82.3 (51.9)	64.8 (60.9)	0.5	<100
Be	0.010 (0.035)	0.012 (0.013)	0.012 (0.013)	0.027 (0.034)	0.029 (0.064)	0.024 (0.066)	–	<0.04
Ca	8078 (5815)	5950 (2498)	12774 (642)	13534 (7829)	12136 (5182)	11021 (8066)	93.4	4000–8000
Cd	0.19 (0.16)	0.22 (0.21)	0.26 (0.17)	0.19 (0.13)	0.12 (0.11)	0.196 (0.199)	–	<0.5
Co	0.16 (0.16)	0.22 (37)	0.24 (019)	0.12 (0.17)	0.17 (0.16)	0.175 (0.239)	–	<1.0
Cr	0.68 (0.96)	0.59 (37)	0.61 (0.76)	1.06 (2.89)	0.82 (1.11)	0.795 (1.7677)	1.6	<1.0
Cu	5.09 (.81)	8.67 (12.4)	8.15 (7.12)	10.0 (6.15)	9.30 (13.6)	7.27 (7.02)	0.4	6–14
F	6.28 (4.15)	7.80 (1.9)	8.34 (5.07)	5.84 (2.56)	4.74 (2.10)	6.24 (4.84)	–	<2
Fe	123 (370)	146 (111)	246 (105)	216 (1635)	131 (79)	159 (901)	94.4	200–2000
Hg	0.10 (0.10)	0.15 (0.40)	0.13 (0.15)	0.11 (0.11)	0.08 (0.09)	0.10 (0.13)	–	<0.06
K	6178 (3209)	5609 (1356)	5639 (1487)	9504 (2761)	9529 (2093)	7503 (3564)	78.5	5000–10000
Li	0.18 (0.18)	0.19 (0.25)	0.17 (0.25)	0.16 (0.14)	0.20 (0.18)	0.18 (0.19)	–	<0.5
Mg	966 (479)	1161 (422)	1088 (455)	1892 (771)	2003 (890)	1458 (1013)	48.9	1000–1500
Mn	977 (783)	635 (865)	1934 (1636)	1026 (970)	1650 ((1079)	1121 (1060)	20.0	1000
N	16645 (5221)	16631 (5431)	17921 (5470)	19754 (6755)	20923 (6170)	18165 (6432)	–	18000–25000
Na	32.2 (38.5)	42.7 (57.1)	43.4 (48.3)	58.5 (28.2)	39.8 (20.8)	42.0 (41.3)	15.0	
Ni	2.60 (2.45)	3.06 (3.44)	3.80 (2.38)	3.87 (3.38)	4.28 (3.08)	3.44 (3.33)	6.8	1–2
Pb	1.73 (2.70)	3.68 (4.48)	2.61 (3.06)	3.66 (11.3)	1.80 (3.85)	2.42 (6.31)	–	2–6
Rb	10.2 (10.0)	6.0 (5.0)	6.1 (7.3)	14.3 (15.3)	10.5 (7.5)	10.8 (11.5)	–	<10
S	1959 (851)	1952 (1010)	2203 (943)	2242 (923)	2236 (1088)	2163 (1056)	0.4	1300–2000
Se	0.048 (0.203)	0.069 (0.046)	0.074 (0.068)	0.058 (0.043)	0.053 (0.045)	0.06 (0.15)	–	0.03
Sr	22.7 (23.9)	10.0 (35.4)	19.9 (35.4)	29.3 (20.3)	21.3 (12.7)	25.85 (25.61)	–	<10
V	0.94 (3.20)	0.98 (4.19)	1.03 (2.10)	0.72 (2.19)	0.44 (1.10)	0.813 (0.612)	16.1	<1
Zn	42.3 (21.3)	57.7 (43.8)	56.9 (37.5)	41.0 (46.5)	25.6 (21.7)	42.7 (34.9)	2.6	20–80
n	1114	105	178	574	126	3063	3063	
% of forest	26.8	7.7	5	29.1	11.3	100	100	

Note: mean – arithmetical mean; SD – standard deviation; *n* – number of samples; Total concentration – arithmetical mean element concentration in all forest tree species, External concentration of individual elements in the stomata foliage, Literature limit values (BOWEN 1979; HUNTER 1994; ICP 1994; INNES 1995; MARKERT 1993 in MAŇKOVSKÁ 1996) forest tree species % of total area 20,000 km² of forest in Slovakia

Table 2. Concentration of heavy metals in mosses and humus in 1994 on 111 monitoring plots (in network of 16 × 16 km, in mg/kg)

Element	Mosses mean (SD)		SE	Humus mean (SD)
	1991	1994	1991/1994	1994
Cd	1.37 (0.78)	1.29 (0.52)	0.665 N	1.14 (0.16)
Cr	5.18 (5.30)	16.9 (14.6)	6.497 **	28.4 (10.2)
Cu	20.6 (11.5)	21.3 (19.7)	0.260 N	19.6 (34.9)
Fe	1878 (1198)	1459 (1735)	1.669 N	11825 (6251)
Hg	–	0.22 (0.72)	–	0.42 (1.50)
Ni	2.21 (1.60)	4.33 (5.20)	3.737 **	21.2 (11.5)
Pb	60.9 (61.6)	30.6 (25.2)	3.519 **	61.4 (2.70)
V	–	1.87 (3.50)	–	10.5 (7.10)
Zn	173 (87.3)	61.8 (37.1)	11.241 **	108 (56.4)

Note: mean – arithmetical mean; SD – standard deviation; SE – statistical evaluation of differences of arithmetical means of element concentration in mosses between 1991 and 1994 evaluated *t*-test
N – unsignificant, $^{**}P < 0.01\%$. mosses (*Pleurozium schreberi, Hylocomium splendens, Dicranum* sp.)

Stress ratio Fe/Mn in the foliage of forest tree species for districts are in Fig. 1 (limit value 0.5). Loading foliage by sulphur for districts are in Fig. 2 (limit value for sulphur is 1,500 mg/kg = 1.5 Kz S – coefficient of loading by sulphur). Nutrition ratio S/N are in Fig. 3 (limit value 0.06–0.09).

The equilibrium of individual elements in plants is a precondition of their normal growth. Similar chemical properties due to roughly equal ion radicals and charges probably cause interactions between individual elements in plant organisms. Synergic and antagonistic relationships between individual elements are disturbed by polluted atmosphere. Well-known are the correlation among P, N, K, Ca and Mg in 54 higher and lower plant species. P and N play role in protein biosynthesis, while Ca and Mg are common enzymatic activator in metabolic physiological processes. Surprisingly, in contrast to data presented by MARKERT (1993), only highly positive correlation pairs ($r > 0.9$) of locally emitted elements were found in aluminium plant for Cr/Pb, magnesite plant Mg/S, metallurgy complex As/Cr, Al/Pb, and in military area for Cu/Na. In the National Park Low Tatras only positive correlation between Cr and Fe, in High Tatras National Park between As and Cu was found. No negative correlation was found among pairs of elements with r exceeding or equalling –0.9. External concentration and higher standard deviation in industrial areas confirm an effect of polluted air.

CONCLUSION

It was determined on the basis of monitoring performed on 3,063 plots in the foliage of forest tree species in Slovakia:

1. The average of element concentrations in the foliage of forest tree species was (in mg/kg): Al (151), As (0.57), Ba (65), Be (0.02), Ca (11,021), Cd (0.20), Co (0.18), Cr (0.80), Cu (7.3), F (6.2), Fe (159), Hg (0.10), K (7,503), Li (0.18), Mg (1,458), Mn (1,121), N (18,165), Na (42.0), Ni

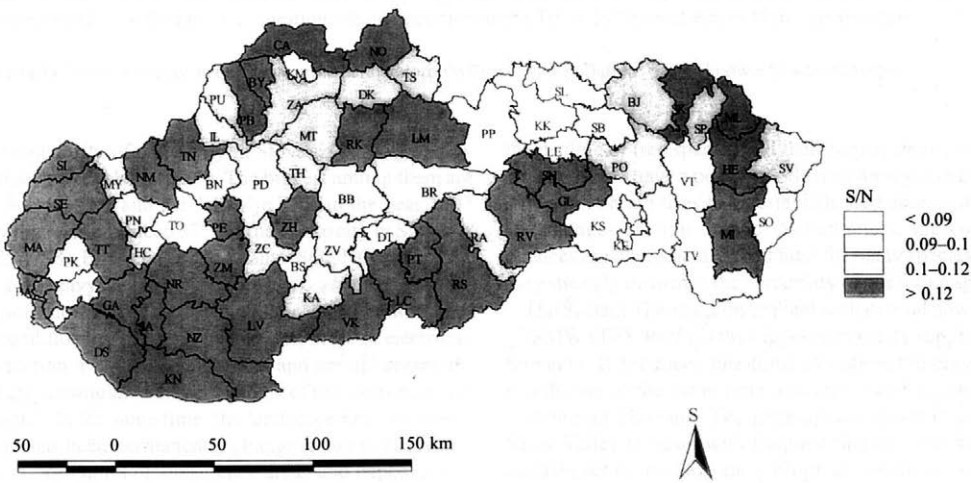

Fig. 3. Ratio S/N in the foliage of forest tree species by sulphur for districts (limit value 0.06–0.09)

(3.44), Pb (2.42), Rb (10.8), S (2.163), Se (0.06), Sr (25.9), V (0.81) and Zn (42.7).

2. Foliage surface of forest tree species contained aluminium as a part of minerals, ashes (Al, Si) and particles Al_2O_3 (vicinity of aluminium plant; iron as a part of particles of minerals, ashes and Fe_2O_3 (vicinity of metallurgy complex and thermal power plant); potassium as a part of mineral and biological particles and Mn, Na, V, Ni, Zn, Cr, As, Ba and Cu were found in the vicinity of non-ferrous plant. This fact is important for the assessment of elements with a significant nutritive value.
3. More than 75% of foliage surface contained Fe, Ca, Al, K. The absolutely highest values of Al, Ba, Be, F, K, and Li were found in the vicinity of aluminium plant; Co, Mg, Rb, and V in the region of magnesite plant; As, Cu, Hg, S, Se, and Zn in the region of non-ferrous metallurgy + mercury plant; Cd, Fe in the vicinity of ferrous metallurgy; N and Sr from military area and Ca, Cr, Ni from the National Park Low Tatras.
4. Mosses and cover humus are sensitive bioindicators of anthropogenic pollution in the atmosphere. In comparison with the content of heavy metals, with exception of cadmium-cover humus, always contained more of such elements than mosses. In comparison with 1991/1994 In comparison 1991/94 the content of Cd, Pb, Zn was reduced and the contents of Cr, Cu, Fe, Ni were increased.

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Biomonitoring of forest ecosystems in areas influenced by the Šoštanj and Trbovlje Thermal Power Plants

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ABSTRACT: Monitoring of the influence of the Šoštanj Thermal Power Plant started in 1987. The condition of the forest ecosystem was evaluated by the analysis of Norway spruce (*Picea abies* [L.] Karst.), the most common Slovenian forest tree species. Reduced sulphur dioxide emissions after desulphurization of exhaust gases from Unit 4 of the Šoštanj Thermal Power Plant resulted in a smaller annual mean ambient air concentration of sulphur dioxide and a correspondingly lower accumulation of sulphur in spruce needles after the year 1995. In the period 1995–1999 both increased defensive mechanisms and better vitality were observed in spruce, as shown by an increase of ascorbic acid in needles in comparison with the previous years. The improvement was partly attributed to the reduced emissions from the Šoštanj Thermal Power Plant and partly to more favourable climatic conditions after the year 1995. Increasing vitality of spruce is a general trend in Europe, as is shown by ten years of forest dieback inventories in 34 European countries. In 1999, we expanded our research project to the Zasavje region, which is also highly polluted by sulphur dioxide. Three sampling sites were chosen in the surroundings of the Trbovlje Thermal Power Plant, which operated without a desulphurization device. The forest ecosystem conditions were assessed by physiological indicators of stress (contents of photosynthetic pigments, ascorbic acid, α-tocopherol, water soluble thiols, total sulphur content) and soil analyses (pH, organic matter, soil sorption ability, phosphorus and potassium). The results showed forests to be highly affected by sulphur dioxide, with a high accumulation of sulphur and a low content of chlorophyll in current year's spruce needles. Soils were very acid at two sampling sites in Zasavje and soil sorption ability was low. Phosphorus and potassium were low as well. The results reveal that the ecological improvement programme of the Šoštanj Thermal Power Plant, on which 360 million DEM has been spent, has resulted in a decrease of the negative impact on forest ecosystems. The desulphurization device on Unit 5 of the Šoštanj Thermal Power Plant, which also includes reconstruction of the electrofilters, is going to start working at the beginning of September 2000. With the introduction of primary measures for reducing concentrations of gases, particulates and wastewaters, the ecological sanation plan for the Šoštanj Thermal Power Plant is complete. Accordingly the basic ecological parameters should correspond to the demands of ISO 14001, IPPC and BAT. Electricity generation in the Šoštanj Thermal Power Plant is adapted to new European market challenges, but questions about operation of the Trbovlje Thermal Power Plant remain open.

Keywords: Norway spruce needles; ascorbic acid; chlorophylls; sulphur pollution; thermal power plants; Slovenia

The majority of electricity in Slovenia is produced by thermal power plants (TPP). The biggest among them are the Šoštanj TPP and the Trbovlje TPP, in the year 1997 they together produced 37% of the electricity in Slovenia (TEŠ 1998). Emissions of pollutants (SO_2, NO_x, CO_2, CO, O_3, HF, heavy metals, radionuclides), which pollute the air, soil and water and consequently change environmental conditions, are in proportion to the scale of electricity production. Pollutants enter plant and animal organisms and are accumulated in the final link of the food chain (i.e. human). At the same time, the landscape near the power plants has been permanently changing due to coal excavation, formation of subsidence areas and deposition of waste products. Soil erosion is very frequent because of the decline of tree species and their root systems, which retain soil and have a positive influence on water cycling. However, nature tries to re-establish the balance unless the changes are too drastic. Nevertheless, the consequences are unpredictable and fatal for many species and they strongly influence the variability of our living space.

The Šoštanj Thermal Power Plant with its total power of 775 MW (TEŠ 1995) is the biggest electricity supplier in Slovenia. It produces one-third of national energy demands, but at the same time it is one of the biggest air polluters in Slovenia. The geographical position of the Šalek Valley (a basin with frequent thermal inversions) contributes to the delicate ecological conditions in the area. The hilly surroundings of the Šalek Valley, espe-

cially areas at altitudes between 900 m and 1,000 m above sea level, are particularly sensitive to air pollution (HRČEK1988). Therefore, a remediation programme for the Šoštanj TPP was adopted in 1987; it anticipated reduction of emissions to the air (dust, sulphur dioxide and nitrogen oxides), reduction of water pollution, as well as monitoring of air quality at different locations in the Šalek Valley and its surrounding hills. From 1990 onward additive desulphurization has reduced the emission of sulphur dioxide by approximately 30%. On Unit 4, the reduction of sulphur dioxide emissions was achieved by some primary measures, while dust emissions were reduced by more powerful electrofilters. In 1995, the desulphurization device on Unit 4 enabled the reduction of sulphur dioxide emission from the Šoštanj TPP by more than 35,000 tons per year; this is equivalent to a 40% reduction of the total sulphur dioxide emissions from the power plant. Moreover, the desulphurization device on Unit 5, the largest unit, started its testing in September 2000. Following its permanent operation the emissions of sulphur dioxide will be reduced to 10,000 tons per year.

The Trbovlje TPP has a long lasting tradition of electricity generation; the Trbovlje coal-mine enterprise started to use electricity for coal excavation as early as 1893. The capacity of the power plant increased over the years and with the construction of the Trbovlje Thermal Power Plant 2 it reached 125 MW in 1968. This power plant is the largest point pollution source in the Zasavje region; its activity intensely affects the quality of the human environment, mostly by air pollution. In the seventies the concentrations of sulphur dioxide in the most exposed areas exceeded the upper detection limits of measuring instruments. The highest concentrations of sulphur dioxide were about 15,000 $\mu g/m^3$ (MAČEK et al. 1972), or even up to 20,000 $\mu g/m^3$ (PARADIŽ 1972). The consequences of excessive emissions of toxic substances in exhaust gases can be seen in the evident degradation of the human environment. Therefore, the subsequent development of the Trbovlje Thermal Power Plant was based on gradual ecological sanation. The first phase in the middle seventies included the construction of a 360 m high chimney and revitalisation of former strongly degraded area in the vicinity of the Trbovlje TPP. The direct influence of the power plant on the nearby environment was reduced tolerably since gases became diluted and spread over the wider region. The second phase included the construction of a gas unit and cessation of production of Thermal Power Plant 1 (which emitted large amounts of sulphur dioxide and dust). The final phase should have included ecological sanation of the Thermal Power Plant 2 and the construction of a new unit of the Thermal Plant Power, the Heating Plant. Additionally, the reduction of dust, nitrogen oxides as well as the construction of a desulphurization device were provided. In 1995, a sanation programme was introduced, containing the replacement of electrofilters and the steam system; some primary measures were introduced as well. By taking these steps, the plant fulfilled the requirements for fly ash, while NO_x emissions should remain below permitted levels for 98% of the operation-time. Among the pollutants SO_2 is the most problematic one because its concentrations grossly exceed the permitted criteria. To achieve the regulation criteria it would be necessary to clean-up gases with 90% effectiveness. This level could be provided only by constructing a cleaning device for desulphurization of gases or replacing the combustion technology (new furnace and steam generating building). Neither the construction of the cleaning device nor the programme for construction of a new building were approved due to the short future life of the plant. Consequently, SO_2 emissions from the Trbovlje Thermal Power Plant 2 (Table 2) are still exceeding the regulative criteria which will be put into force for old buildings in the year 2004. Those criteria depend on sulphur content in coal, as well as the number of operating hours (ČUHALEV 1997).

MATERIAL AND METHODS

In the Šalek Valley, Norway spruce (*Picea abies* [L.] Karst.) has been used as a bioindicator of sulphur burdens in the environment since1987 (RIBARIČ-LASNIK 1991, 1996; RIBARIČ-LASNIK et al. 1996, 1999a,b). In 1999, spruce was also sampled in the Zasavje region, where ecological studies were scarce in the past. However, the earliest studies on spruce in this region date back to the late eighties (ŠOLAR 1989, 1991, 1992); these works were limited to the assessment of trees damage on the basis of visible injuries (defoliation, colour and shape of needles, quality of the crown and branches) and on measurement of the sulphur content of needles. Those results revealed that spruce from the Zasavje region was 2 to 3 fold more damaged when compared to the Slovene average. This fact was confirmed by chemical analyses as well as by data on ambient levels of pollutants. In the period 1995–1997, bio-

Table 1. Emissions of SO_2 from the Šoštanj TPP in the period 1991, 1999 t/year (Šoštanj Thermal Power Plant annual report 2000)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999
Annual emissions	80,757	94,120	86,101	80,516	51,663	51,804	53,095	55,053	47,665

Table 2. Emissions of SO_2 from the Trbovlje TPP in the period 1991, 1999 t/year (Trbovlje Thermal Power Plant annual report 2000)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999
Annual emissions	21,938	28,752	23,453	28,688	25,600	22,852	31,244	33,372	30,229

indication methods were employed to ascertain the level of air pollution and to assess the extent of the area influenced by the Trbovlje Thermal Power Plant (VIDERGAR-GORJUP 1998). The majority of spruce observed were classified in the category of heavy damaged trees, as defined by Slovene methodology (KOVAČ et al. 1995) of forest tree damage assessment. Deficiency of at least one nutrient was found in spruce needles, the consequence of poor mineral availability and disturbances in metabolism due to the effects of pollution. Moreover, the analyses of photosynthetic pigments and ascorbic acid revealed the huge impact of polluted air (VIDERGAR-GORJUP 1998).

In 1999, we selected 15 sampling sites as stated below:
- in the area influenced by the Šoštanj Thermal Power Plant: Lajše, Topolšica, Laze, Veliki Vrh, Graška Gora, Razborje, Brneško sedlo, Kramarica, Kope, Smrekovec;
- in the area influenced by the Trbovlje Thermal Power Plant: Kovk, Dobovec, Ravenska vas;
- on the Pokljuka high plateau (control area).

Weather stations at which concentrations of the most important pollutants (sulphur dioxide, nitrogen oxides, ozone) in the air have been measured continuously are located in the close vicinity of some sampling sites. At those stations some microclimatic parameters (relative humidity of the air, temperature) are measured as well. At each sampling site five spruce trees (60 to 100 years old, visually of good vitality) were chosen. From each tree, we collected needles from the seventh spindle of branches from the top. In needles, we measured the contents of photosynthetic pigments, ascorbic acid, α-tocopherol, sulphur and thiols. The methodology of sample collection and sample preparation was described by BERMANDINGER et al. (1990); a detailed description can also be found in BATIČ et al. (1995) and RIBARIČ-LASNIK (1996). Contents of photosynthetic pigments (chlorophyll *a* and *b*, α- and β-carotene, zeaxanthine, lutein), ascorbic acid and α-tocopherol were determined by HPLC, while the content of thiols was measured by spectrophotometry with addition of DTNB (Ellman-Reagens), following the method described by GRILL and ESTERBAUER (1973) and GRILL (1992). Total sulphur was determined by an AOX-S analyser (coulometric titration).

RESULTS

The average annual sulphur emissions from the Šoštanj Thermal Power Plant have decreased since 1995, when desulphurization started on Unit 4. On the contrary, emissions from the Trbovlje Thermal Power Plant have been increasing in the same period (Table 1 and 2). Our results are in concordance with the emission data. In the Šalek Valley, the sulphur content in spruce needles has been decreasing since 1995 (Fig. 7). Nevertheless, the average contents of sulphur in needles of five spruces in 1999 at all but one sampling site (Laze) were still above normal levels, defined as 0.97 mg/g. The sulphur content is the highest at those sites, which are situated closest to the power plant (Veliki Vrh) or whose altitude coincides with the thermal inversion (Zavodnje). High sulphur contents were found at sampling sites situated in the Zasavje region (Dobovec, Ravenska vas), where the average sulphur content is higher in comparison with the Šalek Valley, while the lowest content was measured on the Pokljuka hight plateau (Fig. 1). However, it should be mentioned that three sites at the Zasavje region were not chosen randomly, but had been previously revealed as the most polluted locations in the region (VIDERGAR-GORJUP 1998).

The content of sulphur increases with age, therefore one-year-old needles contain more sulphur in comparison with current year needles. The high content of sulphur at the Veliki Vrh sampling site indicates that this location is burdened with sulphur dioxide. The conclusion is confirmed by contents of water soluble thiols (Fig. 2) and ascorbic acid (Fig, 3), which increase with altitude as well as with air pollution. The highest contents of thiols and ascorbic acid were measured in samples from Veliki Vrh, where sulphur content in needles and SO_2 concentrations in the air are also the highest in the Šalek Valley.

The improvement of spruce condition in the Šalek Valley after 1995 is also confirmed by a more effective defence ability (higher content of ascorbic acid) and better vitality of trees (higher contents of chlorophyll *a* and *b*). Content of ascorbic acid has been increasing continuously (Fig. 9). The content of total chlorophyll in 1999

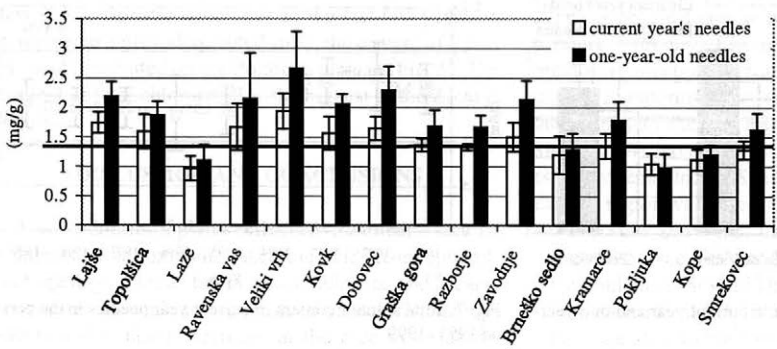

Fig. 1. Sulphur content in current year and one-year-old needles at all sampling sites, sampled in 1999

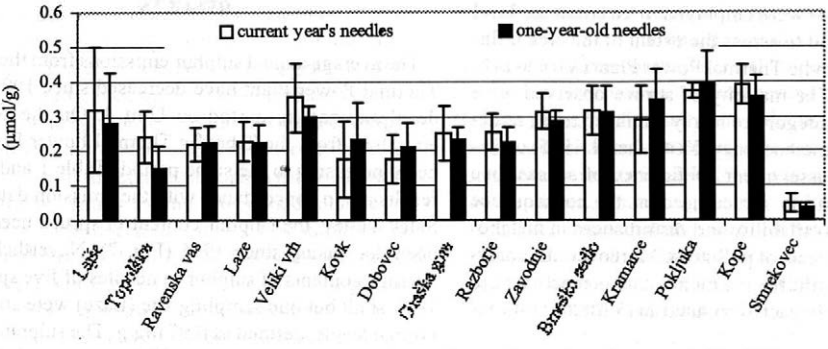

Fig. 2. Water soluble thiols in current year and one-year-old needles at all sampling sites, sampled in 1999

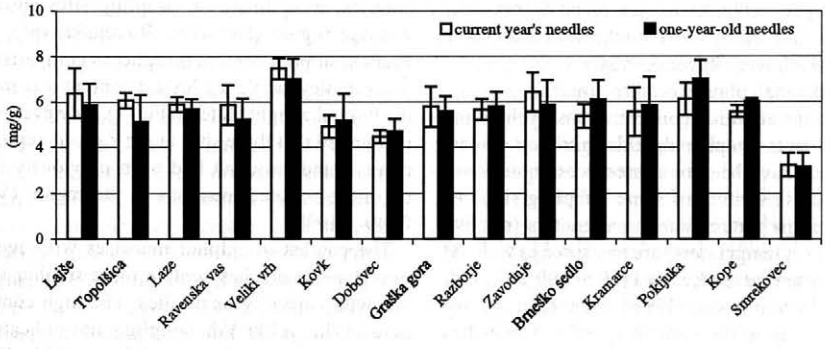

Fig. 3. Ascorbic acid in current year and one-year-old needles at all sampling sites, sampled in 1999

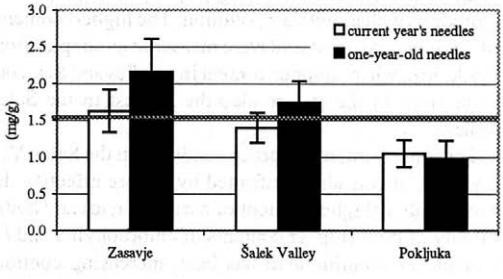

Fig. 4. Sulphur content in current year and one-year-old needles, sampled in 1999

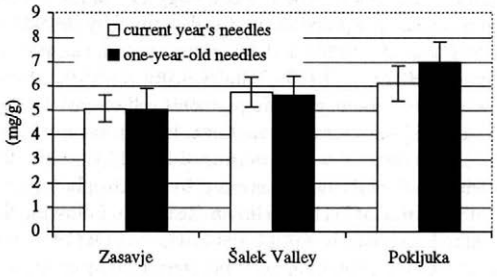

Fig. 5. Ascorbic acid content in current year and one-year-old needles, sampled in 1999

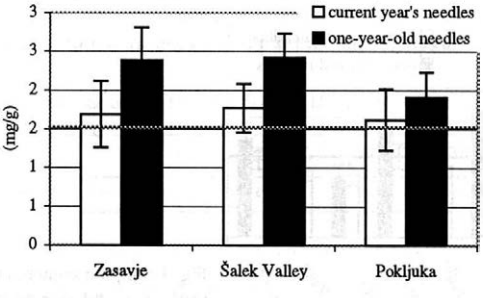

Fig. 6. Total chlorophyll content in current year and one-year-old needles, sampled in 1999

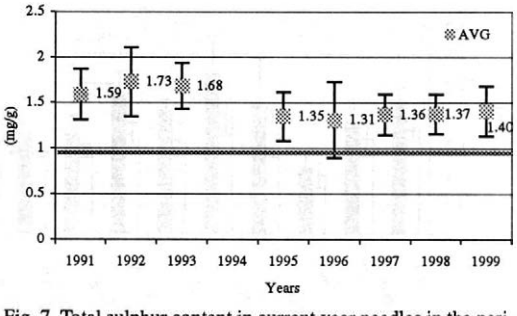

Fig. 7. Total sulphur content in current year needles in the period 1991–1999

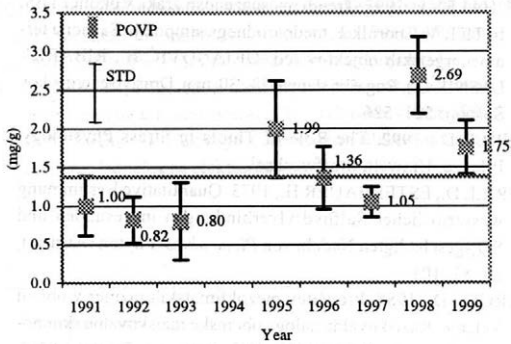

Fig. 8. Total chlorophyll ($a + b$) content in current year needles in the period 1991–1999

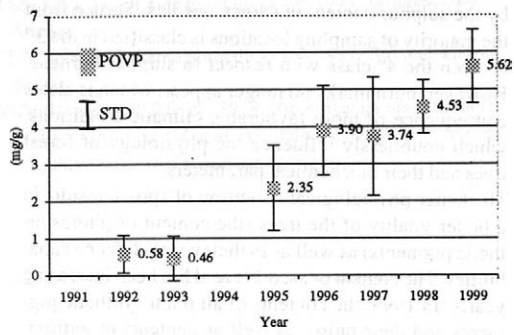

Fig. 9. Ascorbic acid content in current year needles in the period 1991–1999

Table 3. List of sampling sites with their altitudes, average annual concentrations of SO_2, and sulphur content in current year needles (1999) with corresponding classes

Sampling site	Altitude (m)	Mean annual SO_2 concentration ($\mu g/m^3$)	Total sulphur content (mg/g) in the current year needles	Class of total sulphur content in the current year needles
Lajše	400	–	1.74	4
Topolšica	400	17	1.59	4
Laze	460	–	0.97	1
Ravenska vas	480	57	1.67	4
Veliki vrh	570	72	1.94	4
Kovk	590	57	1.56	3
Dobovec	700	41	1.65	4
Graška gora	730	32	1.37	3
Razborje		–	1.33	3
Zavodnje	760	42	1.50	3
Brneško sedlo	1,030	–	1.20	2
Kramarica	1,070	–	1.35	3
Pokljuka		–	1.05	2
Kope	1,400	–	1.12	2
Smrekovec	1,555	–	1.29	3

was lower than in the year before, but was still above 1.5 mg/g (a figure indicating tree injury; KÖSTNER et al. 1990). However, the improvement of spruce vitality in the Šalek Valley is doubtlessly also the consequence of the favourable climatic conditions in the last few years. In comparison with both polluted areas, the content of ascorbic acid is elevated on the Pokljuka plateau (Fig. 5). The content of total chlorophyll is the highest at the Zasavje region.

DISCUSSION AND CONCLUSIONS

The conditions of plants reflect environmental factors. Contents of antioxidants (ascorbic acid, α-tocopherol) and ageing pigments (lutein, zeaxanthine, α- and β-carotene) increase while the contents of photosynthetic pigments (chlorophyll) decrease in the case of oxidative stress. A very powerful indicator of air pollution with SO_2 is the sulphur content in spruce needles. Stress can be the consequence of disturbances in metabolism due to pollutants (SO_2, NO_x, CO_2, CO, O_3, HF, heavy metals, radiation) or physical environmental factors (sunlight, temperature, humidity). The aim of our study was to use the previously mentioned indicators of stress for ascertaining and monitoring the condition of forest ecosystems in the vicinity of the two biggest thermal power plants in Slovenia. We have been monitoring the condition of forest ecosystems since 1987 in the Šalek Valley, while in the Zasavje region we started sampling in 1999.

– Our results show that the conditions of spruce have improved since 1995, when the desulphurization device was built in the Šoštanj Thermal Power Plant. Nevertheless, emission of SO_2 from the plant is still too high for the vegetation in the Šalek Valley, which is confirmed

by the sulphur content in spruce needles. Spruce from the majority of sampling locations is classified in the 3rd or even the 4th class with respect to sulphur burdens. However, burn marks no longer appear, which is also a consequence of more favourable climatic conditions, which doubtlessly influence the physiology of forest trees and their biochemical parameters.

- The better physiological condition of spruce results in a better vitality of the trees (the content of photosynthetic pigments) as well as in their rising defence capabilities. The content of ascorbic acid has been increasing yearly. In 1999, the contents of all photosynthetic pigments and their ratios, as well as contents of antioxidants and their ratios, were within normal levels. The normal trends of increasing antioxidant content and decreasing content of photosynthetic pigments with altitude were perceived. However, air pollution influences the contents of antioxidants and chlorophyll at lower altitudes. Therefore, although the sampling site at the Veliki Vrh has a low altitude, contents of thiols and ascorbic acid are high in spruce needles from this location. Moreover, the sulphur content in one-year-old and current year spruce needles are elevated as well, which is the consequence of high ambient concentrations of SO_2 at the Veliki Vrh.
- Since there has been no ecological sanation for reducing emissions of SO_2 in the Zasavje region, emissions from the Trbovlje Thermal Power Plant have been even increasing. Heavy pollution affects the condition of forest ecosystems, and therefore it is not surprising that the sulphur content in spruce needles is elevated in comparison with the Šalek Valley. Nevertheless, the physiological condition of spruce trees is good as we can conclude from the contents of total chlorophyll in current year needles, which exceed 1.5 mg/g, the limit value beyond which tree injuries occur. Once more, the favourable climatic conditions have contributed to the good physiological condition of the trees.
- The trend of increasing spruce vitality after 1995 is also confirmed by the results of ten-years monitoring of forest dieback in 34 European countries. On the basis of several yearsof forest ecosystems monitoring we can conclude that the forest condition is a result of natural and anthropogenic factors as well as their combination, which is very variable over space and time. However, it is important which factor is predominant and thus the most influential for the condition of the forest ecosystem.

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Nutrient conditions for spruce (*Picea abies* [L.] Karst.) in the area affected by a Thermal Power Plant in Slovenia

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ABSTRACT: Although the trends of SO_2 emissions in Europe are declining, the problem of sulphur pollution in particular areas in Slovenia is still acute. Spruce needles samples were collected from a control plot at Prednji vrh, 8 km from the Šoštanj Power Plant in the northern Slovenia. Over the one-year period the annual cycles of nitrogen, phosphorous, potassium, calcium, magnesium and sulphur content were studied in spruce needles in the polluted area and on another control plot within the relatively unpolluted Pokljuka plateau. The content of sulphur in current-year and one-year-old spruce needles was high (2.39 mg/g d. w.) and indicate increased sulphur immission. The N/S ratio (below 8) shows an inharmonious nutrition status for spruce due to high sulphur content and lack of nitrogen. In the polluted area, sulphur content increased monthly with needle age even in winter, while in the unpolluted area it was constant. Differences between sulphur content in current-year and one-year-old needles were expressed in the polluted area. The annual cycles for other macronutrients (N, P, K, Ca and Mg) were similar for spruces in both the polluted and unpolluted areas.

Keywords: spruce; mineral nutrition; annual cycles; SO_2 immissions; Slovenia

Although the trends of SO_2 emissions in Europe are declining, the problem of sulphur pollution in particular areas in Slovenia is still very acute due to high-intensity short-term SO_2 immissions particularly in the very early stages of needle growth. A study was conducted to investigate the mineral nutrition status of Norway spruce in the area affected by the Šoštanj Power Plant in the northern Slovenia. The aim of the study was to determine the status and annual cycles of macronutrients (N, P, K, Ca, Mg and S) for spruce in a rather polluted area near TPP Šoštanj and in a less polluted area on the Pokljuka plateau (Triglav National Park). Beside plant material analysis and the examination of forest soil, bulk and throughfall deposition and soil solution were carried out in the period 1994–1998 at the Prednji vrh, 8 km from the Šoštanj Power Plant (Simončič 1996).

Analyses of spruce needles are usually used for assessment of tree nutrition status. Determination of soil fertility with soil and foliar analysis gives information about site conditions, properties and nutrients accessibility for trees. In polluted areas, the content of macronutrients (sulphur and nitrogen accumulation) and heavy metals in spruce needles are indicators of atmospheric pollution, particularly in case of SO_2 and NO_x immissions (Fiedler, Thakur 1985; Huttunen et al. 1985; Materna 1985; Wyttenbach, Tobler 1988; Hüttl 1991, 1992). Forest soil degradation processes as a consequence of atmospheric pollution could result in nutrient deficiency or unbalanced tree nutrient status, which could diminish tree vitality. The ratio between macronutrients in tree needles could be an indicator of nutritional disharmony (Schultze et al. 1989; Landman et al. 1995). Time series of nutrients are important for sampling time determination and for knowledge of nutrient behaviour under different site conditions (Höhne 1964; Komlenović 1973; Wyttenbach, Tobler 1988; Ratio, Merilä 1998).

METHODS

Spruce needle samples for the determination of nutrient status were taken in autumn 1994 from the seventh whorl of five healthy approximately eighty-year-old spruces at the Prednji vrh (polluted area) and at the plot on the Pokljuka plateau (unpolluted area). Spruce needles for the determination of seasonal variation of nutrients were taken every fourteen days from the seventh whorl of two approximately twenty-five-year-old spruces growing in the very vicinity of the plots at the Prednji vrh and Pokljuka. The samples were taken from the sun-exposed part of the crown. The sampling period was from June 1993 to July 1994.

Afterwards the needles were oven-dried (60°C for 24 hours) and ground. The total S content was determined using a Sulhomat 12-ADG, total N by the micro-Kjeldahl method, total P spectrophotometrically, K, Ca, Mg, with AAS. Foliar samples were mineralised by wet digestion with $HNO_3/HClO_4$ (5:1). Emissions and ambient levels of pollutants were measured by the power plant's ecological team using standard methods. The entire methodology (crown condition assessment and foliar chemical content) was harmonised with the ICP forestry methodology (Wyttenbach, Tobler 1994).

Table 1. Stand and site characteristics (SIMONČIČ 1996)

Plot	Pokljuka	Prednji vrh (near TPP)
Species	Norway spruce	Norway spruce
Altitude	1,200 m	800 m
Annual precipitation	~ 2,000 mm	~ 1,500 mm
Average T	3.1°C	~ 7°C
Soil type	distric cambisol, podsol	distric cambisol
Parent rock material	mixed moraine	tonalite
N-(NO_3+ NH_4)	~ 11 kg/ha per year	~ 15 kg/ha per year
S-SO_4	~ 11 kg/ha per year	~ 30 kg/ha per year

RESULTS AND DISCUSSION

Average macro nutrient contents and nutrient ratios for N, P, K, Ca and S for current-year needles sampled in autumn 1994 are presented in Table 2. For the determination of optimal nutrition status for spruces, modified literature values (SIMONČIČ 1997) according to GUSSONE (1964), HÜTTEL (1991) and STEFAN et al. (1997) were used. Estimation of tree nutrition status indicated slight nitrogen deficiency on the plot at the Prednji vrh and adequate status for phosphor, potassium, calcium and magnesium on both plots. Total sulphur content in current-year spruce needles on the Pokljuka plot is consistent with the background for Slovenia. Sulphur content in foliar samples from the Prednji vrh is extremely high and indicates extreme sulphur immissions. The nitrogen sulphur ratio for spruce needles from the Prednji vrh (below 8) indicates an inharmonious nutritional status. According to the literature, favourable mineral nutrition ratios for spruce (HÜTTL 1991, 1992) are: N/P ≈ 6–12, N/K ≈ 1–3, N/Ca ≈ 2–20, N/Mg ≈ 8–30, N/S > 8. The ratios which are given in Table 2 1 indicate the relatively harmonious nutritional status for the spruces at the Prednji vrh (except for sulphur) and Pokljuka.

The annual cycles of total sulphur, nitrogen, potassium, phosphorus, calcium and magnesium content (mg/g d. w.) in spruce needles for the Pokljuka plateau and the Prednji vrh plots are presented in Fig. 1a–h.

Needles from 1993 were the most relevant for the investigation of nutrient annual cycles. At the beginning of needle growth the sulphur content was high (on both plots); after first month the content was lower. At Pokljuka there are very small differences between sulphur content in current-year and one-year-old spruce needles, in some cases the difference is even negative (Fig. 2). Differences in sulphur content between current-year and one year-old spruce needles are much more expressed at the Prednji vrh plot, in the polluted area. The annual sulphur

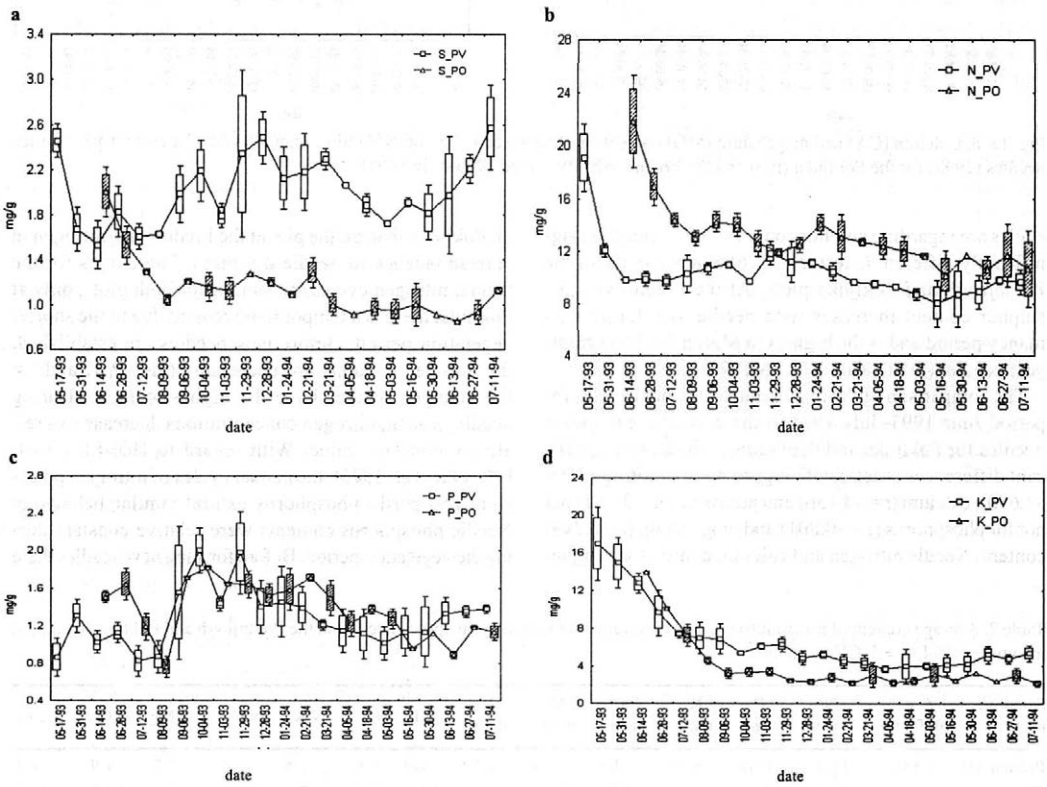

Fig. 1a–d. Sulphur (S), nitrogen (N), phosphorus (P), potassium (K), content (mg/g d.w.) and N/S and N/P ratio's annual cycles for current-year spruce needles (1993) for the Pokljuka (PO) and the Prednji vrh (PV) (June 1993–July 1994)

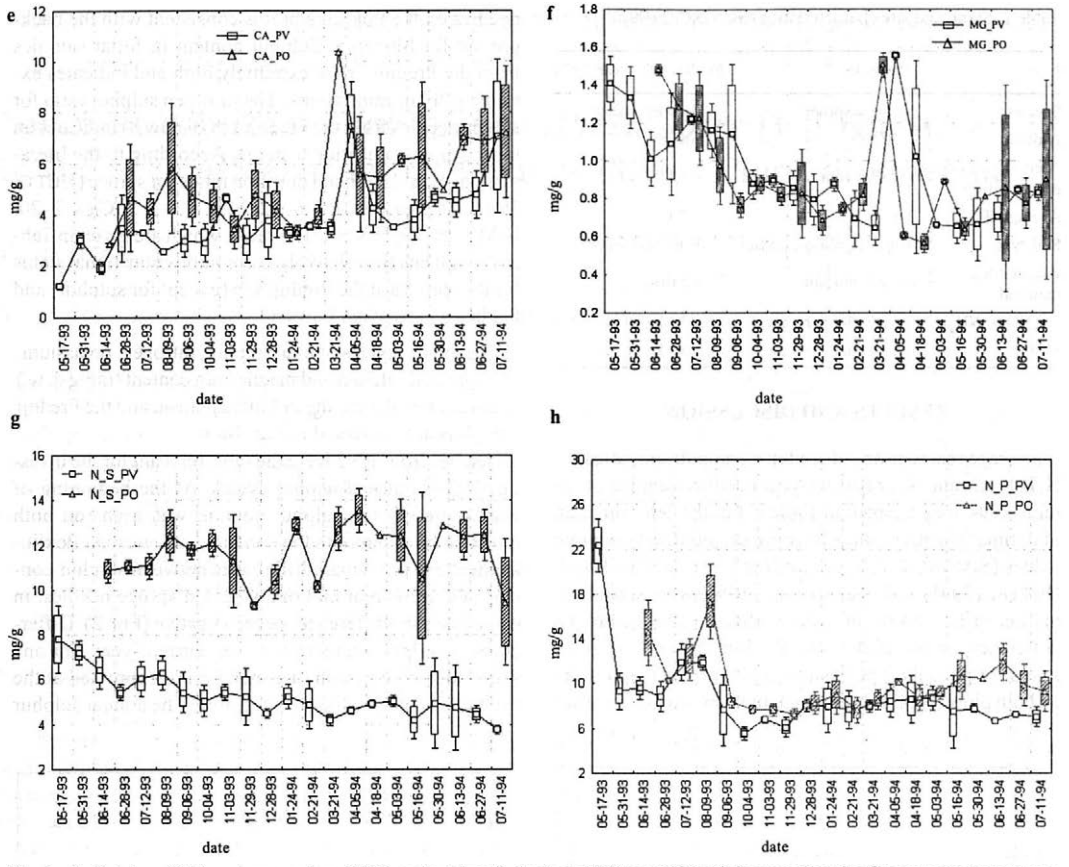

Fig. 1e–h. Calcium (CA) and magnesium (MG) content (mg/g d.w.) and N/S and N/P ratio's annual cycles for current-year spruce needles (1993) for the Pokljuka (PO) and the Prednji vrh (PV) (June 1993–July 1994)

cycles are regarding sulphur content (1993 – needles) significantly different (t-test, $t = 12.666$, $p = 0.000$) for the Prednji vrh and Pokljuka plots. At the Prednji vrh, the sulphur content increases with needle age during dormancy period and is the highest in March for the current-year needles (SIMONČIČ, KALAN 1996).

The comparison of the macro nutrient annual cycles for period June 1993–July 1994 in the current year spruce needles for Pokljuka and the Prednji vrh showed significant differences (t-test) with regard to total nitrogen ($t = -4.690$), calcium ($t = -4.136$) and potassium ($t = 3.381$) but not for phosphorus ($t = -0.801$) and magnesium ($t = 0.249$) content. Needle nitrogen and calcium contents are higher on Pokljuka than on the plot at the Prednji vrh, nitrogen in correspondence to needle dry mass. The curves for the annual nitrogen cycles are similar for both plots, only at Pokljuka there is a temporal movement due to the shorter vegetation period. Before new needles are established, the nitrogen contents are decreasing (also P, K and S); the younger needles have the highest content. During needle growth, nitrogen concentrations decrease to a relatively constant value. With regard to HÖHNE (1964, FIEDLER et al. 1973), the annual cycles of nitrogen, potassium and partly phosphorus exhibit similar behaviour. Needle phosphorus contents were relative constant during the vegetation period. Before forming new needles there

Table 2. Average content of macronutrients and their ratios for current-year spruce needles at the Prednji vrh and Pokljuka (sampled in autumn 1994, $n = 5$, CV % values)

Sampling plot	d. w. 1,000*mg	N mg/g	P mg/g	K mg/g	Ca mg/g	Mg mg/g	S mg/g	N/P	N/S	N/K	N/Ca	N/Mg	K/CA	K/MG
Prednji vrh	4.384	11.1	1.40	3.90	4.09	1.54	2.39	7.9	5.0	2.8	2.7	7.2	0.9	1.8
CV (%)	36.2	15.8	18.6	37.7	29.2	10.4	20.5	16.6	24.7	57.9	33.9	21.1	20.2	28.4
Pokljuka	3.198	12.7	1.22	6.94	3.96	0.84	1.04	10.4	12.2	1.8	3.2	8.6	1.7	8.3

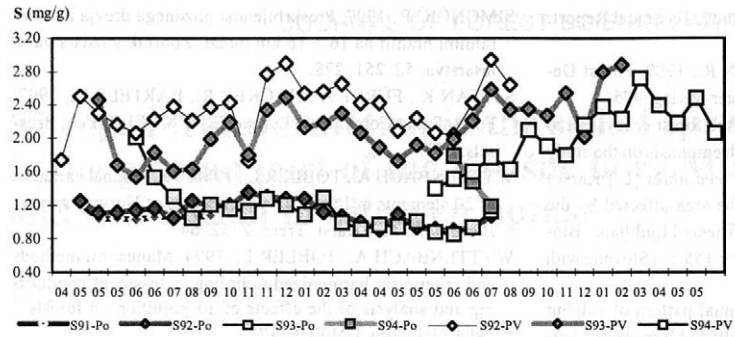

Fig. 2. The annual cycle of sulphur content (mg/g) in current and one-year old spruce needles from Pokljuka (S92-Po, S93-Po, S94-PV) and from the Prednji vrh (S92-PV, S93-PV, S94-PV)

was a minor decrease of phosphorus, and afterwards again an increase. The annual cycles of phosphorus, potassium, calcium and magnesium are very similar for both plots. Ca is accumulated during ageing of spruce needles. The annual cycles of Mg, following Höhne (FIEDLER et al. 1973), had the properties of N, P, K and Ca. The N/S ratio is unfavourable, worse for the Prednji vrh than for Pokljuka.

