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The sawfly *Nematus pavidus* Lep. (*Hymenoptera, Tenthredinidae*): results from the study of its bionomics and harmfulness

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ABSTRACT: The paper deals with the incidence, development and harmfulness of the polyphagous sawfly *Nematus (= Pteronidea) pavidus* Lep., little known in biological and forestry terms, which exhibited a mass outbreak in 1999 on brittle willow (*Salix fragilis* L.) in riparian and accompanying stands along the Svratka River in the Brno region (Brno-City District). The sawfly occurrence on other potential host tree species was not detected. Females laid eggs in one or two groups on the abaxial leaf face from 10 May. The number of eggs in the groups ranged between 30 and 124 (average 62), and from 21 to 82 (average 45) in the laboratory. The average female fertility was 62 eggs. The embryonal development took 9 (in the laboratory up to 4–5) days. The male larvae passed through 4 (female 5) instars in 2 weeks. In the laboratory, at a temperature of 23–26°C, the male larvae were developing mere 8.5 (female larvae less than 11) days. The grown-up larvae crept into earth where they made single-ply cocoons at a depth of about 1–4 cm. In on average 24 days after they left the ground surface, the 1st generation adults hatched in the laboratory. In the period from May to the beginning of September, the sawfly produced 2 and 3 generations in the studied locality and in the laboratory, respectively, and was responsible for up to 10% defoliation of the infested tree species. The male larvae consume about 10 cm^2 (female larvae about 22 cm^2) of *S. fragilis* leaves. The shares of particular instars in the total consumption by the male larvae are as follows: 1st instar 1.7%; 2nd instar 4.1%; 3rd instar 19.2%; 4th instar 75.0%. The shares of particular instars in the total consumption by the female larvae are as follows: 1st instar 0.7%; 2nd instar 1.9%; 3rd instar 6.0%; 4th instar 24.4%; 5th instar 67.0%. The larvae of lower instars utilized the food more efficiently than the larvae of higher (particularly of the last) instars. For example, the 1st instar larvae produced the frass at 0.031 mm^3 from a leaf area unit (1 mm^2), while the 5th instar larvae produced 0.116 mm^3, which is 3-times more.

Keywords: *Tenthredinidae*; *Nematus (= Pteronidea) pavidus*; incidence; bionomics; food consumption

In 1999, the sawfly *Nematus* (= *Pteronidea*) *pavidus* Lep. exhibited an abundant occurrence on brittle willow (*Salix fragilis* L.) in the riparian and accompanying stand along the Svratka River in the Brno region. The sawfly is ranked with the family of sawflies (*Tenthredinidae*), which is represented by a total of 456 species in the territory of the Czech Republic (BENEŠ 1989). The closer determination ranks it with its most abundant and systematically most difficult holarctic sub-family of *Nematinae*, of which 186 (nearly 41%) species occur in the Czech Republic (BENEŠ 1989). Similarly like in numerous other species of this sub-family, the systematic genus classification of the sawfly was accompanied by problems which lasted tens of years.

The sawfly was first described by Lepeletier in 1823 as *Nematus pavidus*. By later revisions of the genus *Nematus* Panzer, 1801 the sawfly was classified in the genus *Pteronus* Konow, 1903 nec Jurine and *Pteronidea* Rohwer, 1911. The rather frequent name of *Pteronidea pavida* Lep. is used for the sawfly for example by ENSLIN (1918), HEDICKE (1930), BERLAND (1947), LORENZ and KRAUS (1957), TSINOVSKIY (1953), FRANCKE-GROSMANN (1953), KONTUNIEMI (1960), MAMAEV et al. (1976) and many others. However, the species falling into the original genus *Nematus* could not be classified into clearly defined genera due to their considerable morphological affinity, and this was the reason for the vaguely differentiated genera of *Pteronus* and *Pteronidea* to merge in the major-

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ity of systematic papers in the 2nd half of the 20th century with the large genus of *Nematus* Panz. (ZHELOKHOVTSEV et al. 1955; BENSON 1958; ILJINSKIY, TROPIN 1965; PSCHORN-WALCHER 1982; ZHELOKHOVTSEV 1988, etc.) with the names of *Pteronus* Knw. and *Ptenoidea* Rohw. having become synonymous.

Many national languages name the sawfly species by the genera of their main host tree species (i.e. willows and poplars). For example, in English it is called the lesser willow sawfly, in German the "Weidenblattwespe", "Pappelsägewespe", or "Salweidenwespe", in Russian the "topolevyy pililshchik", in Hungarian "apró fürdarász" etc. Czech and Slovak have no species name for the sawfly, which is – to a certain extent – reflecting its not exactly abundant occurrence and a considerably limited commercial importance of the sawfly in the territory of the former Czechoslovakia. The local occurrence of the sawfly in this territory can also be documented by its absence in the list of *Symphyta* in Slovakia (BENEŠ 1989).