CONCLUSIONS

The comparison of macronutrient annual cycles (June 1993–July 1994) in current-year spruce needles for Pokljuka (unpolluted area) and the Prednji vrh (near TTP Šoštanj) showed significant differences with regard to total sulphur, nitrogen, calcium and potassium content. There are no significant differences for magnesium and phosphorus needles content.

A slight nitrogen deficiency was observed on the plot at the Prednji vrh, while adequate status for phosphor, potassium, calcium and magnesium was observed on both plots. Concerning high sulphur immissions since 1978 at the plot Prednji vrh (with stand precipitation more than 30 kg S–SO_4/ha per year) mineral nutrition status for trees regarding nitrogen, phosphorous, calcium, potassium and magnesium content and their ratios for current year spruce needles are still adequate. Relatively favourable site conditions and forest management practice (close to nature management practice, mixed stands) are shifting buffering ability of the forests stands and soils concerning SO_2 immissions and acid precipitation.

Total sulphur content in current-year and one-year old spruce needles on the Pokljuka plot indicated the present background level for Slovenia; the sulphur contents in foliar samples from the Prednji vrh are very high and indicate extreme sulphur immissions.

The annual cycles of sulphur in spruce needles in the unpolluted area (Pokljuka) significantly differ regarding sulphur content from the polluted area (Prednji vrh); the accumulation of sulphur occurs also during the dormancy period.

The annual cycles of nitrogen, phosphorus, potassium, calcium and magnesium in spruce needles at both plots are similar but displaced due to different length of vegetation period.

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Nitrogen transformation in the soil of spruce stands in the plateau part of the Krušné hory Mts. (Erzgebirge) and its relation to nitrogen uptake

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ABSTRACT: The study is aimed at the evaluation of nitrogen transformation in soil and the level of mineral nutrition of Norway spruce stands in the plateau part of the north-eastern Krušné hory Mts. (Forest District Janov) in plots with various technology of reclamation measures. The total deposition of sulphur and nitrogen in the region significantly exceeds limits of soil neutralization capacity and forest ecosystems are still in a serious danger. Leaching of cations from soil (particularly Ca, Mg and K), release of aluminium ions (as the result of acid inputs) and trends to excessive nutrition by N (as the result of nitrogen inputs) cause absolute or relative nutrient shortage. Based on the results obtained, proposals are derived for the optimization of site preparation technologies for forest regeneration.

Keywords: Norway spruce; Krušné hory Mts.; nitrogen mineralization; mineral nutrition; ecosystem restoration

The Krušné hory Mts. (Erzgebirge) represent the first area of the Central-European region where effects of the anthropogenic load caused an ecological disaster of forest ecosystems. Main factors which caused the damage were largely industrial pollutants the occurrence of which together with synergetic effects of climatic influences caused changes in the health condition of forest ecosystems. The course of air pollution effects can be characterized by the marked increase of load in the period 1978–1983 with peaks in 1982. From the viewpoint of sulphur potential deposition, the region of the Krušné hory Mts. is endangered from 40.8% by heavy load. More than 10% of the region are exposed to the extreme degree of danger (HADAŠ 1999). From the viewpoint of total deposition of nitrogen, 43.1% of the region are highly endangered and 10% are extremely endangered. Actual values of the total potential deposition of N were from 15.2 to 27.7 kg/ha per year, potential deposition of S from 8.6 to 53.2 kg/ha per year and acid deposition from 1,417–6,064 eq H^+/ha per year. With the increasing air pollution load (particularly SO_2) soil conditions in the region were changed. Although the input of sulphur into ecosystems considerably decreased in the last years (LOCHMAN 1993), long-term effects of air pollutants in connection with nitrogen compounds resulted in the damage to the whole complex of the soil mechanism with the decrease in reserves of available macrobiogenic elements (LOCHMAN 1981; HÜTTL 1993), microbial activity and ammonification level (LANGKRAMER, LETTL 1982). Changes in physical and mechanical properties of soils also occurred (KUBELKA 1992).

A lot of authors pointed out generally negative effects of soil acidification on the development of microbial populations (BECK 1984; ULRICH 1981) leading to the decrease in the number of heterotrophic bacteria and development of microfungi in humus horizons under spruce stands (LETTL, HÝSEK 1994), reduction of the cellulose decomposition (UCHMANSKI et al. 1995), respiration (FRITZE 1991), soil catalase activity (FRANZLUEBBRES et al. 1995) and ammonification (BROWN 1985; LETTL, HÝSEK 1994). According to LETTL (1985), however, changes in the soil microflora in the air-polluted region of the Krušné hory Mts. do not appear to be significant enough to explain Norway spruce dieback. On the basis of leaf analyses, MATERNA (1989) showed insufficient nutrition with nitrogen in forest stands of the Krušné hory Mts. which was only slightly improved as compared with previous years. According to PASUTHOVÁ and LOMSKÝ (1998), values of the nitrogen content in spruce young populations of the Krušné hory Mts. show a certain fluctuation in the range of good nutrition. According to KULHAVÝ (1999), in the Krušné hory Mts. the state of nutrition in localities used for a long time for forestry purposes is worse than on original pastures. According to the author, the nutrition of spruce stands by nitrogen is quite sufficient in the region whereas the largest problems appear with magnesium.

Decreasing vitality of forest stands and changes in nutrients in the soil induced the need for rehabilitation measures. Extensively used liming by dolomitic limestone ranked among the measures. Since the 70s, forest stands were limed virtually in all mountain regions including the

Krušné hory Mts., the Jizerské hory Mts. and the Krkonoše Mts. (LOMSKÝ, UHLÍŘOVÁ 1993; MATERNA, SKOBLÍK 1988, etc.). Liming was to contribute to the elimination of industrial pollutants and to prepare conditions for the development of soil microflora. Of special importance is the evaluation of liming effects on the balance and dynamics of nitrogen substances which can induce the shortage of the element in the nutrition of stands and in rich soils results in its leaching into ground waters (POPOVIČ 1984). According to KUBELKA (1992), it is possible to state that liming is one of the preconditions for the successful regeneration of forests in the Krušné hory Mts. According to LETTL (1991), liming of spruce stands in the Krušné hory Mts. increased the number of bacteria in the upper fermentation layer, reduced the content of total carbon and nitrogen and resulted in the decrease of ammonification and nitrification. According to the author, negative effects of liming can be reduced by grassing and, on the contrary, markedly increased on deforested areas (PODRÁZSKÝ 1992). PODRÁZSKÝ (1994) pointed out favourable effects of experimental liming on young populations of Norway spruce in the air-polluted regions of the Orlické and Jizerské Mts. from the viewpoint of height increment, smaller losses of needles and lower occurrence of chlorotic colouring of the assimilatory apparatus. PODRÁZSKÝ (1992) mentioned the marked intensification of mineralizatin processes after liming and stressed the importance of observing impacts of the measure on the dynamics of organic substances and nitrogen in soils. Generally, impacts of liming on the condition and dynamics of nitrogen are negative.

The aim of the paper is to assess the condition of nitrogen in soils and nutrition of spruce stands of the Krušné hory Mts. on areas used for a long-time for forestry purposes and on forested pastures with some aspects of nitrogen nutrition using liquid fertilizers and liming.

MATERIAL AND METHODS

AREAS STUDIED

The areas are situated in the Krušné hory Mts., Forest District Kienhaida (Forest Enterprise Janov). Areas used for a long time for forest management purposes and forested pastures were selected.

Areas used for a long time for forest management purposes

Norway spruce stands aged 31–50 years, altitude 750 m, forest type 7 K 3, humus podzol. For the purpose of comparisons, on 10 July 1998 some of the plots were treated with PHOTOMAG PLUS – a water substance of a fine-ground dolomite and other additives at a rate of 3,000 kg/ha.

Forested pastures

Variant 1 – spruce stands aged 31 years, altitude 760 m, forest type 6 K 1, oligotrophic Cambisol.

For the purpose of comparisons, on 1 June 1998 some of the plots were limed using dolomitic limestone at a rate of 2,500 kg/ha ($CaCO_3$ 56.7%, $MgCO_3$ 39.6%, SiO_2 2.6%, fractions: > 4 mm 11.9%, 1–4 mm 45.1%, 0.5–1.0 mm 15.5%, < 0.5 mm 27.5%.

Variant 2 – spruce stands aged 21 years, altitude 740 m, forest type 6 K 4, oligotrophic Cambisol.

For the purpose of comparisons, on 10 July 1998 some of the plots were treated with BIOM KHL Konifera using aerial fertilization (liquid fertilizer with an increased content of Mg and K completed with microelements and growth stimulators at a rate of 15 l/ha, dilution with water 1:300).

SAMPLE ANALYSIS

Soil samples were taken from three shallow soil pits in each of the variants (treated or non-treated) in A horizon, surface humus layers were sampled separately. Active and exchangeable soil reaction and other parameters (the content of macro- and micronutrients, the content of available nutrients, adsorption complex) were analysed in the Ekola Bruzovice service laboratory. The content of total carbon and nitrogen was determined using the Leco 2000 analyser, ammonia nitrogen was determined in the soil solution of 1% K_2SO_4 by the indophenol method (ZBÍRAL et al. 1997) and nitrate nitrogen in the same leachate by a manual spectrometric method with sulphosalicylic acid (ČSN ISO 7890-3).

Samples for needle analyses were taken from the 5th–7th whorls, the content of Ca, Mg and K was determined after mineralization (wet method) using $H_2SO_4 + H_2O_2$, the content of C, N and S was determined using the Leco 2000 analyser.

RESULTS AND DISCUSSION

Based on the results obtained, in case of spruce stands managed for a long time for forestry purposes or stands established on original pastures and aged 20–50 years (soil types: oligotrophic Cambisol, humus podzol) there are low values of the soil pH (Tables 1 and 2) in all experimental plots, markedly unsaturated adsorption complex and low content of exchangeable bases.

Although the content of total carbon in particular plots did not show more significant differences between plots managed for a long time for forestry purposes and forested pastures there is a marked difference in the content of the total soil nitrogen and C/N ratio.

Table 1. Active soil reaction (pH/H_2O)

Horizon	Plots managed for forestry purposes for a long time	Afforested pastuires	
		Variant 1	Variant 2
L	4.1	3.9	4.8
F	3.7	4.2	4.0
H	3.6	4.1	3.7
A	3.6	4.1	4.0

Table 2. Exchangeable soil reaction (pH/KCl)

Horizon	Plots managed for forestry purposes for a long time	Afforested pastuires	
		Variant 1	Variant 2
L	3.0	3.6	3.9
F	3.0	3.3	3.4
H	2.8	3.3	3.0
A	2 .8	3.4	3.4

Table 3. Total C/N ratio in the soil

Horizon	Plots managed for forestry purposes for a long time	Afforested pastuires	
		Variant 1	Variant 2
L	22.8	6.6	5.0
F	19.8	7.0	6.3
H	19.3	8.1	8.9
A	23.1	6.1	10.7

The amount of total nitrogen fluctuated from 2.7–10.7% (L), 2.2–6.3% (F); 1.9–3.5% (H) and 0.4–1.4% (A) in soils of all experimental plots being much higher in all afforested plots than in plots managed for a long time for forestry purposes (Table 4).

Also the C/N ratio was much more favourable in forested pastures (less than 10) whereas in plots managed for a long time for forestry purposes ranged from 19.3 to 23.1 (Table 3).

From the viewpoint of mineral forms of nitrogen it is possible to say that the content of NH_4–N reached similar values in all plots and evident differences were in the content of nitrate nitrogen which modified particular localities and changed the NH_4/NO_3 ratio. In all the areas, the amount of ammonia nitrogen ranged from 19.5 to 22.5 mg/kg DM (L), 9.3–18.2 mg/kg DM (F), 11.3 – 18.2 mg per kg DM (H) and 5.2–5.7 mg/kg DM (A).

In plots managed for a long time for forestry purposes, the amount of nitrate nitrogen was similar as in the case of ammonia nitrogen reaching the highest values in H layer (Fig. 1). In afforested pastures, it was possible to see the predominance of ammonia nitrogen in all horizons (Variant 1), on the other hand, however, absolute predominance of nitrate nitrogen amounting to 42.9–51. 8 mg NO_3–N/kg DM in L, F and H horizons (Figs. 2 and 3).

The use of liquid fertilizers and liming in experimental plots affected the course of nitrification, i.e. the content of nitrate nitrogen increased. In plots managed for a long time for forestry purposes, the amount of nitrate nitrogen increased roughly twice, the amount of ammonia nitrogen being similar as in untreated plots (Fig. 4). In afforested pastures with the predominance of ammonia nitrogen (Vari-

Table 4. Total nitrogen in the soil (%)

Horizon	Plots managed for forestry purposes for a long time	Afforested pastuires	
		Variant 1	Variant 2
L	2.7	10.7	8.6
F	2.2	5.9	6.3
H	1.9	3.5	2.4
A	0.4	1.4	0.6

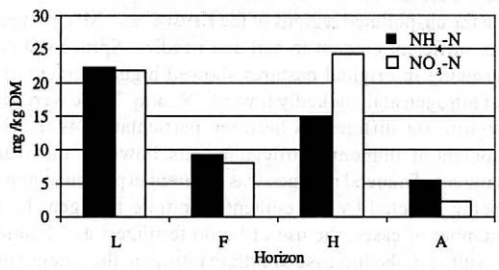

Fig. 1. Ammonia and nitrate nitrogen in soils under spruce stands – plots managed for forestry purposes for a long time

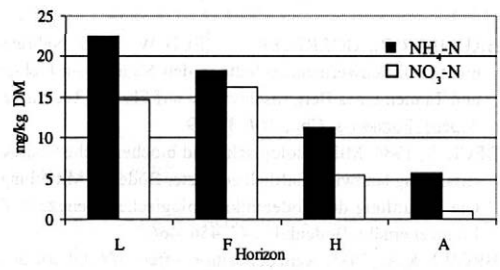

Fig. 2. Ammonia and nitrate nitrogen in soils under spruce stands in afforested pastures (Variant 1)

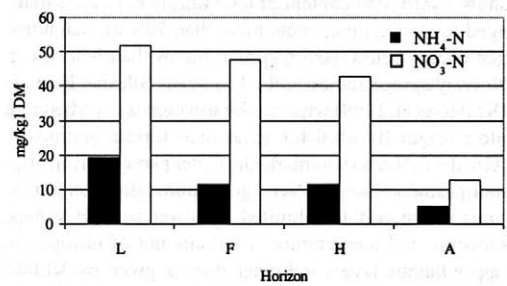

Fig. 3. Ammonia and nitrate nitrogen in soils under spruce stands in afforested pastures (Variant 2)

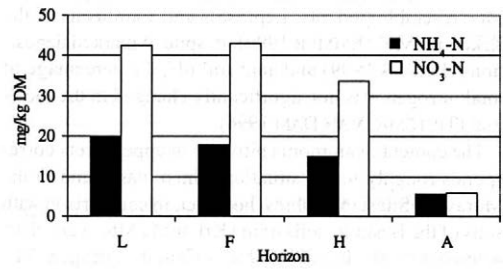

Fig. 4. Ammonia and nitrate nitrogen in soils under spruce stands 442 days after treatment – plots managed for forestry purposes for a long time

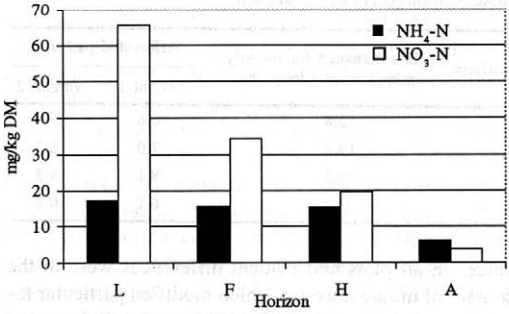

Fig. 5. Ammonia and nitrate nitrogen in soils under spruce stands 442 days after treatment – afforested pastures (Variant 1)

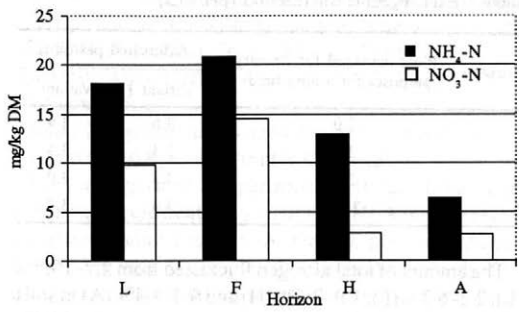

Fig. 6. Ammonia and nitrate nitrogen in soils under spruce stands 442 days after treatment – afforested pastures (Variant 2)

ant 1), the amount of nitrate nitrogen increased considerably due to the treatment, particularly in L and H horizons (Fig. 5), in plots with the original predominance of nitrate nitrogen (Variant 2), the content of this form of nitrogen 442 days after treatment considerably decreased (as compared with untreated plots) ammonia form of nitrogen being dominant (Fig. 6).

In particular plots, the amount of nitrogen in needles of the first generation somewhat shows fluctuated mean values ranging between 1.3 and 1.7% (Table 5). In case of treated plots, the content of nitrogen in young needles increased on average by 0.2%.

Present results obtained by the study of nitrogen conditions in plots managed for a long time for forestry purposes and in afforested pastures of the Krušné hory Mts. show a sufficient content of total nitrogen. In plots managed for a long time, about more than 50% of total nitrogen occurs below young spruce stands than below, e.g. Norway spruce stands in the Moravian-Silesian Beskids (KLIMO et al. 1998) whereas the situation is even better in plots originally used for other than forestry purposes. Also the C/N ratio was markedly better particularly in original pastures showing very good mineralization conditions which could be limited by lower soil pH values, moisture and temperature. Total amount of nitrogen in upper humus layers is higher than is given by KLIMO (1982) for acid brown soils under spruce monocultures in the Drahanská Upland. Values found in plots managed for forestry purposes for a long time in the Krušné hory Mts. resemble podzols, Leptosols and Cambisols of the Krkonoše Mts. (EMMER 1999). In spite of marked depositions (HADAŠ 1999) and acid soil pH, the percentage of total nitrogen was not significantly changed in the localities (TIETEMA, VAN DAM 1996).

The content of ammonia nitrogen in upper layers corresponds roughly to the situation which was found in the Moravian-Silesian Beskids, however, in comparison with soils of the Beskids, soils of the Krkonoše Mts. were characterized by the higher content of nitrate nitrogen. The higher content of nitrate nitrogen can be an indicator (WARING, RUNNING 1998) of ecosystem saturation by nitrogen.

Mean content of nitrogen in needles of the first generation ranged between 1.3 and 1.7% which is, according to HÜTTL (1991), an indicator of the good condition of spruce nutrition by nitrogen. Also according to MARSCHNER (1986), the content of 1.35–1.7% nitrogen in needles of the 1st and 2nd generations is an indicator of the sufficient nutrition of spruce. Possible lack of nitrogen in some cases could be caused for example by an insufficient uptake under conditions of low root activity as was found by BÄUMLER et al. (1995) at higher altitudes. The shortage of Ca and Mg was evident in particular localities.

CONCLUSION

Short-term monitoring of the condition of nitrogen in soil and nutrition of Norway spruce stands aged 20–50 years in the air-polluted regions of the Krušné hory Mts. proved its sufficient content in soil and needles. Spruce stands growing in original pastures showed higher percentage of nitrogen and markedly lower C/N ratio. There were no significant differences between particular plots in the content of ammonia nitrogen in soils, however, the total amount of mineral nitrogen was different in particular plots being affected by the content of nitrate nitrogen. In a number of cases, the use of liquid fertilizers and liming resulted in the increase of nitrate nitrogen, the amount of ammonia nitrogen remained the same as in untreated plots.

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Genetic effects of industrial pollution in Norway spruce

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ABSTRACT: The effects of industrial pollution on the allelic and genotypic structures were investigated by means of isozyme analysis. In a mixed Norway spruce – silver fir forest stand in an area heavily polluted by sulphur dioxide and heavy metals in the region of Spiš (Eastern Slovakia), pairs of neighbouring damaged and apparently healthy trees were selected in two repetitions (44 and 69 pairs in a heavily and moderately damaged stand, respectively). Pairwise sampling of trees with contrasting vitality was applied to reduce potential effects of site heterogeneity on the vitality of sampled trees. No significant differences of allelic and genotypic frequencies were found between the sets of healthy and damaged trees. There are differences in the single-locus heterozygosities, but they are not consistent over the repetitions. However, the set of damaged trees exhibited higher levels of genetic multiplicity and diversity, what can be explained by deleterious effect of rare alleles under the conditions of air pollution. As a consequence, after the abortion of sensitive trees, the remaining stand will be depleted of a part of alleles with unknown adaptive value to future selection pressures.

Keywords: *Picea abies*; isozymes; air pollution

Despite a slightly decreasing trend over the last decade, air pollution and the resulting soil contamination and changes of soil properties remain a serious problem for forestry. Air pollution as a stress factor causes direct injury of vegetative tissues and disturbance of biochemical reactions (JONES et al. 1989; LARCHER 1995). Indirectly, it causes soil disturbances like acidification, change of soil chemism and texture, abortion of soil microorganisms and mycorrhizal fungi (REUSS, JOHNSON 1986). All this leads to the reduction of growth and seed set, what means economical losses and problems with regeneration.

The genotype-dependent variation in the response to pollution stress as the base for viability and/or fertility selection, which changes genotypic and allelic structures of populations, has been proven in many forest tree species including Norway spruce. The sole presence of vital individuals in strongly damaged declining populations is an indication for such variation. However, there is a more direct evidence as well. Broad-sense heritabilities for resistance to air pollution were found to be high (ROHMEDER, SCHÖNBORN 1965). SCHOLZ and VENNE (1989) have shown strong effect of provenance, family, as well as genotype on the resistance against SO_2, O_3 and HF in fumigation and field experiments. Provenance effect on tolerance to aluminium stress was observed by GEBUREK and SCHOLZ (1989). On the physiological level, variation of peroxidase activity in different Norway spruce individuals under SO_2-stress (LUDEWIG et al. 1989), as well as differences in peroxidase patterns between clones differing in their relative tolerance to complex air pollution (SCHINDLBECK 1987) were observed.

Isozyme genetic markers have quite efficiently been used in the study of these selection processes since the seventies. Changes in the genotypic and allelic structures of Norway spruce were observed both in case of gaseous pollutants (BERGMANN, SCHOLZ 1987; GEBUREK, SCHOLZ 1985) and in case of soils contaminated by heavy metals or aluminium (BERGMANN, HOSIUS 1996; GEBUREK et al. 1986; HOSIUS, BERGMANN 1993).

Our study was performed in an old industrial region of Lower Spiš in Eastern Slovakia. The pollution stress in this valley is really long-lasting, since iron and other metal smelters have existed here since the Middle Ages. At present, the main sources of pollution are copper smelters in Krompachy and Rudňany, which use brown coal containing arsenic. In addition, the region is loaded by long-distance transport of air pollution (mainly sulphur dioxide) from the Silesian industrial complex around Ostrava and Katowice. High levels of arsenic, mercury, copper and sulphur were observed in forest biomass in this region (MAŇKOVSKÁ 2000). The aim of our study was to show how this complex pollution stress is reflected in the genetic structure of the local Norway spruce populations.

MATERIALS AND METHODS

Two neighbouring mixed Norway spruce – silver fir stands exhibiting different degree of damage by industrial pollution were selected in the Lower Spiš region near the village Novoveská Huta (48°53' N, 20°32' E): a more exposed, heavily damaged stand in the upper part of a slope, and a more protected, moderately damaged stand

near the bottom of a valley. In both stands, pairs of neighbouring damaged and apparently healthy adult trees were selected. Pairwise sampling scheme was chosen to avoid possible environmental heterogeneity. Healthy trees, apparently tolerant to the pollution load, had dense crowns with green foliage. As damaged trees (putatively sensitive to pollution) were chosen those which exhibited high defoliation levels, frequently with discoloration of needles, with reduced increments at least over the last 10 years. At the same time, they must not show any signs of bark beetle attack, fungal infection or mechanical damage by timber logging or extraction, to avoid the other causes of decline than the pollution load. During the dormancy seasons 1998/1999 and 1999/2000, twigs with dormant buds were sampled from 44 pairs in the heavily damaged stand and 69 pairs in the moderately damaged stand were collected and subjected to isozyme analysis. Buds without scales were homogenized in a Tris-HCl extraction buffer pH 7.3 (LONGAUER 1996). Enzyme separation was performed electrophoretically in 12% (w/v) starch gels using three buffer systems (lithium-borate – Tris-citrate pH 8.1, sodium-borate pH 8.0 – Tris-citrate pH 8.7, and Tris-histidine – Tris-citrate buffer pH 7.0). Staining procedures followed CHELIAK and PITEL (1984). In total, 13 isozyme systems controlled by 22 loci were used. Zymogram interpretation followed MUONA et al. (1987) and LAGERCRANTZ et al. (1988).

Allelic frequencies at each locus were calculated based on diploid genotypes. Differences in allelic frequencies between populations were tested using the probability test (RAYMOND, ROUSSET 1995). Genetic diversity was characterized by the mean number of alleles per locus, proportion of polymorphic loci, observed and expected heterozygosities. Deviations of the genotypic structures from the Hardy-Weinberg equilibrium were tested following ROUSSET and RAYMOND (1995).

RESULTS

No significant differences between the sets of tolerant and sensitive trees were found either in allelic or in genotypic frequencies (not presented for spatial reasons).

Genotypic structures were in general in a good concordance with Hardy-Weinberg expected proportions. Significant deviations towards deficiency of heterozygotes were found in *Lap-B* locus in both tolerant and sensitive trees in the heavily damaged stand, and in the *Mdh-C* locus in the sensitive tree set in the moderately damaged stand. However, no general pattern could be identified.

There are apparent differences between tolerant and sensitive trees in the genotypic structure as expressed by single-locus heterozygosities (Table 1). However, the differences are mostly not consistent over the repetitions. In the severely damaged stand, heterozygosities at *Lap-B* and *Pgi-B* were found considerably higher in the 'tolerant' set, whereas the situation was opposite at *Ap-A*, *Mdh-C* and *Ndh-A*. In the moderately damaged stand, the differences were either not so pronounced, or

Table 1. Single-locus heterozygosities in the investigated sets of Norway spruce trees

Locus	Heavily damaged stand		Moderately damaged stand	
	Tolerant trees	Sensitive trees	Tolerant trees	Sensitive trees
Fest-A	0.089	0.087	0.070	0.092
Lap-A	0.089	0.065	0.099	0.138
Lap-B	0.303	0.200	0.192	0.222
Ap-A	0.222	0.370	0.282	0.338
Px-A	0.067	0.130	0.056	0.077
Gdh-A	0.044	0.065	0.014	0.015
Got-A	0.000	0.022	0.000	0.015
Got-B	0.044	0.022	0.000	0.015
Got-C	0.578	0.587	0.563	0.547
Pgi-A	0.000	0.022	0.000	0.000
Pgi-B	0.511	0.370	0.366	0.477
Mdh-A	0.000	0.022	0.014	0.000
Mdh-B	0.000	0.022	0.014	0.000
Mdh-C	0.022	0.133	0.042	0.031
Idh-A	0.044	0.000	0.085	0.123
Idh-B	0.000	0.043	0.000	0.000
Pgm-A	0.044	0.022	0.014	0.046
G6pd-A	0.244	0.267	0.155	0.200
Skdh-A	0.089	0.065	0.014	0.077
Skdh-B	0.000	0.087	0.014	0.046
Ndh-A	0.395	0.529	0.459	0.377
Pgm-A	0.044	0.022	0.014	0.046
Pepca-A	0.103	0.167	0.177	0.185

Table 2. Characteristics of the genetic multiplicity and diversity in the investigated sets of Norway spruce trees

Set		N	N_a	PP	H_O	H_E
Severely damaged stand	Tolerant	44	2.3 (0.2)	72.7	0.132 (0.036)	0.131 (0.037)
	Sensitive	44	2.6 (0.2)	95.5	0.148 (0.034)	0.150 (0.036)
Moderately damaged stand	Tolerant	69	2.3 (0.2)	81.8	0.124 (0.035)	0.120 (0.034)
	Sensitive	63	2.5 (0.2)	81.8	0.137 (0.035)	0.137 (0.035)

N – mean sample size, N_a – mean number of alleles per locus, PP – percentage of polymorphic loci, H_O – mean observed heterozygosity, H_E – mean expected heterozygosity; Standard errors in parentheses

they were even in the opposite direction at particular loci (*Pgi-B, Ndh-A*).

On the other hand, quite clear and consistent differences were found between the sets of tolerant and sensitive trees as concerns synthetic measures of the genetic multiplicity and diversity. In both repetitions, the sets of sensitive trees proved possess on average more alleles than the tolerant trees. The differences were due to the presence and/or absence of rare alleles. Mean number of alleles per locus is a measure, which is very sensitive to sample size, but in this case, sample sizes of the 'tolerant' and 'sensitive' sets were practically equal in both repetitions, so that this effect need not be considered. In the heavily damaged stand, there was also a pronounced difference in the proportion of loci, which were polymorphic, however, this difference was not observed in the other repetition.

The trends of the genetic diversity were similar. Higher diversity levels were observed on the 'sensitive' sets in both repetitions, whereby the difference was bigger in the heavily damaged stand. It may be partially due to the higher allelic richness in the sensitive trees, but a more regular distribution of allelic frequencies may also have contributed. The differences in the allelic diversity were also reflected in observed heterozygosities, i.e. in the overall genotypic structure. Even if it is surprising, higher proportions of heterozygous loci were observed in the 'sensitive' sets as compared to the 'tolerant' ones.

DISCUSSION

Even though the existence of the selection caused by air pollution and soil contamination is no more a matter of discussion, it is always questionable, to what extent and how this selection can be monitored by gene markers, and what are the underlying mechanisms.

Among the enzymes we used, there are several ones, controlling biochemical pathways which may directly be affected by pollutants (MDH, IDH, NDH, GOT, G6PD, PEPCA), or which are supposed to participate in the resistance to pollution, like peroxidases (BERGMANN, SCHOLZ 1989). Different isoforms of these enzymes may exhibit different activity or inhibition levels under the pollution stress.

Previous experiments have proved changes of genotype and allelic frequencies of several isoenzymes due to the selection by gaseous pollutants as well as heavy metals. SCHOLZ and BERGMANN (1984) found significant differences in genotypic as well as allelic frequencies of the *G6pd-A* locus between spruce clones sensitive and tolerant to SO_2 fumigation. Genotypic frequencies at *Got-B* proved to respond to SO_2 and HF fumigation as well (BERGMANN, SCHOLZ 1987, 1989). However, the same enzyme loci did not respond to pollution in field trials in the Harz and Fichtel Mts., where changes were observed at *Grd-A* and *Pepca-A* loci (BERGMANN, SCHOLZ 1989). The changes in the genotypic structure were reflected by differences in single-locus heterozygosities. However, whereas for some loci, selection prefers heterozygotes (*Got-B, Grd-A, Pepca-A, Ndh-A*), for other loci the situation is opposite (*G6pd-A, Mdh-C, Pgm-B*). However, in field experiments, tolerant genotypes generally exhibit higher levels of heterozygosity (BERGMANN, SCHOLZ 1987, 1989). Heavy metal pollution also causes changes of allelic and genotypic frequencies at several loci (*Lap-B, Pepca-A, G6pd-A, 6pgd-B, 6pgd-C*), but the response is also not equal over loci, at *Lap-B, Pepca-A, 6pgd-B, 6pgd-C* heterozygotes were preferred, whereas at *G6pd-A*, individuals homozygous at the most frequent allele exhibited the highest survival rate (BERGMANN, HOSIUS 1996; HOSIUS, BERGMANN 1993). These results indicate that the air pollution does not always cause selection in the same direction, there are frequently differences between laboratory and field trials.

In our case, we have not found any significant differences in allelic and/or genotypic structures between tolerant and sensitive trees even at the loci, where such changes were observed in previous studies. However, it must be considered that the stress under field conditions is always complex. In our case, there are several heavy metals in combination with sulphur dioxide which exert the selection pressure at the stands under study. There may be synergic effects as well as compensations between these pollutants. What we observed is higher levels of the genetic multiplicity and diversity in the 'sensitive' tree set. Quite many rare alleles were found only in declining trees. The first-hand explanation is that these alleles represent deleterious mutations, what also would be a reason for their low frequencies. On the other hand, deleterious alleles are mostly recessive, so that they should not affect survival of their carriers if they are in heterozygous state. Whatever is the reason for the con-

centration of rare alleles in sensitive trees, the fact is that these alleles will disappear from the investigated population in a short time, either due to selection, or due to genetic drift. Even in case they are actually deleterious under the present conditions, they may have an adaptive value to the other stresses which may occur in the future. Just for example – the gene for human sickle cell anaemia, which is fatal in homozygous state, provides resistance to malaria in heterozygous state – it proves that the term 'deleterious' must always be considered under particular circumstances. The adaptive value of any allele should not be underestimated.

In conclusion: pollution stress causes a genetic impoverishment of Norway spruce and changes in the gene pool due to selection as well as genetic drift.

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Phenotypic selection of plus trees and plus stands of birch for reforestation of the Krušné hory Mts.

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ABSTRACT: Birch sample trees were assessed in the Krušné hory Mts. table-land in 1998–1999. The sample trees represented the most frequent types of damage. The birches are under the influence of a cascade of various stresses of which the climatic stress is primary. Cambium and conducting tissues were damaged by frost. Since the birch ecotypes used here were improper (*B. pendula*), a survey was made of local, autochthonous birch populations (*B. pubescens* agg.). The measurements included particularly older birch populations or individual old trees which were then assessed for possible seed production. The team of authors visited a total of 11 localities situated in the central part of the Krušné hory Mts. and recommended 7 trees and 7 stands for being certified as elite trees and seed stands, respectively. The sources of identified seed can be used for further reforestation.

Keywords: birch; local population; selection; seed; reforestation

Extensive clearcuts due to air-pollution in the territory of the Krušné hory Mts. have been reforested with alternative tree species since the 70s. One of the species used for the purpose was birch which grows on many thousand hectares today. The birch used for the reforestation of the vast area was of unknown origin with the seed imported to the place from different localities of the Czech Republic, particularly from lower altitudes. In 1997–1998, the birch exhibited a heavy damage and even the dieback of stands at some places.

The issue of birch damage and dieback in the Krušné hory Mts. is investigated and assessed from many aspects. In the majority of the cases, however, the birch genus – *Betula* is described as such without its differentiation into individual species or without taking into account at least the fundamental classification into the species of *Betula pendula* Roth and *Betula pubescens* Ehrh. This differentiation is a basic condition for the evaluation of the problem since each of the two species has different site requirements, needs different ecological conditions for its growth and has a different life strategy (Jackson, Black 1993; Fowden et al. 1993).

The project was aimed at a solution of the issue of birch dieback at higher altitudes of the central part of the Krušné hory Mts. in 1998 and 1999 and included the measurement of 136 individuals from the affected localities in order to evaluate the damage of trees in dependence on their species appurtenance. It was found out that the species *B. pubescens* is more resistant to the stresses and thus less damaged or better regenerating (Martinková et al. 1999). Because there are also some remnants of older birch stands in the area under study, our attention was focused on these localities. We were especially interested in the species *B. pubescens* – from the taxonomic viewpoint in a wider conception – i.e. including the species *B. carpatica* W. et K. which is today many times distinguished as a separate species. The aim of the study was taxonomic evaluation the autochthonous birch populations in different sites and to choose suitable individuals or stands as seed sources for further use at the reforestation.

MATERIAL AND METHODS

In August 1999, a basic survey of localities selected on the basis of historical sources was carried out. Particularly stands aged over 100 years were involved i.e. localities with a potentially preserved ecotype of a local birch population. Younger vital stands on peaty soils where their natural origin could be suppoused were also studied. We gradually visited the selected localities by car in order to sample shoots in leaf from the lower third of the crown from at least one specimen in each locality; if the shoot was fructifying and bore catkins, these were also sampled for further measurements. The individual was marked with a plastic tag and its position was plotted into the map. The material for determination was sampled from the most sizeable trees which were most probably also the oldest ones. Trees were assessed in terms of their state of health and measured for diameter at breast height and tree height. In the case of a stand or a larger group of trees, several typical representatives were evaluated after sampling right on the spot and a possibility was considered of us-

ing the population as a seed source for further plantations.

Basic differences between *B. pendula* and *B. pubescens* agg. are as follows:

Betula pendula Roth (silver birch, weeping birch)

The tree reaching the height of up to 30 m, with the heavily ragged, rough and black rhytidome at the stem base when old. The branches of higher orders fine, usually overhanging, current year shoots in older individuals bare, only at young age or in regenerating sprouts hairy, at all times with gum warts. The leaf blade trigonally oval up to rhomboidal, conspicuously double notched with pointed, elongated apex and wide wedge-shaped to cut base. The leaf gets bare soon. In shortened twigs, the leaves are usually by couples. The fruit scales three-bladed, lateral blades wider, bent down, the achene with a winged border overtopping in the upper part the top of stigmata (Fig. 1).

Betula pubescens Ehrh. (common birch) including *B. carpatica* W. et K.

The tree reaching the height of up to 20 m, does not have the deeply ragged rhytidome at the stem base when old. The branches of lower orders projecting, not overhanging on their ends, the annual shoots mildly to densely fluffy, without gum warts (KALIO, MAKINEN 1978). The leaf blade elliptical to oval, with irregular twin score-notching, shortly pointed, with a widely wedge-shaped, rounded to slightly heart-shaped base. The leaf is hairy during the whole growing season at least on its lower face (often hairy also on the upper face). In shortened twigs, the leaves are usually by three. The fruit scales three-bladed, lateral blades pointing to sides (*B. pubescens*), or upwards (*B. carpatica*), a winged border reaches only to the top of the stigmata (Fig. 2).

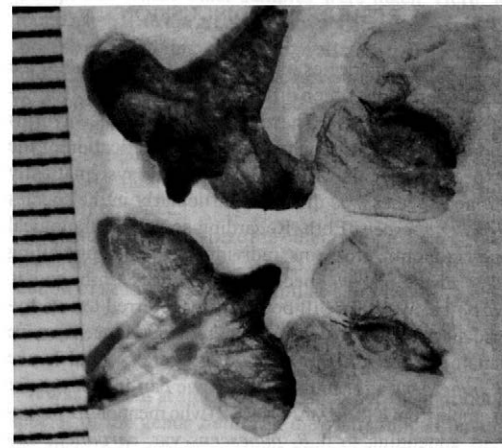

Fig. 1. Fruit scales and seed of *Betula pendula* Roth

Fig. 2. Fruit scales and seed of *Betula pubescens* Ehrh.

RESULTS AND DISCUSSION

There were 5 species of the genus *Betula* found in the area under study, which differed in size, growth, ecological requirements, etc. These species can produce hybrids and this is the reason why a precise classification of the respective specimens into the narrowly systematically defined species was difficult, particularly in the species *Betula pubescens* Ehrh. Regarding some morphological and taxonomic problems, individuals with the prevailing traits of the narrow species *B. pubescens* Ehrh. and *B. carpatica* W. et K. will be hereafter referred to as a hybrid swarm of *B. pubescens*; in the wider conception we can therefore use the term „aggregate" – and hence *B. pubescens* agg. In this context we can follow out for example from KRÜSSMANN (1972) who mentions *B. pubescens* appending to it *B. pubescens* var. *carpatica*. According to KŘÍŽ (1990), the species are determined unambiguously; the author mentions, however, that there are populations of mountain birches alternating in the Krušné hory Mts. which have the prevailing traits of once *B. pubescens* and another time those of *B. carpatica*. Other references mention a hybrid between *B. pubescens*, or *B. carpatica*, and *B. nana* (*B.* × *seideliana*), and even a hybrid of *B. pubescens* in the wider conception with *B. pendula* (*B.* × *aurata* or *B.* × *hybrida*). Nevertheless, these hybrids can be proven only caryotypically which would need more measurements and could be a good stimulation for a further research.

However, the species *B. pendula*, *B. nana*, *B. oycoviensis* and the group of *B. pubescens* (*B. pubescens* agg.) can be unambiguously determined by the morphology of their leaves and shapes of fruit scales and seeds.

LOCALITIES UNDER STUDY

Loučná: The substitute stand of *Picea pungens* and *Betula pendula* comprised a number of damaged and dead specimens of the species *B. pendula*. While the representatives of the species *B. pendula* exhibited a poor regeneration, not only old and bulky trees of *B. pubescens* agg. but also their young progenies, i.e. the natural seeding did quite well in the vicinity of the severely damaged individuals in the north-eastern part of the locality. Two following sizeable old specimens at the altitude of 950 m were proposed for seed collection:

No. 1 – *B. pubescens* agg., girth at breast hight 141 cm, height 16 m, healthy.

No. 2 – *B. pubescens* agg., girth 87 cm, height 14 m, healthy.

The both trees fructify and they can even be recommended as elite trees with their seed suitable for use at higher altitudes, i.e. 900–1,000 m.

Rusová: To the left from the road in the direction of Vejprty, ca. 400 m behind the railway bridge. A sizeable specimen of birch was found out near the brook at the altitude of about 790 m. The tree has an inclined stem which is partly damaged by a breakage in the crown but is still vital. The size indicates that the tree is from the original population.

No. 3 – *B. pubescens* agg., girth 186 cm, height 18 m – very suitable for seed collection, proposed for elite tree.

Fojtovice: On both sides of the road, mainly along a field path turning to the left. Altitude of about 750 m. The species representation in the stand was clearly that of *B. pubescens* agg. (with some transient types), right at the road there was one tree of *B. pendula*. Two following samples were taken for further analyses:

No. 4 – *B. pubescens* agg., girth 66 cm, height 11 m, healthy, in general a straight stem.

No. 5 – *B. pubescens* agg., girth 66 cm, height 11 m, healthy, in general a straight stem.

The stand can be used as a seed source for plantations at altitudes up to 800 m.

Nové Město: Compartment 411, forest type 7R1, waterlogged soils, altitude ca. 850 m, to the right from the forest road. The species representation in the stand was once again unambiguously that of *B. pubescens* agg. with the transient types.

No. 6 – *B. pubescens* agg., girth 36 cm, height 6 m, healthy, in general a straight stem.

No. 7 – *B. pubescens* agg., girths 36, 32 and 22 cm, height 7 m, healthy.

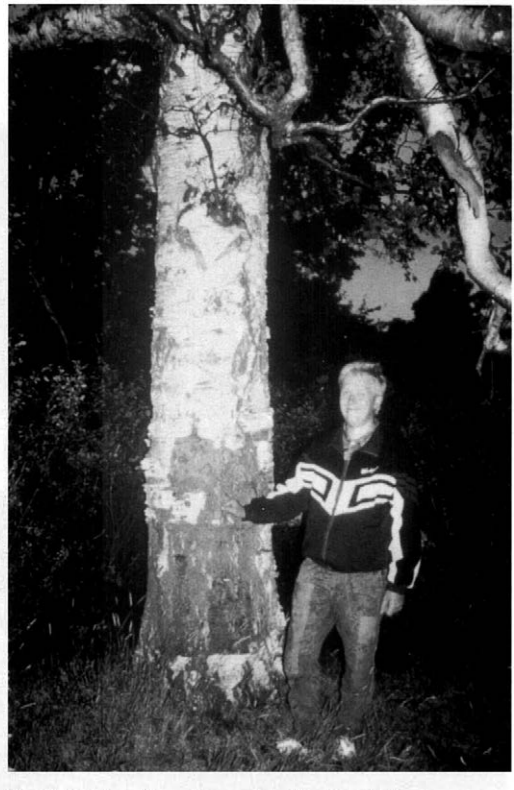

Fig. 3. *Betula pubescens* agg., locality Nový Dům

The locality exhibited a natural regeneration and can be used as a source of seed for altitudes up to min. 850 m.

Černý rybník: A natural reserve – upland moor at the altitude of 800 m. The comparison material was sampled from 3 individuals and it was found out that all trees in the stand are once again *B. pubescens* agg. with the majority of them being closer to *B. pubescens*.

No. 8 – *B. pubescens*, girth 68 cm, height 9 m, healthy.

Regarding the fact that the locality in question is a natural reserve, the seed collection is restricted.

Nový dům – Starý rybník: Stand 128C, altitude about 800 m, forest type 8G3. There is an older solitary birch individual standing on the north-eastern bank of the lake. It is *B. pubescens* agg. whose traits are closer to the typical *B. pubescens*.

No. 9 – *B. pubescens*, girth 128 cm, height 11 m, healthy.

The individual suitable for seed collection, can also be suggested for elite tree. There are more specimens from the stand 128C around the Starý rybník (Lake) suitable for seed collection.

Nový Dům: Altitude 810 m. Near the gamekeeper's lodge, there is a spreading specimen of birch, one of the most sizeable ones found out during the survey. The individual is being damaged by people – nails, shots, etc. – still vital, wounds being occluded. Abundant fruits.

No. 10 – *B. pubescens* agg., girth 196 cm, height 13 m.

The individual very suitable for seed collection, proposed for elite tree (Fig. 3).

Nový Dům – Nový rybník: The lake's dam, altitude about 800 m. Samples were taken on the dam from 3 individuals of different types and different rhytidome colour.

No. 11 – *B. pubescens* agg., girth 127 cm, height 9 m, shining white bark, near the lake.

The whole dam is bordered with descendants from the stand 132C which spreads around the lake. Five samples were taken right from the stand, which are once again *B. pubescens* agg. (with transient types). The stand is being proposed as suitable for certification for seed collection. Seed of good quality can also be obtained from individuals bordering the dam.

Pohraniční: Near the border crossing Hora Sv. Šebestiána – Güst, some 50 m in front of the bridge on the road along the border with Germany in the direction of Načetín at the altitude of 770 m. It is most probably the western end of the Nový Dům peat bog. The stand of older trees at the right side of the road consists of *B. pubescens* agg.

No. 12 – *B. pubescens* agg., girth 144 cm, height 15 m, the stem is severely injurred up to the height of 2.5 m.

The stand is suitable for seed collection, proposed for certified stand, some trees farther on from the road can be proposed for elite trees.

Kalek – Volárenský rybník: Compartment 220, (219), the studied areas are situated along the road connecting the Volárenský rybník (Lake) with the road from Kalek to Boleboř at the altitude of 810 m. *B. pubescens* agg. was determined in the stands, represented on both sides of the road, with more important individuals discovered in the western part – on the border between Comp. 220 and Comp. 222 where other samples were taken. Here, we found a tree with the greatest diameter at breast height, the most sizeable original specimen of all trees in the localities under study. It is at the distance of about 80 m from the road, on the water-logged peat soil of forest type 8R1.

No. 13 – *B. pubescens* agg., girth 210 cm, height 17 m, birds-eye birch, fructifying.

The individual is very suitable for seed collection, proposed for elite tree.

In its surroundings, there are other nice specimens, even in the vicinity of the road, which are suitable for the collection of seed to be used at similar altitudes.

CONCLUSION

It was evident at studying the damage to the individual species of the genus *Betula* in the visited localities that the species *B. pendula* (silver birch) is damaged more often and more severely than *B. pubescens* agg. It is not to be expected that the closed stands of *Betula pendula* can ever be achieved in the most exposed localities. The species has got its maximum at altitudes above 800 m, has never occurred here at a greater representation, only as an interspersed woody species under the protection of surrounding stands. Furthermore, the extensive deforestation evoked changes in the mesoclimate (greater oscillations of climatic characteristics) and no greater success can be anticipated here when using unsuitable climatypes with an increased susceptibility to the given selection pressure at the existing methods of management. This is why we suggest that it should be prefer the progeny of the original, autochthonous birches, i.e. *B. pubescens* agg., to be sown or transplanted into the substitute stands of higher altitudes. It is important, however, to provide for a new equilibrium in terms of the species diversity, i.e. new monocultures should be prevented.

B. pubescens agg. was determined in the studied localities with the original birch at all times. Within the survey, 7 trees were proposed for being certified as elite trees and the following localities were recommended for seed collection: Fojtovice, Nové Město, Starý rybník, Nový rybník, Pohraniční and Kalek – Volárenský rybník. It was found out that the mentioned localities can ensure a sufficient amount of seed for subsequent sowings provided that the seed collection is well organized. It could be useful to establish a seed orchard of birch. It is certain that there are other – by us not investigated – localities with the good reproduction material which could be utilized to ensure the whole amount of seed of the original birch for suitable localities in the region of the Krušné hory Mts.

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Strategy of birch (*Betula* L.) survival in substitute stands of the Krušné hory Mts., air-polluted region

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ABSTRACT: In the plateau of the Krušné Hory Mts. (Erzgebirge), massive premature yellowing of leaves and dieback occurred in substitute stands in spring 1998. The cause of the events was repeated frost damage to the cambial zone of the basal part of stems. While *B. pubescens* agg. showed a trend to shrubby growth and thus elimination of damaged tissues and survival, *B. pendula* Roth maintained arborescent growth supported by a sclerified bark which gives an advantage to the pioneer species on other sites. European birch of unsuitable provenance shows a decreased chance for survival under conditions of higher altitudes of the mountains.

Keywords: *Betula pendula* Roth; *Betula pubescens* agg.; frost stress; regeneration; bark structure; growth form; survival

The Krušné hory Mts. (Erzgebirge) are a problematic mountain range in the Czech Republic (CR). The region attracted public attention in the 80s due to large-scale damage to local forests by phytotoxic air-pollution. Although SO_2 emissions decreased in the last decade of the 20th century roughly by 50% as compared with the 90s, NO_x concentrations stagnate or even increase (AUTHOR COLLECTIVE 1997). The Krušné hory Mts. region always ranks among territories threatened by air pollution of even other character (UHLÍŘOVÁ et al. 1996).

There were extensive clear-cut areas and the felling was followed by several waves of attempts at reforestation of the large clear-felled areas induced by air-pollution, which failed at some places. Other trends were directed to the choice of probably more resistant species. It is these species that form substitute stands on the hill sides today. However, there is still a problem with reforestation of a peneplain situated at an altitude of about 800–1,000 m. Here, we can meet both with areas continually overgrown with the dominant *Calamagrostis villosa* (Chaix) J. F. Gmel. and with larger or smaller plantations of substitute tree species such as *Picea pungens* Engelm., *Sorbus aucuparia* L. emend. Hedl., *Pinus mugo* Turra, *Duschekia alnobetula* (Ehrh.) Pouzar etc. In addition to the species mentioned above, hopes were set on the simulation of initial stages of the secondary succession by means of sowing and planting the pioneer species of *Betula pendula* Roth. with the subsequent underplanting of the substitute stands with climax tree species.

In the studied region of the Krušné hory Mts., it has been found according to various authors that 4–5 original species of the genus birch (*Betula* L.) occur. Between the species interactions (hybridization) can take place. Exact classification of particular trees into closely systematically defined species is, therefore, problematic, particularly in the species group of *Betula pubescens* Ehrh. With respect to some morphological/taxonomical problems, individual trees with prevailing traits of narrow species *B. pubescens* and *B. carpatica* W. et K. can be presented as a hybrid group of *Betula pubescens* so that in a broader sense, it is possible to use the term *B. pubescens* aggregate (MARTINKOVÁ et al. 1999).

Betula pendula is the most distributed species of the genus *Betula* in the region of the CR. It belongs to species sensitive to SO_2, chlorine and fluorine but resistant to O_3 and PAN (SUCHARA 1980; UHLÍŘOVÁ et al. 1996). As for other properties of the species, it is necessary to emphasize particularly its considerable morphological and physiological variability (growth, bark formation, size and shape of leaves, forms with various wood structure etc. (KRAMER 1995) and a huge Euro-Asian range – a northern limit ranges up to the tree limit (latitude 67–71° N) (KALIO, MAKINEN 1978), a southern limit is given by steppes.

Within the natural range, we can differentiate between a northern region where the species is much more abundant and in the central part is also of higher growth and then the central-European and south-European mountain regions where the species is relatively rare ranging from

lower altitudes often up to the forest limit and towards south its lower limits goes up so that the species is a mountain tree. In the northern region, it gradually changes also morphologically from south to north converting into shrubby forms. Biological properties change as well (MATYSSEK et al. 1991). Also in mountains, we can see the shift from lower altitudes to the upper forest limit (SVOBODA 1957).

In the extensive natural range, numerous climatypes were described (JONG 1995). However, there is only poor knowledge on the behaviour of the species after its transfer into different conditions. Nevertheless, there are large differences in the length of the growing season of birch of northern and southern provenances (experiments conducted in Switzerland showed that northern birch coming from Scandinavia exhibited budbreak markedly early, finished growth at the end of the period of the longest day and shed leaves already in August whereas Alpine birch grew until October). With the change of conditions towards north, birch types of a long day occur which are more frost resistant and adapted to the short growing season. The large abundance of morphological forms indicates the large physiological variability of birch in relation to its various origin (KALLIO, MAKINEN 1978).

In the CR, European birch occurs from the planar zone (being absent in typical floodplain forests) up to the montane zone and exceptionally also supramontane zone. Maximum of the occurrence of birch is in the supracollinous zone, i.e. according to ZLATNÍK (1976) in the 3rd–4th forest vegetation zones at an altitude of 200–550 m. The upper limit of distribution occurs at an altitude of 900–1,000 m in the Bohemian Forest, 950–980 m in the Krušné hory Mts. (Erzgebirge), 900–1,000 m in the Krkonoše Mts. (maximum: the Hrubý Jeseník, Malá kotlina, 1,100 m alt.; the Moravian-Silesian Beskids, Lysá hora, 1,150 m alt.) (KŘÍŽ 1990).

Also the species *B. pendula* was used for reforestation of extensive clear-cut areas at altitudes representing the upper limit of its occurrence in the Krušné hory Mts., however, the used seed was of unknown origin. At the beginning, a plan to reforest also the plateau by the species seemed to be a success. In the second half of the 90s, however, a phenomenon occurring with a conspicuous frequency appeared, which markedly showed in the spring of 1998. Trees flushed and then their foliage yellowed and died in several weeks. The damage to birch stands was enormous. There were cases from a slight defoliation with the subsequent regeneration up to the complete dieback of whole trees.

The aim of the study was to determine causes of the phenomenon and the response of particular taxa with respect to the age of trees. Two hypotheses were set down:

1. problem could be very complex if stress factor of air, soil and water pollution occurred in future;
2. the problem could be of less complex character. It could result from the short growing season, insufficient inner control of the dormancy duration and premature start of growth phenophases, i.e. impossibility to avoid the effect of late and early frosts. It could refer to the effect of harsh or long-term winters or episodes of meteorological character, i.e. the occurrence of abrupt temperature changes, wind, heavy snow, glazed frost etc. which could represent destructive effects for non-prepared trees on clear-cut areas.

MATERIAL AND METHODS

DESCRIPTION OF LOCALITIES AND MATERIAL

On the extensive territory of the Krušné hory Mts. peneplain from the SW up to the NE margin, casuistic verification of birch trees was carried out in two terms (July 1998 and August 1999) in such a way to involve the most frequent phases of the type of damage and possibilities of survival in particular taxa with respect to the age of trees.

Full-grown birch trees were found out which were part of forest complexes before about 40 years and survived air pollution damage (55 trees situating in 13 localities were found and examined). Two other localities were also chosen representing newly established substitute birch stands. Within the localities, research plots 50 × 50 m were laid out. Localities Vitíška – Pramenáč (an 8-year-old stand) and Klíny – Obora (a 12-year-old stand) were used (altitude 870 m and 800 m, respectively, longitude 13°43'30" and 13°34' E, respectively, latitude 50°2' and 50°0' N, respectively). In total, 136 trees were evaluated according to the type of regeneration in relation to survival.

From the two localities but also from other accidental places, samples were taken and analysed in detail representing the most frequent phases of damage:

1. Living trees with crowns having green leaves.
2. Slightly damaged trees with sparse foliage and mosaic dying of leaves.
3. Trees which fully flushed in 1998 and then their foliage quite turned yellow by the beginning of July.
4. Trees nearly dead with at least one living branch in their crown.

As control trees, sample trees of *B. pendula* were analysed. The trees come from a locality which belongs to a region with the maximum occurrence of European birch in the CR (Forest Enterprise Třebíč) and where trees of local provenance as well as trees from Karelia origin occur.

From each of the groups whole above-ground systems were taken always of 2 sample trees of comparable age, i.e. 8–15 years. In addition to this, a *B. nana* specimen from the Brno arboretum (Arboretum of Mendel University of Agriculture and Forestry) was used as a comparative species.

METHODS USED

In 55 full-grown trees of original forest complexes following parameters were determined: species, g.b.h., stem form and crown form. Symptoms of damage and regeneration were also found. In sample trees from the Krušné hory Mts. substitute stands and in control sample trees from the Třebíč Forest Enterprise, height, g.b.h., crown

length and width were measured and branches were taken from the top, central and basal parts of the crown. The angle of branches and origin of branches (primary crown, secondary crown) were evaluated, leaf area (by means of image analysis), dry matter and chlorophyll content were determined (by spectrophotometry, ŠESTÁK et al. 1971). The condition of leaf mesophyll and epidermis was also studied (by macroscopy and microscopy with optical instruments NIKON and ZEISS). In stems, the study concentrated particularly on colour, thickness and histology of bark, phloem and xylem tissues and cambial zone and changes in the radial width and total area of annual rings (KOZLOWSKI 1971; EVANS 1972; FINK 1991; SCHWEINGRUBER 1996). Dynamics of the diameter growth changes was compared with the course of temperatures from October to May in 1990–1998. In wood of stems, attention was paid to the occurrence of pith flecks.

In each of the 136 trees growing in localities Klíny – Obora and Vitíška – Pramenáč, determination of species was carried out and growth forms were evaluated (arborescent, shrubby). According to the foliage, leaf colour and the condition of stem base (curvature, bark tissues character, swelling) individual trees were divided into two groups, viz. living (although previously damaged but regenerating by healthy branches) and dead (actually dead or declining with a visible damaged and swelled stem base). Then, it was evaluated (percentage) how many trees within *B. pendula* and *B. pubescens* agg. were living or dead in case of maintaining the arborescent, acrotonic growth and living or dead in case of basitony and assuming the shrubby growth with shoot regeneration at the ground surface.

At the same time, bark histology was compared with that of bark of *B. nana*, a species with a typical only shrubby growth.

RESULTS AND DISCUSSION

SPECIES PROBLEM AND POSSIBILITIES TO OVERCOME UNFAVOURABLE CONDITIONS OF MOUNTAIN LOCATIONS

In all studies of the prosperity and performance of substitute birch stands in the Krušné hory Mts., it is necessary to take into account at least species classification of trees when the origin of seed or plants is not, unfortunately, known. For example, in case of the Vitíška – Pramenáč plot, a mixture of *B. pubescens* agg. and *B. pendula* species was used whereas a stand in the Klíny – Obora plot was established only by the species *B. pendula.*

Old full-grown trees which were as interspersed ones part of forest stands and survived the period of large-scale dieback of the Krušné hory Mts. forests mostly ranked among the *B. pubescens* agg. taxon (see ÚRADNÍČEK et al. 1999). At an altitude of 770–810 m, they reached 87 to 210 cm in girth and total height of 11 to 18 m. In many trees, symptoms of repeated damage to cambium and new regeneration were evident on stems so that the stems were not cylindrical but of curly grain (living parts

Fig. 1. The early stage of the frost split healing of *B. pendula* stem. The frost rib is formed by wounded wood

Fig. 2. *B. pubescens* agg. one off the old trees surviving early stages of ontogenesis under protection of forested landscape not degraded by air pollution impacts is also endangered by winter frost. In the distal part of an extensive old frost rib, gradual differentiation of roots occurs while in the insolated part of healing of another injury, shoots are differentiated

of cambial strips reaching from the crown to roots produced separate increments which were not interconnected laterally). In other cases, it was possible to see extensive frost ribs (Fig. 1). Wound wood often differentiated under the bark of adventitious roots (distally), shoots proliferated on insolated surfaces (Fig. 2). Even crowns were often secondary with numerous breaks and regeneration. However, even these trees were not resistant to stress factors of the environment but showed that they could avoid stress applying regeneration enabled by high air humidity. At somewhat lower localities (alt. 720–750 m), *B. pendula* trees were found, full-grown and vital (girth 66 cm, height 11 m).

Control trees of *B. pendula* from the Třebíč Forest Enterprise exhibited an important result consisting in a fact that in trees originating from Karelia, the short growing season was controlled endogenously, i.e. there was a substantially delayed onset of the budbreak phenophase and earlier onset of the senescence phase and leaf abscission. Another result was finding the formation of thin and little sclerified bark similarly as in *B. nana* (Figs. 3 and 4).

SYMPTOMS OF DAMAGE

Macroscopic level

As for substitute birch stands from the plateau of the Krušné hory Mts., trees reached 1–5 m in height. Their crowns in *B. pendula* showed narrow form under exposed conditions being regularly of secondary origin. Primary crowns were broken due to mechanical influences although primary branches were well embedded in the bearing system (being connected even with pith). Regeneration took place from dormant and adventitious buds of nodal zones of top and central parts of crowns. Branches were there very tapering (57 mm girth/m branch length as compared with 17 mm/m in control sample) and set in sharp angles (< 30°, control samples < 45°).

This type of regeneration gave the trees a typical appearance; instead of being regularly distributed across the whole crown volume, the foliage was concentrated into clusters. This aimed at the formation of more favourable bioclimate, i.e. to increasing the resistance of a boundary layer of leaves and decreasing the exposition of the whole crown. Due to mechanical load, breaks proceeded even in the secondary crown. Particularly bases of branches from surface-established adventitious buds were injured.

In injured places, frequent colour changes were then evident caused both by the formation of anthocyan and oxidation of phenolic substances (getting the tissues red and brown). Crowns died from the basis and at the same time, height growth was reduced so that this event resulted in shorter crowns (see Fig. 5). Similar mechanical injury in crowns concerned also the taxon *B. pubescens* agg.

Leaves of both birch species prematurely turned yellow and blades of even healthy leaves were mechanically damaged – torn so that functional leaf area was markedly reduced.

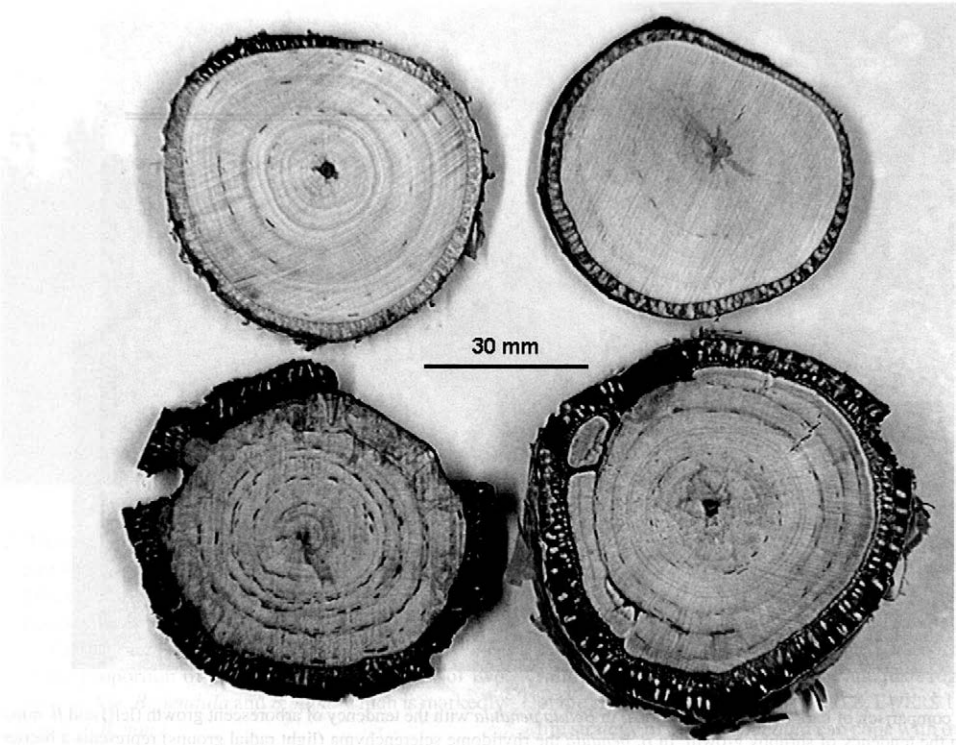

Fig. 3. Transversal sections through young stems of *B. pendula*. The upper two sections show healthy trees (Forest Enterprise Třebíč), the lower two sections represent the types of birch injuries from the Krušné hory Mts. Both lower stems still exhibit some amounts of living cambium which enabled the tree survival in spite of the heavy damage. There can be seen many pith flecks and thick bark on the both lower sections

Stems of trees with prematurely yellowing leaves, particularly in *B. pendula*, were regularly swelled at their base, with hypertrophic lenticels and a prematurely formed tertiary bark.

Microscopic level

In heavily damaged up to dying trees of *B. pendula* (groups 3, 4), regeneration capacity including the function of cambium were preserved in remaining living branches in the crown. One of the sample trees was taken as dead, later on, however, 3 living current shoots were found in its crown. Below the shoots up to a distance of 30 cm, a narrow current year annual ring was formed. Directly below the shoot, the increment showed several layers of cells of differentiated, well lignified xylem but already slightly brownish cambial zone, the annual ring gradually basipetally disappeared and then it was reduced only on an isolated group of cells and at a distance of 35 cm from the living shoot it disappeared totally and the cambium zone turned brown.

Leaves were of heterobaric xerophytic structure, possible damage – yellowing developed first in particular alveoli while other remained alive. With respect to the reduction of leaf area (due to mechanical damage in wind) and leaf yellowing these injured leaves contained only 7–25% chlorophyll ($a + b$) as compared with leaves from living sample trees of *B. pendula*. These leaves of living sample trees from the the Krušné hory Mts. contained only 1.3–2.6 mg chlorophyll per 1 g DM as compared with 5.1–7.7 mg/g leaves of control sample trees from the Třebíč Forest Enterprise. In leaves from the Krušné hory Mts., the ratio of chlorophyll to carotenoids was reduced to 3.6–4.0 while in control trees from Třebíč the values ranged from 6.1 to 7.0. In prematurely ageing leaves as well as healthy leaves of the Krušné hory Mts. birch trees, abundant crystals of calcium oxalate were found which indicated that the species did not suffer from the shortage of calcium under given site conditions.

On cross sections through basal parts of stems, repeated irregularities up to diameter increment stagnation were evident. After severe winter in 1996 (mean and minimum temperature in January amounted to –6.82 and –16.7°C, respectively, mean and minimum temperature in February –6.5 and –18°C, respectively, and mean and minimum temperature in March amounted to –3.07 and –13°C), a marked decrease in diameter increment occurred in the majority of sample trees. In 1997, a very long winter occurred (mean temperatures in November amounted to 1.41°C, in December –6.64°C with minimum temperature –21.3°C, in January –4.1°C, in February 0.8°C, in March and April 2.3°C).

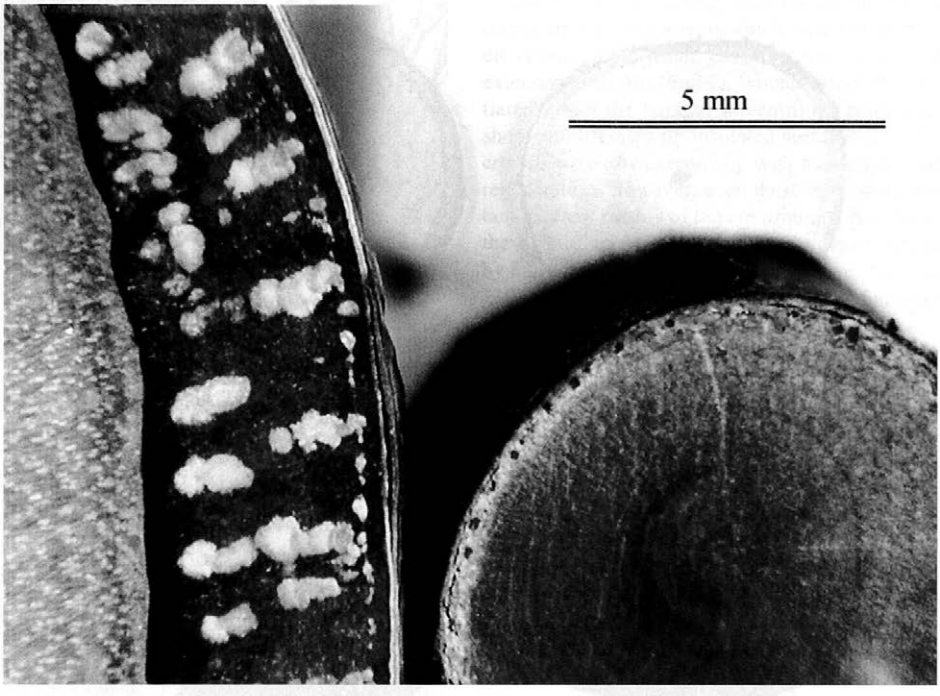

Fig. 4. The comparison of bark (transversal sections) in *Betula pendula* with the tendency of arborescent growth (left) and *B. nana* (right) with the tendency of shrubby growth. In *B. pendula* the rhytidome sclerenchyma (light radial groups) represents a barrier against the proliferation of adventitious buds. In *B. nana*, the bark sclerenchyma is represented at a considerable lesser measure (red lignified areas)

Mean diameter increment slightly decreased, however, particular sample trees responded individually (interval of annual ring width values increased). The year 1998 was a critical year. Weakened trees were affected by late frosts (flushed shoots in young trees of *P. pungens* and *Duschekia alnobetula* froze in the region). In all sample trees of birch representing some of the phases of the phenomenon of premature leaf yellowing it was found that annual rings either partly or totally were absent in this year (Fig. 6).

Gradually reduced formation of annual rings was conditioned by cambium damage (winter frosts in 1996 and late frosts in 1998) on stem bases which generally exhibit low frost resistance in young trees (LARCHER 1995). In wood of even older annual ring generations, repeated or enormous occurrence of pith flecks forming due to low temperatures, short growing season etc. (BALABÁN 1955) was observed and colour changes of wood due to fungal infections (Fig. 3). After removing bark (which did not adjoin the stem already) the occurrence of fruiting bodies was also found.

SURVIVAL STRATEGY

From the morphological point of view, all sample trees exhibited multiple injuries in crowns (branch fractures, mechanical injuries to leaf blades). There were two types of response to these injuries:

1. A strong tendency to regenerate inside the crown, especially in its top and central parts from secondarily formed buds in nodal areas. This type of regeneration gave the trees a typical appearance; instead of being regularly distributed across the whole crown volume, the foliage was concentrated into clusters (Fig. 5).
Our histological investigations revealed that this type of regeneration occurred more frequently in *B. pendula* being connected with the histological structure of bark (or rhytidome) on the base of stems which contains the mosaic extraxylar sclerenchyma (Fig. 7). The network of sclerenchymatic fibres forms a barrier to the proliferation of buds thus restricting epicormic shoots. The high proportion of sclerified tissues in bark and rhytidome originating from phloem/xylem rays and phloem parenchyma appear to be the actual cause of reduced regeneration from the stem. Many individual trees show a tendency to retain arborescent growth and to regenerate at the place of injury or nodes where the sclerenchyma is incontinuous.
CHMELAŘ (1989) found that *B. pendula* regenerated more easily in the crown than on the stem or on its base. On favourable sites and in the phase of medium maturity, the species tolerates, therefore, systematic pruning for the purpose of obtaining materials for various woven products.

Fig. 5. A view on the substitute birch stand of Klíny – Obora locality. The foliage is concentrated into clusters due to a strong tendency to regenerate inside the crown, especially in its top and central parts from secondarily formed buds in nodal areas

2. The second response was regeneration from the basal part of the original stem while the primary crown died. This type of regeneration, proper to *B. pubescens* agg., resulted in shrubby growth. The shrubby growth is particularly typical of *B. nana*. Fig. 3 shows a comparison of the proportion of sclerenchyma in the bark of two species, viz. *B. pendula* and *B. nana* which is markedly lower in *B. nana*.

Based on the comparison of the number of dead and live birch trees in the research plots as related to their arborescent or shrubby growth and if the trees belong to the species *B. pendula* or *B. pubescens agg.*, it is possible to say that the capacity of the shrubby growth is markedly more advantageous from the viewpoint of survival in the given conditions (MOSBRUGGER 1990). The shrubby forms allowed the survival of 89.7% trees while the arborescent forms only 19.9% trees. As for the capacity to survive then 19.1% living trees of *B. pendula* remained in the Klíny – Obora locality, 20.7% in the Vitíška – Pramenáč locality and 89.7% of *B. pubescens* agg. trees survived in the same locality.

It has been found that the chance for tree survival is impaired because the probability of retaining at least a minimum necessary functional percentage of the stem circumference is low. This functional part is vitally important for the possibility of annual rings to grow in the following years (Fig. 3) and for the adequate regeneration of the crown and root system (TYREE, EWERS 1991). The life strategy of birch *B. pendula* can cope with other stress factors than with those of mountain locations. It is a pioneer tree species, typical heliophyte, anemophilous and anemochorous species with the optimum occurrence in the Czech Republic in the supracollinous zone. As such, it must logically prefer the arborescent growth which is a primary condition of its successful distribution (MOSBRUGGER 1990). The mechanical barrier in the bark found by the authors of the paper supports this form of growth; the great percentage of individual trees cannot, therefore, shift to the shrubby growth form which is advantageous (it means "optimum design" according to MOSBRUGGER 1990) for survival under conditions of the Krušné hory Mts. peneplain.

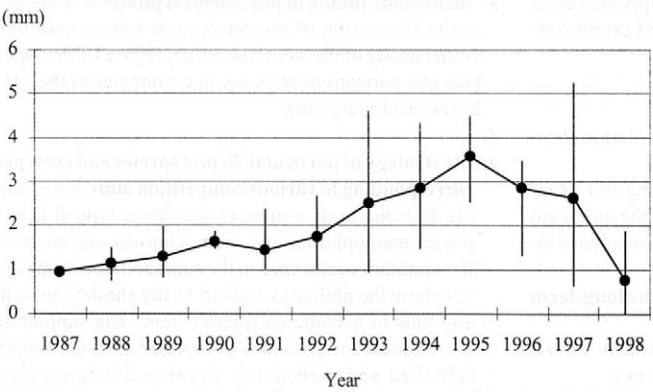

Fig. 6. The radial tree rings width on cross sections through basal parts of stems birch sample trees. Vertical bars mark the interval between maximal and minimal values

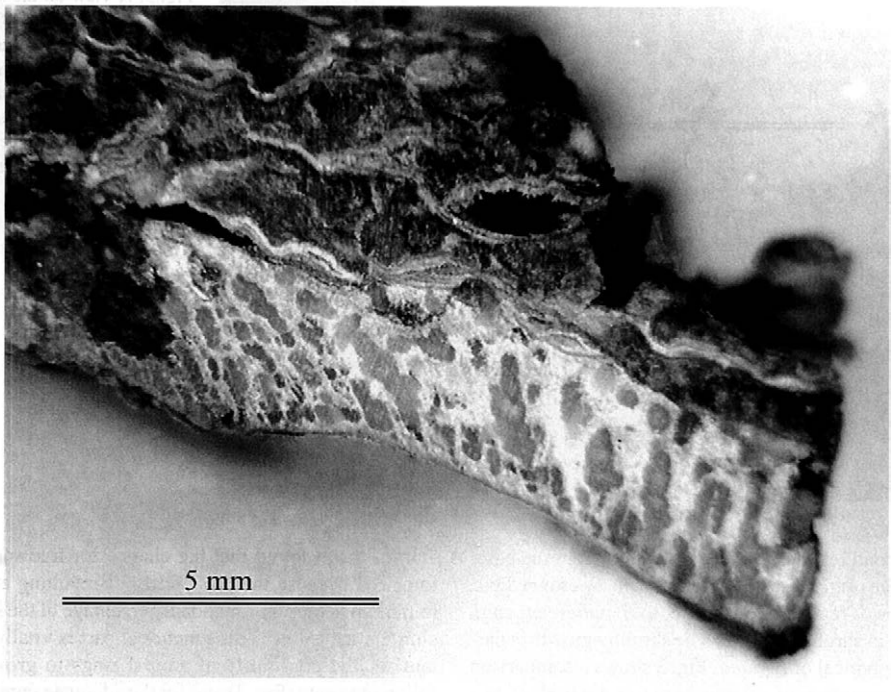

Fig. 7. Sets of sclerenchymatic fibres form a spatial network (light areas) on the radial surface of *B. pendula* rhytidome

CONCLUSIONS

At the beginning of the growing season in 1998, massive yellowing of still not mature leaves of birch trees of substitute stands in the plateau of the Krušné hory Mts. occurred. Casuistic studies have shown that repeatedly weakened trees succumbed to a late frost when the cambial zone of the basal parts of stems was destroyed. Through the root upward pressure, the tree above-ground system was watered, trees flushed, however, the backward flux was interrupted. Leaves entered the premature senescence stage due to the absence of water.

Causes of the described phenomenon of damage to or even dieback of substitute stands of birch appeared to be the result of interactions of both internal and external effects.

As for external effects, it is particularly:

1. mechanical effect

a) wind, hard rime and heavy snow on the plateau (broken crowns, torn leaves),

b) winter frost or repeated phases of thawing and freezing of water in the cambial zone during the quiescent period of particular species (frost splits, stem base injury);

2. effect of unfavourable conditions for the long-term positive carbon budget

a) negative effects of air-pollution load (KUBÍKOVÁ 1991; KUBELKA et al. 1992; UHLÍŘOVÁ et al. 1996),

b) short growing season– while in our country, 170 days of the growing season are available for birch at an altitude of 200–300 m, at an altitude of 900 m, it is only about 100 days (COLLECTIVE 1955),

c) absence of the transpiration of a full-grown forest resulting in waterlogging of sites.

As for internal conditions, it is particularly:

1. decreased leaf area and pigment pool;

2. high and repeated energy requirements for regeneration of damaged parts – related to age, mechanical damage, decreased leaf area and pigment pool and unfavourable conditions for the long-term positive carbon balance;

3. inadequate timing of phenological phases with respect to the fluctuation of meteorological factors and high vulnerability of the stem base of unprepared climatypes (see comparisons of *B. pendula* climatypes in the Třebíč Forest Enterprise);

4.

a) life strategy of particular *Betula* species and ecotypes corresponding to various competition aims. For example *B. pendula* as a pioneer species, a typical heliophyte, anemophilous and anemochorous species, with the optimum occurrence in the supracollinous zone did not show the ability to convert to the shrubby growth and thus to exclude an injured stem. The support of the arborescent growth was ensured through highly sclerified and prematurely developed bark on stem

bases (Fig. 7). Some 19.9% trees of the species survived. On the other hand, another climatype of the same species (originated from Karelia) maintains the endogenously controlled short growing season under conditions of the Třebíč Forest Enterprise and does not form a prematurely rough sclerified bark at the stem base so far. The species *B. pubescens* agg. was represented in a less percentage being similarly damaged, however, it created rather shrubby growth form by means of which eliminated injured above-ground parts. Some 89.7% trees of the species survived;

b) **tree age** – young trees with the small volume of a storage compartment are more sensitive (vulnerable) than full-grown trees. Old trees surviving early stages of ontogenesis under protection of forested landscape not degraded by air pollution impacts are also endangered by factor mentioned above, however, they are able to compensate for the damage by regeneration processes.

The second hypothesis has been proved, viz. that the high mortality in birch stands was caused by the inability of unsuitable *B. pendula* climatypes to overcome repeated stresses of the Krušné hory Mts. peneplain.

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Significance of Phytophthoras and *Pythium* for oak, alder and spruce decline

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ABSTRACT: The results of a survey regarding soil-borne Phytophthoras in 35 oak stands on geologically different sites in Bavaria clearly showed that the most widespread species were identified as *Phytophthora citricola*, *P. cambivora* and *P. quercina*. These three species were only isolated from rhizosphere soil of stands with mean soil pH-values ($CaCl_2$) of 3.5 and higher on loamy, clayey or sandy-loamy soil texture. At these *Phytophthora* stands all root parameters of declining oaks were significantly reduced as compared to healthy looking trees. It is concluded that the above mentioned *Phytophthora* species are involved in oak decline as primary root rot pathogens on clay or sandy-loamy stands with soil pH-values higher than 3.5. A new *Phytophthora* hybrid, called "alder *Phytophthora*", was isolated with high frequency from bark sections of declining alders along several Bavarian rivers and from nursery plants. PCR-RFLP analysis proved that the Bavarian isolates belonged to the same hybrid variants found in Great Britain, Sweden, France or Denmark. Spruce decline was studied in the Bavarian Alps on stands representing various site conditions. Most root parameters were negatively correlated with crown transparency. In addition the total number of lateral roots was significantly lower for declining compared to healthy trees. Remarkably, only *Pythium* species were isolated from rhizosphere soil, which were divided into several groups after PCR-RFLP analysis. In soil infestation tests most of the isolates caused severe root damage on spruce similar to root rot seen on declining trees in the field.

Keywords: *Phytophthora*; *Pythium*; root rot; PCR-RFLP; *Quercus*; *Alnus*; *Picea*

Pedunculate oak (*Quercus robur* L.) and sessile oak (*Q. petraea* [Matt.] Liebl.) have been attacked by a chronic decline since the 1980s in Central Europe. Declining oak stands have also been described for Eastern Europe since the 1960s and for the Mediterranean region since the mid-1980s (Leontovyc, Caper 1987; Ragazzi et al. 1989; Siwecki, Liese 1991). Typical above ground symptoms include yellowing and wilting of leaves, dieback of branches finally leading to high crown transparency. In addition, necrotic stripes in the bark and the phloem of the trunk together with dark exudates can often be seen (Luisi et al. 1993; Kowalski 1991; Blaschke 1991, 1994). Because the described symptoms indicate waterstress and malnutrition of diseased oaks, an assessment of the root systems of declining and healthy oaks in 33 stands all over Central Europe was made. Our results clearly showed a progressive destruction of the fine roots and a dieback of long roots of declining oaks compared to healthy looking ones (Jung 1998; Jung et al. 2000a). Nine different *Phytophthora* species, with *P. cambivora*, *P. citricola* and *P. quercina* as the most frequently ones, were isolated from fine roots and from rhizosphere soil samples (Jung et al. 1996). *P. quercina* was recently described by Jung et al. (1999) and Cooke et al. (1999) as a new distinct species. Several soil infestation experiments proved that these three *Phytophthora* species were the most aggressive pathogens towards oak, causing root rot symptoms comparable with those of declining oaks in the field (Jung et al. 1996, 1999).

In 1993, a massive decline of alder (*Alnus glutinosa* [L.] Gaertn.) along rivers was reported by Gibbs (1995). The symptoms are similar to those of declining oaks, with wilted and chlorotic leaves in the crown. Stripe cankers at the root collar are also typical for the disease. The disease is caused by a new *Phytophthora* hybrid (called "alder *Phytophthora*") evolved from *P. cambivora* and a still unknown second *Phytophthora* species (Brasier et al. 1995, 1999). Declining alders along rivers were also reported from Austria, France, Switzerland, Netherlands, Denmark and Sweden (Cech 1997; Werres 1998). In Germany the disease was first monitored in 1995 (Hartmann 1995). Jung et al. (2000 b) recently showed that the *Phytophthora* disease of alder is widespread along Bavarian rivers.

According to the official forest condition surveys, about 32% of spruce (*Picea abies* Karst.) in the Bavarian Alps are showing heavy crown damages (> 25% crown transparency). This disease has been known for quite a long time and is considered a major threat to the forests, particularly with regard to their multiple protective purposes. During the last 15 years mainly abiotic factors, such as ozone and other photooxidants were discussed to be involved in spruce decline especially at stands at higher altitudes (Kirchner et al. 1992; Paffrath, Pe-

TERS 1988). Only a few studies, however, focused on the root status of the declining trees. In most of these investigations correlations between crown transparency and the fine root status were found. Recently, NECHWATAL (2000) and NECHWATAL, OßWALD (2000) showed that *Pythium* pathogens, isolated from declining spruce stands, are involved in fine root destruction and root rot of spruce.

MATERIAL AND METHODS

SOIL AND ROOT SAMPLING

Soil and root samples from oak were taken in different stands on a variety of sites in Bavaria (JUNG et al. 2000a). Samples from spruce were taken in the Bavarian Alps region (Werdenfelser Land) (NECHWATAL 2000). The trees represented either healthy or poor crown condition, respectively. Crown condition of all trees had been assessed according to the official forest condition survey standards (EC-UN/ECE 1997).

Three to five soil sections (ca. 20 × 20 × 30cm) around each tree were made with a spade ca. 1–1.5 m from the base of the trunk, and roots within each section were removed together with adhering soil. Typically, only soil and roots from Ah-layer, if any, were collected, while L- and F-layer were discarded. Soil adhering to the roots, after being removed by shaking, together with randomly collected soil from each section served as soil samples. For each tree, soil and root samples from each soil section were combined to one sample.

Roots were washed thoroughly under running tap water to release any adhering soil particles. Length of all roots in diameter class 2–5 mm (= small roots) was measured and number of lateral roots was recorded. Afterwards, fine roots (diam. < 2 mm) were cut off their mother roots (= small roots), placed between absorbent filter paper and pressed for several weeks. When completely dry, acquisition of further root parameters was performed using scanner and root analysis software (WinRhizo 3.9, Régent Instruments, Québec, Canada). The programme provides detailed data on fine root length, number of root tips and number of forks. Finally, fine root samples were weighed. The following parameters describing the fine root condition of a tree (i.e. the degree of root branching) were calculated:

1. Number of lateral roots per small root length (nFR/SRL; n/cm); 2. Number of forks per small root length (nF/SRL; n/cm); 3. Fine root length per small root length (FRL/SRL; n/cm); 4. Number of root tips per small root length (nRT/SRL; n/cm); 5. Fine root length per small root dry weight (cm/g); 6. Number of tips per fine root dry weight (n/g = SRTD, specific root tip density).

For statistical analysis, parameter values (means) of all healthy and all damaged trees were pooled to reveal differences between the two categories. Means of the two groups were compared using the non-parametric Mann-Whitney test. Differences in root status due to diverse site conditions and sampling dates were eliminated by transforming absolute into relative values (MEYER 1967, 1987; JUNG et al. 2000a): for each recorded parameter the mean of each stand's healthy tree(s) was set 100% and values of all other trees were related to that value, accordingly. Afterwards, relative values of damaged and healthy trees were compared using the Mann-Whitney test. Rank correlations showing relationships between root parameters and crown condition were calculated using Spearman's correlation coefficient, for both absolute and relative values. All statistical analyses were performed using GraphPad InStat, version 3.00 for Windows 95 (Graphpad Software, San Diego, Ca., USA).

ISOLATION OF *PHYTOPHTHORA* AND *PYTHIUM* SPECIES

For the isolation of *Phytophthora* and *Pythium* species soil samples were subjected to a bait test, in which young leaflets of oak (*Quercus robur*) served as baits (JUNG et al. 1996). After being mixed thoroughly, soil samples were flooded with deionized water, and leaflets were floated over the water surface. Infected baits showing brown discolorations after ca. 3–5 days were blotted dry on sterile filter paper, cut into small segments, and plated onto Petri dishes containing a selective agar medium (PARPNH, TSAO, GUY 1977). Plates were incubated at 18°C in the dark. Developing cultures were transferred to V8 agar plates for further identification and maintenance. Isolates of *Phytophthora* and *Pythium* were identified according to the keys and monographs of WATERHOUSE (1970), VAN DER PLAATS-NITERINK (1981) and KRÖBER (1985). *Pythium* isolates from spruce, however, were not identifiable at species level in most cases. The isolates were, therefore, grouped according to similar morphological characteristics, and, additionally, according to banding patterns after PCR-RFLPs (restriction fragment length polymorphisms). For the latter, isolates were grown in liquid medium according to ZENTMYER et al. (1974) for ca. 2 weeks in the dark. DNA was extracted from fungal cultures using the DNeasy Plant Mini Kit (Qiagen, Hilden, Germany). PCR amplification of ITS regions with primer pair ITS 4 and ITS6 was performed as described by COOKE and DUNCAN (1997). Digests of amplicons were carried out with enzymes *Alu*I, *Msp*I and *Taq*I (Amersham Pharmacia), according to the manufacturer's instructions. DNA fragments were separated on 2.5% NuSieve Agarose (FMC Bioproducts, Me., U.S.A.), stained with ethidium bromide, and visualised under UV light. According to the resultant grouping, isolates were selected for pathogenicity tests.

Isolations from diseased alder trees was routinely carried out from bark and phloem tissue showing symptoms of the disease (bark and cambium necrosis with brown exudations on the stem). Small pieces of these tissues were plated out onto selective agar medium (PARPNH) as mentioned above. Additionally, alder plants from nurseries were tested for the presence of *Phytophthora* sp. in roots, bark, and rhizosphere soil using the methods described above.

SOIL INFESTATION TESTS

Soil infestation tests were made to investigate the potential pathogenicity of the *Phytophthora* and *Pythium* species isolated from oak or spruce towards young oak and spruce plants, respectively. One-year-old oak seedlings and 3-year-old spruce plants grown in the greenhouse were used for the test.

Inoculum was produced as described by JUNG et al. (1996). Colonised medium was mixed with artificial, autoclaved substrate (vermiculite, sand, peat, 1:1:1, v/v/v) at a ratio of 1:50 (v/v). Before planting, roots were washed thoroughly under running deionised water and examined for any damages. Only healthy plants with well developed, intact roots systems were used. Ten spruce and 12 oak plants per isolate were planted in the infested substrate, each in a separate 1 litre rootrainer (Ronaash Ltd., Kelso, UK), and placed together in a 60l plastic container. Containers were kept under natural light (ca. 80–100 mol per m^2/s^2) in a room with constant temperatures of c. 18°C. To induce zoospore production containers were flooded every 2–3 weeks with deionised water up to ca. 1cm above substrate level for 3 days. Plant death and any aboveground symptoms were recorded during the course of the experiment. After ca. 5 months, plants were removed carefully from their pots, roots were washed and examined for root damage. Based on visually estimated root damage, each plant was assigned to one out of seven damage classes (0–10, 10–25, 25–50, 50, 50–75, 75–100 or 100% root damage). After visual estimation, root systems were analysed in detail using scanner and analysis software mentioned above (WinRhizo 3.9).

Reisolations from diseased roots and test substrate were carried out by plating small root pieces onto selective agar plates (PARPNH) or by bait test as described above, respectively. Developing cultures were compared to original isolates on the basis of morphological features.

RESULTS

INVESTIGATIONS ON OAK DECLINE

Three declining oak trees (crown transparency > 35%) and three healthy looking oaks (crown transparency < 25%) were chosen and marked in each of 35 oak stands in seven different Bavarian growth regions in 1997 and 1998. In total 106 healthy and 111 declining oaks were used for our investigations. The mean crown transparency of declining trees was 63.2% and 21% of healthy looking ones.

The baiting results revealed that we could distinguish between 19 stands where *Phytophthora* species were isolated from the rhizosphere soil and 16 stands where no Phytophthoras were found. The by far most frequently isolated pathogen was *P. quercina* followed by *Phytophthora cambivora* and *P. citricola*. *P. quercina* was recently described by JUNG et al. (1999) as a new distinct species, and the description was confirmed by molecular analysis by COOKE et al. (1999). According to morphological features *P. quercina* is homothallic, belongs to Waterhouse group I with papillate zoosporangia, and shows paragynous antheridia. The isolation frequency of *Phytophthora quercina* and all other Phytophthoras, respectively, is summarised in Table 1.

Table 1. Isolation frequency of Phytophthoras (%)

	Declining oaks	Healthy oaks
Phytophthora spp.	80.0	33.6
P. quercina	63.1	23.7

All Phytophthoras were isolated to a much higher extent from rhizosphere soil of declining trees as compared to healthy oaks. Chemical analysis of soil samples of all investigated stands showed significantly higher pH-values and calcium contents for *Phytophthora* stands as compared to *Phytophthora* free regions. The mean pH of stands with Phytophthoras was 4.16, and 3.56 for stands where these pathogens were not found. Remarkably, the lower pH of the pH-range of stands, where most of the Phytophthoras were isolated (Table 2), was almost identical with the pH of the *Phytophthora* free oak stands.

Table 2. pH-range of the most frequently isolated Phytophthoras

Phytophthora spp.	Number of isolates	pH range	
		$CaCl_2$	water
P. quercina	55	3.53–7.00	4.43–7.90
P. citricola	11	3.53–6.63	4.43–7.53
P. cambivora	8	3.65–4.39	4.56–5.29

Further investigations proved that sporangia formation of *P. quercina*, *P. cambivora* and *P. citricola* was strongly reduced at pH 5.0 (measured in water) and almost totally inhibited at pH-values of 4.5 and lower (data not shown).

Statistical analysis clearly showed that crown transparency data were negatively correlated with root parameters, such as the number and length of fine roots per metre long roots, whereas no such correlations were found for oaks in *Phytophthora* free stands. In addition all declining oaks in *Phytophthora* stands showed reduced root systems as compared to healthy trees. However, no differences in root systems were monitored for *Phytophthora* free stands, when declining and healthy trees were analysed (Table 3).

Finally, soil infestation experiments were carried out to investigate the pathogenicity of the isolated *Phytophthora* species towards oak. For this purpose one year old oak plants were inoculated separately with different Phytophthoras. After six months, plants were harvested and their root systems were compared to control plants. The results clearly showed that *P. quercina*, *P. cambivora* and *P. citricola* were the most aggressive pathogens towards oak causing root rot and severe decay of fine roots (data not shown).

Table 3. Comparison of root parameters of declining and healthy oaks on *Phytophthora* and *Phytophthora* free stands

	19 stands with *Phytophthora* spp.					
	nFR/mSR		FRL/gdw SR		nRT/gdw SR	
	healthy	declining	healthy	declining	healthy	declining
Mean	59.2	44.6	121.0	76.1	138.5	88.9
Standard deviation	24.8	19.8	66.8	52.2	75.6	68.1
	***		***		***	
	16 stands without *Phytophthora* spp.					
	nFR/mSR		FRL/gdw SR		nRT/gdw SR	
	healthy	declining	healthy	declining	healthy	declining
Mean	62.8	57.3	174.1	144.6	184.4	156.6
Standard deviation	48.3	35.1				
	n.s.		n.s.		n.s.	

Legend: Statistical analysis were done with the Mann-Whitney test; level of significance: * 0.05; ** 0.01; *** 0.001; n.s. not significant

nFR = number of fine roots (diameter smaller than 2 mm); FRL = fine root length (cm); nRT = number of fine root tips; SR = weak roots (diameter between 2 and 5 mm); gdw = g dry weight

INVESTIGATIONS ON ALDER DECLINE

The results of our investigations on alder decline, regarding Phytophthoras, are summarised in Table 4. The alder *Phytophthora* was isolated from bark necrosis of in total 45 declining trees from 6 out of 9 stands with alders younger than 15 years and from 15 out of 20 stands with alders older than 15 years. Besides *P. citricola* and *P. syringae*, the alder *Phytophthora* was the most frequently isolated pathogen in 21 stands of a total of 29 stands with typical symptoms of alder decline (JUNG et al. 2000b,c).

In most cases declining alders (*Alnus glutinosa*) were located along rivers all over Bavaria. The fact that some first afforestations either without connection to rivers or upstream of declining alder stands, were also infested with the alder *Phytophthora*, indicates that infected nursery stocks might have spread the disease. To prove this hypothesis we purchased alders (total 175 plants) from nurseries which supplied stands with alders years ago, which now show severe alder decline symptoms. Indeed, the alder *Phytophthora* together with a new yet undescribed *Phytophthora* species, *P. citricola* and *P. gonapodyides* were isolated from roots and from soil rhizosphere of alders of all nurseries (Table 5).

Additional genetical analysis (RFLP of ITS1/2) of many alder Phytophthoras revealed that the standard variant was present in all declining stands. Besides this variant we also identified the Dutch and the Swedish variant, but to a much smaller extent.

Table 4. Phytophthoras isolated from bark necrosis of declining alder

	Number of stands with				
	declining alders	typical symptoms of alder decline	alder *Phytophthora*	*P. citricola*	*P. syringae*
Alders younger than 15 years	15	9	6	1	1
Alders older than 15 years	23	20	15	1	
Total	38	29	21	2	1

Table 5. Distribution of Phytophthoras in nurseries

Nursery	Alder	Alder *Phytophthora* (Hybrid)	*Phytophthora* sp.7	*P. citricola*	*P. gonapodyides*	*P. lateralis*
1	*A. glutinosa*	X	–	–	–	–
2	*A. glutinosa*	–	X	X	X	–
	A. incana	X	–	X	X	X
3	*A. glutinosa*	–	X	X	X	–

INVESTIGATIONS ON SPRUCE DECLINE

Similar to our investigations on oak decline, we first examined whether root data of the sampled trees were correlated with crown transparency. It was shown that root destruction was connected with needle loss (Table 6). Correlations were much more pronounced when relative values were calculated (NECHWATAL, OßWALD 2000).

Table 6. Correlation of root parameters and crown status of spruce

	nFR/SR	nF/SR	FRL/SR	nRT(0-1)/SR	SRL	SRTD
			Absolute values			
Spearman *r*	−0.54	−0.22	−0.39	−0.38	0.15	0.12
Significance	**	n.s.	n.q.s.	n.q.s.	n.s.	n.s.
			Relative values			
Spearman *r*	−0.77	−0.47	−0.46	−0.46	−0.51	−0.55
Significance	***	*	*	*	*	**

Legend: nFR = number of fine roots (diameter smaller than 2 mm); nF = number of forks; FRL = fine root length (cm); nRT = number of tips (root class: 0–1 mm in diameter); SR = small roots (diameter between 2 and 5 mm); level of significance: * 0.05; ** 0.01; *** 0.001; n.s. = not significant; n.q.s. = almost significant

Table 7. *Pythium* isolated from rhizosphere soil of different spruce trees

Number of the spruce stand	*Pythium* spp.*	
	healthy tree	declining tree
13	1	1
23	–	–
26	–	–
39	1, 4, 6	–
89	2, 3	1, 2, 3
94	–	1
109	1, 2, 3	1, 3
137	2	1, 4
262	–	–
305	–	1
334	2, *P. anandrum*	2, *P. anandrum*
359	*P. anandrum*	2, 7, *P. anandrum*
389	1	1

Legend: *Species, or group according to PCR-RFLP-analysis

Additionally, the number and the length of fine roots per small root was significantly reduced for declining as compared to healthy trees (data not shown). The baiting results from rhizosphere soil of healthy and declining spruce are summarised in Table 7. Remarkably, only *Pythium* spp. and no Phytophthoras were baited in almost every stand. The different isolates were classified into groups after PCR-RFLP-analysis of the ITS1/2 rDNA regions (data not shown). No differences in isolation frequency and in distribution of *Pythium* species were found for soil samples collected under healthy and declining spruce.

The aggressiveness of the different *Pythium* isolates towards spruce was examined in soil infestation tests. For this purpose three-year-old spruce were inoculated with different *Pythium* species as described in material and methods. After six months all plants were harvested and the root systems were analysed (Table 8).

Table 8. Root rot of spruce infested with different *Pythium* species

Pythium isolates (sp. or group)	Mean root loss/rot (%) (estimated)	Number of plants with	
		dieback	necrosis
Control	6	0	0
Fi 13/14a (1)	20	2	2
Bu 39/20 (1)	23	6	1
Fi 137/35 (1)	19	4	0
Fi 305/6 (1)	17	3	0
Fi 389/13 (1)	17	6	0
Fi 89/16c (2)	12	3	0
Fi 109/8 (2)	10	0	0
Fi 334 (2)	23*	7	1
Fi 89/16 (3)	17	3	1
Fi 359b (*P. anandrum*)	26	6	0

Legend: Level of significance: *0.05

As shown in Table 8, *Pythium* isolates caused fine root loss up to 26%. The most obvious symptom was the destruction of fine feeder roots, as shown in Fig. 1.