The morphology, systematic position, occurrence and distribution of the sawfly *N. pavidus* are discussed in a number of comprehensive hymenopterological, generic entomological and entomological-conservation papers (e.g. BRISCHKE, ZADDACH 1883; ENSLIN 1918; HEDICKE 1930; ESCHERICH 1942; BERLAND 1947; FRANCKE-GROSMANN 1953, PFEFFER et al. 1954; ZHELOKHOVTSEV et al. 1955; LORENZ, KRAUS 1957; BENSON 1958; KONTUNIEMI 1960; BRAUNS 1964; PSCHORN-WALCHER 1982, etc.). However, many renowned entomological and forestry-conservation compendia did not mention it, or refer collectively to the sawflies of the *Nematus* genus, which were often classified with the genus *Pteronidea*, or concretely mention some other species of the genus such as *N. ribesii* Scop. – an important pest in orchards, less the willow sawfly *N. salicis* L., or *N. melanaspis* Htg., *N. melanocephalus* Htg. etc. (e.g. RATZEBURG 1844; HENSCHEL 1895; SCHMIEDEKNECHT 1907; NÜSSLIN, RHUMBLER 1927; SMOLÁK 1941; SCHWERDTFEGER 1944, 1970; ZHIVOINOVICH 1948; SCHIMITSCHEK 1955; MILLER 1956; GUSEV 1961; ILJINSKIY, TROPIN 1965; PADIJ 1965; VASILYEV et al. 1975; MAMAEV et al. 1976; CHINERY 1973, OEHLKE 1986, etc.).

There are only a few papers discussing in detail the incidence and biology of the sawfly *N. pavidus*. The host tree species, oviposition, development of larvae or regulative agents etc. are mainly discussed by BAER (1915), EGGER (1971) and SPAIĆ (1975). Suitability of 7 willow species with different contents of phenolglucosides for oviposition and development of *N. pavidus* and *N. salicis* larvae was studied in detail by ROININEN and TAHVANAINEN (1989). Nevertheless, the level of knowledge about the occurrence, bionomics, population dynamics and harmfulness of the sawfly *N. pavidus* is still considerably unsatisfactory. After all, the situation is very similar also for all other representatives from the sub-family of *Nematinae* (with the exception of *N. ribesii*) living on broadleaves. Unlike several relatively well known spruce and larch sawflies important in forestry, neither the sawfly *N. pavidus* nor any other sawfly species living on the deciduous tree species can be considered troublesome pests. In many cases, heavier damage can result only from the combined action of several phylophagous species.

The goal of the presented work is to deepen the hitherto knowledge about the development, food consumption and harmfulness of the sawfly *N. pavidus*. Regarding the short term of the research resulting from a sudden appearance and exctinction of the local focus of this morphologically and bionomically interesting sawfly, it was unfortunately impossible to learn any closer details about its population dynamics.

LOCALITY UNDER STUDY AND METHODS

All field investigations were made in a riparian and accompanying stand along the Svratka River in the cadasters of two administration units of the City of Brno – Komín and Jundrov (District Brno-City), considerably varied in terms of species, age and space. The stand in question is situated at an altitude of 205–210 m and consists mainly of older tree individuals of brittle willow (*Salix fragilis* L.), white willow (*S. alba* L.), willow *S.* × *rubens* Schr. (= *S. alba* × *S. fragilis*), black poplar (*Populus nigra* L.), white poplar (*P. alba* L.), black alder (*Alnus glutinosa* [L.] Gaertn.), and European white elm (*Ulmus laevis* Pall.). Regarding the predominance of tall and older trees, a detailed study was possible only in younger trees or in low-branching crowns of the older trees. The field research was made in week intervals throughout the whole growing period of the year 1999.

The development of the sawfly *N. pavidus* was in parallel studied also in mass (and occasionally also individual) rearings in the laboratory. The group rearing of larvae, hatched from eggs deposited in the open or in confinement, was conducted with using the glass dishes of 20 cm in diameter and 10 cm in height. Each dish contained the progeny hatched from only one group of eggs. In the case that a group consisted of a large number of eggs, the freshly hatched larvae were distributed into 2 dishes. The larvae were given food consisting of the freshly taken leafy shoots of brittle willow (*S. fragilis*), inserted into the dishes regularly every day, whose leaf area was planimetrically measured previously. In order to prevent the premature wilting of leaves, the shoot bases were wrapped with a mildly moist piece of absorbent cotton.