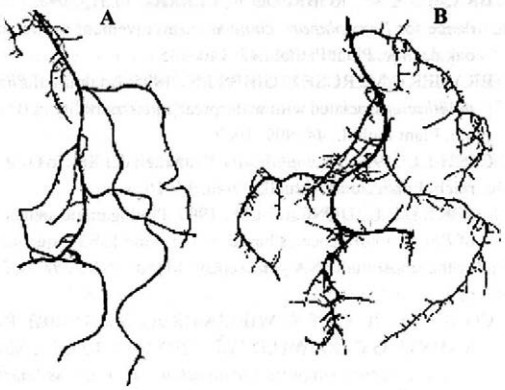

Fig. 1. Fine root destruction of spruce caused by *Pythium*

Legend: A: Root segment infected with *Pythium* (Fi 137/35a); B: uninfected control segment

DISCUSSION

In the investigations on oak decline we showed that different *Phytophthora* species are widespread in oak stands on different geological substrates all over Bavaria. The most frequently isolated species were identified as *Phytophthora cambivora, P. citricola* and *P. quercina*. However, these Phytophthoras were only found on stands with soil pH higher than 3.5, indicating that soil pH might be a limiting factor for the distribution of Phytophthoras in soil. Thus, we can distinguish between stands where Phytophthoras are present and stands without these pathogens. On *Phytophthora* stands the pathogens were isolated much more frequently from the rhizosphere soil of declining oaks than of healthy oaks. In addition, significantly higher fine root damage of declining compared to healthy oaks was only found in *Phytophthora* infested stands. Furthermore, we showed that oaks infested with Phytophthoras exhibited about 20% higher crown transparency than trees without these pathogens.

Recently, these pathogens were shown to cause severe root rot, especially fine root damage, on oak seedlings in soil infestation test after incubation of six months (JUNG et al. 1999). Taking all these results into account, JUNG et al. (2000a) conclude that oak decline can be explained by at least two different complex diseases. In *Phytophthora* mediated oak decline on heavy soils with mean pH values of 3.5 ($CaCl_2$) and higher, chronic fine root loss over several years finally leads to crown transparency due to a strongly reduced water and nutrient supply of infected trees. On sites with sandy soils and mean pH values below 3.5 ($CaCl_2$) climatic (droughts, frost), edaphic (acid soils with low water retention capacity) and various biotic factors (*Armillaria* spp., *Agrilus biguttatus*, defoliators such as *Lymantria dispar* and *Tortrix viridana*) might be involved.

Severe root damage of declining oaks was reported several times in the past. NÄVEKE and MAYER (1990) showed that declining trees had a significant lower number of fine root tips as compared to healthy oaks. VINCENT (1991) proved that a heavy decrease in the fine root biomass of *Quercus robur* occurred before above ground symptoms were visible. Also BLASCHKE (1994) reported on a progressive decay of feeder roots of declining *Q. robur* in Bavaria and histological changes in roots were referred to the invasion of *Phytophthora* species. The characteristic symptoms of declining oaks on roots, the trunk and in the crown are very similar to other well known *Phytophthora* diseases (ERWIN, RIBEIRO 1996) seen on *Q. suber* in Iberia and Italy (BRASIER et al. 1993), on *Eucalyptus* in Australia (ZENTMYER, 1980) or on different fruit trees such as peach, cherry (MIRCETICH, KEH 1970; MIRCETICH, MATHERON 1976) and avocado (ZENTMYER 1980).

Several soil infestation experiments clearly showed that infection of roots by different root rot pathogens impaired water uptake and finally stopped photosynthesis. A sharp decrease in CO_2 assimilation was measured for avocado infected with *Phytophthora cinnamomi* (PLOETZ, SCHAFFER 1989). When infected plants were flooded, assimilation and stomatal conductance were reduced as soon as three days after flooding began, and values declined to zero within one week. *Eucalyptus sieberi*, susceptible to *P. cinnamomi*, showed shoot wilting symptoms 3–15 days after infection. Along with lesion extension a major reduction in net hydraulic conductivity of root systems developed 2–14 days after inoculation, although the pathogen was present in only 8–15% of the root system. DAWSON and WESTE (1984) concluded that the disproportion between the amount of roots infected and the reduction in hydraulic conductivity indicates that the failure of water transport cannot be directly due to the decay of a relatively small portion of roots. WOLF and WOLF (1954) and SCHRAMM and WOLF (1954) suggested that *P. parasitica* var. *nicotianae* produces a toxin that increases xylem resistance in infected tobacco. Recently, HEISER et al. (1999) described small peptides of three Phytophthoras which were released into the culture medium. The peptides of *P. quercina* and *P. gonapodyides* caused severe wilt, chlorosis and necrosis on tobacco leaves and were identified as elicitins which are also known as leaf necrotic proteins.

Recently JUNG et al. (2000b) showed that a new *Phytophthora* hybrid, called "alder-*Phytophthora*" was associated with declining alders along rivers all over Bavaria. The isolates turned out to be identical with the alder-*Phytophthora* described by BRASIER et al. (1999). PCR-RFLP analysis proved that the standard variant was the most frequently isolated one. The *Phytophthora*-caused alder disease was first described in 1993 in Great Britain by GIBBS (1995). The pathogen grows in the bark

and cambium of the stem base, impairing water and nutrient transport. However, the physiological mechanisms which are involved in decline are still unknown. Finally, infested trees suffer from water stress and show severe wilt symptoms on leaves before they die. Further investigations by GIBBS et al. (1999) revealed that the disease might be triggered by an increased nitrogen input into the ecosystem. Alder decline was also reported from other countries such as France, Austria, Switzerland, Netherlands, Denmark and Sweden (CECH 1997) indicating that this new hybrid might be widespread all over Europe.

Recently NECHWATAL (2000) and NECHWATAL, OßWALD (2000) clearly showed that there are significant differences in fine root status of declining compared to apparently healthy spruce trees. Moreover, crown transparency was negatively correlated with important root parameters, proving that trees with high crown transparency revealed reduced root systems. These findings were also reported in the past by LISS et al. (1984), BLASCHKE et al. (1985) and MEYER (1987). In addition, NECHWATAL (2000) and NECHWATAL and OßWALD (2000) isolated several *Pythium* species from rhizosphere soil of declining spruce stands. The isolates were divided into several groups after PCR-RFLP analysis. The isolation frequency of about seventy per cent was remarkably high. Most of the *Pythium* isolates caused severe root rot of fine roots on three-year-old spruce plants in soil infestation tests after an incubation time of six months. On the basis of our results we draw the conclusion that *Pythium* species found might be involved in fine root damage of spruce trees on different stands in the forests of the Bavarian Alps. As a consequence, water and nutrient supply of older needles might be impaired, causing needle loss and crown transparency. Thus *Pythium* species, known as ubiquitous soil inhabitants (DOMSCH et al. 1980), may as well be involved in decline of woody plants as it was shown by HENDRIX et al. (1966), LORIO (1966) and OTROSINA and MARX (1975).

Acknowledgement

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Influence of elevation on the structure of phytophages and fungal pathogens of birch (*Betula pendula* Roth) leaves in the Ore Mts.

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ABSTRACT: In the eastern Ore Mts. the healthy conditions of birch stands (*Betula pendula* Roth) were monitored during 1995–1999. Birch insect pests occur for long-term in their basic stage with local increased proportion, e.g., of miners from the genus *Eriocrania,* of mites (*Phyllocoptes lionotus* Nal., *Aceria rudis* Can.). The presence of phytophages with gradation potential and of new species not studied hitherto (*Epinotia trigonella* [L.], *Melasoma lapponica* L.) makes birch stands of the eastern Ore Mts. endangered continuously. The elevation differentiated mites' occurrence, proportion defoliation by miners (*Eriocrania* sp., *Coleophora serratella* L.) and that by weevils (at lower elevations), and distribution of leaf fungal pathogens *Discula* sp. (at higher elevations). Independent in these aspects were free-living caterpillars.

Keywords: birch *Betula pendula;* insects; mites; fungal pathogens; *Discula* sp.; Ore Mts.

After the large-scale dying out of spruce stands in the early 1980s, the birch (*Betula pendula* Roth) has become one of the most important tree species in the Ore Mts. Extensive birch monocultures, established under site conditions of long-termed air-pollution disturbance, were afflicted by gradation of willow leaf beetle (KULA 1988a,b), loopers (BADALÍK 1988), case-bearer (*Coleophora serratella* L.) (KULA, VACA 1995) and of miners from the genus *Eriocrania* (KULA 2000). In 2000, the occurrence of *Chrysomela (Melanosoma) lapponica* L. was found in the forest district Sněžník (KULA, unpublished). Of the wide spectrum of 861 moth species taken by light trap (KULA 1997a), 123 species had their caterpillars linked with birch, and using the method of shaking down, the existence of 119 species of caterpillars were documented within the birch crown fauna (KULA 1997b). Of phytophagous representatives, the highest impact on birch defoliation is done by moths with free-living and mining caterpillars, weevils (*Curculionidae*) and by willow leaf beetle. The mean degree of the assimilation surface area disturbance by phytophages and fungal pathogens in the study transects was determined in 1999 under spring aspect as 9.6–12.8% and under summer aspect as 13.4–16.5%, when individual stands in a transect differed significantly (4–55%) (KULA et al. 1999a,b).

The contribution is aimed at assessing the elevation influence on development of phytophages and leaf fungal pathogens in birch stands of the air-polluted area in the eastern Ore Mts. and Děčínská Sandstone Upland.

MATERIAL AND METHODS

In the territories of the forest district Sněžník (Děčínská Sandstone Upland) and of the forest districts Klášterec, Janov, and Litvínov (the eastern Ore Mts.) four transects of 100 m gradient were established at the elevation of 500–1,000 m a.s.l. At each elevation gradient according to situation, monitoring control stands of 20, 20–40 and 40–60 years in age were selected. Stands over 40 years are usually missing at the elevation of 900–1,000 m a.s.l. In each of 56 birch stands (forest districts: Sněžník – 12, Litvínov – 15, Janov – 14 and Klášterec – 15) 3 permanent sample trees were designated, subject to annual spring and summer control of their damage state in assimilation organs (during 1994–1999). We preferred trees situated in stands and noted for open canopy in order that we might take also biomass for leaf analyses.

Control branches (0.5–0.7 m long) were taken in the youngest stands from the level of 2–3 m, in 20–40 years' stands from the level 3 and 6 m. In stands over 40 years old, branches were cut at the levels of 4, 6, 8 and 10 m. Till the treatment, which followed during 12–24 hours after sampling, branches were stored in water and shadow.

The harmful factor according to SCHNAIDER (1991) and damage extent were determined on the set of 70 leaves taken randomly from each control branch and ranged in the following categories: non-damaged, damaged to 10%, 11–50%, 51–75% and 76–100% of surface area each year (1995–1999), 40,000 leaves were controlled.

Controlling of the assimilation surface area lost and of representation by harmful agents occurred during two periods: spring aspect June/July and summer aspect August/September.

DESCRIPTION OF THE STUDY AREA

The forest district Sněžník birch stands under study are situated on the upland undulating plateau with prevailing cool mountainous climate, annual mean temperature of 6°C and precipitation of 800 m. The growing season duration is 110–120 days. Stands were established at the elevation of 450–600 m a.s.l., in the zone of maximum (A) and strong (B) air-pollution damage and noted for marked degree of weed infestation, with dominance of the species *Calamagrostis villosa* (Chaix.) Gmel. and *Avenella flexuosa* (L.) Pirl.

The eastern Ore Mts. are characteristic of upland plateau most frequently at the elevations of 700–1,000 m a.s.l. Till 1995 the territory of the Ore Mts. was loaded by high SO_2 concentrations with the absolute daily maxima of 100–1,000 μg/m^3 from resources concentrated in the Sub-Ore Mts. basin and also from foreign resources (Saxony). The established transects (Klášterec, Janov, Litvínov, Sněžník) were differentiated by SO_2 concentrations (KULA et al. 1999). In individual transects, deviations in air-pollution load appeared but in general SO_2 concentrations declined with the elevation (KULA et al. 1997).

The characterization of the eastern Ore Mts. was presented in detail by KUBELKA et al. (1992).

RESULTS

The long-termed development trend in spring defoliation (1995–2000) differentiates the transects under study. The forest district Klášterec was characterized by the lowest defoliation extent in 1997 (7.8%) with subsequent increase up to 19.2% in 2000. Similarly, the defoliation developed under conditions of the forest district Janov. A continuous increase of birch leaf damage (10.8–22.8%) was found in the forest district Litvínov, while in the forest district Sněžník, after five years of damage declining, a partial increase (15.2–9.4%; 18.2% respectively) was manifested. The long-termed development trend in summer defoliation (1995–2000) was increasing in the territory of the transects Klášterec (11.9–20.0%) and Litvínov (9.9–22.8%). In the transect Janov, the defoliation was balanced 1995–1999 (12.5–15.0%) and increased in 2000 (22.6%). A continuous balanced level of defoliation 1995–1998 was interrupted and a level of defoliation increased at the area of the forest district Sněžník 1999–2000 (17.1–20.9%) (Fig. 1).

This trend is proved also by the development at various elevations, when under spring aspect, the loss increased markedly at 500–800 m a.s.l. as late as in 2000, while at 700 m and 1,000 m a.s.l., a decline appeared after culmination in 1999 (Fig. 2). In 2000 at the lower elevations, mites developed significantly, and at the highest elevations, the development of leaf fungal pathogens was slown down which, in contrast, was accelerated in 1999 (Fig. 2). From the long-term mean of assimilation surface damage degree under spring aspect at 500–900 m a.s.l., a balanced state is evident (13.5–13.4–12.2–11.5–13.6%), and a growth occurs only at 1,000 m a.s.l. (20.4 %). The summer aspect is characteristic of balanced leaf surface area decrease at 500–800 m a.s.l. (13.6–14.0–11.8–12.2%) with marked increase at 900 m and 1,000 a.s.l. (18.6%; 27.6% respectively). These changes are caused by different site conditions in upland plateaus of the Ore Mts. by harmful agents' different structure and their different responses to the weather course during individual years.

Of pests and harmful agents acting during the spring season, they were free-living caterpillars, independent on the elevation, damaging birch stands along the elevation whole profile (500–1,000 m a.s.l.) (Fig. 3). With increasing elevation, the occurrence of miners (*Coleophora serratella*, *Eriocrania* sp., *Anisostephus betulinus* [Kieff.]) and mites (*Aceria rudis* Can.) receded, but the occurrence of the rust *Discula betulina* (Westland) was increasing (Fig. 3).

During the summer season, the proportion of free-living caterpillars and hymenopterous larvae was confirmed to equal extent in defoliation along the transect whole elevation profile (Fig. 3). With species receding along the elevation gradient, weevils (*Apion* sp.), mites (*A. rudis*, *Phyllocoptes lionotus* Nal.) and rust (*Melampsoridium*

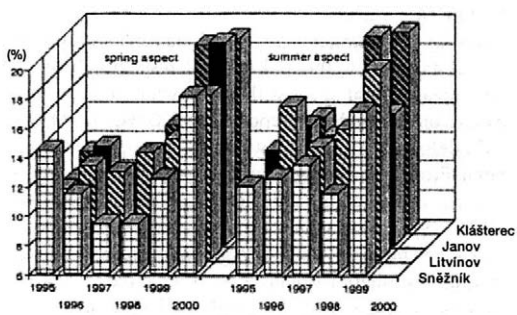

Fig. 1. Mean loss of the leaf surface area in birch stands at the transect level (%)

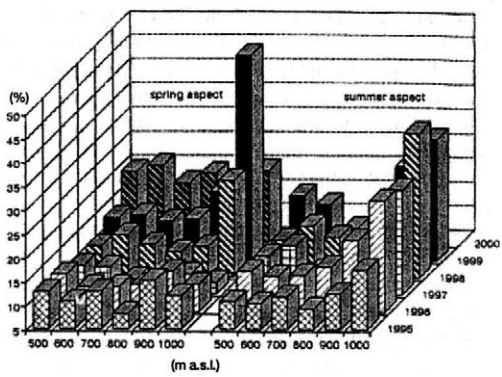

Fig. 2. Mean loss of the leaf surface area in dependence on the elevation (during 1995–2000) (%)

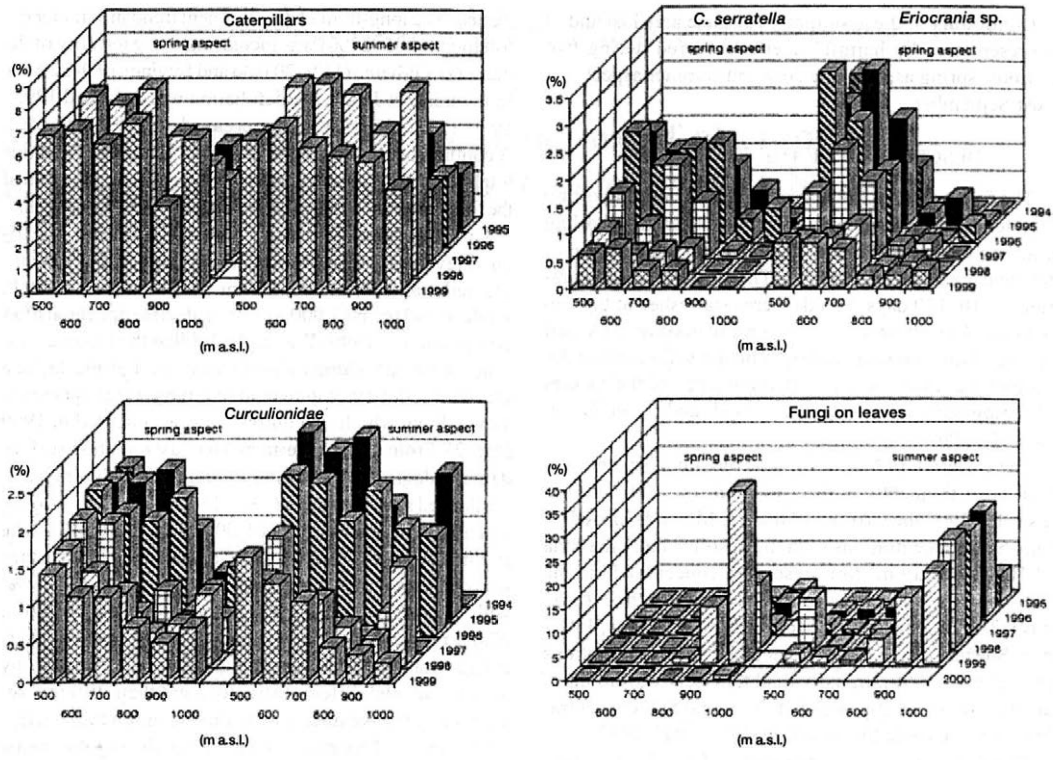

Fig. 3. Proportions of biotic pests in damage of the birch leaf surface area in dependence on the elevation (during 1994–1999) (%)

betulinum [Pres.] Kleb.) ranged. *D. betulina* belongs to significant harmful agents at the higher elevations (Fig. 3).

From assessments of individual pathogens' parallel occurrence along the elevation, it is evident that, in free-living caterpillars, case-bearer, miners from the genus *Eriocrania* and weevils along the elevation whole profile, the ratio was maintained with the dominant proportion of caterpillars which had partly different dynamics of feeding extent during the years of our study. In general, of course, the caterpillars' importance has increased. The other phytophages receded from the elevations of 900–1,000 m a.s.l. (Fig. 4). Leaf pathogens of *D. betulina* type started to activate in the spring season. At the lower elevations, their occurrence was ascertained sporadically, while at the elevation of 800 m a.s.l. and more, a clear development was evident.

The summer aspect structure was more simple, the importance of miners disappears and fungal pathogens set in as accompanying component for free-living caterpillars and weevils. With exceptions, it can be stated in general that the dominant proportion of free-living caterpillars and hymenopterous larvae in damage of birch leaves from 800 m a.s.l. up declined and was replaced by fungal pathogens. Weevils maintain the same level along the whole profile. Birch rust (*M. betulinum*) was found only at the lower elevations (Fig. 5).

DISCUSSION

Birch stands in the Ore Mts. are affected, besides site stressing conditions (air-pollution, weather), by biotic factors (insects, fungal pathogens). After birch not flushing in 1997 (KULA, RYBÁŘ 1998), afflicted stands are weakened also physiologically and with reduced foliage (KULA et al. 1997, 1998, 1999a). Long-term investigations on health state of these forest ecosystems under various aspects have brought complex information on their development and site conditions, and they facilitate the process of decision about rehabilitation and revitalisation of the Ore Mts. forests.

Spring and summer aspects with dominant proportion of leaf damage of 10% and 10–50% respectively and its total mean height suggest the state which does not endanger birch stands. As reported by KOPPONEN (1978), 15% defoliation caused by insects does not endanger birch. From our investigations along the elevation profile, the previous outcomes are confirmed (KULA et al. 1997, 1998, 1999b) that not only the birch crown fauna structure is changed but also its importance and disturbance extent in birch assimilation organs. Localities at the highest elevations are less endangered by phytophages than by other biotic factors (leaf rusts). Extant leaf surface area of birch in upland areas of the Ore Mts. was disturbed by

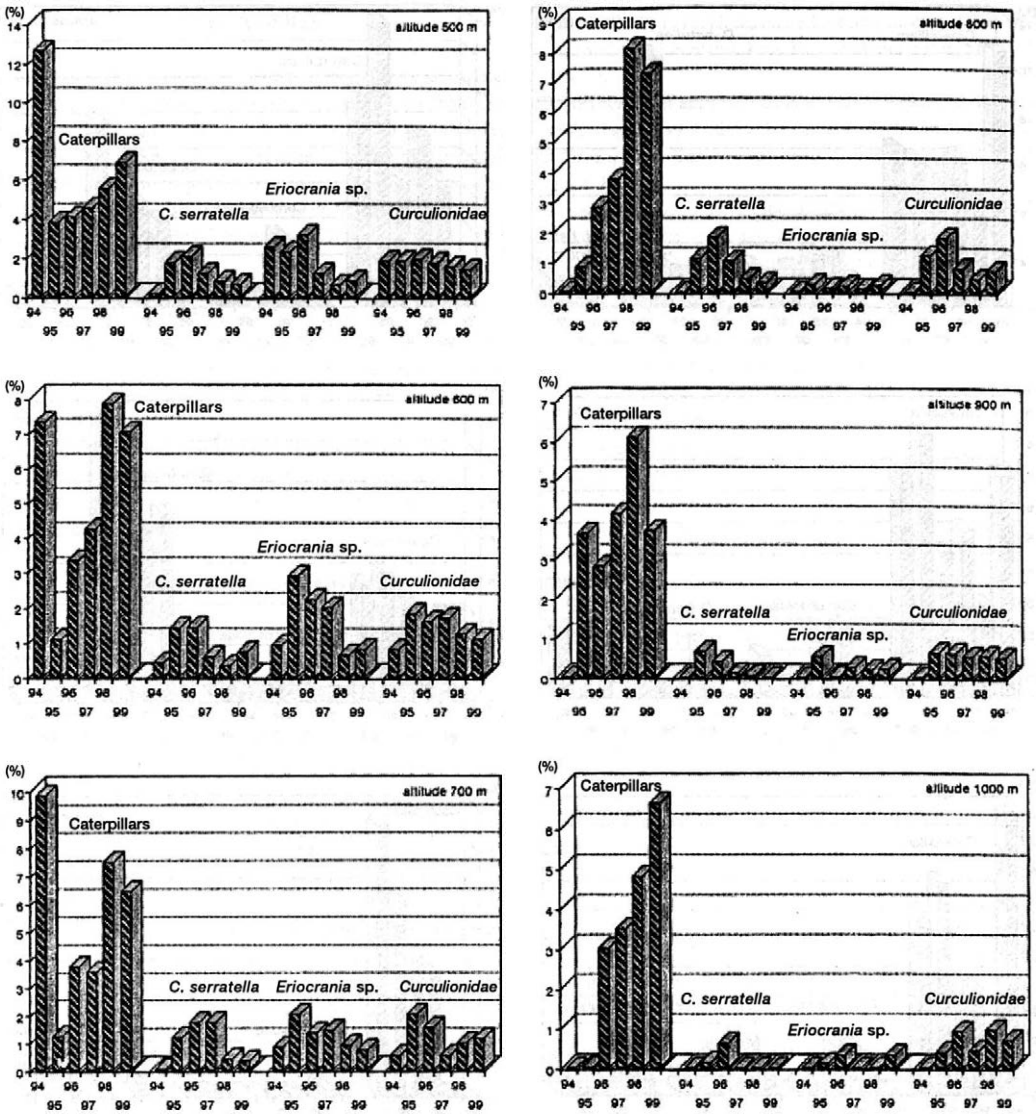

Fig. 4. Structure of dominant factors disturbing the leaf surface area quality of birch in dependence on the elevation under spring aspect (during 1995–1999) (%)

40–50%, when trees due to repeated infestation by pathogens were noted only for 50% and less of foliage extent. Trees get dry, and under site extreme conditions (at 900–1,000 m a.s.l.), they die-back. In 1999, the physiological endangerment was manifested even at the low elevations (due to combination of drought and fructification) when a premature total defoliation with generally low proportion of phytophages appeared (transect Litvínov). Despite that, an unfavourable developmental trend in defoliation occurs by insect feeding, first of all, by free-living caterpillars. The stand age can affect the pest occurrence and so also the damage extent; e.g., willow leaf beetles prefer young stands (KULA 1988, 1990). The area under study outgrew this pest, and it is not found more in the transects examined. On the contrary, caterpillars represent a permanent threat because they are not dependent on stand age, and as well site conditions, except for the highest elevations, are not constraining for them. The wide spectrum of 119 species from this group (KULA 1997b) constitutes permanently the potential endangerment of overcrowding by certain representative. An example can be in 1999 the ascertained caterpillar population increased density and feeding by *Epinotia trigonella* (L.) at the high elevations of the forest district Klášterec, and the appearing *Ch.* (*M.*) *lapponica*.

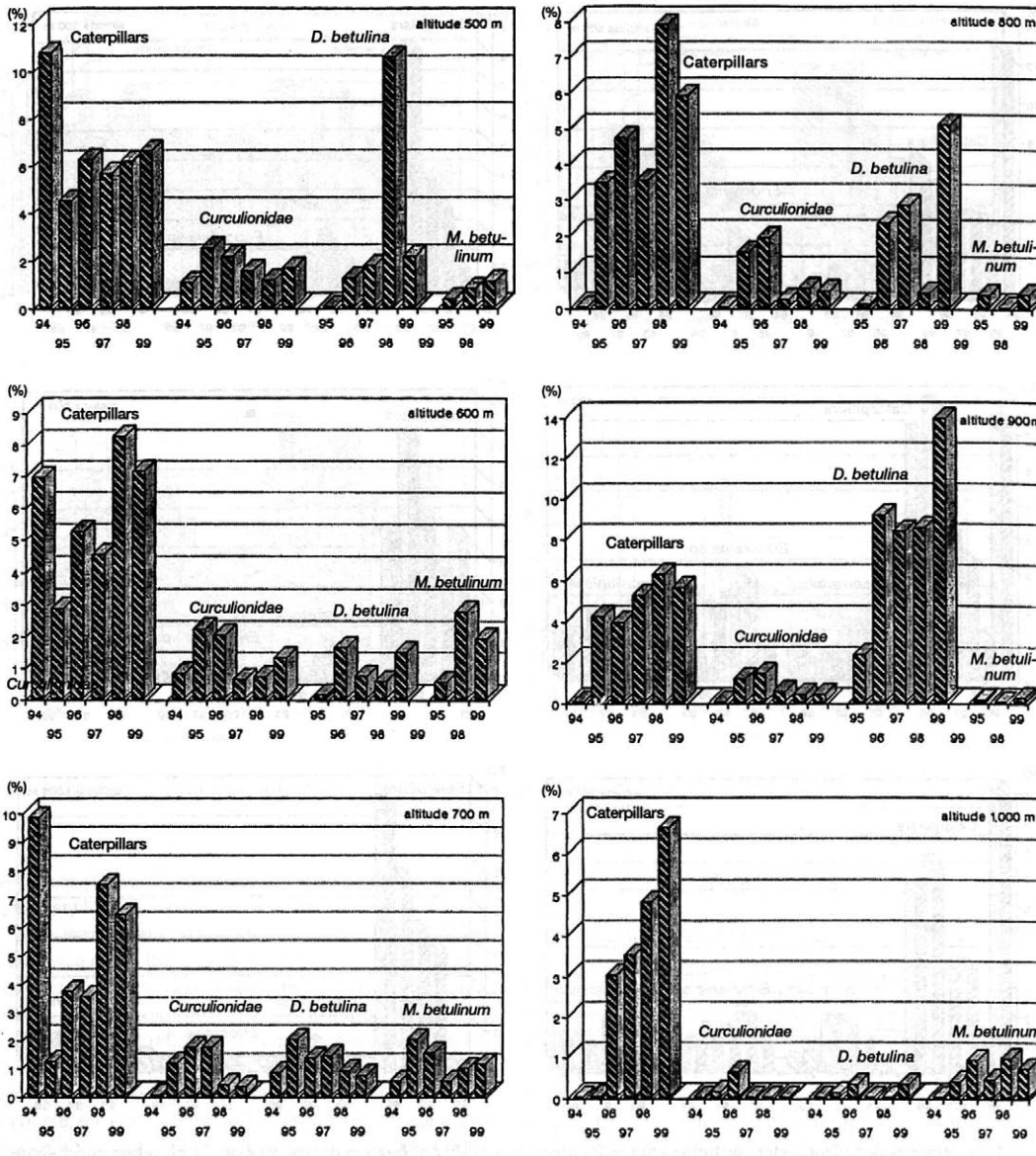

Fig. 5. Structure of dominant factors disturbing the leaf surface area quality of birch in dependence on the elevation under summer aspect (during 1995–1999) (%)

The pest species spectrum was stabilised in the second half of 1990s, after this territory was subject to overcrowding of several harmful species (willow leaf beetle, casebearer, *Eriocrania* sp.). Extraordinarily at the lower elevations and in several sites, mites (*A. rudis*, *Ph. lionotus*) activate that do not cause direct defoliation but participate in physiological weakening of a fertile tree species. The weakening extent and conditions of their local distribution are not know.

Permanent problems in birch stands at the higher elevations, regarding causes of tree weakening by decreased assimilation and premature leaf shedding, are leaf pathogens of *D. betulina* type. The leaf infestation increased in 1999 due to favourable weather course and pest accelerated development. At higher elevations due to severe defoliation, advance regeneration and bud break for substitute shoots appeared. Similar was the birch response after its non-flushing (KULA et al. 1997, 1998). New leaves were not infested more so markedly because they were formed as late as during the period of pest reduced intensity. The premature leaf cast due to rusts (*D. betulina*, *M. betulinum*, *Marssonina betulae* [Lib.] Magn.) is reported from Saxony (BÄUCKER, HEYDECK 2000).

CONCLUSION

- Birch insect pests occur for long-term in their basic state with local increased proportion, e.g., of miners from the genus *Eriocrania* (FD Sněžník) of mites (*Ph. lionotus*, *A. rudis*; FD Sněžník, FD Klášterec). The presence of phytophages with gradation potential and of new species not studied hitherto (*E. trigonella*, *M. lapponica*) makes birch stands of the eastern Ore Mts. endangered continuously.
- The elevation differentiated mites' occurrence, proportion defoliation by miners (*Eriocrania* sp., *C. serratella*) and that by weevils (at the lower elevations), and distribution of leaf fungal pathogens (at higher elevations). Independent in these aspects were free-living caterpillars.
- Long-termed development (dynamics) of pests (in 1995–1999) indicates the proportion increase in defoliation by caterpillars, decrease in weevils and miners, and leaf infestation increase by rusts.

Acknowledgements

The Project *Betula* aimed at solving the problems about birch in the North-Bohemian region was funded, within decisive part, from the Grant task of the Grant Agency of the Czech Republic No. 526/98/0537, and VaV/830/3/00 with the financial contribution by the Ministry of Agriculture, Forestry of the Czech Republic, obtaining also sponsors' support by regional joint stock companies and enterprises: Obalex s.r.o. in Jílové, Netex s.r.o. and Alussuise a.s. in Děčín, Okresní úřad in Děčín and Teplice, Setuza a.s., Teplárna a.s. in Ústí n. L., ČEZ a.s., Elektrárna Ledvice, Prunéřov and Počerady, Lafarge Cement a.s. in Čížkovice, Severočeské doly a.s. Chomutov, Dieter Bussmann s.r.o. in Ústí n.L.

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Birch dying in the Ore Mts. in 1997 – probable causes and new developments

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ABSTRACT: On the base of the course of mean monthly temperature, the authors have proven the extremity of meteorological factors, which are supposed to play a role in the birch die-back started in spring 1997 in the Ore Mts. The difference between mean April and March temperatures was lowest for the whole period when birch was planted as the substitutional species. In 1990, when the temperature development was also atypical, there were no frost episodes after the warm period. Frost injury of the shallowly distributed root system after snow melting during the warm period in March 1997, could be one of the possible mechanisms of the dieback. This hypothesis is supported by a different pattern of rooting depth between heavily damaged and healthy birch stands, and also by transpiration measurements at trees of different level of damage. Recent health state development of birch trees shows a high mortality of the trees of 80% defoliation and higher; trees up to 50% defoliation seems to be much more stable. Results from the stands with both *Betula pendula* and *Betula pubescens* confirm higher vitality of *Betula pubescens* in the Ore Mts. top plateau.

Keywords: Ore Mts.; substitutional stands; birch dieback; meteorological factors; rooting depth; sap flow

The Ore Mountains – Krušné hory – Erzgebirge are known as a heavily polluted area. Pronounced dieback of forests caused by high SO_2 concentration has been observed there during the 20th century (MATERNA 1999). In the turn of seventies and eighties most of the spruce forests in the mountain range location (above 700 m a.s.l.) has died, and was felled. The large clear-cuts have been reforested by the substitutional forest stands, composed mostly of the tree species, which were supposed to be more resistant against air pollution. Blue spruce (*Picea pungens* Engelm.), birch (*Betula pendula* Roth), and mountain ash (*Sorbus aucuparia* L.) were the most common among them. Birch was planted at more than 10,000 ha (KUBELKA et al. 1992). Birch was not a traditional "target" species in the Czech forestry, so there was a lack of appropriate seed material for reforestation – allochthonous seeds of different origin and quality were used. It was known, that the birch stands are not stable for longer period, and its rotation was planned in twenty to forty years (JIRGLE, TICHÝ 1981). All the stands, however, grew well during eighties and the first half of nineties, with the exception of some mechanical damage caused by hard-rime events (e.g. winter 1995/96 – LOMSKÝ et al. 1996; FABIÁNEK 1997).

In spring 1997, rapid dieback of the birch stands has been observed at the Ore Mts. plateau, at the altitude above 800 m a.s.l. In some localities the trees did not burst, in most of the cases, however, they had burst normally and shed its leaves during April (LOMSKÝ et al. 1997). Based on the first analyses, it was stated that the meteorological factors during winter and spring 1997 were the triggering factor of the damage. The warm period during March, and subsequent frost events in April are supposed to disturb the physiological processes leading to flushing, or to cause a xylem cavitation (LOMSKÝ, ŠRÁMEK 1999). Several questions, however, are still left open – e.g.: Was the course of weather really so extreme, that it can explain the damage in 1997? What was the mechanism of the damage? What will be the development of the damaged stands?

The article is based on different outputs from the research project focused on birch dying in the Ore Mts. It incorporates new information, which can, at least partly, elucidate some of the questions.

MATERIAL AND METHODS

METEOROLOGICAL FACTORS

The monthly mean temperature values from the station Nová Ves v Horách (800 m a.s.l), operated by the Czech Hydro-Meteorological Institute (CHMI), were used to evaluate the extremity of the weather course during March and April 1997. The data were compared to the temperatures as measured in the time period since 1956 (beginning of measurement) to 1999. Daily mean temperatures coming from the same station were used to compare the development in the first half of 1990, and 1997.

Since 1998 the meteorological parameters were measured also close to the stand where the tree transpiration was observed. They included a continuous registration of the global radiation (Li-200 pyranometer) and air temperature at 2 meters above the soil surface and soil temperatures in different depths. All thermometers used Pt100 sensors. The air temperature gauge was placed in usual radiation shield.

ANALYSE OF ROOTING DEPTH

Thirty soil pits were dug in the birch stands of different level of damage, in 1999. The assessment, regularly provided by the forest personnel, was used as a basis for determining of the level of damage. Ten pits were located in (1) non-damaged stands (2) slightly damaged stands and (3) heavily damaged birch stands. Pits were sized 1.5 × 0.5 m, 0.5 m deep or at least to the mother rock at shallow soils. Percentage of the birch roots in the 5 cm thick horizons was estimated visually. The relative number of roots in the upper soil horizon (20 cm) and the rooting depth of 80% of the roots were evaluated.

SAP FLOW MEASUREMENT

The transpiration was measured as the sap flow on the branch level. Five gauges of T693.1 sap flow meters (EMS Brno, CZ) were located on different branches of two neighbouring trees in upper part of crown. The branches were oriented mostly in south to west direction. The branch diameters just bellow the gauges ranged from 14 to 18mm. The same arrangement was used on both differently damaged plots. The measurement was running more than one week on each plot.

On the base of the data measured, a simple model of the relationship of branch transpiration to the meteorological conditions, characterising evaporation demands of the atmosphere was worked out. In all the cases a linear relationship of the flow and the sun radiation and temperature proved to be optimal, by a general equation

$$Q = a \times R + b \times T$$

where: Q – flow,
R – global radiation,
T – air temperature,
a, b – parameters of the equation obtained by linear regression.

In searching the a and b parameters, the periods with precipitation and after precipitation have been excluded from the data set.

DEVELOPMENT OF THE HEALTH STATE

Development of birch dying was evaluated at 10 monitoring plots, established in June 1998 (ŠRÁMEK 1998). Each plot of 50 birch trees is characterized by a different level of damage. Tree height, breast-height diameter and mortality was recorded for each tree, in June 1998. Defoliation, discoloration, stem and branch damage were evaluated in June and August 1998 and 1999. These parameters were monitored for 30 trees at each plot as a standard, at three plots of high morality all the 50 trees were evaluated. In the article these data are used to evaluate the risk of mortality for differently damaged trees, the probably development of moderately damaged trees and the correlation between the tree height and the level of damage. The development of defoliation for common birch (*Betula pendula* Roth) – 20 trees – and downy birch (*Betula pubescens* Ehrh.) – 10 trees – at the plot of Rudolice is compared.

RESULTS AND DISCUSSION

METEOROLOGICAL FACTORS

In March 1997, the mean monthly temperature at the station of Nová Ves v Horách was 2.5°C. When comparing it to the period of 1956–1999, it can be seen, that March 1997 was warmer than usual (Fig. 1). The temperature 2.5°C corresponds to 71% percentile – during the last fifty years there were only twelve years warmer than the 1997. The high March temperature was influenced by the temperature inversion of the upper layer situated approximately at 700 to 800 m a.s.l. (LOMSKÝ, ŠRÁMEK 1999). This situation resulted in low temperatures and foggy weather in the Ore Mts. basin. At the same time, warm, sunny daytime weather, and low temperatures in the night in the mountain ridge were recorded. April, on the other hand, was relatively cold. The mean monthly temperature in April 1997 was 2.7°C. There were only seven colder

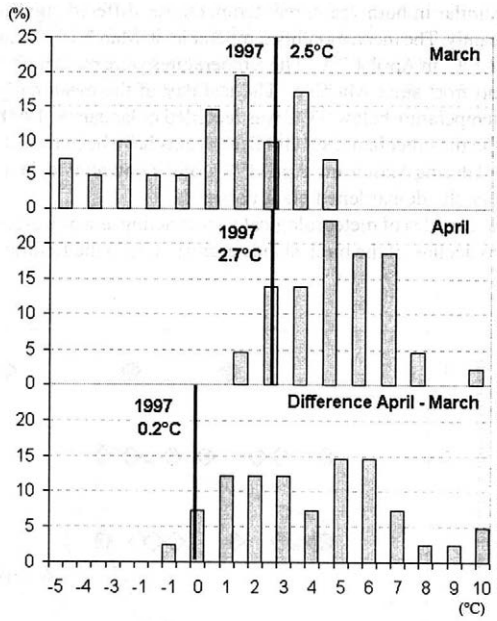

Fig. 1. Distribution of mean monthly temperature for March, April and the temperature difference April–March in the period from 1956 to 1999, Nová Ves v Horách

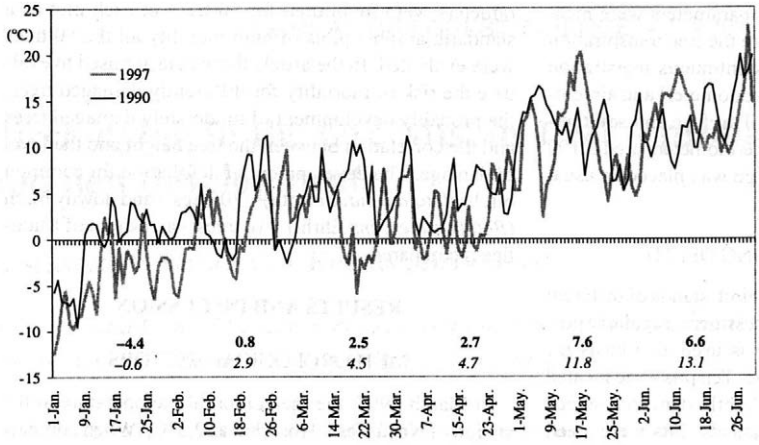

Fig. 2. Development of mean daily temperature in 1997 and 1990 Ore Mts., Nová Ves v Horách

The numbers at the bottom of the chart illustrate the development of mean monthly temperatures. In bold for 1997, in italic for 1990

years during the period of 1956 to 1999. The percentile of 1997's temperature is 19%.

The mean temperature difference between April 1997 and March 1997 is very low. April was only in 0.2°C warmer than March. The percentile of this difference for 1997, within the 1956–1999 temperature series, is 6%. There is one only year in the period measured, when this difference was even lower – negative. It was in 1977, when April was –0,8°C colder than March. However, there were no extent birch stands at the ridge localities in that time.

Only in 1990 the temperature difference April–March was the same as in 1997. It can be seen (Fig. 2) that in spite of the fact that the course of the temperature curve was similar in both years, real temperatures differed significantly. The mean monthly temperature in March 1990 was 4.5°C, in April 4.7°C. The temperatures were quite high – no frost since March 5. The last day of the mean daily temperature below –3°C was recorded in January 9, 1990. On the other hand, several frost events have been recorded during March and April 1997, of the potential to damage the de-hardened plant tissue.

The idea of meteorological factors acting as a precursor to decline of the birch stands corresponds to the findings of BRAATHE (1957, 1995) and JONES et al. (1993), who analysed widespread die-back of birches (*Betula papyrifera, Betula alleghaniensis*) in the northern United States and Canada.

ANALYSE OF ROOTING DEPTH

The results of the analysis of rooting depth are shown at the Figs. 3 and 4. Fig. 3 shows the correlation of the damage intensity and relative number of roots in the soil depth to 20 cm. It can be seen, that in heavily damaged stands (class 3) the majority of roots was spread in the upper soil horizon. In average it was 75.6%. Lower relative number of roots can be find in the upper soil horizons of slightly damaged stands. Its percentage ranged from 35% to 84% with the mean value of 56.7%. The non-damaged stands have in average only 46.7% of roots in the depth to 20 cm.

At the Fig. 4 the rooting depth of 80% of the roots can be seen for the stands of different level of damage. At heavily damaged stands, the birches have 80% of their root system in upper 24 cm of the soil profile as the average. For slightly damaged stands the depth limit for distribution of

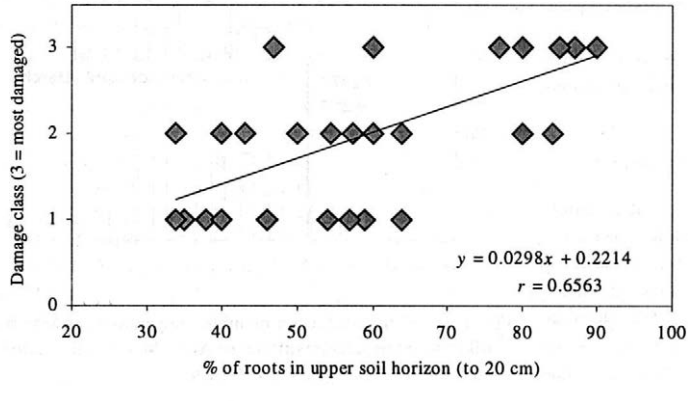

Fig. 3. Dependence of damage intensity on number of roots in upper soil horizon (0–20 cm)

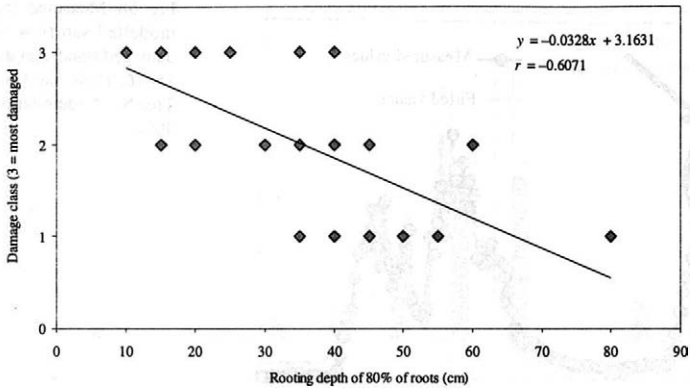

Fig. 4. Dependence of damage intensity on depth of birch rooting (80% roots)

80% roots was 37 cm as a mean. At non-damaged stands the mean depth for rooting of 80% of roots was 46 cm.

There is significant difference, of 95% probability level, between the non-damaged and heavily damaged stands in both parameters. Shallow rooting at heavily damaged birches was induced either by water regime (ŠRÁMEK 1998) or by insufficient depth of soil.

The existing hypothesis supposes that the physiological processes leading to bursting have been disrupted (LOMSKÝ, ŠRÁMEK 1999). However, the fact that the trees did burst and have lost their leaves by the end of April 1997 is contradictory. Above-mentioned results imply that there is a consequence of the rooting depth and the birch damage. Supposed frost-damage of the birch roots located in the upper soil layers (e.g. after thawing of snow cover during warm period) can explain the delay in the tree reaction. Similar results are described by POMERLEAU (1991). After artificial removing of the snow cover he observed the same symptoms of damage on birches as can be seen in the Ore Mts.

SAP FLOW MEASUREMENT

When comparing the real transpiration and the model values, derived for this purpose from the data on temperature and global sun radiation, more or less significant limit can be observed at the mid-day for all the branches of the stand defoliated. This limit is visible only at sunny days, in cloudy weather it can be hardly observed. The transpiration flow of the healthy stand follows the diurnal curve of potential evapotraspiration more or less precisely (Figs. 5a and 5b) when comparing with the diurnal pattern of sap flow coming from heavily damaged plot.

Limited transpiration is less significant in cloudy days, when the high evaporation demands occur in short time period only. The situation described can be explained by strongly limited water uptake due to high resistance of root/soil compartment or due to limited internal hydraulic resistance. The short-time evaporation demands are likely covered with the water stored in the internal water reservoir in the stem or branches bellow the measuring point,

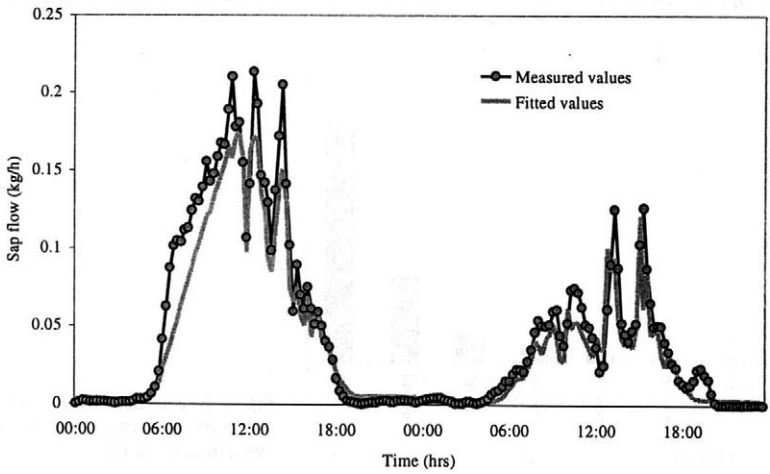

Fig. 5a. Measured and modelled sap flow of healthy birch stand, August 20, 1998; sap flow tree No. 49 (defoliation 10%)

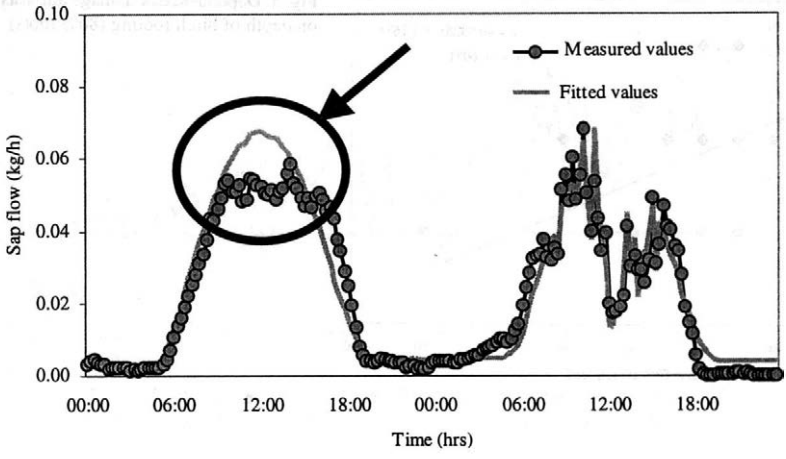

Fig. 5b. Measured and modelled sap flow of damaged stand, August 15–16, 1998; sap flow Tree No. 4 (defoliation 40%)

which is refilled from the soil in the time of lower evaporation demands. However, the conducting tissues, most probably due to high hydraulic resistance as mentioned above, are not able to follow the high potential evapotranspiration during a longer part of day. Due to limited water income the water potential of the leaves increases and the stomata are closed – this is visible as a flat shape of the daily transpiration curve.

Most of the works, describing daily flow curves under the soil moisture limit, present a characteristic shape of the maximum value before noon, and decreasing gradually during the afternoon (ČERMÁK et al. 1992). Such a decrease of the transpiration flow can be connected with the decrease of water content in the soil and following increase of the soil moisture potential and hydraulic resistance. These factors act as a positive feedback mechanism, and they cause monotonous decrease of the transpiration flow, in certain level independently of the value of potential evapotranspiration. In this case, however, the horizontal, even some times slightly up-going shape, of the limited part of the daily curve, together with a high soil moisture, does not support this explanation, thus the limit of hydraulic conductivity has to be found more probably in a tree itself; in a stem or roots. Besides a root damage caused by low temperatures, also cavitation of the vascular bundles in the stem should be considered, described for paper birch (*Betula papyrifera* L.) by COX and MALCOM (1997). In the light of these results we can suppose that the normal flushing of the birch stands and gradual leaf area development has started. Due to the root damage there was a insufficient water supply at certain stage, resulting, according to its intensity, in an increased defoliation or even decay of the birch trees.

DEVELOPMENT OF THE HEALTH STATE

The previous defoliation level at the beginning of damage (July 1998) was evaluated for currently dead birches (Fig. 6). Nearly two thirds of them were dead already at the start of the damage. About 30% of currently dead birches was heavily defoliated from the very beginning, exhibiting leaf loss over 85%. On the other hand, few examples of currently dying trees of the defoliation below 50% in July 1998 can be found, and the cause of the dam-

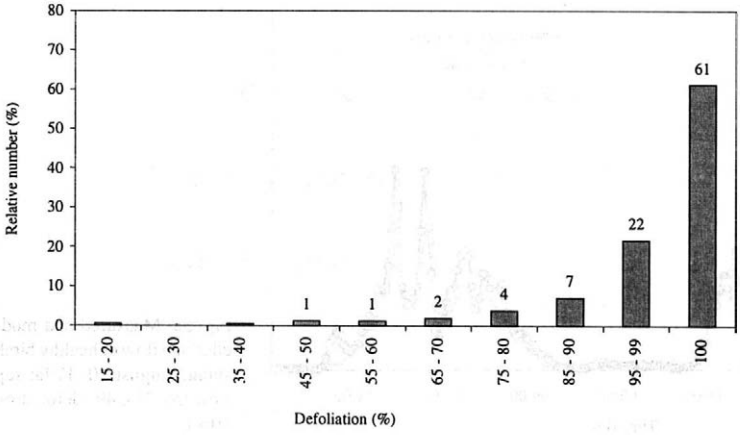

Fig. 6. Recent defoliation (Juny 1998) of currently (September 1999) dead birch trees

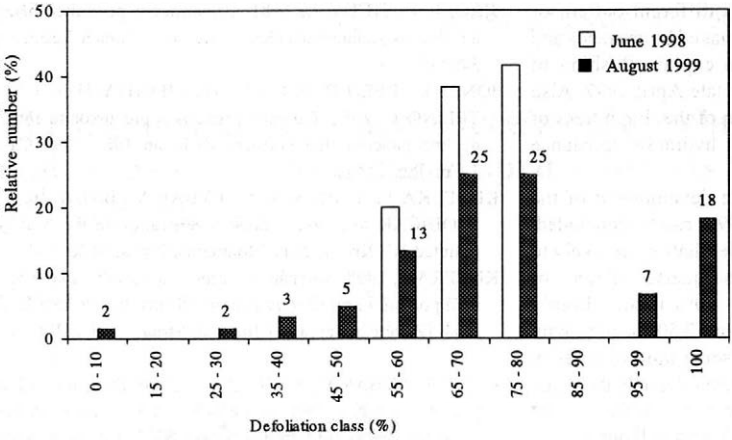

Fig. 7. Development of health state of moderate damaged birches (defoliation 55 to 80%)

age can be explained by other factor, e.g. stem damage by red dear.

The health state development of the birches of defoliation ranging from 55 to 80% in June 1998 is shown at Fig. 7 for August 1999. It can be seen, that the majority of trees (63%) was at the same level of defoliation. A quarter of them was declining or nearly dead. Only 12% of the birches, originally only moderately damaged, showed signs of regeneration.

In June 1996 more than 2,500 ha of heavily damaged birch stands was reported, over 2,000 ha of moderately damaged birch stands and about 800 ha of weaken birch stands in the Ore Mts. (KULA et al. 2000). In the view of presented results rather rapid deterioration can be expected in heavily damaged stands. In moderately damaged and/or weak stands the situation seems to be more stable, there is a danger of any additional stress, however.

When comparing the health state and development of *Betula pendula* and *Betula pubescens* at the plot of Rudolice (Fig. 8), we can see that the defoliation of *Betula pubescens* is significantly lower. Also the development of defoliation since August 1998 seems to be more favourable for *Betula pubescens*, even though not on the significant level. These findings support the opinion of higher resistance of *Betula pubescens* supposed to be of native origin in range localities reported also by KUBELKA et al. (1992), VACEK and BALCAR (1999) and MARTINKOVÁ et al. (2000).

CONCLUSION

Weather conditions were rather extreme during the early spring of 1997. When evaluating the whole period, when the birch stands are being planted in the Ore Mts., the difference between mean temperatures in March and April was lowest in 1990 and 1997. In 1990, however, the temperatures were relatively high, with no frost events in April and May. In 1997 the situation was different. The low temperatures in April 1997 with several frost events could start a damage of birch – at least from the bioclimatological point of view.

Frost injury of the superficially distributed root system after snow melting, during the warm period in March 1997, could be one of the possible mechanisms of the dieback.

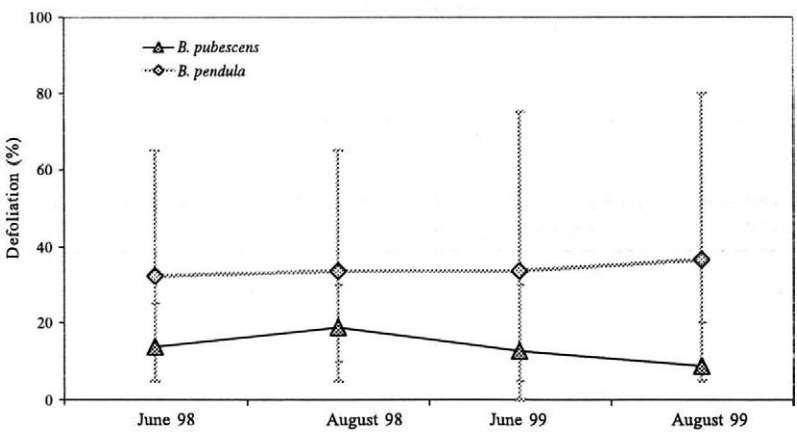

Fig. 8. Development of defoliation of *Betula pubescens* and *B. pendula*, Rudolice

This hypothesis is supported by different pattern of rooting depth between heavily damaged birch stands and non-damaged stands, and it can explain flushing of birches and shedding of leaves in late April 1997. Also the pilot study of the transpiration of the birch trees of different level of damage shows hydraulic resistance either in roots or stems.

On the base of the health state development of the damaged stands during 1998–1999 it can be concluded, that the trees of 80% and higher defoliation are likely to die in next few years. About one quarter of trees of defoliation ranging from 50 to 80% is also highly endangered. This imply that more than 2,500 ha of heavily damaged birch stands will need some kind of forestry reconstruction in a near future. The moderately damaged and/or weaken stands seem to be more stable, at least unless no other secondary stress factors will appear.

Acknowledgement

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The importance of stand succession for elasticity and conversion of damaged spruce forests and birch pioneer woods

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ABSTRACT: The wood and forest ecosystems of the Erzgebirge (Ore Mts.) are characterised by intense instability. In severely damaged spruce stands the development of stages of pioneer wood is a decisive character of elasticity. The development found here tends to a stabilisation of elemental cycles. The regeneration of the productive functions of wood ecosystems demands an artificial introduction of intermediary or climax tree species. Damages to birch found since 1998 occur mainly with common birch. In the medium mountainous range the regenerative processes of the ecosystems are mainly governed by rejuvenation of mountain-ash and birch. On the other hand, successional processes in the birch pioneer woods of the upper mountainous range are directed towards the formation of grass stages with long term stability. Therefore, functionality of these wood ecosystems can be only secured by silvicultural measures.

Keywords: state of forest-ecosystems; state of soil; damage to spruce and birch; transformation of strong damaged spruce stands; transformation of birch stands; successions

Forest and wood ecosystems in the area of the Erzgebirge (Ore Mts.) are characterized by marked **loss of stability.** The dynamics of these ecosystems are dominated by **allogeneous successions.** As reason extremely high immissions must be stressed. The destructive power of their pressure is intensified by the predominantly **low elasticity** of these ecosystems.

The formation and even more the maintenance of ecologically unstable spruce forests was rendered possible only by continuous, systematic input of additinional energy. Apart from various short periods of permanent wood movement, these spruce forests determined the silvicultural systems of the last two centuries.

Sustainability was even understood as fiscal sustainability of timber production on the level of management classes by tolerating spatial and temporal uncoupling of constructive and destructive processes.

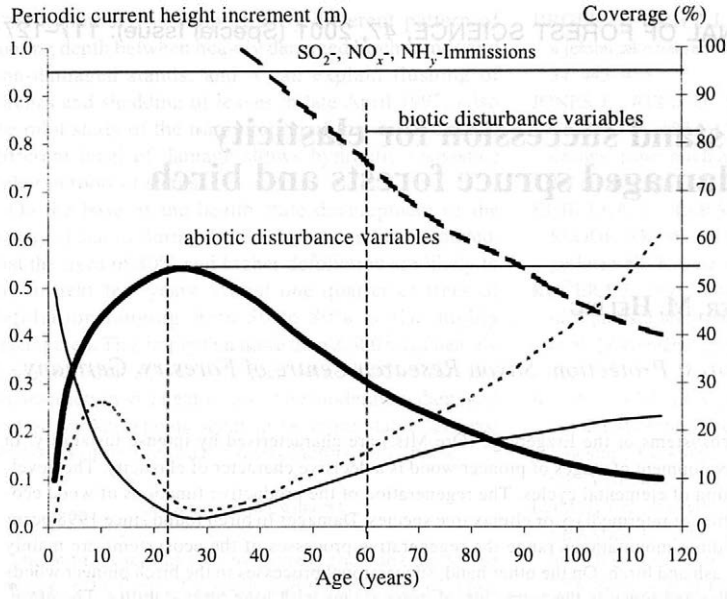
Processes of stabilisation as an immanent character of systems, for example the spread of inferior broad-leaved trees, were eliminated by continuous **browsing by game**. These damages were paralleled by tending of cultures and young stands of spruce. In this way the development of a greater potential of admixed tree species was rendered impossible. As such situations lasted for several decades uninterruptedly, the diaspora immigration even of such species was scaled down considerably which usually initiate successions in spruce-forests ecosystems: mountain-ash, birch, aspen and sallow.

Therefore, **niches for competing species**, as they turned up with the appearance of damages in spruce timberstands and as they culminated with accelerated decay of these stands, could not be occupied by an emerging shrub layer of inferior broad-leaved species. Furthermore, the assumption seems to justified, that during this decay selective browsing directed the spread of herbaceous coupe flora increasingly towards grass overgrowth. In addition to these factors, the more continental microclimate of spruce stands with opened-up canopies strengthened the competitive power of *Calamagrostis villosa* in phytocenoses (Fig. 1).

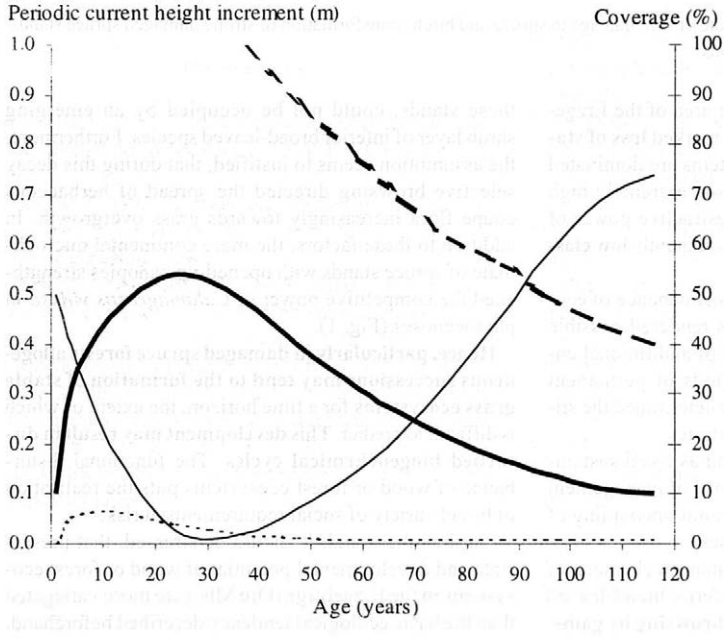
Hence, particularly in damaged spruce forests allogeneous successions may tend to the formation of stable grass ecosystems for a time horizon, the extent of which is difficult to predict. **This development may result in disturbed biogeochemical cycles**. The functional disturbance of wood or forest ecosystems puts the realisation of broad variety of social requirements at risk.

On the other hand, it should be stressed, that present state and developmental potential of wood or forest ecosystems in the Erzgebirge (Ore Mts.) are more variegated than the basic ecological tendency described beforehand. If population dynamics of ruminant hoofed game species are regulated in accordance with the urgent regeneration of the primary production of the wood ecosystems, successions could be integrated to different degrees into forming and stabilising such ecosystems. Direction and intensity of succession process, compared with **silvicultural targets**, indicate necessity and intensity of silvicultural **regulation requirements**.

In this context forest management depends on the **targets issued by the forest owners** and brought into agreement with **social requirements**. The silvicultural principles for



A
ecosystem dynamic in connection with low intensity of browsing and cleaning of young stands from inferior broad-leaved tree species



B
ecosystem dynamic modified by intensiv browsing and cleaning from inferior broad-leaved tree species

current height increment
coverage of spruce
coverage of *Calamagrostis villosa*
coverage of broadleaved tree species

Fig. 1. Immissions, biotic and abiotic disturbance variables, selective browsing and cleaning of young spruce stands from inferior broad-leaved tree species as factors strengthened the competitive power of *Calamagrostis villosa* in clear spruce stands

the state forest of Saxony constitute a frame of these targets. As to the non-state forest these principles mean an orientation, however, they may become decisive for the support of forestry measures.

Based on these silvicultural principles the following restrictions limit possible silvicultural options:

– For the state forest an ecologically adapted forestry is obligatory.

- The principle of ecologically adapted forestry is substantiated by ecological demands, ranging equally with economic ones:

Ecologically there are the following basic demands:
- site-adequate choice of tree species,
- appropriate presence of the tree species of the natural woodland community,
- horizontally and vertically structured stands.

Economically the following demands should be met:
- minimisation of production risks,
- production of a high proportion of first- rate timber coming from many tree species and consisting of several assortments,
- input optimisation by systematic utilisation of natural processes (biological rationalisation).

The frame given by silvicultural principles is substantiated by the stand-objective types of Saxon state forest. The **process-directed silvicultural realisation** of these medium-term to long-term objectives demands not only knowledge on the given state of the ecosystems, but also **solid information on alterations of geotopes, on changes of the attractors and on responses of the existing woods**. This information is based on a **network of various monitoring systems together with long term experimental plots of forest research** (Fig. 2).

ACTUAL STATE OF WOOD AND FOREST ECOSYSTEMS

STATE OF SOIL

In the geotopes of the Erzgebirge (Ore Mts.) the **geological substrata** of soil formation are gneiss, slate and granite with moderate capacity to neutralise acid substances. Amongst soil types brown soils of different degree of podsolisation are predominant.

The **actual acidity** is found in the depth range of strongest rooting (10 to 30 cm) mainly in the aluminium buffer range. In the O_h-horizon of the organic top layer and in the depth range of 0 to 5 cm the aluminium buffer range is predominant. In the western part of the Erzgebirge the exchange buffer range is only in the depth range of 30 to 60 cm whereas in the eastern part even this depth layer is belonging to the aluminium buffer range .

The **potential acidity** of the depth range of 10 to 30 cm indicates the extreme acidification events of the past by ph (KCl)-values in the aluminium-iron buffer range.

Low (5 to 15%) and very low (< 5%) base cation saturation illustrates a similarly **low elasticity** of the mineral soil to acid impacts.

The **saturation of the cation exchange complex with exchangeable acids** in the depth range of densest rooting

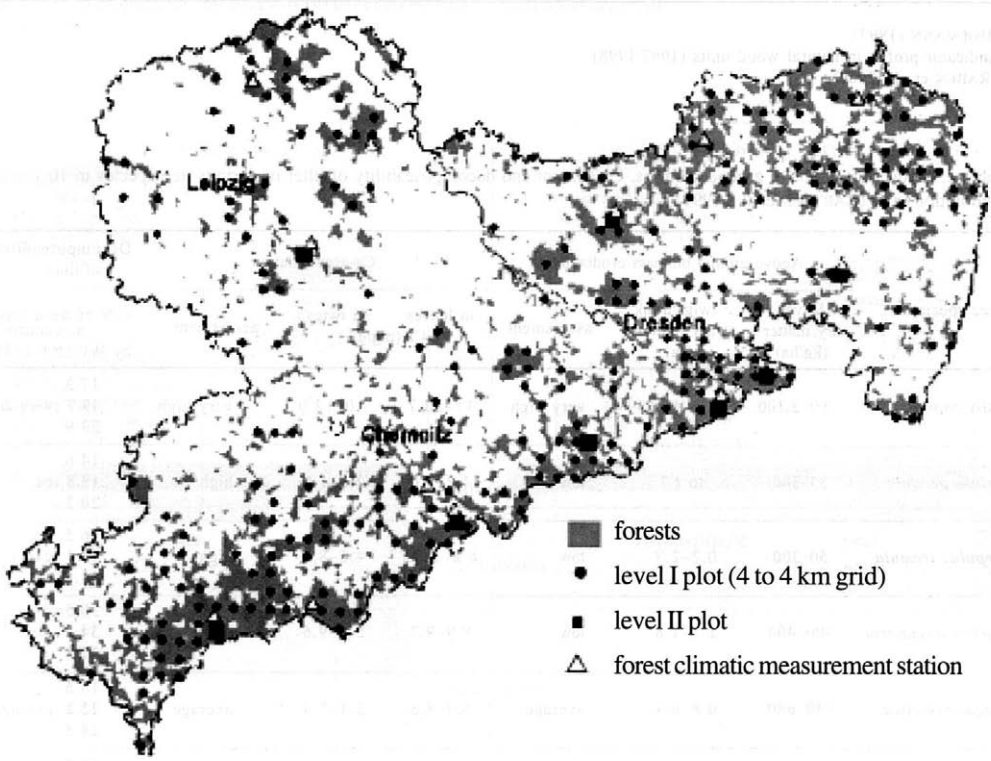


Fig. 2. Network monitoring systems as information basis for ecological sustainable silviculture

is highly important for the assessment of the risk potential of forest trees. **An aluminium saturation above 80%** in depth range between 10 to 60 cm induces an **immense risk potential of Al- and H-sensitive tree species**. That applies in particular to beech with its high importance to actual forest conversion projects (RABEN et al. 2000).

The prevalent ecologically unfavourable **mould and raw humus forms** cause a marked accumulation of organic matter. In the long run, therefore, **material cycles tend to be uncoupled**. In particular nutrient cations and nitrogen are removed from the elemental cycle of the forest ecosystems, and consequently the imbalance between proton production and proton consumption will further increase.

In this context it should be mentioned that, according to information of the study group for forest site mapping (Arbeitskreis Standortskartierung 1996 in: RABEN et al. 2000), cation reserves reach the following levels:

- calcium **moderate** to medium (**500**–1,100 kg/ha)
- magnesium **moderate** to medium (**150**–300 kg/ha)
- potassium **low** to moderate (**200**–550 kg/ha); however, they are bound in the top humus layer.

Therefore, the actual state of forest soils induces

- a **considerable loss of elasticity to further waves of acidification,**
- an increased **risk for acid-sensitive tree-species,**
- a **considerable reduced buffering capacity of soils in spruce forests, compared with beech-wood ecosystems in comparable geotopes** (Table 1),
- **the fixation of a major part of the moderate to medium nutrient stock of forest soils in the organic top** layer and

Table 1. Base saturation under beech forest communities, managed beech forests and clear spruce stand on phyllit-brown-soils

Depth range	Base saturation (%)			
	Luzulo-*Fagetum sylvaticae*[1)]	*Calamagrostio villosae-Fagetum sylvaticae*[1)]	Beech with beech-undercrop[2)]	Clear spruce stand[3)]
0–5 cm	12 bis 15	8 bis 12	20.3	9.6
5–10 cm	12 bis 15	8 bis 12	9.9	7.0
10–30 cm	12 bis 15	8 bis 12	7.1	7.5
30–60 cm			7.7	12.2
60–90 cm			9.8	17.6

[1)] HOFMANN (1997)
[2)] indicator profils in natural wood units (1997/1998)
[3)] RABEN et al. (2000)

Table 2. Production of above ground biomass, Ca-content and decomposeability of litter of various tree-species in 10 years old melioration trials (BARTELD et al. 1999)

Tree species	Above ground biomass production			Ca-accumulation			Decomposeability of litter
	leaves dry matter (kg/ha)	twigs/trunk dry matter (t/ha)	assessment	in leaves Ca (mg/g)	in twigs Ca (mg/g)	assessment	C/N of fresh leaves – assessment by WITTICH (1943)
Salix caprea	60–2,100	0.2–10.6	very high	11–20.7	7.0–12.0	very high	17.3 **19.7** (very easy) 23.9
Betula pendula	35–300	to 1.7	low	4.2–9.0	2.2–5.0	high	14.6 **18.8** (easy) 20.2
Populus tremula	50–300	0.2–2.7	low	8.8–16.6	4.6–8.6	high	16.5 **18.3** (easy) 20.8
Sorbus aucuparia	300–400	1.7–1.8	low	8.9–9.7	5.9–9.6	high	30.5 **34.2** 37.8
Fagus sylvatica	140–680	0.8–6.4	average	5.4–8.8	3.1–7.4	average	18.6 **22.2** (average) 28.5
Picea abies	1,600–1,800	2.6–3.1	high	6.6–7.8	3.1–3.6	average	39.8 **42.8** (difficult) 45.9

– **the advancing tendency towards uncoupling biogeochemical cycles**.

Consequently, **ecological sustainability** is being lost.

This state of geotopes and biotopes, respectively, leads to **a high risk potential** and to a **relatively low stabilisation potential** of these ecosystem compartments. In the biocoenosis the state of soil is being reflected by damages to spruce as dominant tree species, but also by such to beech.

Within the framework of forest management the following measures may possibly influence the **stabilisation of forest soils**:

– **meliorative liming** and compositional liming in combination with
– the **activation of nutrient reserves fixed in the organic top layer** and
– **support or stabilisation of inferior broad-leaved tree species** in the course of successional processes and/or during the introduction of target tree species and
– a long-term **alteration of tree-species composition and the phytocoenosis structure**.

The **ecological efficiency of liming measures** demands as far as possible a large-scale inclusion of inferior broad-leaved trees (sallow, mountain-ash, birch, Table 2, Fig. 3) in stand succession or in rejuvenation structures (BARTELD et al. 1999).

On the sites which are discussed here **meliorative liming** is part of **standard procedures of forest conversion** (LEUBE 2000).

VITALITY OF SPRUCE AND ELASTICITY OF DAMAGED SPRUCE STANDS IN RELATION TO THE DAMAGED AREA OF THE WINTER FROM 1995 TO 1996

Vitality of spruce

The extreme course of atmospheric conditions and of SO_2 immissions in the winter from 1995 to 1996 led the acute damages in spruce stands of the upper range and ridge of the Saxon mountainous region. These damages are characterised by the following constellation of factors

– **between November and March** continuous pollution from **immissions surpassing the critical threshold value for spruce needles of 70 µg/m³ as daily average and reaching maximum values above 1000 µg/m³**, locally 2000 µg/m³, (Fig. 4),
– continuous **inversion-weather situations** in connection with **air advection from south-east**,
– **physiological activation by relatively high air temperatures on frozen soil in March** (frost-induced draw) **following icing and long lasting low temperatures** (Fig. 5).

As external symptom red-coloured or necrotic needles appeared abundantly from March in a **damage area of approximately 50,000 ha.** These needles were lost during the growth period. On an area of about **3,000 ha the majority of spruces died acutely**, and on **10,000 ha severe damages turned up**.

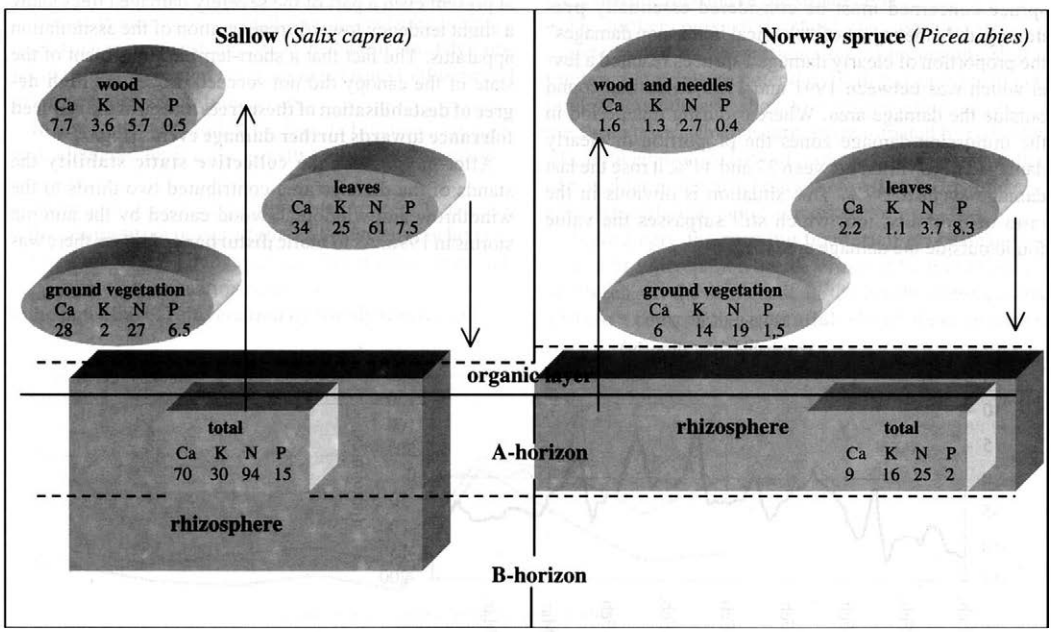


Fig. 3. Schematic comparison of elemental cycles (kg/ha per year) under sallow and spruce stands (BARTELD et al. 1999)

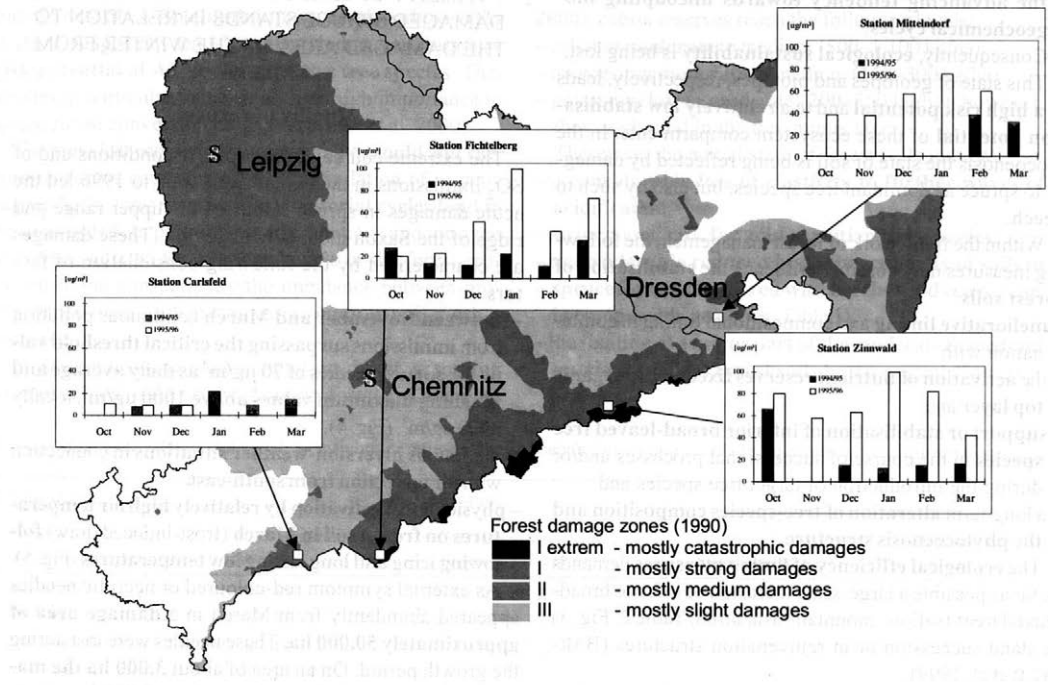


Fig. 4. Month average of SO_2-immissions in the winter 1994/95 and 1995/96 at different stations in Saxony

The damage area is completely situated in the immission-damage zones determined in 1990. From this the spruce concerned must be considered essentially **predamaged**. In the region of "classical immission damages" the proportion of clearly damaged spruces reached a level which was between 1991 and 1995 twice that found outside the damage area. Whereas during this period in the immission-damage zones the proportion of clearly damaged trees varied between 37 and 44%, it rose the last damage event to 59%. This situation is obvious in the ratio of mortality, too, which still surpasses the value found outside the damage area (Fig. 6).

In principle regeneration of damaged spruce stands could be observed (HELBIG et al. 2000). In this connection, at present even a part of the severely damaged trees show a slight tendency towards regeneration of the assimilation apparatus. The fact that a short-term improvement of the state of the canopy did not succeed proves the **high degree of destabilisation of these trees** as well as the **reduced tolerance towards further damage events** (Fig. 7).

After having lost the **collective static stability** the stands of the damage area contributed two thirds to the windthrow and windbreak wood caused by the autumn storms in 1996. As to **biotic disturbance factors** there was

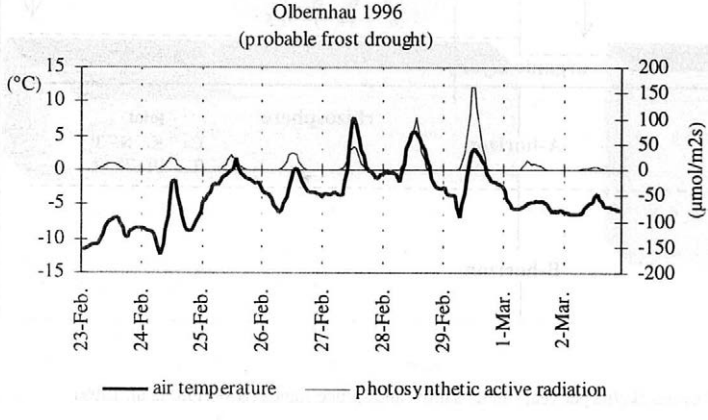


Fig. 5. Temperature dynamics in the winter and spring 1996

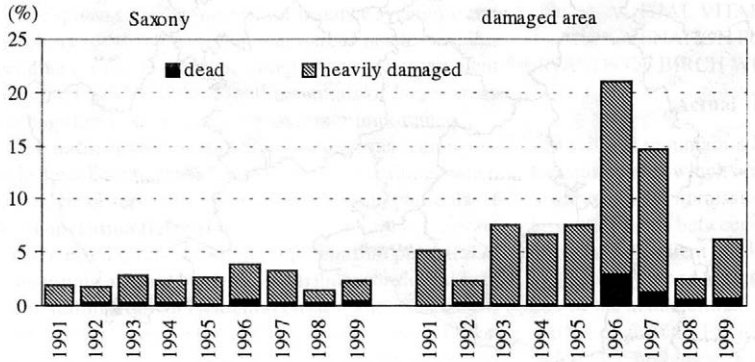


Fig. 6. Percentage of heavily damaged and dead trees from 1991 to 1999

a shortly increased infestation of standing trees with bark beetle. This plague, however, did not reach major importance due to atmospheric conditions in the subsequent years as well as to consequent forest hygiene.

As result of the disturbance dynamics of damaged spruce forests succession mosaics are developing in dependence on the local developmental potential. They consist of **stages of pioneer wood and grass overgrowth**, complemented by temporary and/or small-area dominance of shrubs or small-area aggregations of lying dead trees.

In order to judge the possibility, whether **stabilisation processes which are immanent to the given system** can be integrated into silvicultural measures this **succession potential** must be analysed **on its relation to the silvicultural objectives**.

Elasticity of damaged spruce stands

Elasticity on the level of the phytoceonosis is determined in forest ecosystems also by **developmental dynamics of the rejuvenation reserves in relation to the spread of suppressive vegetation covers**.

In this context the following factors function as regulatory elements during the sensitive phase of stand successions:

- the mosaic of dominating ground-layer vegetation types,
- **the competitive power of the still existing tree layer** in relation to the ground layer vegetation and to eventually existing rejuvenation reserves,
- **the potential of rejuvenation by woody species** and
- **the intensity of browsing stress**.

The action system of these factors is deciding whether the competition network of dissolving spruce forests develop niches for stages of pioneer wood. The structure of the rejuvenation reserves can be used as complex information in order to characterise ecosystemar developmental potentials of a greater regional scenary.

In **damaged pole and timber stands of spruce in medium altitudes of mountainous region** with a canopy density degree of 0.3 to 0.4 the sensitive stage of stand succession is characterised by the spread of *Sambucus racemosa*. The **height-class distribution** shows the **abundance of a vertical differentiation** which is **due to competition**. The medium rejuvenation density with biomass accumulation in the height classes above 50 cm indicates the tendency towards a considerable, ecologically **active nitrogen accumulation in the shrub layer**.

The further course of the stand succession is essentially determined by the participation of mountain-ash and birch in rejuvenation potential. Both tree species in particular mountain-ash, show high rejuvenation rates under the shrub layer, which is hitherto dominated by red elder. The rejuvenation density of mountain-ash surpasses that of red elder in height-classes up to 50 cm. This true also for birch, although being as marked.

Accordingly, the **running formation processes** in the course of rejuvenation are determined by mountain-ash and birch. At the same time in the height-classes above 130 cm a **competitive potential** of both these species is

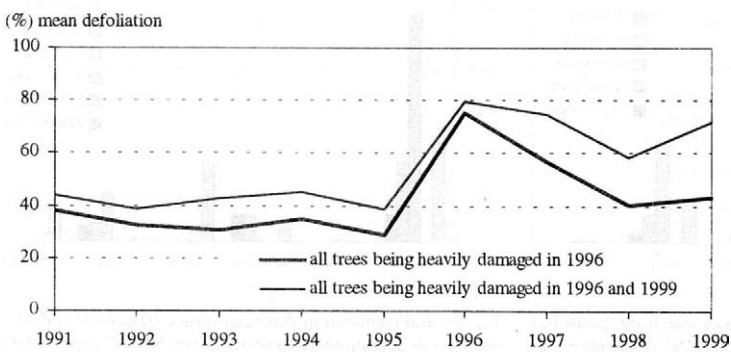


Fig. 7. Mean defoliation of trees being heavily damaged in 1996 (and 1999)

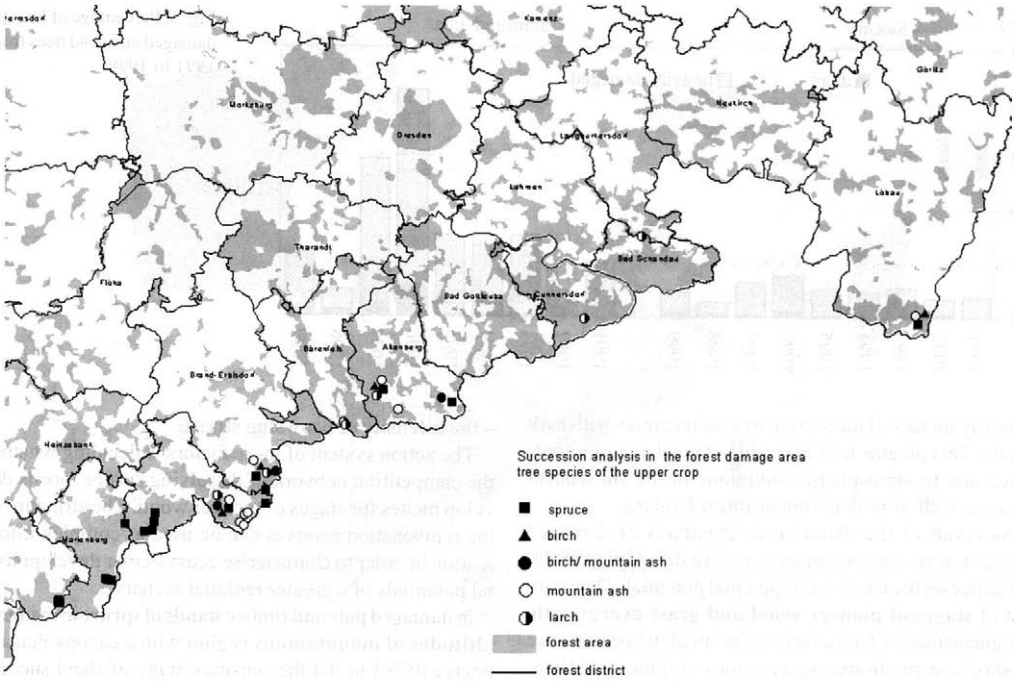


Fig. 8. Experimental plots with analysis of secondary succession in stands of various tree species in the immission-damage zones of the Ore Mts. and the upper Lusatia

developing. A rejuvenation density of 10,000 mountain-ashes and 6,000 birches, respectively, only in the height-class from 50 to 130 cm can contribute to the further succession course by the considerable **accumulation of Ca and Mg**, by unproblematic **circulation** of these elements, due to easy decomposability of the litter and, in the end, by the **stabilisation of elemental cycles** (Table 2, Fig. 3).

As one of the potential target species sycamore (*Acer pseudoplatanus*) is **locally** benefiting by immigration (Fig. 9a).

In the **upper mountainous region** red elder becomes less important. The sensitive initial stage of the stand succession is distinguished by the **mountain ash** (Fig. 9b). In addition **birch** is present, too. Both species tend to **vertical differentiation** and high rejuvenation density in the height-class of 50 to 130 cm, as a whole, on the places investigated. Compared with the previous example here, too, the further accumulation in the rejuvenation course of woody species is declining for the time being.

The conclusions drawn on the influence of pioneer tree species on the stabilisation of elemental cycles apply basically also to the upper range of the mountainous region.

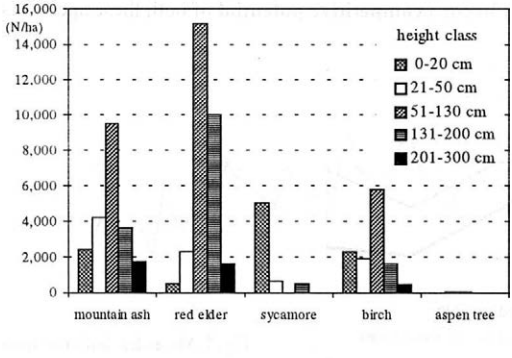


Fig. 9a. Rejuvenation in damaged spruce stands on (podsolic) brown soils in altitudes from 450 to 700 m NN (72 sample plots)

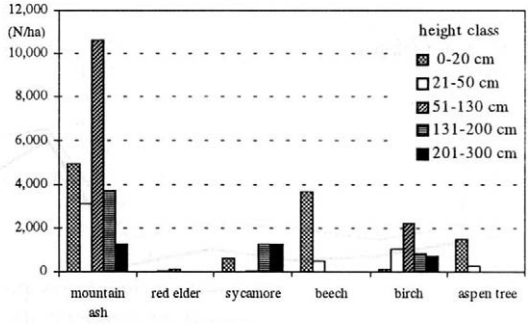


Fig. 9b. Rejuvenation in damaged spruce stands on (podsolic) brown soils in altitudes from 650 to 850 m NN (92 sample plots)

The spread of other species, for instance sycamore and beech, is restricted to a few main areas occurrence depending on the diaspora potential. As to the assessment of silvicultural developmental potentials of larger areas findings these species are only of minor importance.

The **natural processes** outlined for a greater region provide the following clues for ecological silviculture, which should be observed by the forest rangers, in particular if **local operational decisions** have to be found:

- In damaged spruce stands the **rejuvenation potential of mountain ash and birch can contribute considerably to the stabilisation of elemental circles**. The efficiency of an artificial input of Ca and Mg depends essentially on the participation of these tree species in the regeneration processes of wood ecosystems.
- **In the medium range of the mountainous region the marked spread of red elder, too, contributes to the stabilisation of the N-cycle**.
- From this succesional processes are usually directed to the **formation of pioneer wood stages**, which may become considerable competitive potential to prospering grass overgrowth.
- Natural processes may **restrict the formation of mice's habitats**.
- Vertically differentiated stages of pioneer wood cause a considerable improvement of the site conditions for **an artificial introduction of target tree species** as well as **risk minimisation** to the influence of biotic and abiotic damage factors.
- The developing stages of the pioneer wood render it possible to introduce target tree species in a more extensive way.
- Hence, **natural processes** contribute decisively to the **regeneration of ecological sustainability** understood as lasting functionality of wood ecosystems by spatial and temporal continuity of constructive and destructive processes.
- This contribution **secures mainly the protective activity** of wood ecosystems, whereas for the regeneration of the **productive activity** the artificial introduction of target tree species is necessary.
- The formation of the rejuvenation potential of woody species given in stands which are not totally overgrown with grasses depends essentially on **pressure by browsing**.
- In damaged spruce stands with a ground layer which is **almost completely dominated by *Calamagrostis villosa* a meliorative soil cultivation** is indispensable for the immigration of pioneer tree species. An **active introduction of these tree species** may be considered if conditions are extreme.

For each place these general results should be substantiated by **analysing horizontal distribution patterns** in relation to the regulatory factors which were discussed. In the end an optimal decision on rejuvenation of each individual demands procedures of inventory which are manageable in an **operational decision-making by forest rangers**.

ACTUAL VITALITY OF BIRCH AND REJUVENATION POTENTIALS IN PIONEER STANDS OF BIRCH WITH OPENED-UP CANOPIES

Actual vitality of birch

Birch and mountain ash contribute only 8% to the afforestation area which originated from the areal die-back of spruce in the immission–damage region of the Erzgebirge (Ore Mts.) between 1962 and 1991. This percentage means an equivalent of 736 ha. Both tree species are likely to yield only wood assortments which cannot be utilised due to the actual climatic conditions of the upper range and the ridge of the Erzgebirge (Ore Mts.). The protective function of both tree species was already mentioned.

Since 1998 there are many reports on wide-spread **damages to birch in altitudes beyond 700 m above sea level**. A concentration of the damages **on sites with water supply above average** is obvious. In these altitudes birch stands cover 464 ha, including 30 ha moor birch. On the base of an inventory the damages are compacted to 70 ha. They occur in particular in the forest ranger district of Deutscheinsiedel (35 ha). As to their appearance the damages are characterised by losses of leaves and cracks in the stems.

The exterior damages were followed by an acute or gradual die-back. Preceding phytopathological investigations (BÄUCKER, HEYDECK 1999) revealed the presence of *Marsonina betulae* on the leaves of damaged birches. In literature this species is described as debility parasite. Detailed information on aetiology and pathogeny are not available. Infection experiments carried out under the influence of simulated stagnant moisture did not show positive results.

To analyse and to scrutinise the phenomenon a system of monitoring plots was established. It represents various sites and altitudes.

Remarkably damages occur mainly with **common birches**. **Moor birches** were only rarely attacked. As to the state of foliation there was a significant difference between both birch species on all experimental areas in August. Defoliation rates surpassing 70% reveal intensive damages in the forest range of Deutscheinsiedel, that is in the ridge range of the Erzgebirge (Ore Mts.).

Analyses carried out on stems show irregularities of wood formation at the beginning of the vegetation period 1997, which was marked by severe late frosts in a large area of Saxony.

Results so far indicate a **reduced ecological capacity of common birch** particularly **on moist mineral sites of the upper range and the ridge of the Erzgebirge** (Ore Mts.). At present the silvicultural importance of the hitherto almost unknown damages in birch stands is considered relatively low for the Saxon part of the Erzgebirge. **Stronger damages**, however, demand an anticipated conversion of these stands in order to have the following wood regeneration protected by the birch canopy. This conclusion applies in particular to **birch stands on terrestrial sites**. For moist mineral sites an extensive tree species conver-

sion to moor birch should be considered (see: BÄUCKER, EISENHAUER: Damage to common birch in higher altitudes of the Ore Mts.).

Rejuvenation potential in pioneer woods of birch with opened-up canopies on terrestrial sites of the medium and higher mountainous range of the Erzgebirge

The rejuvenation potential in pioneer woods of birch with opened-up canopies in the medium mountainous range originates mainly from common birch and mountain ash (Fig. 10a). Therefore, a **pioneer wood–pioneer wood-succession** (p-p-succession) can be assumed, in which at present the natural immigration of target trees does not play a major role.

Exceptions can be found in cases of an **abundant local diaspora potential of target tree species** (for instance beech and sycamore). Under such circumstances the spread of the tree species concerned may become silviculturally relevant.

The **reaction of the pioneer wood on its site** is comparable with returns spent by pioneer woods stages on damaged spruce stands. The rejuvenation densities which were found mark progressing stabilisation of elemental cycles likely. In comparison with the primary stages of pioneer wood indamaged spruce stands rejuvenation densities of mountain-ash and birch are clearly smaller; quite obvious is the reduced participation of red elder.

This development is possibly caused by less favourable conditions for the production of seedlings by the species concerned, in particular by increasing grass overgrowth in birch pioneer woods with opened-up canopies. This process correlates apparently with an increasing accumulation of nitrogen. From this for the geotopes investigated the following hypothesis could be derived: **A p-p-succession of mountain ash and birch means a temporary stabilisation. In contrast, the successional development or formation of stable wood ecosystems is regarded to be bound to the natural immigration or artificial introduction of intermediary or climax tree species.**

Accordingly, the **prognosticated attractor**, the birch-mountain ash pioneer wood, secures temporarily the protective activity of the wood ecosystems, whereas securing the **productive activity** requires the artificial introduction of target tree species.

In the **upper mountainous range** birch stands with opened-up canopies rejuvenation is predominantly bound to **mountain ash,** showing densities considerably below the level of the preceding examples. The rejuvenation stock is found almost exclusively in the height class up to 20 cm (Fig. 10b). The formation of a competitive potential in relation to the exploratively spreading ground layer cannot be expected for this unstable stage of rejuvenation. **With advancing senescens and thinning of the first generation of pioneer wood constructive and destructive processes are endangered to be uncoupled**. This may eventually lead to the establishment of stable stages of grass overgrowth. In the end, **long-term functional disturbances** of these wood ecosystems would put also the lasting preservation of their **protective activity** at risk.

Therefore, freely proceeding natural processes were by no means able to meet a **demand of social priority**: the lasting maintenance of the **protective function** of the wood. For the particular case of the object of investigations there were, beyond this, a basic **contradiction to the owners priority**: the **regeneration of the productive function** of the wood.

The **silvicultural realisation** of the regeneration of the protective as well as productive functionality of these ecosystems depends on the availability of additional energy. The silvicultural minimum choice leading to the temporary preservation of the pioneer wood would consist in a meliorative soil cultivation combined with the sowing-in of birch and/or mountain ash. The regeneration of productive functions depends on the introduction of the target tree species of stand-objective type "mixed spruce mountain forest". In view of observations having been described here it must be considered, whether this step, compared with possible provisional variants, can contribute to the formation of wood ecosystems.

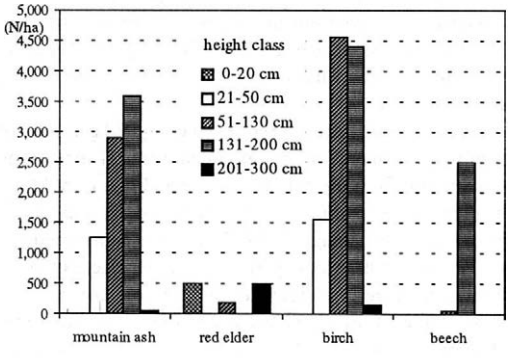


Fig. 10a. Rejuvenation in damaged birch stands on (podsolic) brown soils in altitudes from 450 to 700 m NN (40 sample plots)

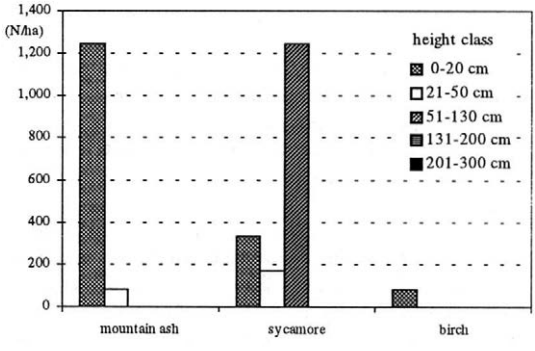


Fig. 10b. Rejuvenation in damaged birch stands on (podsolic) brown soils in altitudes from 650 to 850 m NN (12 sample plots)

Regarding the disturbed spruce forests and birch pioneer woods of the Erzgebirge (Ore Mts.) the preliminary results presented here constitute the frame for subsequent investigations. In this context **analysing horizontal distribution patterns** of the rejuvenation of woody species in relation to the already mentioned regulatory factors is likely to deepen silvicultural and ecological conclusions. The **ecological assessment** demands the development of prognosis models on dynamics of biomass and element accumulation for silviculturally relevant geotopes and phytocoenoses. Taking **hierarchies of social objectives** into consideration **ecologically and silviculturally founded stand developmental types** are to be determined.

These types constitute the base of a **frame for silvicultural treatments**, which must be specified for each place by the **local manager**.

Optimising the rejuvenation scheme for an individual stand demands an **inventory**, which must be suitable for the **forest ranger** in charge to pass an **operational decision**.

SUMMARY

The wood and forest ecosystems of the Erzgebirge (Ore Mts.) are characterised by intense instability. This situation becomes obvious for instance by parameters of acidity and elasticity of the forest soils. As they were obtained in the course of the forest soil survey.

The actual state of the biocoenotic stability is determined by the high damage level of spruce in the immission-damage zones (defined in 1990). This level rose further in the winter 1995/96 due to acute immissions. Consequently spruces died back on an area of 3,000 ha. In severely damaged spruce stands the development of stages of pioneer wood consisting of mountain ash and birch with strong participation of red elder in the medium mountainous range is a decisive character of elasticity. The development found here tends to a stabilisation of elemental cycles. The immigration of intermediary or climax tree species is restricted to only a few places with proper diaspora potential. Therefore, the regeneration of the productive functions of wood ecosystems demands an artificial introduction of these tree species.