The course of embryonal and postembryonal development of the sawfly was monitored in the laboratory conditions every day between 7 and 10 o'clock (and longer if needed). The growth stage of the larvae was determined by the micrometric measurements of head shell width. A millimeter scale was used to measure body length of the larvae of particular instars. Food consumption was determined every day (in mm^2) by subtracting the planimetrically measured area of leaf remainders unconsumed by the larvae from the total leaf area offered to the larvae the day before. The fertilized eggs provided mixed progenies with ca. 2/3 predominance of females. The unfertilized

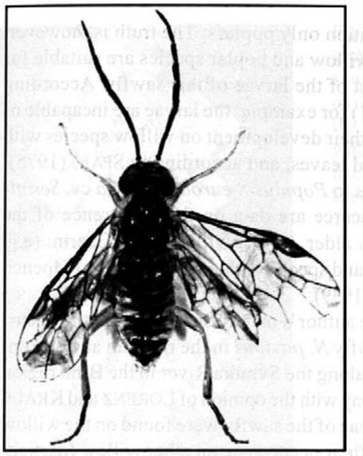

Fig. 1. Male sawfly *Nematus pavidus* Lep. Actual body length without feelers and legs is 5.4 mm

Fig. 2. Female sawfly *Nematus pavidus*. Actual body length without feelers and legs is 7.4 mm

eggs deposited in the laboratory gave only male larvae due to arrhenogenic parthenogenesis. A safe separation of male and female larvae hatched from the fertilized eggs based on the head shell width was not possible even in the older larvae. Therefore, the food consumption by the female larvae, measured in the group rearings, is not quite precise. With respect to the social life of the larvae during the major part of their development, individual rearings of larvae are more difficult and results obtained by them are also loaded with a certain error.

In addition, the number and size (length and width) of frass produced by the larvae of particular growth stages were measured in the laboratory every day. After the measurement, the rearing dishes were always thoroughly cleaned. In the period of maturation, an about 3 cm high layer of mildly moist garden earth was inserted into a part of the rearing containers (out of the reach of the falling frass), in which the grown-up larvae wound up into cocoons. The freshly hatched imagoes were placed into the same glass rearing containers with the freshly cut leafy parts of brittle willow (*S. fragilis*) shoots whose bases were wrapped in a mildly moistured absorbent cotton. Then an observation was made of the oviposition and the life time of adult sawflies. The dead females were subjected to the microscopic dissection in order to detect the number of unlaid eggs. Actual and potential natality was then derived from the numbers of laid and unlaid eggs. The 2nd generation of the sawfly was studied in the laboratory using the same method. An orientation test for the trophic affinity of the larvae to some tree species was made in the laboratory.

RESULTS AND DISCUSSION

NOTES TO THE MORPHOLOGY OF ADULTS AND LARVAE

Adult males of the sawfly *N. pavidus* (Fig. 1) originating from the locality in Brno are 5–5.9 (average 5.4) mm long, with feelers long 4–4.5 (average 4.3) mm. Adult females (Fig. 2) are 6–8.2 (average 7.4) mm long, with feelers long 4.2–5.6 (average 4.8) mm. A similar size of the females (ca. 7 mm with feelers of about 10 mm) is mentioned by EGGER (1971); different sizes of both males and females (6–7 mm) are mentioned by PSCHORN-WALCHER (1982). Both males and females are black on the upper face of thorax and yellow on thorax sides (at the level of wing wedging). The tergal side of the yellow abdomen is all black in males (in females only on the first 2 to 3 tergites). Adults of both sexes have the mesothorax black on its ventral side. Ends of the last pair of tibiae including the plantae and deeply cloven claws are somewhat darker. The head is for a great deal black with the exception of the yellowish "mouth" appendages including their closest surroundings and 2 stripes, narrow at the beginning and widening in the backward direction into a pear-like shape, stretching along the internal margins of the greyish-black compound eyes as far as the head rear margin. Simple eyes are yellowish to reddish-brown. Filiform and towards the end clearly narrowing feelers of 9 segments are black, only the connection between the 1st and the 3rd segment exhibits a ring-shaped lightening.

The 1st instar larvae of the sawfly *N. pavidus* have a light-brown head with dark ends of mandibles. Their trunk is yellowish-green, with no dark texture; only the claws on the thoracic legs are dark. The 2nd instar larvae have a head somewhat more pigmented and their trunk is without any dark texture (with only 2 lower lateral stripes consisting of tiny stains being weakly traced). The 3rd instar larvae have a black head, their trunk is yellowish-green with a clear black texture on the sides but with only a weakly delineated dorsal line. This more or less throughpassing median line cannot be well seen until the larvae of the 4th instar. The larvae of the 4th and 5th instars have the through-running dorsolateral stripe always better developed than the median stripe. The lower lateral row is formed in these larvae by 3 black spots (1 large and elongated, and 2 smaller and dotted). The lowest lateral (so called "semicolon") row consists of 2 spots (1 larger and elongated, and 2 smaller and dotted). The head of maturing larvae is black, the trunk of live larvae is light green with only the 1st and 1 to 2 last trunk segments being yellow. A precise description of the grown-up larvae is mentioned by LORENZ and KRAUS (1957).

DISPERSAL AND HOST WOODY SPECIES

The sawfly *N. pavidus* is a widely distributed and abundant European species (ENSLIN 1918; HEDICKE 1930; BERLAND1947; BENSON 1958, etc.). Similarly like the other sawfly species of this genus, it lives mainly on woody species from the family *Salicaceae*. The sawfly occurrence on *Salix caprea* L., *S. alba* L., *S. babylonica* L. and *S. pentandra* L. in Europe was studied by Vollenhoven (in DALLA TORRE 1894), and on *Populus tremula* L. by Zaddach and Brischke (in DALLA TORRE 1894). PSCHORN-WALCHER (1982) even considers it to be the most abundant sawfly species on willows, particularly on the rough-leaved *S. caprea* L. and *S. aurita* L. However, according to him the larvae also feed on the smooth-leaved willows (e.g. *S. alba*) and on the poplar *P. tremula*. According to TSINOVSKIY (1953), the sawfly occurs on *P. tremula* in Latvia only very rarely. On the normal development of the sawfly on *S. caprea* and *S. alba* reports SPAIĆ (1975). Some authors (e.g. HEDICKE 1930) mention that the main host tree species are willows and seldom also poplars. The main trophic link of the sawfly to *S. caprea* in Finland is mentioned for example by KONTUNIEMI (1960) and ROININEN and TAHVANAINEN (1989).

According to ROININEN and TAHVANAINEN (1989), the sawfly *N. pavidus* is more polyphagous than the relative willow sawfly (*N. salicis* L.). In their laboratory rearings, females laying eggs markedly preferred the hybrid willow *S.* cv. *Aquatica Gigantea* and to a lesser extent *S. caprea*, *S. pentandra*, *S. nigricans* Sm., and *S. phylicifolia* L. The sawfly *N. salicis* deposited eggs usually on *S. fragilis* and much less on *S. pentandra* and *S. nigricans*. In non-selective experiments, the females of the sawfly *N. pavidus* deposited eggs on all 6 tested willow species (particularly on *S.* cv. *Aquatica Gigantea*, *S. nigricans* and *S. caprea*) while the females of the sawfly *N. salicis* only on *S. fragilis* and *S. pentandra*, and sporadically also on 3 other willow species. The *N. pavidus* larvae clearly preferred *S.* cv. *Aquatica Gigantea* and *S. viminalis* L., and relatively often fed also on other willow species. The *N. salicis* larvae developed best on *S. fragilis* and *S. pentandra*. The larvae of the sawfly *N. pavidus* in their rearings did best on willows with the low content of phenolglycosides while the *N. salicis* larvae did best on willows with the medium content of phenolglycosides.

According to LORENZ and KRAUS (1957), the sawfly *N. pavidus* occurs in the open also on *S. fragilis*, and according to EGGER (1971) on *S.* × *smithiana* Willd. (= *S. caprea* × *S. viminalis*). The majority of authors (e.g. BAER 1915; ESCHERICH 1942; FRANCKE-GROSMANN 1953; PFEFFER et al. 1954; ZHELOKHOVTSEV et al. 1955, etc.) generally rank willows and poplars as the sawfly host tree species and some of them (e.g. GUSEV, RIMSKIY-KORSAKOV 1953) mention only poplars. The truth is, however, that far not all willow and poplar species are suitable for the development of the larvae of this sawfly. According to EGGER (1971) for example, the larvae are incapable of accomplishing their development on willow species with smooth and hard leaves, and according to SPAIĆ (1975), the same applies to *Populus* × *euroamericana* cv. *Serotina*. Generally scarce are data on the occurrence of the sawfly on black alder *Alnus glutinosa* (L.) Gaertn. (e.g. BENSON 1958) and speckled alder *A. incana* (L.) Moench (e.g. CAMERON 1939).

Results of the author's own observations on the occurrence of the sawfly *N. pavidus* in the riparian and accompanying stands along the Svratka River in the Brno region are in full harmony with the opinion of LORENZ and KRAUS (1957). The larvae of the sawfly were found on the willow *S. fragilis* with their occurrence on other willow (particularly on *S. alba* and *S.* × *rubens*) and poplar (*P. nigra* and *P. alba*) species not having been evidenced although the larvae kept in the laboratory normally consumed the leaves of *S. alba*, *S.* × *rubens* as well as those of *P. nigra*. They damaged the leaves of pedunculate oak (*Quercus robur* L.) only to a minimum extent and soon died. They entirely refused to eat the leaves of European white elm (*Ulmus laevis* Pall.), and – surprisingly – also the leaves of black alder (*A. glutinosa*). This unsuitability of alder for the development of the larvae population of the sawfly *N. pavidus* is very surprising since some authors consider alder to be its host tree species.