Damages to birch found since 1998 occur mainly with common birch. For this tree species a high damage intensity is found on moist mineral sites of the upper range and the ridge of the Erzgebirge (Ore Mts.). After all the extent of the damages is of second-rate importance for the forest management. The formation of birch pioneer woods in this region is influenced by far more by two other factors: a marked disposition to damages by snow breakage and icing and an early senescence. In the medium mountainous range the regenerative processes of the ecosystems are mainly governed by rejuvenation of mountain-ash and birch. In spite of rejuvenation densities which are clearly smaller the assumption seems to justify that these processes are sufficient to secure a proceeding stabilisation of the elemental cycles.

On the other hand, successional processes in the birch pioneer woods of the upper mountainous range are directed towards the formation of grass stages with long-term stability.

Therefore, functionality of these wood ecosystems can be secured only by silvicultural measures.

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Vitality of Norway spruce (*Picea abies* [L.] Karst.) in Slovenia

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ABSTRACT: The first research activities in Slovenia in the field of forest damage caused by air pollution began in the late 1960s. Today we have an integrated forest monitoring system. We perform an annual forest condition survey on a systematic 16 × 16 km grid net, and also on a more dense 4 × 4 km grid every five years. In 1995 we performed a co-ordinated inventory of tree damage and tree nutrition status. The vitality of Norway spruce was analysed on 30 plots out of a total 43 in the Slovenian 16 × 16 km net. To this end, the crown conditions and the density of lichens population were assessed on permanent control plots. Nitrogen, phosphorous, potassium, calcium, magnesium, sulphur and heavy metals contents in spruce needles and the pH value of the upper mineral soil layer were analysed on the same plots. Different parameters were compared. We found stronger correlations between crown conditions and lichens population (IAP), lichens population and sulphur content, magnesium content and pH values of mineral soil.

Keywords: Norway spruce; IAP; crown condition; nutrition status; Slovenia; air pollution

Human activities have had influence on forests for thousands of years. But until recently these have been scarcely noticeable. In the last few decades the extent of the activities and their influence on forests have changed (ABRAMOWITZ 1998).

During the 1970s the condition of the forests deteriorated remarkably in different parts of Europe. Trees lost their foliage or showed discolouration of needles and leaves, and the vitality of forest trees decreased. As a result, the issue of forest decline rapidly became one of the most widely discussed environmental topics.

In Slovenia the first research into forest decline began as early as 1969, and the first survey on a systematic grid (4 × 2 km) was carried out in 1984 (ŠOLAR 1997). Since 1987, Slovenia has been active in the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). Under the scope of the programme on large scale monitoring, crown conditions and the occurrence of damage easily identifiable as biotic or climatic stress are assessed annually. Furthermore, soil condition data and foliar element contents were recorded in 1995.

METHODS

Annual inventories of forest health have been conducted since 1991. The inventory is carried out on a 16 × 16 km grid net, including 986 trees on 41 plots, and every five years on a 4 × 4 km net, including over 17,000 trees on more than 700 plots. The survey of forest health includes an assessment of defoliation, discolouration and the occurrence of damage caused by natural stress factors (defoliating insects, adverse weather conditions, etc.).

At the same time, the monitoring of air pollution using epiphytic lichens is carried out. For that purpose a simplified bioindication method was developed, where the mapping of thalli types (i.e. crustose, foliose and fructicose) was implemented, as well as consideration of the coverage and frequency of all thalli and also the height of the trees where lichens were observed. A very simple quantification of the assessment of these parameters was introduced, and by using a formula, an index of atmospheric purity was calculated for each observation plot (BATIČ 1996).

For the analysis of foliar chemical content, needles were taken from the seventh whorl of healthy trees, from the sun-exposed part of the crown (the trees belong to predominant and dominant classes – forest with closed canopy). Afterwards the needles were oven dried (60°C for 24 hours) and ground. The total S content was determined by Sulhomat 12 – ADG, total N by the micro-Kjeldahl method, total P spectrophotometrically, K, Ca, Mg, Al, Fe, Mn, Zn, Pb and Cd with flame (FLAAS) or electrothermic (ETAAS) AAS (Manual on methods and criteria for ... 1994). Foliar samples were mineralised by wet digestion with $HNO_3/HClO_4$ (5:1) (ÖNORML 1085). Soil pH value was determined with pH electrode (0.01 M $CaCl_2$ extractant).

The entire methodology (crown condition assessment and foliar chemical content) was harmonized with ICP for-

est methodology (Manual on methods and criteria for ... 1994).

RESULTS

CROWN CONDITION

In 1991 and 1995 the inventory of Norway spruce crown condition was carried out on 4,077 trees; in all the other years 294 trees were included. For all the years the same trees are compared ($N = 294$).

In Norway spruce (*Picea abies*), a slow deterioration in crown condition was observed between 1991 and 1999 (Fig. 1). The average defoliation of Norway spruce was at all times except 1994 and 1997 higher than the average defoliation for all trees, regardless of species.

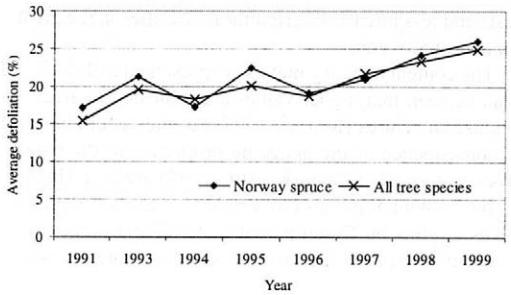

Fig. 1. Changes in average defoliation for Norway spruce and all tree species between 1991 and 1999

While the proportion of trees with defoliation of up to 10% slowly decreased, the proportion of trees with more then 25% defoliation increased (Fig. 2). The greatest increase was observed in trees with 26–60 % defoliation, with an increase from 14.4% to 26.5% (1991–1999). The share of trees with up to 10% defoliation decreased from 39.0% (1991) to 24.5% in 1999.

Temporal changes in defoliation were assessed using 10% defoliation intervals. We found out that a stronger deterioration in crown condition began in 1996. Since then the proportion of trees with 0–10% defoliation decreased from 43.8% in 1996 to 23.5 % in 1998. Simultaneously, the portions of trees defoliated 20–40% increased from 20.1% in 1996 to 34.4% in 1998. In 1999 a small improvement was observed.

EPIPHYTIC LICHENS

On a part of the trees (six per plot) which were assessed for decline symptoms, the frequency and coverage of crustose, foliose and fructicose lichens were also assessed. Lichen maps were constructed on the basis of the data gathered. Two maps for observations on Norway spruce are presented in Figs. 3 and 4. The impact of air pollution is well expressed around the main pollution sources in Slovenia and in the western and south-eastern parts of the country, where transboundary pollution takes place. These findings were in accordance with the knowledge about air pollution situation in Slovenia and other data (forest decline and air pollution measurements).

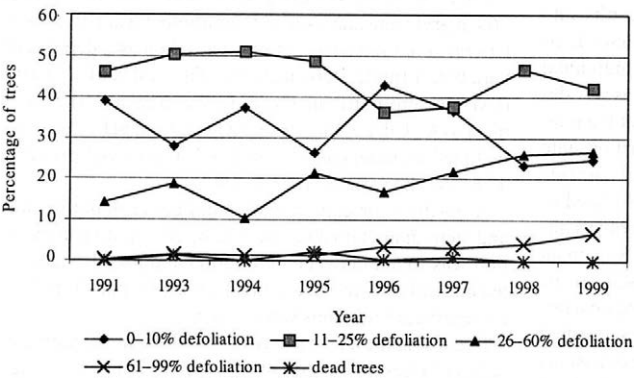

Fig. 2. Changes in defoliation in Norway spruce 1991–1999

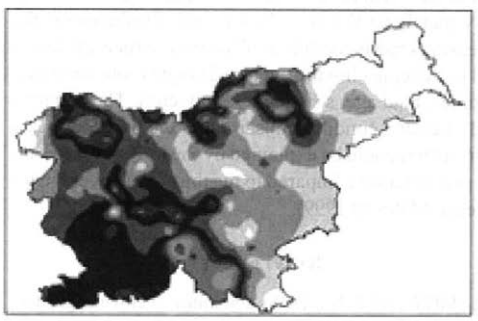

Fig. 3. Values of IAP for Norway spruce in 1991

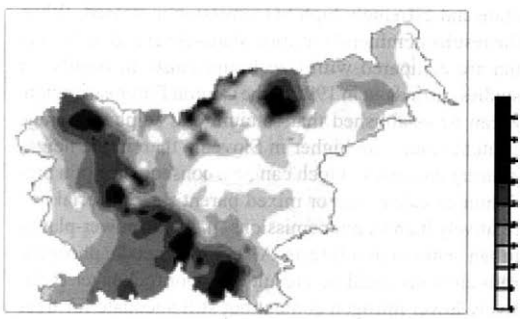

Fig. 4. Values of IAP for Norway spruce in 1995

Table 1. The minimum, maximum and average content of macro-nutrients and heavy metals in current-year spruce needles in the 16 × 16 km Slovenian net (comparison with some results from Central European countries) sampled in 1995 (SIMONČIČ 1997; KALAN 1997; STEFAN et al. 1997)

Country	*n*	N (mg/g)	P (mg/g)	K (mg/g)	Ca (mg/g)	Mg (mg/g)	S (mg/g)
Slovenia	30	9.40–16.00	0.57–2.65	2.83–10.30	2.20–15.53	0.75–2.30	0.79–1.67
average		**12.71**	**1.26**	**6.55**	**6.18**	**1.11**	**1.23**
Austria	72	11.32–17.04	0.96–2.44	2.63–9.68	1.69–10.61	0.77–2.49	0.78–1.45
average		**13.60**	**1.53**	**6.33**	**4.93**	**1.36**	**0.98**
Czech Republic	34	11.45–18.43	1.30–2.18	2.89–9.44	2.29–7.30	0.57–1.51	0.75–1.53
average		**15.17**	**1.60**	**6.27**	**4.23**	**0.99**	**1.04**
	n	Al (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Cd (mg/kg)
Slovenia	30	18–453	21–73	121–2,218	21–135	0.3–6.9	< 0.1–1.1
average		71	42	912	42	1.1	0.3

A slight improvement of IAP can also be observed between 1991 and 1995. This is also in accordance with the air quality improvement, with respect to sulphur emissions in the last ten years, but nitrogen emissions have increased in the same period.

FOLIAR CHEMICAL CONTENT

The tree nutrition estimation for spruce from 1995 gave a relatively weak but not critical nutrition status for nitrogen, magnesium and phosphorous on 30 plots on the Slovenian 16 × 16 km grid (Table 1). The nutrition status of potassium and calcium were optimal. Data from the literature (SIMONČIČ 1997) were used for tree nutrition assessment and for the classification of analysis results into content classes (deficient – adequate – optimum). Estimation of nutrition status by ratios between individual nutrients in needles showed us that in most cases – despite a low content of individual nutrients – that the relations between them indicate a harmonious nutrition state for trees. In the period 1985–1993 total sulphur contents in spruce needles of current-year and year-old needles from the 16 × 16 km bioindication net at 76 spruce sampling plots were used for SO_2 emissions in the Slovenian forests assessment (KALAN et al. 1995). Based on the analysis from 1995, when we repeated sampling on a minority of previous bioindication plots, it was established that the number of plots with increased sulphur emissions was on the decrease, while the number of plots with moderate and extremely high SO_2 emission increased. When the results of mineral nutrition status for spruce in Slovenia are compared with Czech and Austrian results for studies carried out in 1995 in the Central European region, it can be established that calcium and sulphur average content values are higher in Slovenia than in the neighbouring countries, which can be a consequence of a predominant calcareous or mixed parent rock material and relatively high sulphur emissions (industry, power-plants, urban centres) into forests. Also, lower needle phosphorous contents could be a result of a poor rock layer. Relatively lower nitrogen content but still adequate for trees are related to site conditions, well preserved natural forests and less intensive agricultural activities in the greater part of Slovenia.

The content of heavy metals are presented in Table 1. It can be seen that higher values are indicated in areas of industrial centres (KALAN 1997) but they could be also a consequence of the geogenic properties of the parent rock material. Following KNABE (1984), we found higher foliar content of metals (Al, Zn, Mn) in foliar samples of trees at plots on flysch parent material and higher zinc contents at plots in the vicinity of old iron ore deposits.

DISCUSSION

Data sets from monitoring activities in 1995 on the 16 × 16 km grid were analysed with multiple linear regression. Crown condition (defoliation) was taken as a dependant variable. Altitude, stem diameter (dbh), index of air purity (IAP), macro nutrients (N, P, K, Ca, Mg and S), heavy metals (Al, Cd, Fe, Mn, Pb and Zn) and soil pH value were included as independent variables. The model explains 47.6 % of the variance ($R^2 = 0.4762$).

A positive correlation was found between defoliation and stem diameter (dbh); the strongest negative correlation was found between defoliation and the pH value of the mineral soil layer at a depth between 10 and 20 cm. But no significant relations were found.

Regarding the analytical results of the mineral nutrition status of trees on the grid (1995) we did not observe significant deficiencies or excesses of macro nutrients and heavy metals on the 16 × 16 km grid. Furthermore, the decreasing crown condition of Norway spruce can be related to extreme climatic events (drought), site condition (altitude, stand age, soil degradation, etc.). The negative trend of crown condition observed in the past four years (1996–1999) could be explained by the lower average annual precipitation compared to the thirty-year average for Slovenia (MAVSAR 1999).

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The effect of liquid fertilisers application on the damaged spruce stands in western part of the Ore Mts.

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ABSTRACT: In spring 1999, within the western part of the Ore Mts. (west from Klínovec) vast damage of the spruce stands was observed, characterised by colour changes – yellowing of the older needle years and gradual drying and fall of the needles of all age classes. Changes in colour confirm so called "new damage" of forest stands, caused by the long-term impact of air pollution, mainly acid deposition, in the forest soil. Soil degradation can be observed, caused by acidification of the upper layers of the soil profile and leaching of nutrients, mainly basic elements, from the sorption complex. The investigation has confirmed critical lack in basic nutrients, mainly Mg and Ca. Also the nutrient content in needles was very low, reaching nearly the insufficiency threshold (N, P, Ca, Zn), or physiological minimum (Mg – 250–300 mg/kg). In many cases irreversible damage and fall out of assimilation organs occurred. Low contents of S and F have confirmed that it was not acute damage but long-term trend affecting negatively the nutrient status. To stop the negative development, aerial fertilising by liquid fertilisers and liming by dolomite lime was recommended.

Keywords: the Ore Mts; yellowing; Norway spruce; magnesium; fertilising

In spring 1999 damage of the spruce stands has become evident in western part of the Ore Mts., demonstrated by the discoloration – yellowing of older needle year classes and gradual drying and fall-out of the needles. Spruces of all age classes were affected. Such colour changes are characteristic for the novel forest decline – "Neuartige Waldschäden", which is connected with severe magnesium and calcium deficiency at pure acid soils. The long-term impact of acid deposition plays a role in the process of soil degradation due to acidification of upper soil layers and nutrient leaching (mainly basic cations) from the sorption complex.

The same type of the spruce yellowing of spruce needles has been observed also in Germany (Fichtelgebirge and Bayerischer Wald) since 1970s, mostly in localities with acid soils and low content of basic elements at higher altitude (above 700 m a.s.l.). Yellowing affected spruce stands of all age classes, colour changes appeared mostly on one-year-old and older needle classes, current-year-needles remained green till the next spring (difference from the chlorosis caused by N or Mn lack). Yellowing began from the tips and without distinct contours passed over the needle basis, at the same time the upper part of the branches yellowed sooner and more intensively than the bottom one. Intensity of yellowing developed during the vegetation season, the most important is during the sprouting of new needles, when the nutrients necessary for growth of new needles are mobilised (Mies, Zottl 1985).

Yellowing is caused by the lack of magnesium and calcium in the needles (Kandler et al. 1990), also the zinc and potassium content is insufficient. The highest content of these elements is in the youngest needle year, element concentration decreases in older needle years due to leaching and partly also due to transportation to the current one. Kaupenjohann and Zech (1989) give magnesium content between 350 and 400 mg/kg, potassium content 2,400 mg/kg and nitrogen content 1.4% for damaged stands. If concentration of Mg is lower than 300 mg per kg, photosynthetic intensity is decreasing (Schulze et al. 1987).

Nitrogen supply is usually sufficient by the damaged trees, phosphorus supply is in many cases excessive, microelements (Mn, Fe, Cu, Bo) content is sufficient as well (Kaupenjohann, Zech 1989). Negative dependence on nitrogen and magnesium supply is observed, increasing nitrogen uptake causes growth increase and then more evident magnesium lack on the acid soils (Schulze et al. 1987). When magnesium content was medium, yellowing affected older needle years only, the current needle year was green. On the other hand, when magnesium content was low, all needle years become yellow. The ratio between chlorophyll a and b was higher and ratio between chlorophyll and carotene was lower (Mehne-Jakobs 1994).

There are significant differences of Mg and Ca content in mineral layers between damaged and healthy stands. The ratio Mg/Al is also considerably lower in damaged stands (Zöttl 1985). Disease of spruce stands in north-eastern Bavaria (Fichtelgebirge) is connected with nutrition disorder – imbalance between high N content caused by the high atmospheric deposition and low Mg content

caused by soil acidification and its leaching from the sorption complex. This hypothesis was experimentally verified in ten-year old spruce stands next to the dying mature spruce stand (BUCHMANN et al. 1995). Increase of N content caused decrease of Mg content in the needles.

Slightly damaged stands can regenerate spontaneously (KANDLER et al. 1990). Improving is possible with liming and fertilising on natural acid and poor soils. Liming has been used for reducing damage since the eighties. It is one of the supplements of silvicultural measures:

- fundamental fertilising (liming) of older closed stands or ensuring the successful regeneration,
- combination of fertilising and establishing of deciduous forests,
- repetition of fertilising has to be eliminated in the same year (several years) in order to protect nitrate leaching from the soil.

Magnesium fertilisers used improved Mg supply in young spruce stands (20–60 years) during 1–3 years. Lime application is effective for longer time, differences between limed and control stands were observed only after five years. Liming also improves regeneration of forest stands, root growth and mycorhiza, but must be planned for each locality separately (KAUPENJOHANN, ZECH 1989).

In the Forest Administration Horní Blatná the liquid fertilisation of damaged stands was applied in 1999. The fertilisers with higher magnesium content were used. In this study the initial soil condition survey and the main nutritional changes during and after fertilising are presented.

MATERIAL AND METHODS

Initial field investigation was carried out on May 11, 1999. At the same time the needle samples were taken from the trees showing colour changes (yellowing). Mainly the young Norway spruce (*Picea abies*) stands were selected, suitable for aerial fertilising, as they were supposed to react more quickly to nutrient uptake. To compare the results also older Norway spruce stand and young blue spruce (*Picea pungens*) stand were selected.

The samples were taken at three localities – Milíře – old Norway spruce stand, Jelení – young stand, and Horní Blatná – young blue spruce stand at the bulldozed plots. The samples were taken from the upper part of the crown – forth whorl. The content of Mg, Ca, K, P, N, Zn, S, F was analyzed in both the first and second needle years.

On the basis of the preliminary investigation the most damaged stands were selected and the samples of humus layer, mineral soil and needles were taken in younger spruce stands. Samples of humus and mineral soil were taken as a mixed sample of three soil pits in each stand, humus layers F and H and mineral soil to the depth 30 cm, except bulldozed plots, where the organic layers were removed. Needle samples were also taken as mixed, from the upper part of the crown of five trees at each plot. Content of Ca, Mg, K, P, N, Zn, S, F was analysed in needles, and Al, Ca, Mg, K, Zn (extract of NH_4Cl), total P, N, Cox, pH(H_2O), pH(KCl).

APPLICATION OF LIQUID FERTILISERS

The fertilisers MgN-sol and Lamag were selected as the most suitable, both containing magnesium as the main substance. MgN-sol contains also nitrogen, in Lamag there is also molybdenum. Foliar fertilising was performed in three phases till the end of July. The concentration of the fertiliser was lowered in the first phase, to prevent damage of growing new needles. The doses were gradually increased.

Fertilisers were applied in three terms:

1. 2 July, 1999 – MgN-sol 93 kg/ha, Lamag 150 kg/ha (i.e. 20.1 kg Mg/ha, 7.4 kg N/ha)
2. 16 July, 1999 – Lamag 150 kg/ha (i.e. 14.5 kg Mg/ha)
3. 27 July, 1999 – MgN-sol 200 kg/ha, Lamag 150 kg/ha (i.e. 26.5 kg Mg/ha, 16 kg N/ha)

One week after each application of fertilisers needle samples were taken, and the content of individual elements (Mg, Ca, K, N, P, Zn, S) in the first and second needle year classes was analysed.

Because of limited number of samples per sampling date, no statistical evaluation was applied.

RESULTS AND DISCUSSION

SOIL ANALYSES

Very strong acid reaction was found in all humus samples (exchangeable pH values ranged between 2.61 and 3.60), reaction of mineral soil was from strong acid to very strong acid (exchangeable pH values ranged between 2.85 and 4.2). pH values above 4 were found only at the bulldozed plots in the forest district Horní Blatná. Former fertilising by solid fertilisers (Silvamix) is probable at this plots.

Soil reaction can be evaluated as strong acid, although the range was from very strong acid to medium. Reaction of humus was strong acid at the plots of Milíře and Jelení, and very strong acid at the plots of Horní Blatná, where pH values were below 3.0.

The Mg supply was medium (35.6–256 mg/kg) in the humus layer, the lowest was the supply at the plot Jelení (average 62 mg/kg). In mineral soils the Mg supply was very low, with the exclusion of two samples of the blue spruce stand at the plot of Horní Blatná, where good Mg supply (previous application of fertilising tablets) was

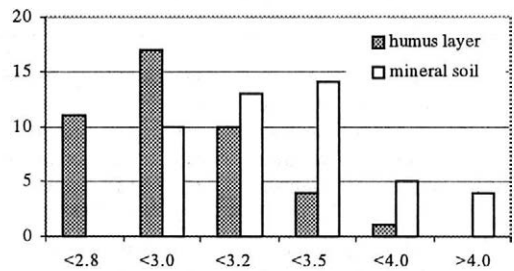

Fig. 1. Soil reaction on the plots on Horní Blatná – pH(KCl) frequency

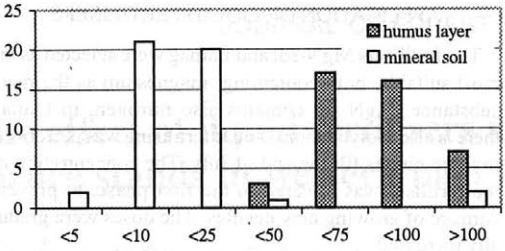

Fig. 2. Exchangeable Mg content frequency in the soils on Horní Blatná

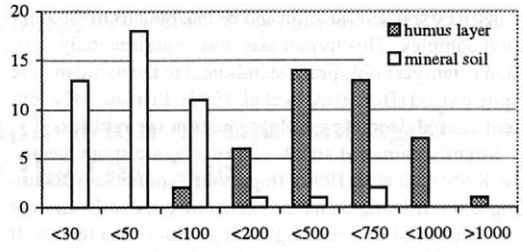

Fig. 3. Exchangeable Ca content frequency in the soils on Horní Blatná

half of all the samples analysed, the rest of them was only slightly above this value.

Low content of Ca is connected with very strong acid reaction of the soil. The Ca supply in humus layer was very low, only one sample has exceeded the value of 1,000 mg/kg. In mineral soil the Ca supply was also very low, with the exclusion of the bulldozed plots. The lowest supply was found out at the plots of Jelení, the average value there was 26.2 mg/kg only.

Nitrogen content in humus layer has ranged between 0.91% and 2.93%, the supply was very good. In mineral soil only two samples have exceeded 0.2%, most of them were between 0.1–0.2% and the supply can be characterised as medium.

Phosphorus content in humus layer was variable from very low to very good supply, values ranged between 30–70 mg/kg. Lower content of P was found out in mineral soil, in 15 cases the supply was very low (below 15 mg/kg), mostly at the plot Milíře; at the other plots the supply was medium. Phosphorus availability for the roots could be improved after application of dolomitic lime and increase of pH.

Potassium content in humus layer was relatively high at all the plots, the supply was characterised as very good. Potassium supply in mineral soil was very low to low at all the plots, only in three cases it has exceeded 45 mg/kg. There was no difference among the plots.

FOLIAR ANALYSES BEFORE AND AFTER FERTILISING

The results of the preliminary investigation have proved critical lack of basic nutrients, mainly magnesium, calcium, zinc and nitrogen, both in the soil and in the needles. Nutrient content in the needles was so low, that irreversible damage of the assimilating apparatus and fall out of needles occurred. Load elements (S, F, Cl) concentrations were not significantly increased.

Evaluation of the results is focused on the lacking elements – magnesium and nitrogen, included in fertilisers. Potassium content was not influenced by the fertilising, calcium was partly influenced – an increased Ca content was proved in the second needle year class at the plots of Jelení only.

Table 2. Nutrient content in the needles before (June 1999) and after (September 1999) applications of fertilisers (mg/kg)

Forest district	Stand No.	N.Y.	Plot	Before application of fertilisers						After application of fertilisers				
				Mg	Ca	N	K	P	Zn	Mg	Ca	N	K	Zn
Milíře	108D1	1	control	897	2,157	1.43	10,420	1,784	34.3	697	2,658	1.25	6,892	28.43
	108D1	2	control							746	4,622	1.37	6,183	25.44
	110C1	1	fertilised 1	924	2,021	1.79	9,687	3,145	38.8	830	3,955	1.65	6,141	19.7
	110C1	2	fertilised 1	393	3,055	0.96	1,216	1,175	19.3	435	3,668	1.18	5,552	18.0
	115A2	1	fertilised 2	946	1,716	1.58	10,122	3,190	44.2	1,012	3,646	1.63	6,656	23.0
	115A2	2	fertilised 2	536	2,321	0.95	5,903	1,413	21.4	539	2,942	1.26	5,948	15.10
Jelení	27D3	1	control	980	1,492	1.93	9,963	2,862	45.8	625	2,372	0.98	7,078	18.4
	27D3	2	control	462	2,512	0.95	4,478	952	24.1	348	2,510	1.11	6,594	11.9
	18A1	1	fertilised	991	1,805	1.69	9,312	3,044	40.1	830	4,592	1.41	6,682	27.8
	18A1	2	fertilised	451	2,677	0.95	4,572	1,251	20.9	671	6,415	1.21	5,774	24.2
	17 E5	1	fertilised	740	1,396	2.10	9,883	3,192	28.4	506	1,849	1.35	5,602	16.0
	17 E5	2	fertilised	427	2,705	1.34	4,724	1,778	17.6	414	2,724	1.27	5,024	10.1
Horní Blatná	830E1	1	control	1,173	1,700	1.49	10,370	3,096	40.9	920	3,739	0.83	5,000	33.2
	830E1	2	control	1,087	3,467	0.64	4,246	1,182	47.7	760	6,713	0.78	4,334	47.3
	830C1	1	fertilised	1,206	1,742	1.46	10,352	3,478	31.9	1,323	3,387	0.99	4,898	36.3
	830C1	2	fertilised	896	2,823	0.67	4,194	1,397	25.5	1,041	4,190	0.83	4,111	47.1

FOREST DISTRICT MILÍŘE – NORWAY SPRUCE (*PICEA ABIES*) STANDS

In the unfertilised control (stand 108 D1) the content of Mg in both current and second needle year class decreased during the vegetation season 1999 and winter 1999/2000 (Fig. 4). The lowest value was found in April 2000, when the magnesium content was 473.9 mg/kg in the first year needle class and just 294.8 mg/kg in the second year class. During following vegetation season the contents of magnesium increased at similar level, which is illustrated by analyses from August 2000, when the current year needle class (2000) obtained 723 mg/kg and the second needle year class (1999) 626 mg/kg of magnesium. If we compare this values to the magnesium level from September 3, 1999 (697 mg/kg and 746 mg/kg, respectively) there is a evidence of relatively steady annual cycle of this nutrient.

The nitrogen content was irregularly fluctuating in the whole period of assessment ranging in current year needles from 1.16 to 1.46% and in the second year needles from 0.90 to 1.38% (Fig. 5).

In the fertilised stands (110 C1 and 115 A2) the magnesium content developed in a different way. The analyses show (Fig. 4) gradual increase of concentration in both the current and the second needle year class till the October 1999, when values of 776 mg/kg (110 C1) and 663 mg/kg were found in the current year of needles and 842 mg/kg and 658 mg/kg in the second year needle class. Before the start of the vegetation season 2000 it came to the decrease of magnesium content. The nutritional status of needles, however, was higher than by control stand for both sampling terms in April and August 2000.

No clear trend could be seen for N content development. Irregular increase of concentration in 1999 was identified in the stand 115 A2 , for the current needles from 0.96% in June up to 1.44% in October 1999, for the second year needles from 0.95% up to 1.32%. This is partly valid also for the stand 110 C1 where, however, the highest N content was analysed in June 1999 (1.79% of the current year needles, 1.58% of the second year needles). After a drop of this values to 1.44% and 1.35% respectively, nitrogen concentration grew to 1.65% in both years of needles in September 1999. In the stand 115 A2 the current year needle's N content in August 29, 2000 (1.36%) is higher than that analysed in September 3, 1999 (1.18%). In the forest stand 110 C1 this relation with values 1.37% for year 2000 and 1.65% for 1999 is completely different.

In the forest district of Milíře the fertilisers used have strongly stimulated the growth of the new biomass in the treated stands. Thanks to the application of fertilisers significant decrease of Mg during the growth of the new needle year class did not occur. In the stands fertilised the Mg content in the first needle year class was of

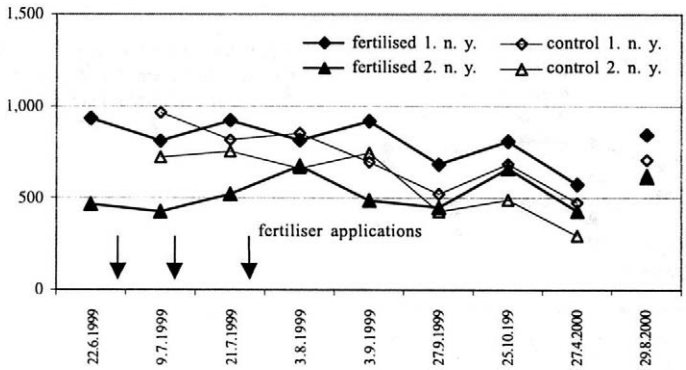

Fig. 4. Mg content in the needles on the plots at Milíře (mg/kg) for control (108 D1) and fertilised stands (average 110 C1, 115 A2)

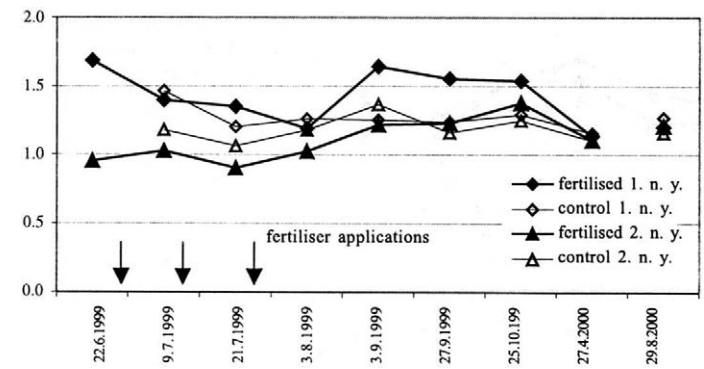

Fig. 5. N content in the needles on the plots Milíře (%) for control (108 D1) and fertilised stands (average 110 C1, 115 A2)

80–200 mg/kg higher than in the control stand. Also in the second needle year class there was an increased Mg content.

The N content was significantly higher at the end of the vegetation period 1999 in the fertilised localities. The differences between fertilised and control stands oscillated between 0.2–0.4% and the content was insufficient in the needles of the control stands only. In samples from April and August 2000 there were no significant differences identified between the fertilised and control stands

FOREST DISTRICT JELENÍ – NORWAY SPRUCE (*PICEA ABIES*) STANDS

In the unfertilised control stand 27 D3 the development of magnesium content in needles was similar as in controls stand in locality Milíře with more pronounced growth in September and October 1999 (Fig. 6). The Mg content in both needle year classes was decreasing during the vegetation period, in August the content in the first needle year class was at the deficiency threshold (632 mg per kg), in second one it was even lower (445 mg/kg). In September and October an increase of Mg was found out in both needle year classes (above 1,100 mg/kg in the current, 564 mg/kg in the second needle year class).

Also the N content has decreased in both needle year classes and it was about 1.00% in August (Fig. 7). At the end of the vegetation period an increase of the N content could be observed, the content was 1.64% and 1.28%, respectively.

The reaction of spruces on fertilising was different in two followed forest stands in dependence of their age.

In the stand 18 A1 (young spruce stand) the Mg content in the first needle year class has temporarily increased after the application of fertilisers, reaching up to 1,000 mg per kg in July 1999. Than magnesium decreased to the values from 830 to 970 mg/kg. The second needle year class has reacted more positively. The original Mg content of 451 mg/kg increased after fertilisation up to 750 mg per kg, and keep the level of around 600 mg/kg for the whole period of observation with lowest value in April 2000 (570 mg/kg).

The N content was decreasing gradually both in the first and second needle year classes, only in the second needle year class the N content has increased slightly after the first application of fertilisers. From September the N content has slightly increased, at the end of the vegetation period it was about 1.5% in both needle year classes.

The older (aged around 50 years) spruce stand 17 E5 did not react to fertilising in significant way. The Mg content in the current needle year class has decreased from 740 mg/kg to 500 mg/kg by August 1999. This content did not change till the end of the vegetation season, when the assessment of this stand was stopped. There was strong deficiency of Mg in the second needle year class,

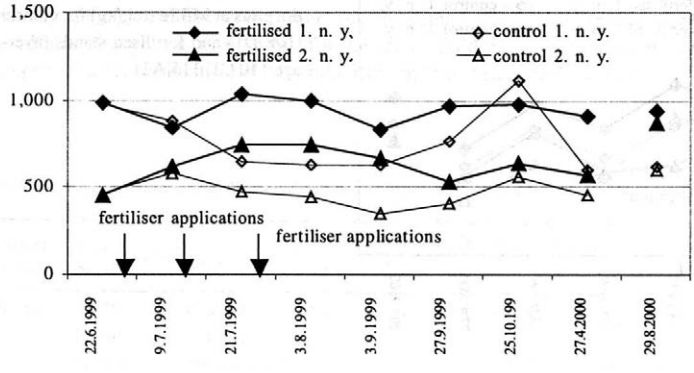

Fig. 6. Mg content in the needles on the plots Jelení (mg/kg) for control (27 D3) and fertilised stand (18 A1)

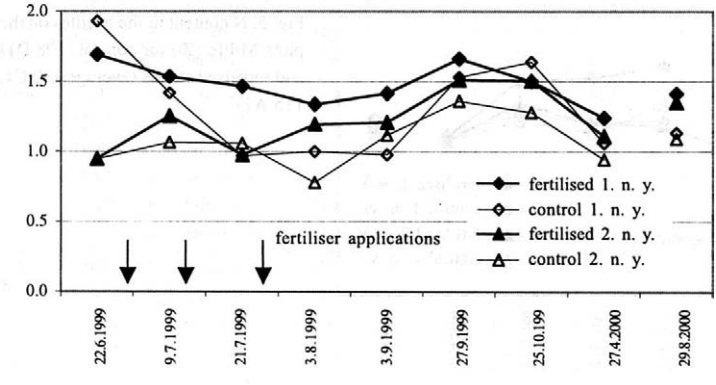

Fig. 7. N content in the needles on the plots Jelení (%) for control (27 D3) and fertilised stand (18 A1)

and the Mg content has decreased to 270 mg/kg in August. In spite of a slight increase in September it was also strongly insufficient, under 400 mg/kg at the end of the vegetation period.

The N content was decreasing in both the needle year classes, in the first one from 2.1% in spring to 1.25% at the end of the vegetation period, in the second one the N content was lower (1.4%) in spring. In spite of slight increase after the second application of fertilisers, it dropped down during the vegetation period, reaching the values similar to those of the first needle year class. From September to the end of the vegetation period the N content has moderately increased both in the first and second needle year classes, it was about 1.50%.

The Mg content has increased temporarily in the current needle year class of the younger spruce stands after the second application of fertilisers. The originally insufficient Mg content in second year needles reacts more markedly. There was no reaction in Mg content identified by older stand, probably due to higher biomass and those relatively smaller amount of applied magnesium.

Nitrogen content has increased in the second needle year class after the application of fertilisers, than it has decreased during the vegetation period, the deficiency was found out only in the second needle year class of the control stand, in October.

FOREST DISTRICT HORNÍ BLATNÁ – BLUE SPRUCE (*PICEA PUNGENS*) STANDS

In the unfertilised control stand 33 C1 lowest values of magnesium were found in the first half of the vegetation season (Fig. 8). The difference in the Mg content between the two needle year classes was minimal. In August the values were about 800 mg/kg. The Mg content was 904 mg/kg in the first needle year class, and 793 mg/kg in the second, at the end of the vegetation period.

The N content was the same in the two needle year classes, comparing to the fertilised stands, it has increased from 0.6% to nearly 1.0% at the end of the vegetation period (Fig. 9).

In fertilised stand No. 830 E1 the increase of magnesium was identified for both the current and second needle year classes. In spite of mild decrease in August, both values were above 1,000 mg/kg. The Mg content in the first needle year class has reached 1,346 mg/kg, in the second one it has reached 1,204 mg/kg at the end of the vegetation period. Also in April and August 2000 the Mg contents were significantly higher than in control stand.

After the first application of MgN-sol an increase of N was found in the second needle year class, then the decline of N observed (below 0.7%) in both needle year classes during the next period. When the growth of the new needle year class was finished in August, the N con-

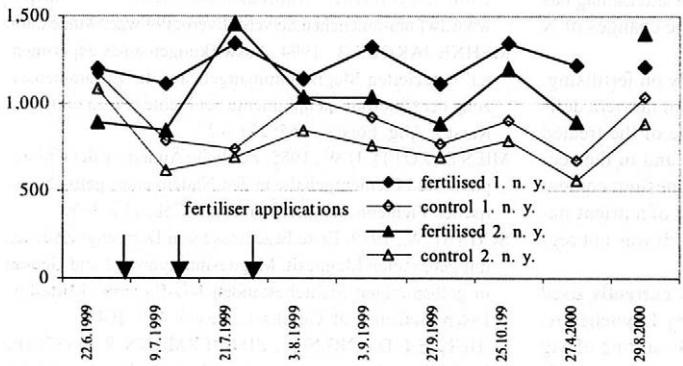

Fig. 8. Mg content in the needles on the plots Horní Blatná (mg/kg) for control (830 E1) and fertilised stand (830 C1)

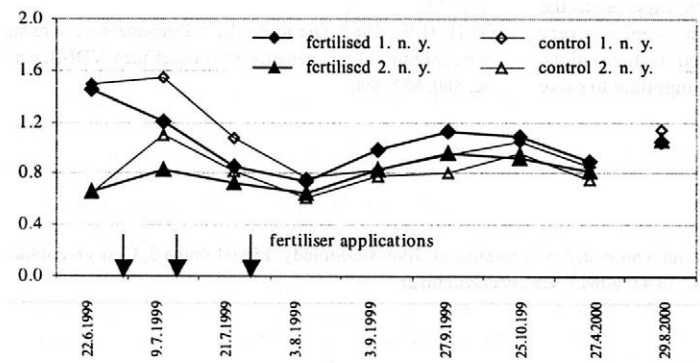

Fig. 9. N content in the needles on the plots Horní Blatná (%) for control (830 E1) and fertilized stand (830 C1)

tent has increased both in the first and second needle year classes. The values were under the deficiency threshold – 1.09% and 0.92% in both cases.

Blue spruce has reacted more sensitively on the three applications of liquid fertilisers. The Mg content in the first needle year class increased immediately after the first application of fertiliser and this trend had continued till the autumn period. The difference between fertilised and control stand was exceeding 400 mg/kg.

Even the three applications of fertiliser however did not improve the N content in needles sufficiently. The autumn analyses have proved its deficiency in needles at both the fertilised and control stands.

CONCLUSIONS

At all the plots assessed very strong acidity of soils was found, very low magnesium and calcium supply, low content of potassium and phosphorus and medium nitrogen supply in mineral soil. Application of dolomitic lime can improve the soil reaction, which will contribute to improving the availability of other nutrients, their leaching from decomposed humus layer, and at the same time to gradual increase of magnesium and calcium content in the soil. It is supposed that the health state of the spruce stands could improve, as the low nutrient content in the needles is closely connected with the low supply of them in mineral soil.

Application of liquid fertilisers MgN-sol and Lamag has influenced the Mg content in needles. The changes of N nutrition were less pronounced.

Not all the stands have reacted similarly on fertilising. The results depended mainly on the level of nutrient deficiency in the needles and the health state of the treated stands. In stands with severe deficiency and in the second year needle class the changes in magnesium content were more pronounced. The improvement of nutrient status in older spruce stands (ca. 50 years old) was not registered.

The results have proved, that besides currently used types of fertilisers (MgN-sol produced by Lovochemie, comp. Lovosice) Lamag can be useful. By storing of Mg and N in the second needle year class the trees have made certain reserve of these mobile elements for the next year. Mg and N uptake from the soil cannot be expected as the content of these nutrients in the sorption complex is very low, and the humus layer was removed at many plots. Together with the foliar fertilising it is important to solve also the problem of soil amelioration by liming as the Mg content in the soil should be increased urgently.

The problem of nutrition of the blue spruce stands should be considered separately. The stands are mostly growing at the bulldozed plots. It is recommended to use an application of liquid fertilisers and complementary fertilising by the Silvamix tablets.

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Thinning of substitute stands of birch (*Betula* sp.) and blue spruce (*Picea pungens*) in air polluted area of the Ore Mts.

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ABSTRACT: Investigation of the thinning effect on development, stability and functions of birch (*Betula* sp.) and blue spruce (*Picea pungens* Engelm.) substitute stands began in 1989 in air polluted areas in the Ore Mts. (Northern Bohemia). Attention has been paid to two types of thinning: negative selection from below and positive selection from above. both compared to control plot without thinning. Experimental treatment started in 1990 when the stands were 9 years old. Growth of experimental stands was monitored by annual measurements of DBH of all trees and height of model trees. The health status was assessed on the basis of defoliation. Received data showes, that the initially good condition of the experimental stands has deteriorated since 1994 in accordance with increased salvage causing a decrease in basal area in 1998 on the control plot and on the plot with positive selection from above. The results from the experiment suggest the possibility of a positive effect of more dense canopy (control plot, positive selection from above) on the health condition of birch stands and, on the other hand, the superior regeneration ability of the stand with negative selection from below. The presence of the birch layer on the control plot as well as on plots with thinning negatively influenced the basal area of blue spruce. Freely-grown blue spruce exhibited a basal area increment more than three times higher than that of individuals under the cover of birch even reduced by thinning.

Keywords: thinning; substitute tree species; substitute stands; birch (*Betula* sp.); blue spruce (*Picea pungens* Engelm.); Ore Mts.; Krušné hory Mts.

Forest stands of substitute tree species (STS) were established in the 70's and the 80's in the heavily air polluted areas of the Ore Mts., especially on the sites where the declining spruce monocultures could not be replaced by ecologically suitable tree species.

At present, STS occupy 26,000 hectares of forest land. The largest percentage (ca. 72%) of this area is covered by birch (*Betula* sp.) and blue spruce (*Picea pungens* Engelm.) or mixtures of these two species. Next important species in STS with ca. 14% of the area is European larch (*Larix decidua* Mill.), which is in the 6th vegetation zone considered as target tree species. Other tree species as European mountain ash (*Sorbus aucuparia* L.), European aspen (*Populus tremula* L.) and conifers (e.g., pines such as *Pinus rotundata* Link. and *Pinus contorta* Loudon) occur to a lesser extent.

The main objective of STS cultivation is to create more favourable growing conditions for gradual regeneration of forest stands by target tree species more suitable to the ecology and management of the region. However, because of the age structure, relatively large area, variations in quality and, especially, the complicated immission and ecological conditions of the Ore Mts., stand conversion of STS is the long-term problem. Until the opportunity for stand conversion arises, stands of STS must be stabilized using various silvicultural treatment including thinning.

Investigation of thinning effects on growth and development of substitute birch stands with admixture of blue spruce with respect to their conversion has been initiated on experimental series Fláje I since 1989 (Fig. 1).

The paper summarizes the data from the experimental plots mentioned above and offers some practical conclusions.

RESULTS OF EXPERIMENTS WITH THINNING OF STANDS OF SUBSTITUTE TREE SPECIES

BIRCH STANDS

Given the primary need for stand stabilization and preservation of forest functions, silvicultural research in substitute birch stands is oriented towards on verifying the effect of various thinning regimes on the development of birch stands, their health condition and stability. In 1999, we also examined the growth characteristics of individual blue spruce trees under the canopy of variously thinned birch stands and in pure blue spruce monocultures.

DESCRIPTION OF THINNING SERIES FLÁJE I

Thinning series Fláje I was founded in 1989 in order to study the effect of various thinning regimes on development of substitute birch stands with admixture of blue spruce. The experimental stand is situated on apical part

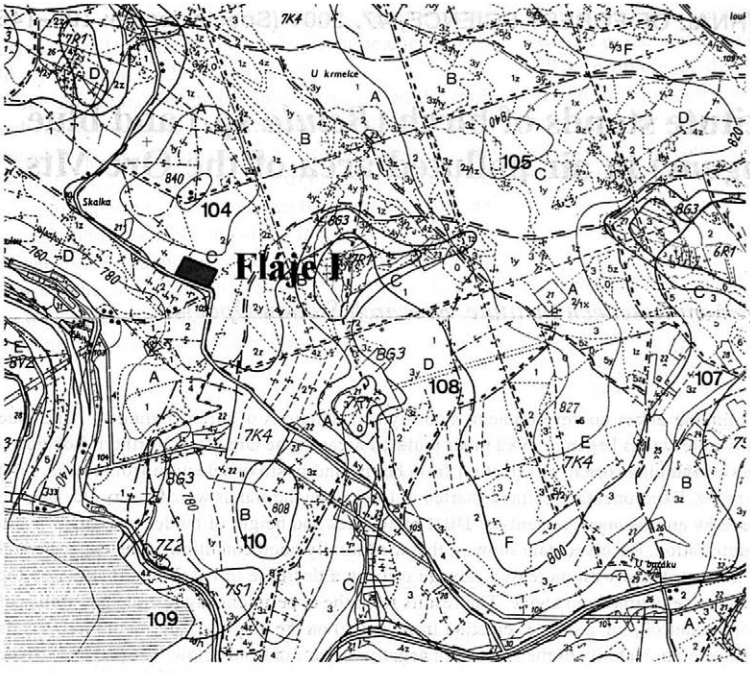

Fig. 1. Location of experimental series Fláje I

of the Ore Mts., on the southern slope at an elevation of 800 m. Typologically, this site belongs to the acid category of the 7th vegetation zone (acid beech-spruce forest), zone of air pollution A (expected survival of mature stands 20 years).

Experimental series Fláje I consist of five comparative plots:

plot 1 – underplanting of mixed birch-blue spruce stand with target tree species (not evaluated in this article),
plot 2 – thinning from below with negative selection (TB),
plot 3 – thinning from above with positive selection (TA),
plot 4 – control plot without thinning,
plot 5 – pure blue spruce monoculture without the birch cover.

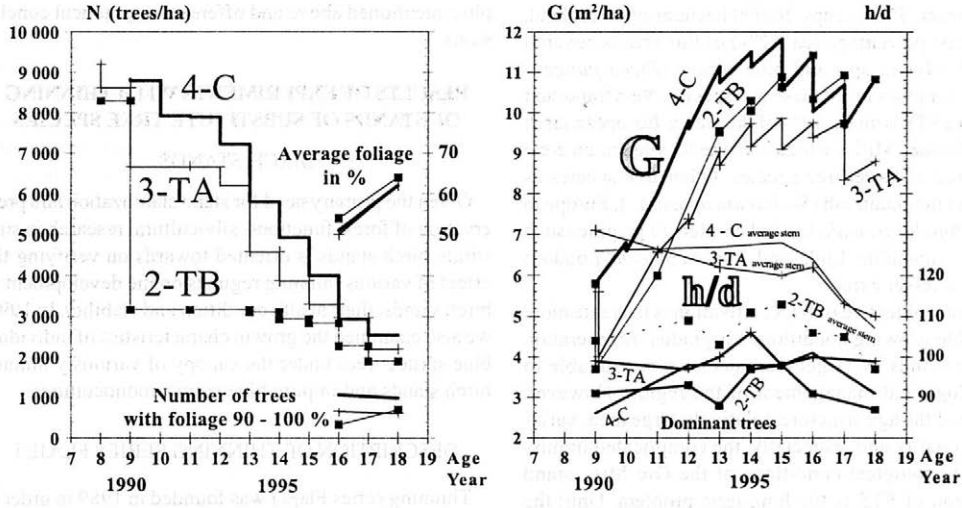

Fig. 2. Number of birch trees (N), mean foliage (%) and number of trees with foliage 90–100% (left) and basal area (G), h/d ratio of mean tree and h/d ratio of dominant trees on partial plots of experiment Fláje I (right) (2 TB – thinning from below with negative selection, 3 TA – thinning from above with positive selection, 4 C – control plot without thinning)

Table 1. Basic data from comparative plots on experiment Fláje I. (birch stands)

Index	Comparative plots	Age 9 years	Thinning	After thinning	Unregulated thinning (UT)	Age 18 years	Increment 9–18 years	Increment 0–18 years	Increment without UT
N (trees/ha)	2 TB	8,300	5,250	3,050	1,140	1,910	–	–	–
	3 TA	8,620	1,960	6,660	4,460	2,200	–	–	–
	4 C	8,825	0	8,825	6,275	2,550	–	–	–
G (m^2/ha)	2 TB	5.80	2.20	3.67	2.99	10.85	12.37	16.04	13.05
	3 TA	5.40	1.60	4.00	2.98	8.79	8.70	12.70	9.72
	4 C	5.81	0	5.81	4.76	10.86	9.79	15.60	10.86
d (cm)	2 TB	3.0	2.3	3.9	5.8	8.5	2.8	–	–
	3 TA	2.7	2.5	2.8	2.9	7.1	2.6	–	–
	4 C	2.9	0.0	2.9	3.1	7.4	2.7	–	–
h (m)	2 TB	3.8	–	3.8	–	8.3	4.1	–	–
	3 TA	3.6	–	3.6	–	7.8	4.1	–	–
	4 C	3.6	–	3.6	–	8.2	4.6	–	–
h/d	2 TB	107	–	127	–	98	–10	–	–
	3 TA	134	–	133	–	109	–24	–	–
	4 C	124	–	124	–	111	–13	–	–

N – number of trees, G - basal area, d – diameter at breast height, h – height, h/d – h/d ratio, comparative plots: 2 TB – thinning from below with negative selection, 3 TA – thinning from above with positive selection, 4 C – control plot without thinning

Experimental thinnings began in 1990, when the stands were 9 years old, after an introductory investigation of comparability of plots inside of the series. Original stand density before thinning varied between 8,300 to 8,600 individuals per hectare (Table 1). On comparative plot 2 (TB), 5250 individuals (representing 63% N and 8% G) were removed by negative selection from below and, on comparative plot 3 (TA), 1960 individuals (representing 23% N and 30% G) were removed by positive selection from above. Position of thinning on the stand structure and the situation after thinning is illustrated in Fig. 2 and Table 1.