Literature references and the author's own results indicate that the sawfly *N. pavidus* ranks in Central Europe with polyphagous species living mainly on numerous willow and more rarely poplar species. The occurrence of the species on alders can probably be expected only in Western Europe (e.g. British Islands). According to SPAIĆ (1975), the larvae can make use of poplar and alder leaves in the case of total defoliation on willows, i.e. mainly in order to accomplish their development. It is said to be little likely that it would also be the young larvae that feed on the leaves of these tree species in the open.

OVIPOSITION AND EMBRYONAL DEVELOPMENT OF EGGS

The sawfly *N. pavidus* winters as an eonymph in cocoons in the upper soil layer. In spring, the eonymphs transform into pronymphs and those into pupae. Adult imagoes of the wintering generation appear in the open towards the end of April and in May (ILJINSKIY, TROPIN 1965; SPAIĆ 1975) or from the 1st half of May (EGGER 1971), or in May (PSCHORN-WALCHER 1982). According to ROININEN and TAHVANAINEN (1989), the adults appear as late as in June and July. According to the author's own observation, the first adults occurred in the locality under study in 1999 from 10 May. The beginning of development of the sawfly in the cocoons, its further course and thus the appearance of adults considerably depend on the general climate and on the actual weather conditions in the given year. Also, the climatic and meteorological

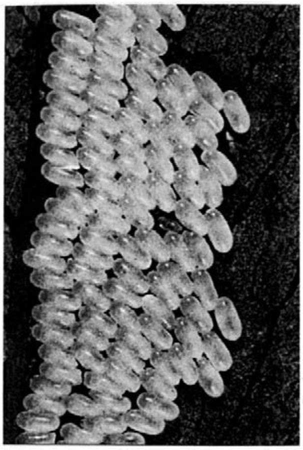

Fig. 3. Part of the group of eggs of the sawfly *N. pavidus* on the abaxial face of the leaf of brittle willow (*Salix fragilis*). Komín (District Brno-City), 15 May 1999

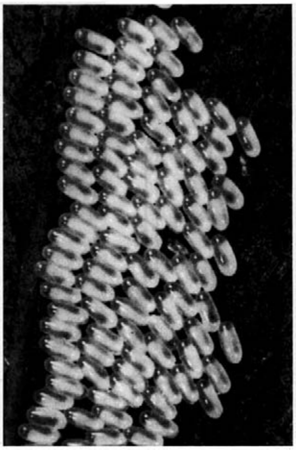

Fig. 4. Part of the group of eggs of the sawfly *N. pavidus* on the abaxial face of the leaf of brittle willow (*S. fragilis*) close to the hatching of larvae. Laboratory rearing, 18 May 1999

factors essentially influence the whole subsequent development of the sawfly.

Soon after having left the cocoons, the adults mate and the females lay eggs. Sister mating between adults originating from eggs laid by the same female is (similarly like in the sawflies *N. melanocephalus* Htg. and *N. melanaspis* Htg. – URBAN 1993, 1999) limited by a moderate (in the laboratory about 5-day) protandry. The sawfly's reproduction is usually amphigonic. However, it can also be parthenogenetic when the unfertilized eggs give always only the individuals of male sex (arrhenotoky).

The sawfly *N. pavidus* is one of the species which do not sink their eggs into plant tissues during the oviposition but simply stick them on the plants. Its females (similarly like the females of *N. melanaspis*) lay the eggs into irregularly delineated groups or plates on the abaxial leaf face (Fig. 3). The groups of eggs use to be localized on any part of the leaf blade with the exception of its both end parts and the outermost edges. The individual eggs are of rounded cylindrical up to elongated oval shape. The freshly deposited eggs are glass transparent and shiny, their size being about 1.0 × 0.4 mm (1.0 × 0.3 mm according to EGGER 1971). Their arrangement in groups is horizontal, in several more or less regular rows, with the longitudinal axis perpendicular, slant or parallel to the main leaf vein. The freshly laid eggs are partly in mutual contact or – more rarely – they can partly overlap as scales (roofing tiles).

The number of eggs in the groups greatly varies and according to LORENZ and KRAUS (1957) often exceeds 80. According to CHAPMAN (1920), a group can contain from 4 up to 98 (usually 50 to 80) eggs. A similar average number of eggs in the group (61) is mentioned by ROININEN and TAHVANAINEN (1989), and a much lower average number of eggs (35) is mentioned by EGGER (1971). SPAIĆ (1975) had the females most often with 30–40 eggs in a group, with 51 eggs (60 eggs in the open) being the maximum. According to EGGER (1971), the females hatched in confinement lay a total of about 75 eggs in 2–3 groups.

In the author's own laboratory rearings the females of the sawfly *N. pavidus* which were kept in confinement as long as from the stage of the egg deposited 21 up to 82 (average 45) eggs in a group. In total, the females laid 21 up to 95 (average 52) eggs, usually only into 1 (more rarely into 2) group. The females started their oviposition usually as late as on the 2nd (more rarely on the 3rd) day after they had left the cocoons. The second group of eggs was laid in 6 hours after the first group at the latest. The second group of eggs always contained only a low number of eggs (average 15). More than 3/4 females laid the whole stock of eggs while in confinement. In the open nature, the number of eggs in the groups was ranging from 30 to 124 (average 62) eggs. The research results indicate that the eggs in female ovaries mature all at once and this is the reason why they are usually lump deposited. The general potential and ecological fertility of the females is 30–124 (average 62) eggs.

The adult sawflies live shortly. They do not take in any solid food; they only suck water or plant juices and die soon after the oviposition. Males and females in the rearings without any additional feeding were often observed to suck water from the moistened paper rolls. Individuals of both sexes lived to the same age of 2–6 (average 4) days, and died in 1–2 days after the end of their reproduction. In rearings studied by EGGER (1971), the females additionally fed with forest bee-honey lived up to 13 days but without any further egg laying. The life length of imagoes depends mainly on temperature. The males and females with no additional food kept at the lower temperature (about 12.1°C) and at the higher temperature (about 21.4°C) lived on average 4.6 and 7.3 days, and 3 and 4.1 days, respectively (SPAIĆ 1975). The total adult life in the open can be estimated to be 1–2 weeks.

The period of embryonal development is markedly affected by temperature. According to EGGER (1971), the eggs hatch as early as in 3 days; according to SPAIĆ (1975) in 12 days at a temperature of 10.4°C and in 6 days at a temperature of 22.1°C. In the author's own laboratory experi-

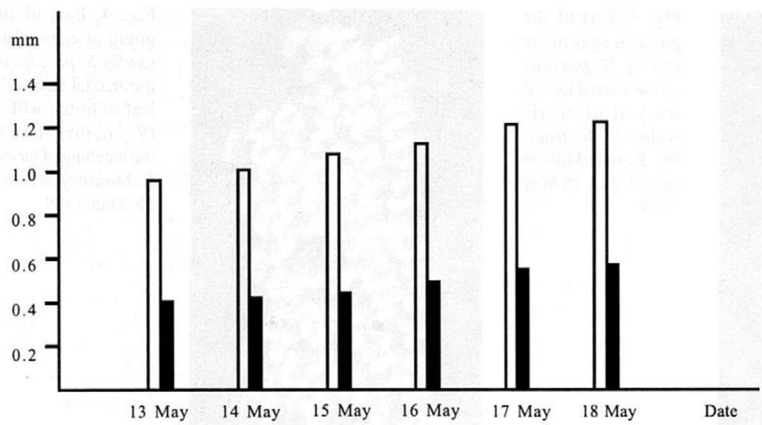

Fig. 5. The increasing length (open columns) and width (solid columns) of eggs of the sawfly *N. pavidus* during the embryonal development (in mm). Laboratory rearing, 1999.

ments, the embryonal development lasted 4 to 5 days at a temperature between 23 and 25°C. A detailed description of the course of embryonal development was made by EGGER (1971). The central section of eggs gets milky through the semitransparent chorion in the first stages of the embryonal development, and in the laboratory conditions, the eyes, ends of mouth organs and claws on the thoracic legs of the embryo (Fig. 4) start to take on more colour as early as after 3 days. During the embryonal development, the size of eggs is gradually increasing due to the osmotic water uptake from the outer environment with the gaps between the individual eggs being reduced to minimum. Prior to the hatching of the larvae, the eggs reach an average length of 1.24 mm and width 0.59 mm (Fig. 5). In the same groups of eggs, the embryos are usually oriented with their heads towards the central leaf vein or to the leaf top.

DEVELOPMENT OF LARVAE

After having perforated the egg covers, the larvae of the sawfly *N. pavidus* get released through the slit in the chorion in 60–100 (average 80) seconds. The larvae from a group average in number hatch about 2 hours and 30 minutes; the larvae from a group above-average in number may hatch over 3 hours. For example, the larvae from the most abundant group of 124 eggs, found in the field on 13 May 1999, hatched in the laboratory conditions on 18 May from 12.00 to 15.15 hours. The larvae hatching proceeds from the earlier deposited eggs to the eggs which were deposited later, i.e. usually at a direction from the leaf top to the basal part of the leaf (Figs. 6 and 7). The freshly hatched larvae gradually creep over to the leaf area in the vicinity of the egg covers, where they dwell on leaves long after hatching.