NUMBER OF TREES AND BASAL AREA OF EXPERIMENTAL STANDS

Between 1990 and 1994, the experimental stands developed without problems. No major mortality was observed and the basal area of comparative stands increased during that period on control plot 4 by 91%, on plot 2 (TB) by 162% and on plot 3 (TA) by 125%. Since 1995, mortality has appeared and gradually accelerated on control plot 4 as well as on plot 3 (TA) and, since 1997, on comparative plot 2 (TB). At the same time, the basal area increment declined. The downward trend in tree number is more obvious on control plot 4 and comparative plot 3 (TA). In these two plots, the observed mortality was caused primarily by mortality of smaller trees from suppressed sublayer trees that were removed on plot 2 (TB) by thinning in 1990.

Since 1996, the annual decline of basal area on control plot 4 has exceeded the annual increment and similar picture was found on plot 3 (TA). The decline of the stand basal area on comparative plot 2 (TB) has been recognized since 1997 (Fig. 2).

Despite the unfavourable development of the last few years, the basal area of the experimental stands of series Fláje I oscillates around 10 m^2 at the age of 15 years. Using the growth tables (SCHWAPPACH 1943), it corresponds to 30 year-old birch stands of the 1st (the best) site index (11.5 m^2).

The height-diameter (h/d) ratio of mean stems ranged from 107 (plot 2 – TB) to 134 (plot 3 – TA) before the first experimental thinnings and, up to the age of 15 years, it slowly increased on control plot 4 and plot 2 (TB). At age 16, the h/d ratio started to decline. The h/d ratio of the mean stem on plot 3 declined during the entire study period (1990–1999). The increased decline in h/d in the last three years was caused primarily by increased mortality of slender trees from lower tree classes. The positive effect of thinning can be seen only in comparative stand 2 (TB) owing to removal of unstable understory.

The h/d ratio of dominant trees, which was not influenced by the removal of slender suppressed trees, was mostly below 100. The effect of thinning on static stability of overstory was statistically insignificant.

HEALTH CONDITION OF BIRCH STANDS

Classification of health condition of comparative stands in the series Fláje I has started since 1997, when defoliation could be detected on the tree crowns. It was apparent, that the majority of the heavily damaged trees on all three comparative plots was from the lower tree classes and, the higher tree classes had increasing proportions of

relatively healthy trees with the foliage over 90% (Fig. 3). Based on the total number of trees on comparative plots 2 (TB), 3 (TA) and 4 (C) in 1997, there were 340 (12%), 660 (20%) and 1075 (27%) individuals with relatively undamaged foliage. Two years later, in 1999, a marked drop in tree number (between 33–36%) was observed on all variants. Approximately half of individuals classified as heavily damaged in 1997 was dead in 1999.

The number of relatively healthy trees on comparative plots with dense canopy (control plot 4 and plot 3 – thin-

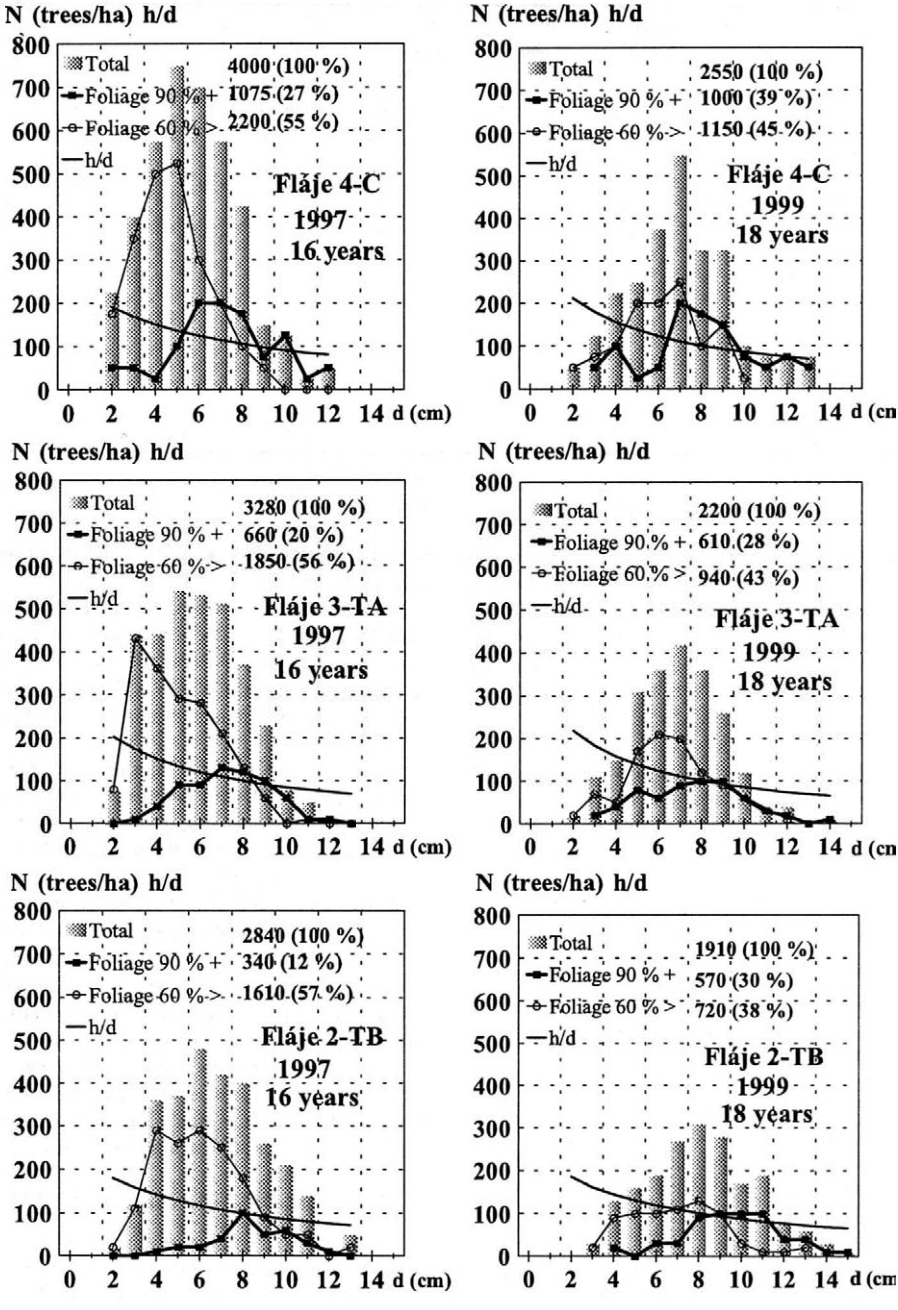

Fig. 3. Diameter structure (N/ha), number of trees with foliage 100–90% (thick line), number of trees with foliage less than 60% (thin line) and h/d ratio (line without markers) on comparative plots of Experiment Fláje I (birch) in 1997 and 1999 (2 TB – thinning from below with negative selection, 3 TA – thinning from above with positive selection, 4 C – control plot without thinning)

ning from above) has hardly changed. Surprisingly, in the comparative stand 2 (TB) with an open canopy, the number of healthy trees has doubled. These results indicate the possibility of a positive effect of a dense canopy on the health condition of birch stands influenced by stress factors and, on the other hand, good regeneration ability of stands after thinning from below.

ADMIXTURE OF BLUE SPRUCE

The basal area of blue spruce growing in different light condition under the dominating birch overstory on plots 2 (TB), 3 (TA) and 4 (C) increased from 0.4 – 0.5 m^2/ha in 1993 (age of 12 years) to 1.3 – 1.4 m^2 in 1999 (age of 18 years). At the same time, the basal area of the pure blue spruce monoculture (plot 5) increased five times from 0.98 m^2 to 5.38 m^2 (Fig. 4). The presence of the undisturbed birch overstory (control plot 4), as well as the presence of overstory opened by various thinning regimes (plot 2 – thinning from below, plot 3 – thinning from above) negatively impacted the growth in basal area of the admixed blue spruce.

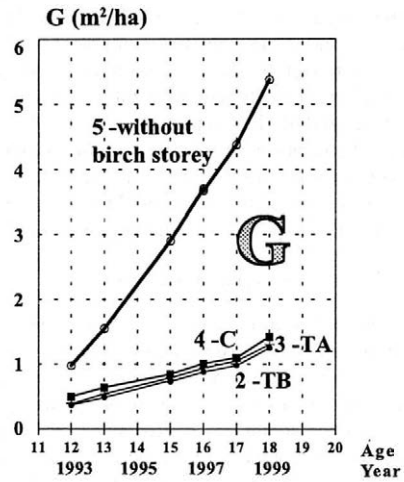

Fig. 4. Basal area of blue spruce on comparative plots with birch storey (plots 2, 3, 4) and without birch storey (plot 5)

CONCLUSIONS FROM THE EXPERIMENT

The initial positive development of the experimental birch stands has changed since 1994, when increased mortality resulted in decline in the total basal area of stands on the control plot and plot 3 (positive selection from above and) in stagnation of basal area on plot 2 (negative selection from below).

The effect of thinning (both negative selection from below and positive selection from above) on static stability of dominant trees was not statistically significant. The lower h/d ratio of the mean stem in plot 2 (TB) was caused primarily by removal of slender trees in the initial thinning.

Heavy defoliation was observed mainly on trees from the lower tree classes.

After the acute damage in 1997, there were a higher percentage of relatively undamaged trees in stands with a denser canopy (control plot 4 and plot 3 with positive selection from above).

The results from the experiment Fláje I suggest a positive effect of a denser canopy on the health condition of birch stands afflicted by stress factors and, on the other hand, good regeneration capability of stands thinned from below with negative selection.

The presence of the undisturbed birch overstory (control plot 4), as well as the presence of overstory opened by various thinning regimes (plot 2 – thinning from below, plot 3 – thinning from above) negatively impacted the growth in basal area of admixed blue spruce. The basal area freely-grown pure blue spruce monoculture at the age of 18 years was more than three times higher than blue spruce admixed in birch stands.

CONCLUSIONS FOR PRACTICE

Thinning of STS stands is differentiated according to their functions and forestry objectives. The STS stands were differentiated into four categories (SLODIČÁK 1999):

Stands of good and suitable genetic quality, providing ecological and wood-production functions of forest, or expected to perform these functions in future.

Stands with generally low and unsuitable genetic quality, performing only ecological functions, but not the wood-production function and this function is not expected to be performed in future.

Stands which do not perform ecological nor wood-production functions and which are not expected to perform these functions in future.

Stands of STS which are not substantiated (smaller parts of forests in relatively favourable growing conditions).

BIRCH STANDS

Thinning of birch stands must be initiated in the phase when they achieve the maximal ecological effect, i.e. at the period of canopy closure. The positive effect of thinning can be expected only in the phase of "progression" characterized by biomass increment. Later, when the stand enter the phase of "regression" and it is gradually disintegrating (increment of the biomass is lower than its decay), thinning can be recommended only as a part of a process of forest conversion (in stands where using the target tree species is possible), or as a part of reconstruction (in stands, where the long-term presence of STS is expected).

Generally, in birch stands, or in the stands with predominant birch, we recommended thinning from above with positive selection. There are at least two good reasons for this recommendation:

Thinning from above with positive selection only minimally disturbs the canopy and consequently, more favourable growing conditions are created for gradual

regeneration by target tree species more suitable from the viewpoint of ecology and management.

Compared to negative selection from below, positive selection from above is less laborious and time-consuming and less expensive.

In the birch stands in the first category, i.e. in the stands of good and suitable genetic quality, performing ecological and wood-production functions of forest, or expected to perform these functions in future, it is possible to use negative selection from below. This type of thinning is especially suitable in stands, where wood-producing function is possible and the increased expenses of thinnings will be economically substantiated. Thinning from below can also be practised in birch stands of the 4th category, i.e. in not substantiated stands of STS in relatively favourable growing conditions

In the birch stand of the second category, i.e. in the stands with generally low and unsuitable genetic quality, but with sufficient density, the most suitable thinning technique is positive selection from above. This thinning method disturbs the ecological functions of a stand (stand climate, nutrient accumulation in ecosystem, nutrient cycling, etc.) to a lesser extent than other methods. The wood-production function in these stands of STS is not considered.

In the birch stand of the third category, i.e. in the stands which do not provide ecological or wood-production functions and which are not expected to provide these functions in future, thinning is not recommended. Additional reduction of the canopy will negatively impact its remaining function. Such stands of STS must be reconstructed using the cover effect of particular trees or tree groups.

MIXED STANDS OF BIRCH AND BLUE SPRUCE

The results of investigation confirmed previous conclusions on the inappropriateness of evenaged mixtures of birch and blue spruce. In such mixtures, blue spruce does not grow well and, even if it is released, its growth is much slower comparing to pure birch stand or pure stand of blue spruce.

In mixed birch and blue spruce stands of the first category, i.e. in the stands of good and suitable genetic quality of birch (genetic quality and suitability of blue spruce is rather problematic), which perform both ecological and wood-production functions, it is advisable to support birch because of its better amelioration effect, sufficient ecological cover and better wood-production quality. If the admixture of blue spruce is desirable, the group mixture with complete release of blue spruce should be chosen. In the case of increased interest in wood-production, more expensive negative selection from below can be used in thinning, otherwise using positive selection from above supporting ecological functions is advisable. Thinning from below can also be practised in the mixed stands of the 4th category, i.e. in not substantiated stands of STS in relatively favourable growing conditions.

In mixed birch and blue spruce stands of the second category, i.e. in the stands with generally low and unsuitable genetic quality, performing now and in future only ecological functions, preference of birch or blue spruce depends on objectives of stand conversion. If the stand conversion is planned in 20 years period and the stand age at the beginning of conversion does not exceed 40 years, mixed birch-blue spruce stand is treated as pure birch stand, i.e. the blue spruce admixture, which is gradually disappearing, is not taken into account.

In case when the age of birch in the period of stand conversion overstep 40 years, or in case when birch component is already disintegrating, support of blue spruce as tree species with longer expected survival is more efficient.

In birch-blue spruce mixed stands of this category, similarly as in pure birch stands, the most suitable way of thinning is positive selection from above, which supports the most vigorous stand components, and, at the same time, disturbs the required ecological effects in a less extent. Thinning in these stands is efficient to connect with initiation of stand conversion.

In the mixed birch-blue spruce stands of the third category, i.e. in the stands, which do not perform ecological nor wood-production functions and which are not expected to perform these functions in future, thinning is not suggested similarly like in pure birch stands. Remaining ecological effects of particular trees or tree groups is suitable to use for stand reconstruction. New stand of STS on the most exposed localities should be based on wider spectrum of tree species of suitable provenance.

STAND OF BLUE SPRUCE

Information required for specifying the thinning principles in blue spruce stands has not been still confirmed by experiments, particularly with respect of specific site conditions. Investigation of thinning effects on blue spruce stands has started since 1997. Hitherto results and experience confirm the problems connected with detected frost damage, snow-breaks, colour changing of needles, etc., on one side, and on the other side, there is evidence of relatively rapid biomass increment of blue spruce stands on various localities.

Blue spruce stands are divided only into three categories:

- category 2 (stands with generally low and unsuitable genetic quality, performing now and in future only ecological functions),
- category 3 (stands, which do not perform ecological nor wood-production functions and which are not expected to perform these functions in future),
- category 4 (not substantiated stands in relatively favourable growing conditions).

Thinning is topical only in blue spruce stands of category 2. With respect of the distinct height and diameter differentiation even before the canopy closure, negative selection from below connected with stand conversion,

or with stand reconstruction (in less favourable growing conditions) is more efficient. Both stand conversion and stand reconstruction should be done with wider spectrum of species taking into account the provenance.

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Ecological impact analysis of mechanised site preparation techniques

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ABSTRACT: Analysis of the state and dynamics of degraded forest ecosystem is presented on the example of Permanent Research Plot Boleboř (Community Forest Jirkov Town, Ore Mts, NW Czech Republic). Plot was bulldozed, limed and plantations of preparatory species, i.e. blue (Colorado) spruce and birch were established. During 20 years of their growth, blue spruce was documented as unfavourable from the stand- as well as soil forming potential point of view, birch restoring the site relatively well. Bulldozing of sites as a part of site preparation has to be considered as soil devastating, causing humus displacement, bad tree species nutrition, stand growth and development.

Keywords: Ore Mts.; site preparation; forest restoration; plantation growth; preparatory species

Forest decline in the Ore Mts. (Czech Republic) was a result of extensive industrial development, not respecting ecological limits and consequences. In the time of maximum air pollution, i.e. in the mid-80ies, the year sulphur dioxide production in the Czech Republic reached 2.5 mil. t, another almost 3.0 mil. t was imported by winds, especially from Western countries. This resulted in sulphur deposition reaching 400 kg/ha per a, rapid decline of forests and heavy acidification as well as complex degradation of forest soils.

As a counteraction, large-scale measures were accepted. They were based on the general meanings and administrative decisions rather than on scientifically based analyses. Results and objections of the research specialists were rejected and technical, easy (but with big expenses) to provide treatments were adopted. Among them, the most deteriorating one, was the application of bulldozers in the site preparation for following planting, liming and other care. Its use was promoted by several reasons:

- bulldozing is a treatment easy to provide in favourable terrain condition, prevailing in the plateau of the Ore Mts.,
- it is expensive, so favourable in the economics, aiming at maximum financial flow,
- it enables use of following treatments with high machinery application rate,
- it was believed by the administration and management spheres, that the removal of uppermost "acid" soil horizons will improve the growth and state of new plantations, despite different opinion of researchers.

Only in the last period, the ecological analysis of this (and similar treatments) is accepted by the administration and decision spheres. Aim of the presented study is to document, how the bad political decisions affect the quality of environment and also to document the necessity of the ecological analysis before similar decision is done.

SITE AND USED METHODS

Research was done on the research plot "Boleboř" (name of the nearest village) in the Ore Mts. (Czech Republic). It was established for study of the development dynamics of stands of preparatory species, i.e. blue (Colorado) spruce (*Picea pungens*) and birch (*Betula alba*) in the year 1994. The site is degraded by the use of bulldozers during reforestation activities. Plantation of the blue spruce was 8 years old in this year. Locality is a part of municipal forests of the Jirkov town, forest stands 236A1 and 237F1. The altitude of the plot is 860 m a.s.l., forest site group is estimated as 7K – acid beech forest (forest type 7K4), soil type is Cambisol, immission zone is classified as A (vitality of spruce stands less than 20 years). Climatic region is determined as C1, slightly cool. Forest road divides the plot into 2 parts. First one was planted and the birch sowing took place here. Birch is the dominant tree on this part today. On the second one, spruce plantation is cleaned from invading broad-leaved trees.

The birch stand was characterised by these parameters in 1994 (MORAVČÍK, MORAVČÍKOVÁ 1991): 42,100 individuals per ha, mean height 2.55 m, mean width 1.2 cm, basal area 4.76 m^2. Biomass amount was measured as 14.29 t/ha in this stand, being 1.76 t/ha in the spruce stand only. Average year increment of the total biomass was determined as 1.75, respectively 0.55 t/ha in both stands, stem increment was 1.46, respectively 0.18 t/ha.

Measurements were provided in the dependency on the site disturbance in October 1994 and 1999. The first site type was selected just on the border of windrow (i.e. in the 1st line of blue spruce, planted parallel with them – this can be considered as the minimum disturbed site). Second sampling site type was then in the 2nd line from windrow (medium disturbance), and the 3rd one between 4th and 5th lines (maximum disturbance, characterising ca. 80% of the bulldozed area). In the stand with birch dominance, only the last variant was sampled. On each site type, two (1994) and four (1999) replications were conducted. Steel frame 25 × 25 cm was used for sampling of ground vegetation horizons L + F_1, F_2 and H, if it was possible to distinguish.

Methods of particular horizons separation were according to GREEN et al. (1993). L horizon is formed by litter, which is altered slightly only and its origin is easy to determine. Only light colour changes and leaching can occur, as well as coarse mechanical fragmentation. Horizon F is composed from more heavily fragmented and fermented material, but original structure is still obvious. Two sub-horizons can be determined: F_1 is loosen, like L layer, F_2 compact, more similar to H. Bulk samples from more horizons with similar character are grouped together, if they are too thin for differentiated sampling. Besides the ground vegetation bulk biomass, surface humus, the mineral soil (uppermost layer – A horizon) was sampled. This last sampling was not quantitative. In lines of blue spruce mentioned above, the youngest needles were collected for foliar analyses (bulk samples) and the height growth was measured (30 replications). Spruce needles collection took place also under birch. Because birch leaves did not still showed signs of colour changes, sampling of birch foliage was performed too: between windrows, on windrows and separately of birches with bad healthy state. Also the individuals of blue spruce showing visible deficiency symptoms (especially colour changes and dwarf growth) were sampled separately.

ECOLOGICAL ANALYSIS – RESULTS AND DISCUSSION

As shown in the Table 1, spruce growth differs very significantly on particular site types. The best, undisturbed growth was documented in the 1st line, slighter one in the 2nd line and the slightest in the last case, i.e. between rows. Higher occurrence of spruces with heavy deficiency symptoms was obvious between rows. Suppressed height growth under birch is to expect because of light deficiency – on the contrary colour changes did not occur here.

Table 1. Height growth of the blue spruce plantation on the Boleboø locality on differently disturbed sites

Height (m)	1	2	4–5	Under birch
1988	0.93	0.91	0.67	0.55
1990	1.18	1.07	0.77	0.65
1991	1.38	1.20	0.85	0.70
1992	1.59	1.27	0.93	0.77
1993	1.87	1.48	1.03	0.85
1994	2.16	1.68	1.15	0.97
1995	2.49	1.98	1.33	1.01
1996	2.68	2.23	1.52	1.15
1997	2.92	2.42	1.68	1.30
1998	3.22	2.67	1.87	1.42
1999	3.60	2.98	2.10	1.62

Besides other possible factors, cause of bad spruce growth and healthy state can be ascribed to insufficient nutrition, as foliar analyses revealed (Table 2). With increasing distance from windrow, the nitrogen nutrition deteriorated heavily, this situation being more evidently in the period 1994–1999. In 1999, spruces with defect growth and colour changes showed moreover heavy magnesium deficiency. Nutrition of spruces under birch canopy was improved by the ameliorative function of this preparatory (pioneer) species. It can be concluded, that bulldozing caused prominent site degradation with unfavourable impact on the nutrition of subsequent forest stand. Similar results documented JIRGLE (1983, 1984).

This statement can be supported by the analysis of birch nutrition in the same stands (Table 3). Also in this case was the nitrogen nutrition between windrows much worse, than in their vicinity or directly on them. Other nutrients, similar in spruce, showed (with slight exception of P) other dynamics – none of them was in the deficiency range. Higher content of bases on the scarified surface can be ascribed to the liming, affecting especially this site type (PODRÁZSKÝ 1992). The declining birch indicates even worse nitrogen (and also copper) nutrition.

Table 2. Nutrition of blue spruce on the locality Boleboř on differently disturbed sites (1994–1999)

Line	1		2		4–5		Deficiency	Under birch
	1994	1999	1994	1999	1994	1999	1999	1999
N (%)	1.43	0.968	1.07	0.838	1.06	0.758	0.734	1.054
P (%)	0.31	0.302	0.13	0.252	0.15	0.744	0.388	0.401
K (%)	0.36	0.523	0.36	0.417	0.36	0.597	0.459	0.697
Ca (%)	0.24	0.228	0.28	0.353	0.43	0.729	0.068	0.316
Mg (%)	0.023	0.0378	0.019	0.0533	0.053	0.0456	0.0150	0.0739

Table 3. Nutrition of birch on the Boleboř locality on differently disturbed sites (1994–1999)

Site	N	P	K	Ca	Mg	Na	Zn	Cu	Mn
1994									
Between rows	2.56	0.41	0.61	0.360	0.140	–	–	–	–
1999									
BR rows	2.94	0.191	0.992	0.449	0.1111	70	228	21	1,513
BR between rows	2.132	0.415	0.723	0.729	0.1740	62	138	20	806
BR declining	1.572	0.420	0.848	0.474	0.1834	73	88	8	185

Nutrition analysis shows, that for the bad growth and development of both spruce and birch stands, is the decisive factor represented by the disturbance of nitrogen nutrition. Bulldozing caused this state and its use is responsible for declining of plantations in the Ore Mts. on large areas, including the newly documented so called "birch decline".

These conclusions are supported by other analyses and measurement:

- the root systems of forest trees, especially of spruce is of the surface type, fine roots uptake maximum of elements is in the holorganic layers (TIETEMA 1992; WESEMAEL 1992),
- removal of surface humus leads to the declined nutrition, especially with nitrogen (partly with phosphorus), on the contrary the loss of bases, especially of Ca and Mg, is balanced by large-scale liming,
- this situation is reflected by the amount and nutrient content of ground vegetation (Table 4),
- majority of surface humus is so eliminated from the planting sites, together with nutrients (Table 6), the further dynamics includes further decomposition and losses of relatively intact parts (line 1 and 2), slight accumulation due to grass development on plots between windrows (line 4–5) and relatively more pronounced accumulation under birch (Table 5),
- development of the nutrition status in the future can be expected as unfavourable and with disturbances in nutrients dynamics, further research and ameliorative treatments are necessary.

CONCLUSIONS

Bulldozing as a part of site preparation is a site degrading treatment, disturbing the humus layer and natural dynamics of nutrients, its propagation as one of the subsidised treatment in forest restoration (in the Ore Mts.) is documented as site disturbing and unfavourable from the viewpoint of forest rehabilitation process, state subsidy for treatments without research basis is harmful and contra-productive, prevailing of political and economical (in deformed meaning) interests above the ecological ones is often in deformed societies, it causes more problems in the future. Research and scientifically based knowledge

Table 4. Biomass of ground vegetation (dry matter – DM), and macronutrient content on the Boleboř locality on differently disturbed sites (1994–1999)

Line	1		2		4–5		Under birch	
	1994	1999	1994	1999	1994	1999	1994	1999
DM (g/m^2)	370	325	194	328	133	212	45	188
N (%)	1.240	1.35	1.240	1.22	1.180	0.88	1.080	1.240
P (%)	0.154	0.11	0.174	0.11	0.178	0.08	0.128	0.13
K (%)	6.000	0.56	5.002	0.40	5.250	0.42	6.250	0.50
Ca (%)	0.100	0.14	0.300	0.24	0.160	0.12	0.060	0.18
Mg (%)	0.199	0.060	0.120	0.060	0.100	0.038	0.070	0.054

Table 5. Accumulation of surface humus on the Boleboř locality on differently disturbed sites (1994–1999)

Line	1		2		4–5		Under birch	
DM (g/m^2)	1994	1999	1994	1999	1994	1999	1994	1999
L+F$_1$	376	311	226	–	201	–	145	–
F$_2$	932	549	444	–	310	–	211	472
H	4,524	2,624	694	978	495	1,452	434	900
Total	5,832	3,484	1,363	978	1,004	1,452	802	1,372

Table 6. Content and amount of total nutrients in the surface humus layers on the Boleboř locality on differently disturbed sites (1994)

N	1		2		4–5		Under birch	
1994	(%)	(kg/ha)	(%)	(kg/ha)	(%)	(kg/ha)	(%)	(kg/ha)
$L+F_1$	1.26	47.38	1.19	26.89	0.84	16.88	1.43	20.74
F_2	1.64	152.85	0.86	38.18	0.86	26.66	1.59	33.55
H	1.44	651.46	0.88	61.07	0.85	42.08	0.94	40.80
Total	–	851.68	–	126.15	–	85.62	–	95.08
P								
$L+F_1$	0.102	3.835	0.121	2.735	0.103	2.070	0.132	1.914
F_2	0.110	10.252	0.102	4.529	0.074	2.294	0.145	3.060
H	0.124	56.098	0.096	6.662	0.067	3.317	0.087	3.776
Total	–	70.185	–	13.926	–	7.681	–	8.750
K								
$L+F_1$	0.344	12.934	0.494	11.164	0.673	13.527	0.510	7.595
F_2	0.390	36.348	0.710	31.524	0.766	23.746	0.418	8.820
H	0.620	280.488	0.835	57.950	0.805	39.848	0.310	13.454
Total	–	329.770	–	100.64	–	77.121	–	29.869
Ca								
$L+F_1$	0.318	11.957	0.532	12.023	0.710	14.271	0.840	12.180
F_2	0.287	26.748	0.980	43.512	0.640	19.84	0.400	8.440
H	0.240	108.576	0.640	44.416	0.320	15.84	0.860	37.324
Total	–	147.281	–	99.951	–	49.951	–	57.944
Mg								
$L+F_1$	0.110	4.136	0.061	1.379	0.100	2.010	0.091	1.320
F_2	0.069	6.431	0.119	5.284	0.107	3.317	0.096	2.026
H	0.091	41.168	0.189	13.117	0.075	3.713	0.132	5.729
Total	–	51.735	–	19.780	–	9.040	–	9.075

represents starting point for environmental management and connected problems of development attached to agriculture and forestry.

Acknowledgement

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Some experience of European birch (*Betula pendula* Roth) and Carpathian birch (*Betula carpatica* W. et K.) planted on the ridge part of the Jizerské hory Mts.

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ABSTRACT: Development of birch plantations was investigated on research experimental series in the Jizerské hory Mts. The experimental area is located on the mountain ridge at an altitude of 940–980 m a. s. l., and is exposed to climatic stresses and air pollution load. European birch (*Betula pendula* Roth) was planted in 1990, 1992, 1993, Carpathian birch (*Betula carpatica* W. et K.) in 1993. First injury symptoms due to complex ecological stresses in European birch appeared in 1997 (11% injured and dead trees), then in 1998 (17%), 1999 and 2000 (87%). Carpathian birch has been found much more tolerant. Numbers of injured and dead trees were: 1997 = 3%, 1998 = 7%, 1999 and 2000 = 5%. Observation results confirm the importance of proper species choice, when birches are planted in the mountains. Vitality of Carpathian birch (naturally growing on peaty soils) was negatively influenced by finely ground dolomitic limestone application.

Keywords: *Betula pendula*; *Betula carpatica*; Jizerské hory Mts.

Birch is considered as the tree species relatively tolerant to ecological stresses in the Central Europe. When large areas of forest in the Czech mountains were damaged by air pollution and removed, birch had replaced sensitive Norway spruce stands on many places as the substitute tree species. Importance of birch increased rapidly, and definition of its growing properties became an object of research attention. Therefore birch was included in planting experiment in the ridge part of the Jizerské hory Mts. The aim of the experiment is to assess applicability of various tree species (26 species) for reforestation in the mountain areas. In Carpathian birch, support of plantations by amelioration is tested.

MATERIAL AND METHODS

Planting experiment in the ridge part of the Jizerské hory Mts. was established in spring 1990. Experimental series are situated at an altitude of 940–980 m a.s.l., mean air temperature of the site is nearly 5°C and annual precipitation 1,200 mm. Bedrock is biotitic granite, soil type was determined as a mountain humus podzol, some places changing to peat podzol (BALCAR, PODRÁZSKÝ 1994; PODRÁZSKÝ, BALCAR 1996).

On the experimental plot, these birch species are tested: European birch (*Betula pendula* Roth), Carpathian birch (*Betula carpatica* W. et K.), and their spontaneous hybrid from the Krkonoše Mts. close to European birch (*Betula sp.*). European birch, recommended in lower-elevated localities (LOKVENC 1988), has been planted by reason of its properties on the base of verification and comparison with other birch species. Age of the planting stock was from 1 to 3 years, number of transplants 100–200 (Table 1). In Carpathian birch plantation, possibility of support by liming and crushed basalt application was investigated. (Non-standard – coarse grained – type of applied basalt

Table 1. Planting stock

Planting	English name	Scientific name	Symbol	Amelioration
1990	European birch	*Betula pendula* Roth	BP90	
1992	European birch	*Betula pendula* Roth	BP92	
1993	European birch	*Betula pendula* Roth	BP93	
1990	European birch (hybrid)	*Betula* sp.	BS90	
1993	Carpathian birch	*Betula carpatica* W. et K.	BC93C	
1993	Carpathian birch	*Betula carpatica* W. et K.	BC93L	limestone
1993	Carpathian birch	*Betula carpatica* W. et K.	BC93B	basalt

Table 2. Texture of dolomitic limestone and basalt used for amelioration (in %)

	Grains (diameter in mm)			
	< 0.2	0.2–0.5	0.5–1.0	> 1.0
Dolomitic limestone	57.5	20.4	16.3	5.8
Basalt	8.2	12.6	19.3	59.9

Table 3. Some element content (%) and origin of limestone and basalt

	Ca	Mg	P	K	Origin
Dolomitic limestone	21.5	11.3	–	–	Lánov u Vrchlabí
Basalt	8.6	6.1	0.4	1.0	Frýdlant v Čechách

was tested for local foresters requirement, BALCAR, PODRÁZSKÝ 1995.) Both ameliorative admixtures – finely ground dolomitic limestone (1 kg per 1 tree) or crushed basalt (2 kg per 1 tree) were mixed with soil in the planting hole when trees were planted (Tables 2 and 3). Health condition observations were performed twice a year (spring and autumn), heights of trees were measured once a year (autumn). Samples of Carpathian birch leaves were analysed. Meteorological measurement is performed by NOEL 2000 station.

RESULTS AND DISCUSSION

DEVELOPMENT OF PLANTATIONS UP TO 1996

European birch plantations showed relatively high mortality during the first three years. Namely first plantations (1990) damaged by voles (*Microtus agrestis* L.) lost nearly three quarters *Betula pendula* trees and one half *Betula* sp. trees (Table 4). European birch planted later (1992–1993) lost nearly one third of trees for the first three years. The later mortality of these species up to 1996 was negligible (0–7%) with exception of plantation 1993 which lost 14%. Mortality of Carpathian birch was much lower, 6% during the first three years, then (up to 1996) 4%.

Height growth of all birch plantations up to 1996 had a similar trend. In short reduction term (2 years) after planting out, all plantations increased their height increments (Fig. 1). Carpathian birch plantations grew faster than European birch.

Table 4. Mortality (%) of birch plantations up to 1996

Scientific name	Symbol	Up to	
		3 years	1996
Betula pendula Roth	BP90	74	74
Betula pendula Roth	BP92	32	37
Betula pendula Roth	BP93	34	48
Betula sp.	BS90	47	54
Betula carpatica W. et K.	BC93C	9	13
Betula carpatica W. et K.	BC93L	0	4
Betula carpatica W. et K.	BC93B	9	12

In spite of relatively high losses in some tested variants during the first three years after planting, performance tested birches was assessed as fairly suitable for clear-cuts reforestation in the mountains up to 1996 (BALCAR 1997).

DEVELOPMENT OF PLANTATIONS AFTER 1996

After 1996, large damages and dieback of young birch stands had been observed on many sites in the Sudeten Mountains (KULA et al. 1999; LOMSKÝ, ŠRÁMEK 1999; VACEK, BALCAR 1999). First injury symptoms on experimental series Jizerka appeared in summer of 1997. Number of injured trees was relatively small, and during the first year (up to 1998) slowly increased (Table 5). Next spring

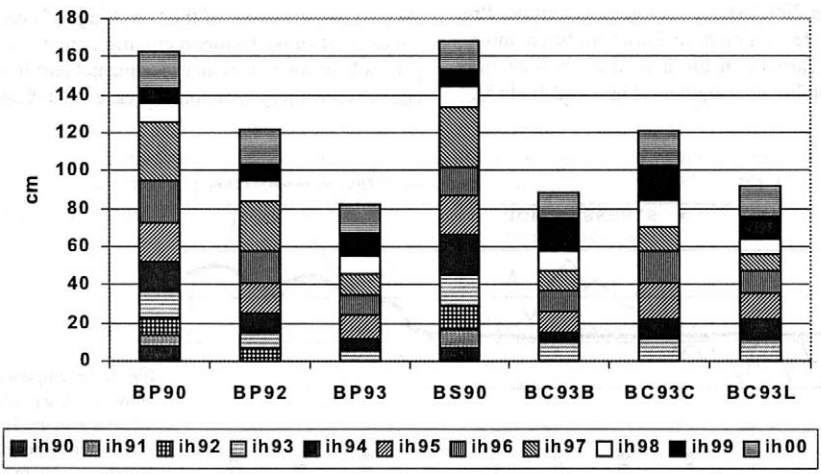

Fig. 1. Height increment of tested birch plantations on the experimental plot Jizerka (Symbols of plantations see Table 1)

Table 5. Frequency of injured trees and cumulative mortality 1997–2000

Species	Symbol	1997			1998			1999			2000		
		I	M	T	I	M	T	I	M	T	I	M	T
Betula pendula	BP90+BP92	1	4	**5**	10	7	**17**	87	12	**99**	79	16	**95**
Betula pendula	BP93	0	18	**18**	3	21	**24**	36	32	**68**	32	40	**72**
Betula sp.	BS90	8	3	**11**	9	3	**12**	83	10	**93**	71	18	**89**
Betula carpatica	BC93C	1	1	**2**	4	2	**6**	0	2	**2**	2	3	**5**
Betula carpatica	BC93L	0	2	**2**	5	3	**8**	0	3	**3**	1	2	**2**
Betula carpatica	BC93B	1	4	**5**	2	4	**6**	2	6	**8**	1	6	7

I – injured trees (%), M – mortality from 1997 (%), T – total (I+M)
Number of living trees in 1996 = 100%

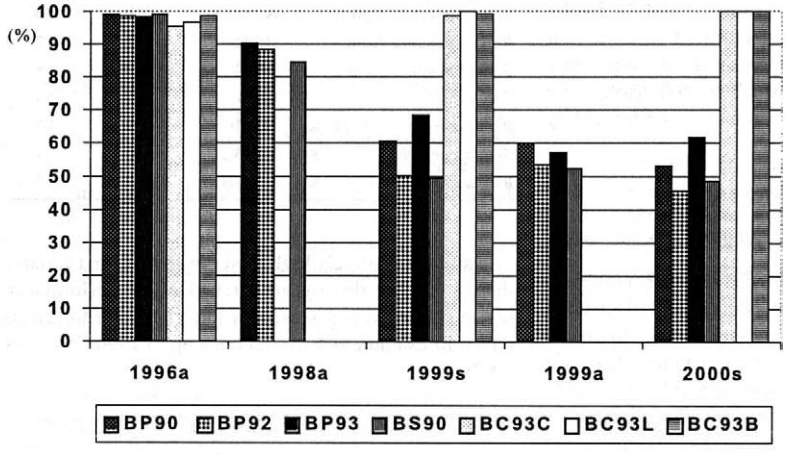

Fig. 2. Average foliage (%) of birch plantations on experimental plot Jizerka (s = spring classification, a = autumn classification. For technical reasons, 1998a – classification for BP93 and all BC, and 1999a – classification for all BC were omitted. Symbols of plantations see Table 1)

(1999) most trees of European birch and hybrid birch showed serious injury symptoms. On the contrary, Carpathian birch plantations regenerated, and up to the present (autumn 2000) show very good condition. Progressive injury development in European birch and regeneration in Carpathian birch is also obvious from foliage and mortality development (Fig. 2 and Table 5).

Bad health condition of European birch plantations had been seen also in markedly decreasing height increments in 1998 and 1999. In 2000 height increments increased (Fig. 1). As the cause of the "birch injury"concerns, the complex of stress factors including climatic extremes is generally presumed. So in experimental plot Jizerka, linkage between injury symptom increase in 1998 and damage

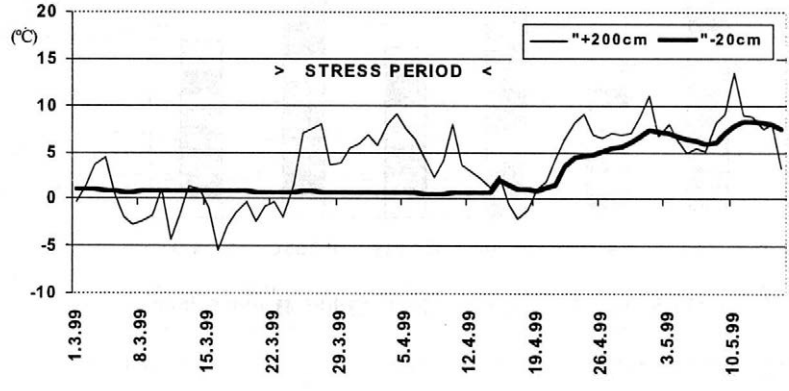

Fig. 3. Air temperature 200 cm above surface ("+200cm) and soil temperature 20 cm below surface on experimental plot Jizerka ("–20cm) March 1st –May 15th 1999

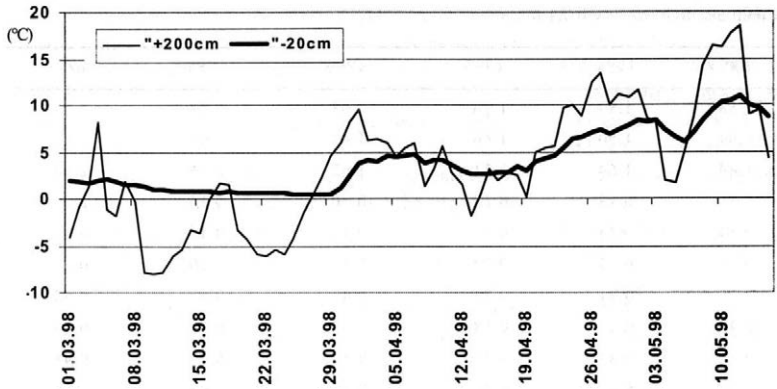

Fig. 4. Air temperature 200 cm above surface ("+200cm) and soil temperature 20 cm below surface on experimental plot Jizerka ("–20cm) March 1st–May 15th 1998

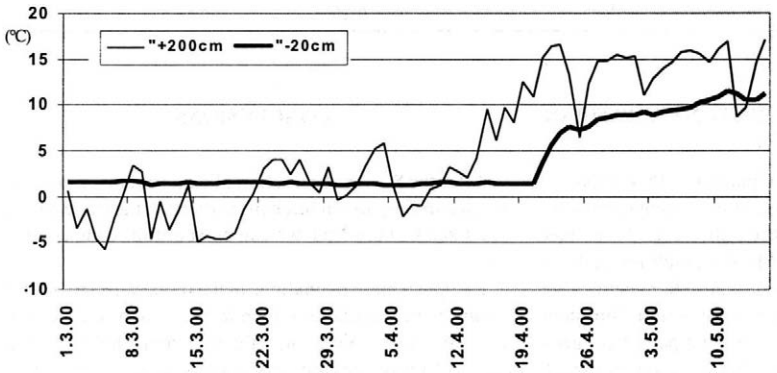

Fig. 5. Air temperature 200 cm above surface ("+200cm) and soil temperature 20 cm below surface on experimental plot Jizerka ("–20cm) March 1st–May 15th 2000

due to hail in May 1998 was obvious. Next (dramatic) damage progress in European birch was (in our opinion) influenced by climatic stress in spring 1999. The temperature of air at the end of March increased markedly, but the soil temperature was near 0°C until the half of April. This temperature imbalance lasted about 17 days ("stress period", Fig. 3). With comparison of previous and following years (1998 and 2000) this long time climatic stress was exceptional (Figs. 4 and 5).

The difference between present bad health state of European birch and good state of Carpathian birch planted in the ridge locality of the Jizerské hory Mts. (altitude of about 970 m a.s.l.) is in accordance with natural dispersal of these birch species. Natural dispersal of birches was the base of previous recommendation stated by Lokvenc and others (Table 6, LOKVENC 1988; LOKVENC et al. 1992; LOKVENC, VACEK 1993). Our results proved validity of this recommendation.

Table 6. Natural dispersal and applicability of birches in the Krkonoše Mts. (by LOKVENC 1988)

English name	Scientific name	Natural dispersal	Applicability
European birch	*Betula pendula*	up to 900 m a.s.l.	up to 850 m a.s.l.
White birch	*Betula pubescens*	up to 1,100 m a.s.l.	up to 1,000 m a.s.l.
Carpathian birch	*Betula carpatica*	1,000–1,400 m a.s.l.	above 1,000 m a.s.l.

Table 7. N- and Ca-content in Carpathian birch leaves (% dry mass)

Symbol	Element	1993	1994	1995	1996	1998	1999
BC93C	N	1.58	1.83	1.76	2.03	2.28	2.64
BC93L	N	1.84	1.50	1.66	1.62	1.91	2.15
BC93B	N	1.44	1.54	1.71	1.62	2.36	2.33
BC93C	P	0.14	0.13	0.16	0.20	0.16	0.21
BC93L	P	0.14	0.14	0.15	0.18	0.12	0.17
BC93B	P	0.15	0.15	0.20	0.19	0.20	0.20
BC93C	K	0.48	0.31	0.35	0.43	0.41	0.52
BC93L	K	0.43	0.27	0.38	0.38	0.31	0.40
BC93B	K	0.46	0.33	0.37	0.45	0.45	0.45
BC93C	Ca	0.50	0.47	0.39	0.46	0.63	0.53
BC93L	Ca	0.76	0.47	0.58	0.60	0.89	0.66
BC93B	Ca	0.35	0.36	0.37	0.48	0.63	0.53
BC93C	Mg	0.28	0.36	0.39	0.25	0.11	0.14
BC93L	Mg	0.22	0.24	0.22	0.21	0.10	0.14
BC93B	Mg	0.34	0.35	0.38	0.25	0.09	0.15

EFFECT OF AMELIORATION UPON CARPATHIAN BIRCH

In the course of first 8 years of planting (1993–2000), no marked difference in health condition among tested Carpathian birch plantation has been observed. All planted variants performed very good health condition and low mortality. The difference in height growth dynamics see Fig. 1. Plantations with finely ground dolomitic limestone (1 kg per 1 tree) or crushed basalt (2 kg per 1 tree) grew more slowly than control plantation (without any treatment).

Leaf analyses results proved distinct changes in nutrition content (Table 7). After limestone application, calcium content in leaf samples increased and other element content decreased (N, P, K, Mg). Content reduction was obvious especially in nitrogen and potassium. In accordance with BERGMANN (1988), decreased values of nitrogen and potassium in tested birch plantations are below sufficient nutrition values (sufficient N-content for birch 2.50–4.00%, potassium content 1.00–1.50%), while calcium values were in all cases in ranges of sufficient nutrition values (sufficient Ca-content for birch 0.30–1.50%). Below critical values, according to leaf analyses, were in some terms phosphorus (critical level = 0.15% P) and magnesium (critical level 0.15% Mg). Nutrition imbalance was obviously induced by changes in soil chemistry due to liming (cf. PODRÁZSKÝ, BALCAR 1996), and influenced Carpathian birch plantation negatively. In case of basalt application, no such distinct and explicit changes of element content in leaves were proved. We presume, that the height growth reduction of tested trees, especially obvious during the second year after basalt application, was influenced by changes of soil texture and moisture content after addition of coarse-grained basalt.

CONCLUSIONS

After the 8-year observation of experimental European birch and Carpathian birch plantations in the ridge part of the Jizerské hory Mts. we can present following conclusions:

European birch plantations in the mountains are limited by growing conditions. Climatic stress (and complementary stresses of biotic and abiotic origin) heavily damaged all European birch plantations tested on the top of mountain ridge at the altitude of about 970 m a.s.l. Carpathian birch, good growing in the same site conditions, was proved as a more suitable species for reforestation of mountain ridge areas with harsh climatic conditions. Performance of both birch species is in accordance with previous forest research recommendation based on birch species natural dispersal.

Health state of Carpathian birch (injury symptoms, foliage condition, and mortality) was not significantly influenced by any applied ameliorative measures. Height growth of Carpathian birch (naturally growing on peaty soils) was negatively influenced by finely ground dolomitic limestone application.

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Damage to common birch (*Betula pendula* Roth) in higher altitudes of the Ore Mts. (Erzgebirge)

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ABSTRACT: Since 1998 severely damaged common birches were observed in Saxon locations of an altitude of 750 m above sea level and higher. These stands are often characterised by waterlogging, rough climate, long-time immissions, nutrient depletion and acidification of the soil. The size of the area with damaged birches in the Ore Mountains (Erzgebirge) is approx. 70 ha; a centre of strong damage is the forest ranger district of Deutscheinsiedel (approx. 35 ha). The damage is marked by stem cracks, crown defoliation and fungal attack on leaves by *Marssonina betulae*.

Keywords: Saxony; damage to common birch; altitude; sites; symptoms; fungal attacks

In ecologically adapted silviculture birch belongs to the important tree species, since it softens climatic extremes of the open land. In many places it constitutes a shelter for the rejuvenation of mixed spruce mountain-forests. Therefore, diseases of birch are seen increasingly with apprehension.

MATERIAL AND METHODS

To improve our knowledge of the size of damage in the year 1998, the damage process and the influence of predisposing factors on this damage sampling plots were realised in 1999 and 2000 (locations are situated near the border to the Czech Republic).