The egg larvae have a relatively large light-brown head of 0.54 mm in width, a shiny greyish-white trunk and are about 2.27 mm long. They start taking in food in 1 to 2 hours after eclosion. The chlorophyll contained in the food gives their body a green colour. At first, the larvae bite out small holes in the leaves from their abaxial face, whose diameter is about 1 mm. Then they gradually enlarge the holes up to the diameter of about 2.5 mm and move to their edge (Fig. 8). The leaf holes get further

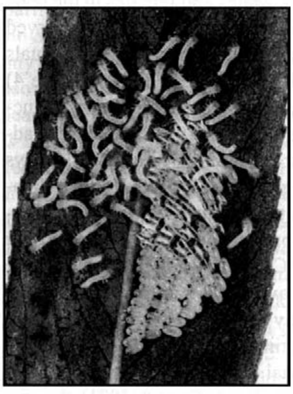

Fig. 6. The hatching egg larvae of the sawfly *N. pavidus*. Laboratory rearing, 18 May 1999

Fig. 7. A detail from the hatching of the sawfly *N. pavidus* egg larvae. Laboratory rearing, 18 May 1999

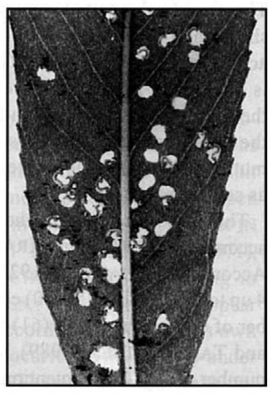

Fig. 8. The 1st instar larvae of the sawfly *N. pavidus* windowing the leaf of brittle willow (*S. fragilis*). Laboratory rearing, 18 May 1999

Fig. 9. The 1st instar larvae of the sawfly *N. pavidus* windowing the leaf of brittle willow (*S. fragilis*). Laboratory rearing, 19 May 1999

Fig. 10. The 3rd instar larvae of the sawfly *N. pavidus* at marginal feeding on the leaf of brittle willow (*S. fragilis*). Laboratory rearing, 25 May 1999

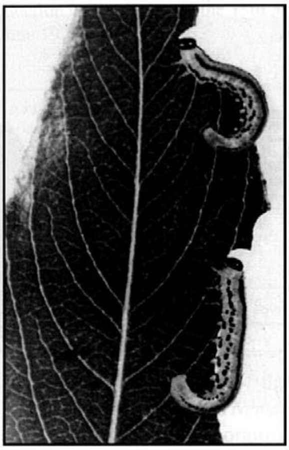

Fig. 11. The 4th instar larvae of the sawfly *N. pavidus* at marginal feeding on the leaf of brittle willow (*S. fragilis*). Laboratory rearing, 28 May 1999

irregularly larger due to the feeding of the larvae of this instar, and often merge so that there are many a time more larvae feeding on the edge of the larger holes (Fig. 9). Characteristic for the feeding of the larvae of this lowest growth stage is that the larvae never damage the leaf veins of the 1st and 2nd orders, and usually not even the 3rd order leaf veins. In the laboratory, the egg larvae first moulted on the leaves after about 2 days of feeding.

The 2nd instar larvae partly window the leaves of the willow *S. fragilis* and partly eat them together starting from their edges. During the marginal feeding, they line up one after another and bite the leaves off starting from their circumference and the end or central parts towards the central leaf vein and to the leaf base. The leaf veins of the 1st and 2nd orders are hardly ever damaged by the larvae. Differences in the size of male and female larvae start to show from the 2nd instar. The average head shell width in the male and female larvae of this instar was 0.71 mm and 0.76 mm, respectively; the average body length of the grown-up male and female larvae was 5.0 mm and 5.5 mm, respectively. After about 2 days of feeding, the 2nd instar larvae moulted for the second time.

Fig. 12. The 5th instar larvae of the sawfly *N. pavidus* at feeding on the leaf of brittle willow (*S. fragilis*). Laboratory rearing, 30 May 1999

Fig. 13. The growing up larvae of the 5th instar of the sawfly *N. pavidus* at feeding on the leaf of brittle willow (*S. fragilis*). Laboratory rearing, 1 June 1999

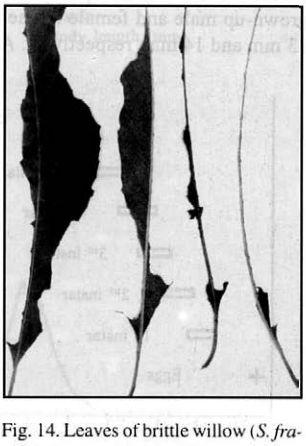

Fig. 14. Leaves of brittle willow (*S. fragilis*) damaged by the 5th instar larvae of the sawfly *N. pavidus*. Laboratory rearing, 31 May 1999