The damage assessment was concentrated on the following aspects:

- classification of the growing birch-trees into two species groups (common birch group and non-common birch group),
- visible stem cracks following cambium damage,
- defoliation of the crown (scale: 10% steps),
- number of infected trees and degree of fungal attack on leaves by *Marssonina betulae* (scale: 5 steps: without infection 0%, 0–25%, 26–50%, 51–75%, above 75%) – number of dead trees.

In the current year, the regenerative capacity of the common birches was registered additionally (sprouting buds at the root collar).

Extent and density of the assessments varied broadly (Table 2).

In a cultivation experiment in the forest ranger district of Schellerhau, Finnish provenances of common birch (Joutsa, Taiplasaari) were compared with an indigenous progeny in regard of stem cracks and fungal attacks on leaves by *Marssonina betulae*.

To obtain knowledge on the pathogenicity of *Marssonina betulae*, weekly artificial infections of leaves were carried out with potted common birches in an open ground experiment in the Saxon Research Centre of Forestry (LAF) Graupa. These birches were exposed to the natural course of weather and to simulated stagnant moisture. Since lice and bugs were living on the birch leaves, the epidermis was not artificially injured prior to infection experiments.

Microscopic stem analyses were performed with damaged common birches of the experimental area in Olbernhau in order to determine the degree of cambium damage.

Open ground weather data of 1997 were made available by the Saxon meteorological stations; data of stand climate and soil were obtained from the forest meteorological station of the LAF department of silviculture in Olbernhau*.

RESULTS

SPECIES GROUP

Damage occurred mainly in the tree species *Betula pendula*. 41% of all classified common birches showed stem cracks. In comparison with the group of non-common birches the degree of foliage was significantly reduced in *Betula pendula* (in the forest ranger district of Deutscheinsiedel the percentage of foliage reached only 30% in average).

The fungal attack on the leaves by *Marssonina betulae* was only a problem of the species *Betula pendula*.

* I should like to express my thanks for the provision of these data.

Table 1. Stand characteristics of the sampling areas in 1999

Forest office	Forest ranger district	Logging unit	Altitude above sea level (m)	Annual average		Soil type	Age (years)	Kind of origin	Damage since	State of tending
				temperature (°C)	precipitation (mm)					
Eibenstock	Carlsfeld	278 a1	940	4.0–5.0	990–1,100	Riesenberg granite-podsol	12	natural seeding	1996	orderly
Altenberg	Schellerhau	186 a3, a5	840	< 5.5	960–1,000	Altenberg quarzporphyr-humus-stagnant gley	15	unknown	1999	orderly
Altenberg	Schellerhau	193 a2	840	< 5.5	960–1,000	Altenberg quarzporphyr-podsol	8	plantation	1999	orderly
Marienberg	Steinbach	145 a9	825	< 5.5	960–1,000	Oelsengrund gneiss-brown soil	16	natural seeding	1998	orderly
Olbernhau	Deutscheinsiedel	15 a1	780	< 5.5	960–1,000	Pfaffroda gneiss-brown soil	13	seeding	1996	insufficient
Ehrenfriedersdorf	Grumbach	460 a2	760	< 5.5	960–1.000	Jöhstadt gneiss-brown soil	ca. 50	unknown	1999	orderly
Ehrenfriedersdorf	Annaberg	411 a2	720	< 5.5	960–1,000	Rothenthal gneiss-humus-stagnant gley	13	seeding	1998	insufficient

Table 2. Statistical characteristics of the investigations into birch damages

Denomination of the area	Size of the area (ha)	Number of assessed trees per birch group		Extent of sampling
		Common birch	Non-common birch	
Carlsfeld 278 a1	5	38 common birch		VIII/1999, VIII/2000
Schellerhau 186 a3; a5	30	38 common birch	134 non-common birch	VI, VII, VIII/1999, V, VI,VII,VIII/2000
Schellerhau 193 a3	710	1,953 common birch	220 non-common birch	VIII/1999
Steinbach 145 a9	30	121 common birch		VI, VII, VIII/1999, V, VI,VII,VIII/2000
Deutscheinsiedel 15 a1	3.3	225 common birch	136 non-common birch	VII, VIII/1999, V, VI,VII,VIII/2000
Grumbach 460 a2	–	20 common birch	10 non-common birch	VIII/1999, VIII/2000
Annaberg 411 a2	0.8	42 common birch	4 non-common birch	VIII/1999, VIII/2000

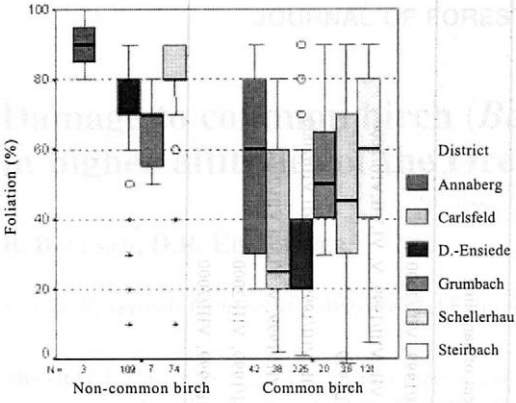

Fig. 1. Foliage status of birches in August of 1999

As to the provenances of common birch which were included in the investigations, the indigenous progeny was superior and consequently best adapted for its foliage and its resistance to attacks by *Marssonina*. On the other hand, the indigenous progeny was most severely damaged by stem cracks.

The moor birch from Finland and the indigenous non-common birches reached a good state for all assessed characters on the conditions of the Ore Mts. (Erzgebirge).

INVESTIGATION OF STEM CRACKS

In the centre of cross-sections of stems, a kind of rot appeared (*Deuteromycotina*, no further determination), transgressing longitudinally by far the visible crack. The radial cracks ran parallel to the stem axis and were restricted to the local cambium damage.

Some cambium passages had died off entirely; on other passages callus tissue appeared (Fig. 2).

The investigations of the stem cracks revealed failures in wood formation, datable to spring 1997. These failures looked like anomalous wood rays being spread only across parts of the annual ring (Fig. 3).

Besides the open cracks, which were used for damage assessment, further damages to the cambium were found. Although they are marked on the outside by brownish or deepened bark passages, they remained mostly hidden by dead bark and, therefore, they could not be included into damage assessment.

In the group of non-common birches only 10.9% of the individuals showed open cracks. As to common birches the respective percentage amounted to 40.9%.

The cracks occur above the root collar, sometimes also in higher stem regions, without a preferential cardinal point.

The proportion of common birches with stem cracks was highest in the forest ranger district of Carlsfeld, that is in the highest altitude (940 m) (Table 3).

In the observation period the proportion of common birches with open stem cracks did not change.

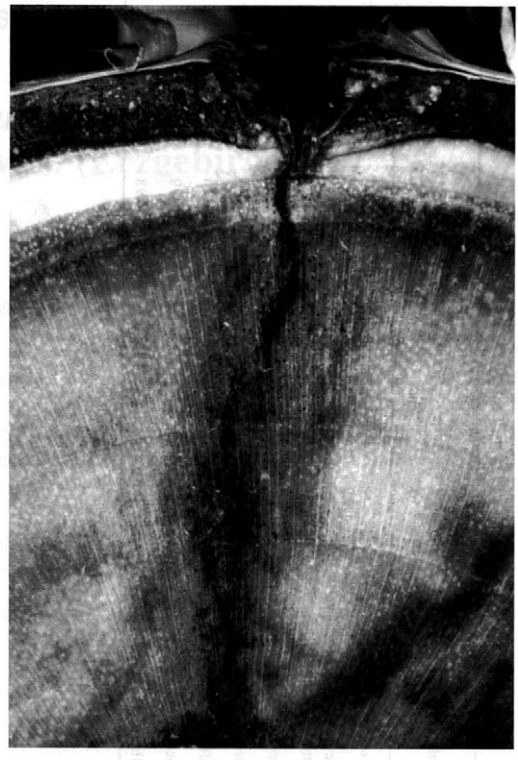

Fig. 2. Cambial damage on common birch (microscopic photo)

As a possible reason of the cambium damage the late frost events in May 1997 may be discussed. Saxon meteorological stations registered frost in open places in the night from the 24th to 25th of May, following a longer period of warmth (Fig. 4).

The forest meteorological station of the Department of Silviculture in Olbernhau registered this frost event as well, however, in the upper soil layer (10 cm) temperatures remained above 5°C (Fig. 5).

CROWN DEFOLIATION

Within the period of observations, common birches did not improve their state of foliage significantly. Accordingly, their degree of defoliation was nearly the same in 1999 and 2000 (Table 4).

Many common birches which showed high defoliation already at the beginning of May 2000 (foliage lower than 10%) died slowly back.

Number of infected trees and degree of fungal attack on leaves by *Marssonina betulae*.

The leaf infection by *Marssonina betulae* (Figs. 6–8) occurred at the beginning of the vegetation season, and so the regeneration of damaged birch trees was complicated or even prevented. Infections of non-common birches by *Marssonina betulae* have never been observed.

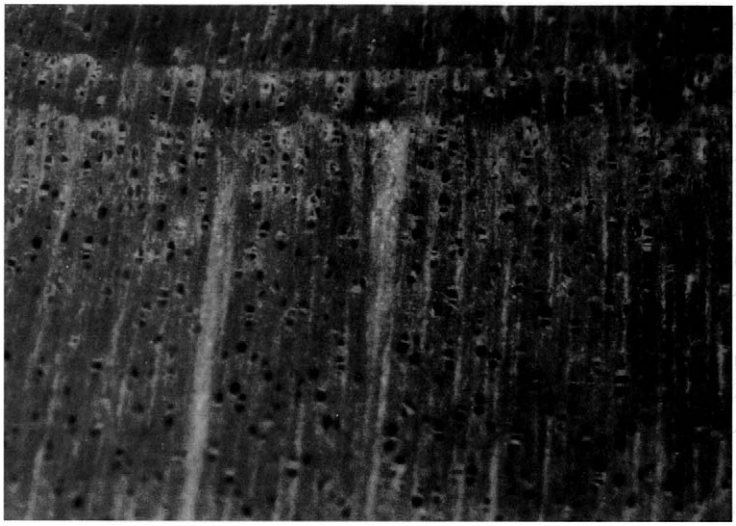

Fig. 3. Failures of wood formation caused by cambial damage (microscopic photo)

Table 3. Percentage of common birches with stem cracks

Forest ranger district	Altitude (m a.s.l.)	(%)
Carlsfeld	940	78.9
Schellerhau	840	52.6
Steinbach	820	18.2
Deutscheinsiedel	780	43.1
Grumbach	760	30.0
Annaberg	720	54.8

The leaf infection of common birches by *Marssonina betulae* differed from area to area and was dependent on the altitude (Table 5).

In the year 2000 the fungal infection occurred later (in July) and to a smaller extent than in the previous year.

Leaf infections by the fungus *Discula betulina*, being widespread in the lowland, are obviously rare in higher altitudes (no occurrence above 840 m). Laboratory investigations in the years 1999 and 2000 led to positive results for the experimental area in the forest ranger district of Altenberg (720 m). Here *Marssonina* infections occurred sporadically.

PERCENTAGE OF DEAD TREES

The proportion of dead common birches was considerable already at the time of the first assessment (1999) (Table 6). In the current year it increased only slightly (on average about 4%).

ARTIFICIAL INFECTION

Experiments to produce artificial infections failed. This outcome may be due to the high vitality of the potted

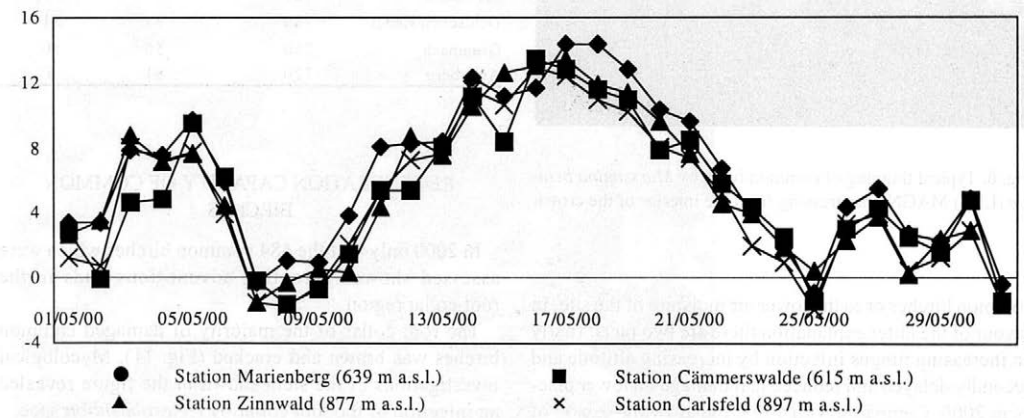

Fig. 4. The daily minimal air temperatures in May 1997 at several Saxon weather stations

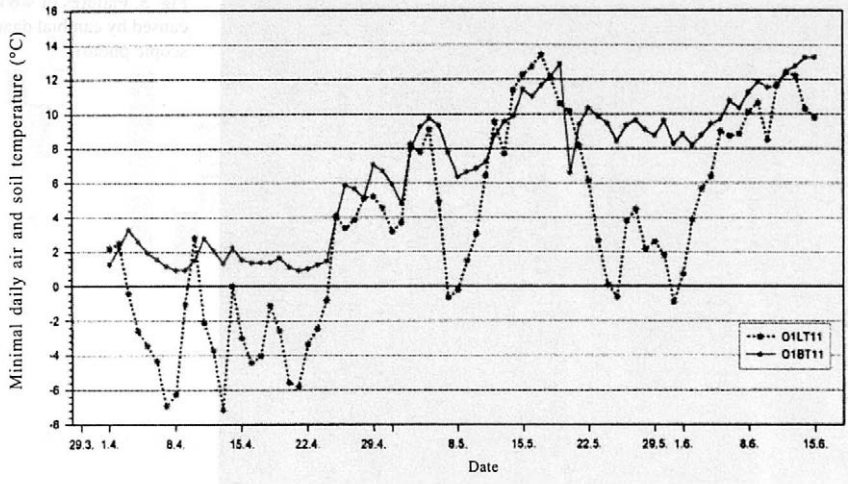

Fig. 5. The daily minimal air and soil temperatures in May 1997 at the forest meteorological station Olbernhau

Fig. 6. Typical thinning of common birch by *Marssonina betulae* (LIB.) MAGN., progressing from the interior of the crown

common birches or to the lower air moisture of the site. In favour of the latter explanation there are two facts: firstly an increasing fungus infection by increasing altitude and secondly delayed and reduced leaf damage on lower places in 2000. Compared with 1999, the growing-season of 2000 was distinguished by an extremely dry spring (Figs. 9 and 10).

Table 4. The average foliation (percentage) of the common birch in several stands

Forest ranger district	Altitude (m a.s.l.)	1999 (%)	2000 (%)
Carlsfeld	940	37	43
Schellerhau	840	47	51
Steinbach	820	56	60
Deutscheinsiedel	780	29	47
Grumbach	760	55	57

Table 5. Percentage of infected common birches in several stands

Forest ranger district	Altitude (m a.s.l.)	1999 (%)	2000 (%)
Carlsfeld	940	95	94
Schellerhau	840	76	78
Steinbach	820	78	79
Deutscheinsiedel	780	97	51
Grumbach	760	50	50
Annaberg	720	81	5

REGENERATION CAPACITY OF COMMON BIRCHES

In 2000 only 4 of the 484 common birches which were assessed showed sprouting adventitious buds in the root-collar region.

The root collar of the majority of damaged common birches was brown and cracked (Fig. 11). Mycological investigations of the stem shown in the figure revealed an infection of the root collar by *Heterobasidion* spec.

Time and extent of root infections of common birches by *Heterobasidion* spec. are presently unknown.

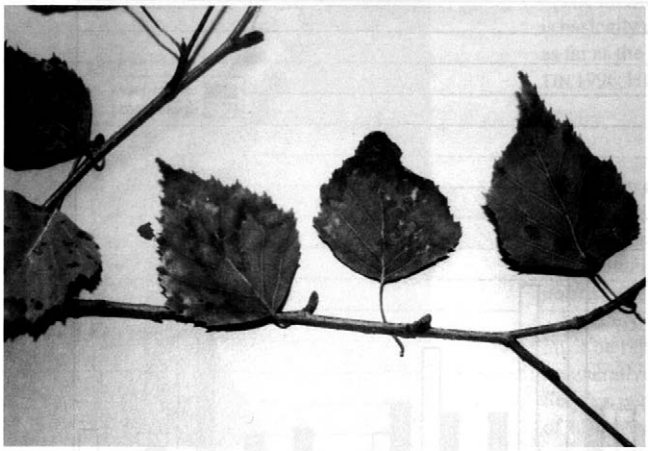

Fig. 7. Visible marks of leaf infection by *Marssonina betulae* (LIB.) MAGN. on common birch

Table 6. Percentage of dead common birches

Forest ranger district	1999 (%)	2000 (%)
Deutscheinsiedel	47	52
Carlsfeld	28	33
Annaberg	39	39
Steinbach	11	17
Schellerhau	5	8

DISCUSSION

The investigation of common-birch damage were started with an initial set in autumn 1998 and so there were no adequate clues to temporal relationships between cambium damage, crown defoliation and fungal attacks.

The events which triggered the damages are presumably abiotic stresses on both the Czech and the Saxon side of the Ore Mts. (Erzgebirge).

According to investigations by ŠRÁMEK (1998) and BALCAR (1998) on birches in the Czech Republic, anomalous meteorological courses in February and March 1997 caused damage to rootlets and interrupted the water-supply in the stem. On the Czech as well as on the German side of the the Ore Mts. damaged birches grow mainly on waterlogged soils.

On the other hand, cambium damage of common birches in the Saxon part of the Erzgebirge were probably caused by a late frost from the 24th to the 25th of May 1997.

The optimal and upper critical temperatures for release from winter dormancy in *Betula* are about 0–5 and 12°C, respectively, according to estimates by MYKING (1997).

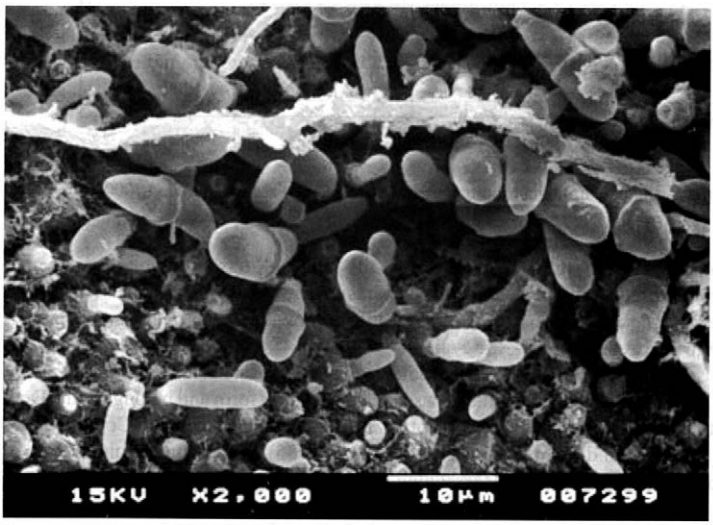

Fig. 8. The characteristic spores of *Marssonina betulae* (LIB.) MAGN. (uni- or bicellular, 17–22 × (5) 8–10 µm); [SEM – picture]

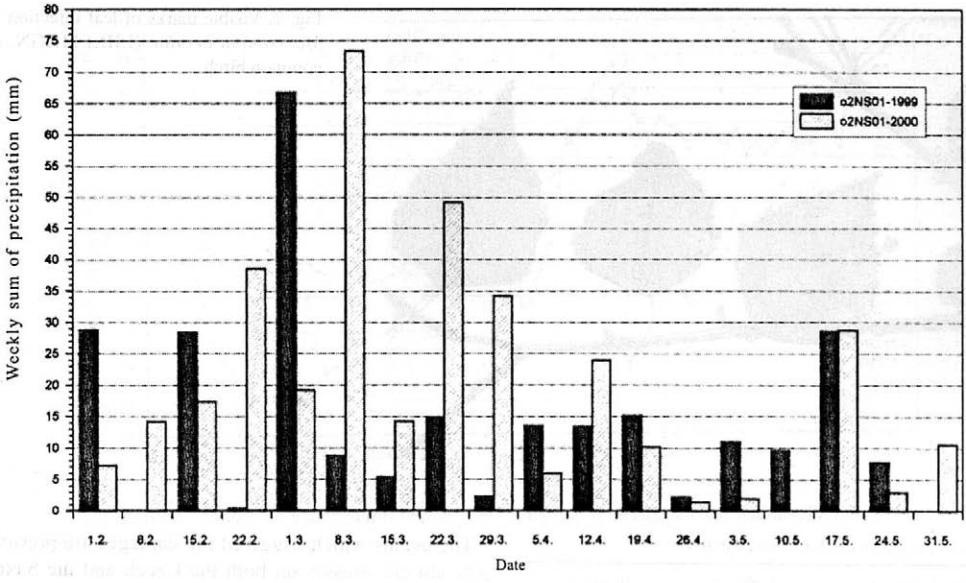

Fig. 9. The weekly sum of precipitation at the forest meteorological station Olbernhau in relation spring 1999 and 2000

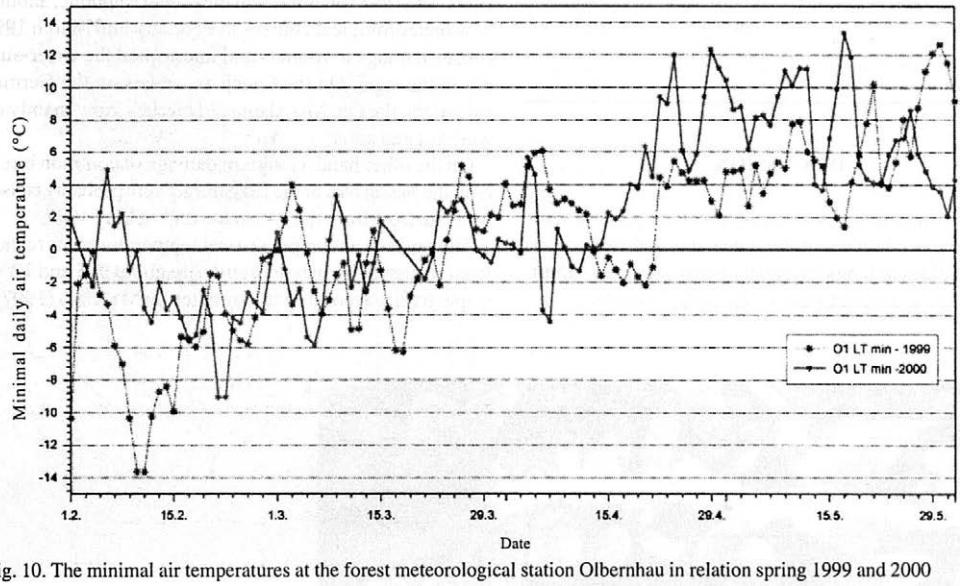

Fig. 10. The minimal air temperatures at the forest meteorological station Olbernhau in relation spring 1999 and 2000

The warm period at the beginning of May 1997 has presumably broken the winter dormancy. Consequently an activation of the cambium of *Betula pendula* may have occurred. In this early stage the cambium is extremely sensitive to frost.

The insufficient regeneration of damaged common birches can be seen in connection with the reduced transport capacity caused by cambium necroses and stem cracks; but also with fungal infections of leaves and/or roots.

In literature the fungus *Marssonina betulae* is characterised as an parasite on weakened individuals (SINCLAIR et al. 1987). Little is known about its pathogenicity and its life cycle.

As to botanical systematics, *Marssonina betulae* constitutes a secondary fruiting form and belongs to the Deuteromycotina in the botanical order of Coelomycetes (BRANDENBURGER 1985). The primary fruiting form of *Marssonina betulae* is still unknown, however, it may be found in the Ascomycetes (genus *Drepanopeziza*) in agreement with findings for other *Marssonina*-species.

Fig. 11. The trunk of a severely damaged common birch with a diagnosed infection by *Heterobasidion* spec.

Marssonina betulae is obviously only capable to infect leaves of weakened, perhaps already dying common birches. An successful infection seems to depend on high air moisture.

Birch species with pilose leaf surface (*Betula pubescens, B. carpatica*) are presumably not attacked because of the hydrophobic properties of such a surface.

Contrary to leaf infections by other fungi *Marssonina betulae* becomes infectious already at the beginning of the vegetation season. It reduces both assimilating surface and assimilation continuously and may finally lead to the death of the birch.

The missing regenerative capacity of damaged birches is basically due to root infection by *Heterobasidion* spec. as far as the majority of damaged trees is concerned (BUTIN 1996; HEYDECK 2000).

CONCLUSIONS

In higher altitudes of the Ore Mts. (> 750 m a.s.l.) common birch (*Betula pendula*) should not be cultivated on moist mineral soils. On such localities, other birch species are recommended, in particular *B. pubescens* and *B. carpatica*.

Severely damaged pioneer-forests of common birch must be rejuvenated preferentially in view of their lost regenerative capacity by introduction of other species. For this purpose, seeding of moor birch and/or planting of target-tree species is advised in dependence on the state of the site, on the probability of temporarily high immissions, on the forest function as first priority and on available financial resources.

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ALAI-02D – a new instrument in forest practice

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ABSTRACT: Health status evaluation of forest stands in the Czech Republic is based on the estimation (by sight) of a defoliation degree. Leaf area index (LAI) is a parameter describing the amount of bearing assimilatory apparatus within the canopy. For an objective LAI estimation, a lot of instruments exist, but a high cost, as well as difficulty of management and LAI calculation are their disadvantages. This contribution allows us to introduce a new moderate instrument with a wide application in forest and ecological branches, respectively.

Keywords: defoliation; leaf area index; photosynthetic active radiation

Health status of the Czech forest stands is mostly evaluated on the basis of Norway spruce (*Picea abies* [L.] Karst.) or Scots pine (*Pinus sylvestris* L.) forest trees defoliation. In areas without any forest stand composed of these two species, stand health status is evaluated from the deciduous tree disintegration phase evaluation (see the 3rd Intimation of the Ministry of Agriculture about determination of the health hazard zone under emission influence No. 78/1996, emitted on March 18th 1996). Defoliation percentage described the amount of leaves loss within tree crowns. Conversely, leaf area index (LAI) quantifies the amount of bearing assimilatory apparatus in a plant canopy. LAI is widely used in physiological studies (NEMANI, RUNNING 1989), but unfortunately, not yet in forest practice. However, the evaluation of leaves loss amount results from a subjective method, when defoliation is evaluated by sight. Inversely, an indirect method for LAI estimation using an optical instrument is much more objective when considering foliage amount in canopy evaluation. Thus, a new instrument in forest practice will be presented. This instrument is an ALAI-02D (FINEMECH, CR) which is enabled to be used for both LAI estimation and for photosynthetically active radiation (PAR) measurements, as well. The theoretical approach of LAI estimation is based on Lambert-Beer law modified by MONSI and SAEKI (1953), when the attenuation of radiation during its transition way throughout the canopy depends on leaf area density within the canopy. The ratio of above-and-below-canopy radiation value refers to the canopy gap fraction, as well (GOWER, NORMAN 1991).

Several instruments (WELLES 1990; WELLES, COHEN 1996) estimate LAI indirectly. One of them is the LAI-2000 Plant Canopy Analyzer (LI-COR, Lincoln, NE), which could be taken, thanks to its wide application, as a "standard". The LAI-2000 measures diffuse blue light radiation (400–490 nm) simultaneously in five distinct angular bands or rings (7°, 23°, 38°, 53° and 68°) around the zenith (LI-COR, 1991a). Effective LAI (LAI_e) is a value produced by LAI-2000 (BLACK et al. 1991). To obtain a correct LAI value, the LAI_e value needs to be multiplied by a correction factor depending on tree species (GOWER, NORMAN 1991; FASSNACHT et al. 1994; STENBERG 1996). Moreover, there are some assumptions that must be considered when assessing LAI calculation to be correct (LI-COR 1991a; CHEN 1996). Several ways exist for LAI calculation from above – and below-canopy radiation readings. In this way, the simplest one for the forest practice was selected. A nomogram for effective LAI value estimation from a known transmittance value was build on a comparative basis between an ALAI-02D and a LAI-2000.

BRIEF THEORY

Foliage quantity is often normalized by ground area (i.e. LAI- leaf area index, m^2/m^2), or by canopy volume (i.e. LAD- leaf area density, m^2/m^3). Leaf area index is mostly defined as the hemi-surface (i.e. half of total) leaf area per unit area of ground (WATSON 1947). LAI is possible to measure or estimate by many experimental methods (NORMAN, CAMPBELL 1989; WELLES 1990; POKORNÝ, OPLUŠTILOVÁ 1999). From all of them, indirect methods for LAI estimation appeared to be the best. Unfortunately, use of the appropriate instrument is usually limited by its cost (WELLES 1990). Therefore, we decided to develop an instrument which could be used very easily by people from forestry and ecology branches, respectively. As mentioned previously, this new instrument called ALAI-02D (FINEMECH, CR) is based on indirect method for LAI values estimation. Thus, the main theoretical approaches are as following:

– The foliage transmission and reflectance for PAR (400–700 nm) is minimal.
– The foliage is randomly distributed within a certain canopy volume (or foliage-containing envelopes).
– The foliage elements are small compared to the area of sensor view. The distance from the sensor to the nearest leaf (or canopy element) should be at least equivalent to four times the leaf (canopy element) width.
– The foliage is azimuthally randomly oriented.

An extreme difference from the above mentioned approaches can not be ignored, because of its high influence on LAI estimation accuracy!

INSTRUMENT DESCRIPTION

Instrument comprises mainly the two following sensors: i) a photodiode with an infrared (IR) filter and a diffuser – for LAI estimation (in details Fig. 1b), and ii) a photodiode with an IR filter and a diffuser made up of a cosine correction for oblique incoming radiation – for PAR measurements. Because of unit-less transmittance, radiation readings by the first sensor are then made in mV. Readings from the second sensor need to be multiplied by a constant value to get the PAR value in the correct unit (i.e. mmol/m^2/s). The PAR sensor needs to be timely recalibrated. Briefly, measurement unit is a compact instrument, which comprises: i) some manage elements (2, 3, 4, and 6), ii) a display (1), iii) an inside-placed sensor (7), iv) an electronic module for digital expression of sensor analog signal, v) a power source (9), and vi) an added sensor for PAR measurements (8) (Fig. 1a,b).

LCD display exhibits values in theoretical range from 0.1 to 200 mV. The inside-placed sensor sensitivity is adjusted by a multi-turning trimmer screw. Fig. 2 presents the sensor sensitivity throughout the wavelength interval of incident radiation < 200, 1,000 nm >. Moreover, display signalizes stoning of displayed value by DH, noted in the left up display corner. Batteries voltage insufficiency is displayed by BT, noted in the left down display corner. Electronic module consists of an integrated circuit with a 0.5s time lag reactivity. The system works under temperature ranging from 0°C to 40°C, whereas, the interval from 25°C to 70°C is used as a storing range temperature. Energy is supplied by two 1.5V batteries.

MEASUREMENT PROCEDURE

Transmittance value is estimated as radiation values ratio (Bc/R), estimated at a certain canopy level (or below the canopy, Bc) and above the canopy (or on a free place, R). It is suitable to measure under stable synoptic situation and slowly changing radiation results (i.e. in time close to sunrise or sunset when sky conditions are clear, or under covered sky conditions). A pair of instruments for radiation measurements are more useful.

A simple scheme of measurement procedure is mentioned as following:
– to select an appropriate amount of measurement points in a grid or in transects below a canopy adequate to the forest stand structure,
– to find a free place in the purpose to determine above-canopy radiation readings,
– to select a cranny restrictor orientation,
– to proceed to the sensor sensitivity adjustment,
– to keep the instrument in a vertical position during the readings of above- and below-canopy values, to check that an identical restrictor orientation is used, to watch at the weather conditions, and in case of measurement with a pair of instruments to keep a time agreement between the measurements, and to record the data.

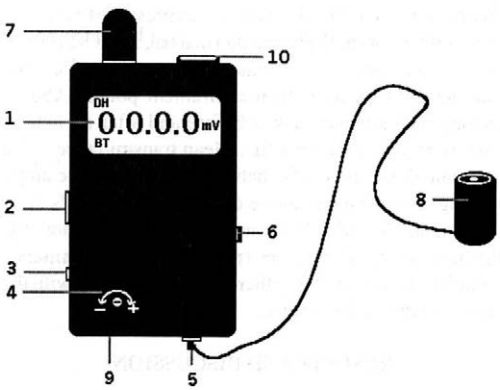

Fig. 1a. ALAI-02D basic version. The components enclosed in the instrument are: 1) a LCD display, 2) a key for stoning displayed values, 3) an on/off button, 4) a screw for the first sensor sensitivity adjustment, 5) a connector for added sensor, 6) a button for switching on/off between different sensors, 7) an inside-placed sensor, 8) a PAR sensor, 9) a power source, and 10) a water level for keeping instrument in a vertical position

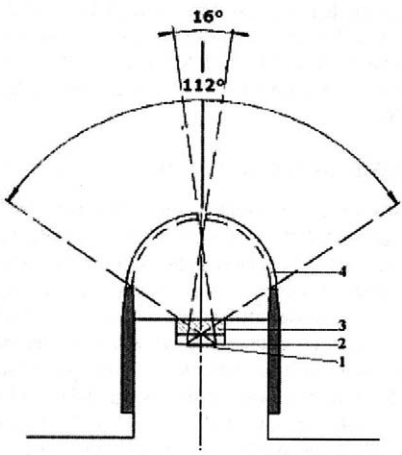

Fig. 1b. Figure shows in details the construction of the inside-placed sensor for incident radiation measurement, respectively for transmittance estimation. This sensor is composed of the following parts: 1) a photodiode, 2) an IR filter, 3) a diffuser, and 4) a cranny restrictor

For LAI value derivation from the radiation readings several possible ways can be used. For example, LANG et al. (1991) presented one of them, where he showed two different processes of LAI calculation in case of homogeneous and non-homogeneous forest stands. Shortly, his recommendations were as following: i) to compute a mean transmittance ($T = (t_1 + t_2 + \ldots + t_n)/n$, where e.g. $t_1 = Bc_1/R$, Bc_1 is below canopy reading, and where R is a mean reference value) value for each set of measurement points (i.e. transect), ii) to compute a logarithm (ln (T) for all transects, and iii) to compute an average logarithm from all transects ($Ln = [\ln (T_1) + \ln (T_2) + \ldots + \ln (T_n)]/n$). Conversely to the above described process for a homogeneous forest stand, a logarithm of each transmittance value at first ($\ln (t_1).\ln (t_n)$) and then a mean logarithm need to be computed in non-homogeneous stands. The other ways, how to calculate a LAI, are based on manual input of data to the appropriate PC programs. However, the most simple way taken into consideration was, when a nomogram for effective LAI values estimation from mean transmittance values was build. Theoretically, we presumed that the LAI_e (or transmittance) values estimated by two different instruments must be related to each other, because of a certain amount of assimilatory apparatus within the forest stand canopy. Therefore, the objectives of our work were: i) to compare the ALAI-02D and the LAI-2000 instruments above and below the canopy, ii) to estimate effective LAI (LAI_e) values by the LAI-2000 and mean reciprocal transmittance (R/Bc) values by the ALAI-02D on identical forest stands, respective transects, and iii) to found some relationships between LAI_e and R/Bc values.

MATERIAL AND METHODS

The measurements were carried out on some beech (*Fagus sylvatica* L.) and Norway spruce *(Picea abies* [L.] Karst.) stands in the Ore Mts. (NW Bohemia, 50°35' N, 13°15' E, 775 m a.s.l., see POKORNÝ, OPLUŠTILOVÁ 1999) and in the Beskydy Mts. (NE Moravia, 49°30' N, 18°32' E, 908 m a.s.l., see KRATOCHVÍLOVÁ et al. 1989) in the Czech Republic.

COMPARISON OF ALAI-02D WITH LAI-2000

Firstly, to make a possible comparison between ALAI-02D and LAI-2000, it was necessary to create a special restrictor (with a 112° view angle) for the LAI-2000, and to add a special water level to the ALAI-02D basic version. This water level permitted to adjust the ALAI-02D to the consistent angles of the sensor view in a strictly identical manner as for the LAI-2000 (see above). Specifically, the LAI-2000 angular band width was equivalent to 13° (0°–13°), 12° (16°–28°), 11° (32°–43°), 11° (47°–58°) and 13° (61°–74°), respectively. Thus, it was consistent with the 16° ALAI-02D angular band width (Fig. 1b). The comparisons were done according to the four following combinations: (A) above the canopy (respectively on free plot over all obstacles), (B) above the canopy, when direct sun rays incoming directly on the both LAI-2000 and ALAI-02D sensor restrictor edge were shaded (by operator), (C) under coniferous canopy, and (D) under deciduous canopy. The measurements in A and B combinations were done continuously throughout the full daytime under clear sky conditions with a perpendicular-opposite (ALAI-02D) and/or an opposite (LAI-2000) orientation of sensor viewing area to the sun. The measurements in C and D combinations were done under clear sky conditions close to sunrise or sunset to avoid an influence of sunflecks and light reflectance of direct sun rays. The first measurement was taken with the LAI-2000 across all angular bands, and then immediately for the same bands with the ALAI-02D. Values obtained with the ALAI-02D were manually stored in a notebook. All the measurements were taken at the same identified places, continuously. Furthermore, measurements were repeated about every five–ten minutes according to the changed radiation conditions.

EFFECTIVE LAI AND TRANSMITTANCE MEASUREMENTS

Due to a different reference plot area and orientation as well as a different forest stand orientation, it was not possible to use just one restrictor for the LAI-2000. Unfortunately, the special restrictor was not used as at the A–D combinations. However, we employed a self-developed and practically quite attested procedure to compute the accurate stand LAI values from radiation reading values. This procedure mainly included: i) a mask for the last two LAI-2000 ring readings (zenithal view angle is at its maximum at 43°), ii) an interpolated method application for above-canopy readings, and iii) measurements in a dense grid (i.e. length interval between measurement points shorter than 1m) for below-canopy readings (POKORNÝ, MAREK 2000). Then, the correction factors presented by GOWER and NORMAN (1991) can be used. LAI calculation theory from the LAI-2000 values was presented by STENBERG (1996) (or see the instruction manual, LI-COR 1991a). In our case, one or two transects created one file. One transect consists of 5–10 measurement points. Above-canopy readings were taken before and after all below-canopy readings within a file. Mean transmittance value was calculated as a ratio between mean below-canopy reading (Bc) and mean above-canopy reading (R). No further calculation of LAI values was done. Additionally, the mean R/Bc ratio values (reciprocal to transmittance value, Bc/R) were put together into a relationship with the corresponding LAI_e values.

RESULTS AND DISCUSSION

The radiation reading values obtained by both ALAI-02D and LAI-2000 instruments were entered in some relationships, and correlation coefficients according to Pearson (r) and Spearman (r_s) were determined. In (A) as well as in (B) combination, the both coefficients were very high. Under (A) combination ($n = 45$), r and r_s (in brackets) coefficients for ring readings at 7°, 23°, 38°, 53° and

68° were as following: 0.98 (0.99), 0.99 (0.99), 0.99 (0.99), 0.99 (0.89) and 0.89 (0.85), respectively. Adjusted coefficients of determination (r^2) in the same sequences were as following: 0.96, 0.98, 0.99, 0.98 and 0.80. Likewise, under (B) combination ($n = 50$), r and r_s coefficients according to the same above mentioned rings were of: 0.98 (0.99), 0.98 (0.99), 0.99 (0.99), 0.99 (0.99) and 0.99 (0.99), respectively. Adjusted coefficients of determination were: 0.97, 0.95, 0.99, 0.98 and 0.99. In fact, a strong relationship between radiation reading values measured with an ALAI-02D and a LAI-2000 exists. The extraction of direct sun rays which incoming directly on the sensor restrictor edge (B) had no effect on determination coefficients, except in the case when view angle reached a value below 61° of the zenithal direction. Therefore, not only canopy element arrangement (NORMAN, CAMPBELL 1989; CHEN 1996) but also light reflectance on restrictor cranny edge can generate an influence on a LAI underestimation in case of view angle close to horizontal direction.

As mentioned above, instrument sensors have different spectral properties. Thus, differences can be highlighted under plant canopies, because coniferous as well as deciduous plant canopies strongly influence the light spectral composition passing through them (CELNIKER 1978). These presumptions are exhibited under the both compared canopies (combinations (C) and (D)). Coefficients of determination, under Norway spruce canopy (C combination, $n = 17$), increased proportionally as view angle decreased close to horizontal direction (0.34, 0.43, 0.82, 0.92, 0.91). Pearson and Spearman's coefficients varied within a range of < 0.58, 0.96 > and of < 0.73, 0.98 > respectively. Coefficients r_s were slightly higher than r ones. Under beech canopy (D combination, $n = 54$), coefficients of determination varied as following: 0.79 (for a view angle of 7°), 0.23 (23°), 0.62 (38°), 0.94 (53°), and 0.91 (68°), respectively. Conversely, in this case, the Pearson's coefficients were slightly higher than Spearman's ones. As showed previously, the highest coefficients of determination were found under both canopies when sensor view angle was below 47°. Moreover, under spruce canopy, the coefficients of determination decreased as view angle rose to a vertical direction. Under beech canopy, the poorest coefficient of determination occur at a 23° view angle (i.e. when taking an angular band from 16° to 28°). Differences in coefficients of determination, according to different view angles, in both canopies could appeared thanks to the following facts: i) differences in light spectral properties of coniferous and deciduous canopies (CELNIKER 1978), ii) differences in canopy structure, respective in canopy element organization within both canopies (i.e. high clumping effect of needles and branches within the conifer tree crown, branch elevation angle, etc.) (NORMAN, CAMPBELL 1989; CHEN 1996), iii) higher penumbra effect on needles (shoots) edge than on deciduous leaves (OKER-BLOM 1985; STENBERG 1995), iv) differences in sensors sensitivity (Fig. 2, LI-COR 1991a), and v) slight difference between the LAI-2000 and ALAI-02D sensor angular band width and view area especially (Fig. 1b, LI-COR 1991a).

The strongest relationship between R/Bc (respective Bc/R) ratio and LAI_e values ($n = 61$) was examined in the purpose to determine a simple nomogram (Fig. 3). A majority of values ($n = 54$) was estimated under spruce canopy, only the last seven values estimated under beech canopy were added into the nomogram to made a much wider range of transmittance and LAI_e values. When these values were excluded from calculation, the equation and the coefficient of determination changed negligibly. Mean above-canopy radiation value (R) was calculated from two readings and mean below-canopy radiation value (Bc) was calculated from at least five radiation readings. Radiation is exponentially attenuated by canopy (MONSI, SAEKI 1953). Thus, a logarithm relationship was found as the strongest relationship between transmittance and LAI_e values. It is in agreement with the previous presented results (LANG et al. 1991).

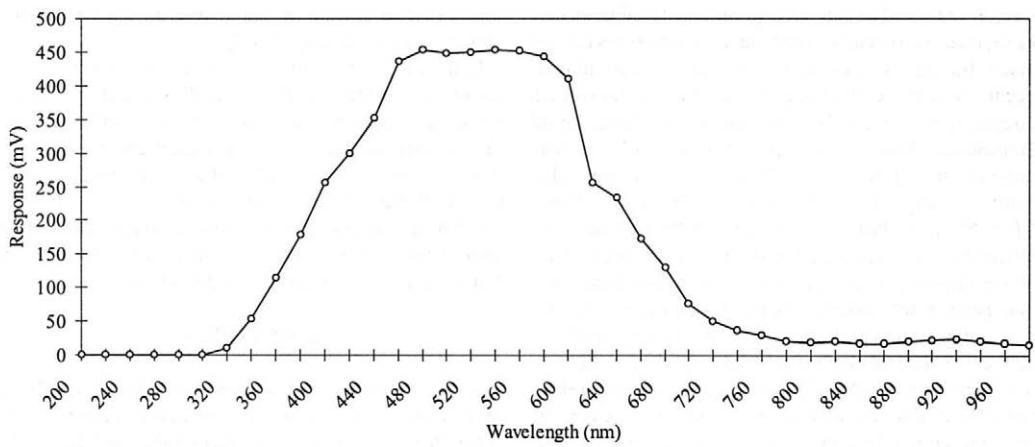

Fig. 2. The curve shows inside-placed sensor sensitivity response to the radiation along different wavelengths (20 nm step) within an interval comprised from 200 nm to 1,000 nm

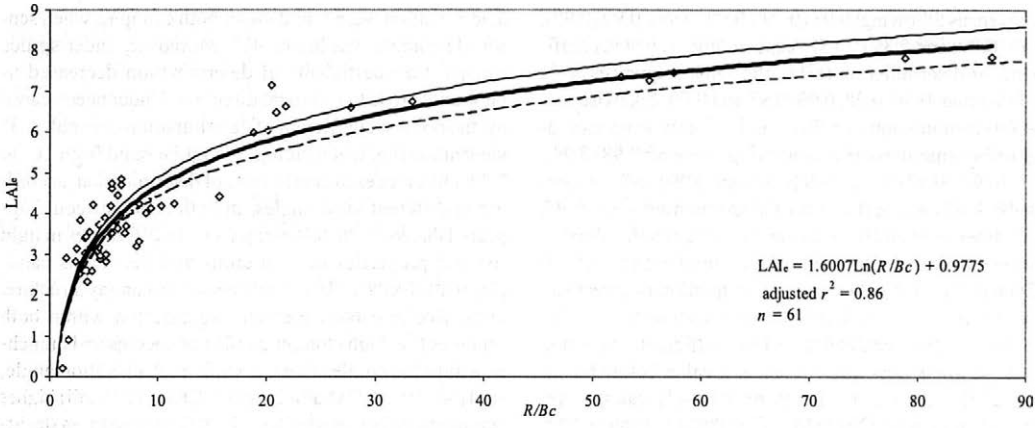

Fig. 3. Nomogram for LAI_e estimation from the *R/Bc* values. Dotted lines represent the reliability interval for the LAI_e estimation

For coniferous canopies, after the calculation of a mean transmittance value logarithm (ln *R/Bc*) and of an effective LAI value derivation from the presented nomogram (Fig. 3), the LAI_e value needs to be multiplied by a correction factor to provide the true hemi-surface LAI value. It is possible to use for different tree species the correction factors presented by GOWER and NORMAN (1991). Specifically, the correction factors for the two chosen species were as following: 1.49 for European larch (*Larix decidua* Mill.), and 1.60 for Norway spruce. A correction factor for Norway spruce was verified by us, as well (POKORNÝ, MAREK 2000). For broad-leave canopy, to assess a true LAI value, the LAI_e value estimated after leaf fall (skeleton index) needs to be subtracted from LAI_e value estimated during the vegetation season.

In addition, on the basis of our experiences in matter of LAI estimation, a set of recommendations and notes can be presented, respectively. Special water level added to the basic instrument version enables the instrument to measure radiation under different zenithal angles. Therefore, from these data sets, an angular leaf distribution can be derived. Secondarily, some other restrictors need to be made, because: i) an underestimation of transmittance occurs at large zenithal angles (i.e. close to horizontal direction), which may be due either to the clustering of branches in whorls which results in an increase in gaps at large zenith angles or to the blue radiation scattered by conifers at large zenith angles etc. (CHEN, BLACK 1991; CESCATTI 1997; POKORNÝ, MAREK 2000), ii) a radiation reflectance on restrictor edge at large zenith angles (see above, the compared results from A and B combinations) may have an influence on measurement values, iii) low radiation reading values (< 1) and low sensor sensitivity (at the first decimal number) of ALAI-02D below the canopy were usually recorded, and iv) difficulties in selection of available free plot for *R* measurement. A narrow restrictor cranny involve to perform measurements with the ALAI-02D under a wide range of synoptic situations. A second advantage of a narrow restrictor cranny arises on radiation measurement (*R*) possibility on a relatively small free plot (closed valleys, forest roads etc.). But as mentioned previously, a problem with low values and sensitivity can occur. A wide restrictor cranny involves measurement under low radiation results, but some of the other problems must be avoid (see above).

So, under unstable weather conditions, especially when clouds rapidly go across the sky, just a mean *R* value from the two above-canopy readings (taken before and after the measurements in the transect) is insufficient for an accurate transmittance value calculation. Thus, more than two above-canopy readings are needed. Likewise, the accuracy may be improved when transmittance will be calculated from timely closed below-canopy readings. Short time intervals between above- and below-canopy readings, and then itself below-canopy readings made in a dense grid of measurement points are necessary to be kept. Moreover, bellow-canopy measurements in a dense grid or in transects with small length intervals between measurement points ($\leq$ 1 m) can avoid the problem of different LAI calculation in homogeneous and non-homogeneous canopies, respectively.

In the case of mistake in *Bc* readings (i.e. omitted *Bc* reading in transect, illegible stored *Bc* value etc.), a bad or missed *Bc* reading is possible to be replaced by the *Bc* reading estimated at the nearest measurement point in a grid or transect. Additionally, if some *Bc* value appear greater than the R one, we recommend to replace this *Bc* value by a value equivalent to the *R* value or rather just slightly lower. Strict elimination of *Bc* values greater than *R* ones from the calculation is unthinkable.

CONCLUSION

Although leaf area index estimation with ALAI-02D is more laborious and more time consuming than with LAI-2000, due to the necessity to recompute the ALAI-02D manual readings etc., ALAI-02D is an instrument available for LAI estimation in forest plant canopies. Its very

low price is a great advantage. However, further experiments are needed, particularly in the improvement of LAI estimation accuracy to obtain a large set of data for coniferous and deciduous canopies (or even separately for each tree specie), and to evaluate stand structure and weather influence on LAI estimation with an ALAI-02D. This new instrument seems to offer very good perspectives in forest practice, especially because LAI value estimation with ALAI-02D is much more objective than defoliation estimation by sight.

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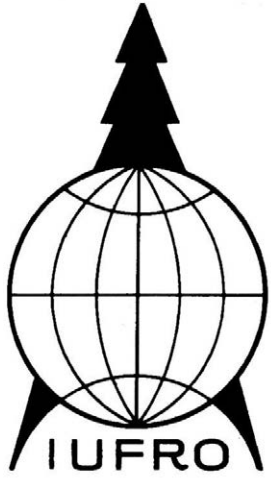

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