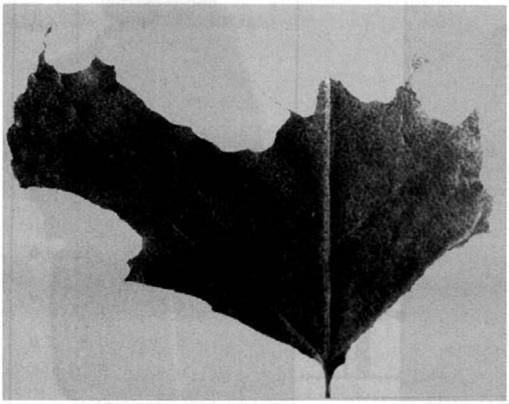

Fig. 15. A leaf of black poplar (*Populus nigra*) damaged by the 4th instar larvae of the sawfly *N. pavidus*. Laboratory rearing, 26 May 1999

Fig. 16. Cocoons of the sawfly *N. pavidus* (male – top; female – bottom). Laboratory rearing, 5 June 1999

The 3rd instar male and female larvae of the sawfly *N. pavidus* (Fig. 10) always eat the leaves of the willow *S. fragilis* from the edges. The leaf blade is sometimes consumed together with the apical parts of the veins of the 2nd order. From this instar, the laboratory rearings showed slight symptoms of the so called waste feeding. The average head shell width of the 3rd instar male and female larvae was 0.97 mm and 1.10 mm, respectively; the average body length of the grown-up male and female larvae was about 9.0 mm and 10.0 mm, respectively. After about 2 days of feeding, the larvae moulted for the third time.

The 4th instar larvae (Fig. 11) usually consume the whole leaf blade with the exception of the main leaf vein. The male and female larvae have the head shell width of about 1.31 mm and 1.4 mm, respectively; the body length of the grown-up male and female larvae of this instar is about 13 mm and 14 mm, respectively. After about 2.5 days of feeding, the male larvae of the 4th instar accomplished their development and retreated into garden earth on the bottom of the rearing dishes where they produced cocoons at a depth of 0.5–3.0 cm. The female larvae moulted for the fourth time after about 2.5 days of feeding.

The 5th instar larvae (Figs. 12 and 13) eat the leaves up to the main leaf vein (Figs. 14 and 15) and sometimes they do not even spare the apical parts of the main veins. Their head shell is wide about 1.64 mm and the body length of the grown-up larvae is about 17 mm. After about 2.5 days of feeding, the 5th instar larvae grew up and retreated into the earth for pupation.

In the author's own laboratory rearings of the sawfly *N. pavidus* on the willow *S. fragilis* the male larvae of the 1st generation were developing over 4 instars and the female larvae over 5 instars (Figs. 16 and 17). The average period of development of the male and female larvae from

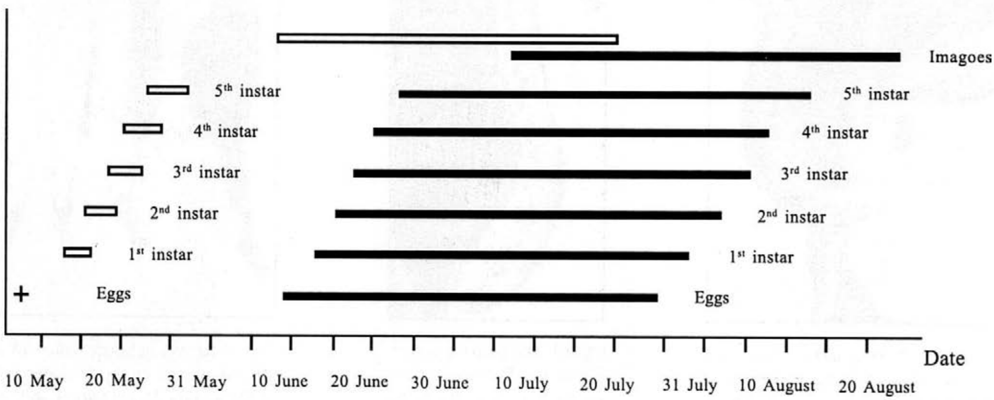

Fig. 17. The course of development of the 1st and 2nd generations of the sawfly *N. pavidus* on brittle willow (*S. fragilis*) from eggs laid on 13 May 1999 (see the cross). The 1st generation of the sawfly is marked with the light (2 dark) figures. Laboratory rearing, 1999

Table 1. Period of development, average daily food consumption and average daily frass production by the larvae of the 1st to 5th instar of the sawfly *N. pavidus* on brittle willow (*S. fragilis*). Laboratory rearing, 18 May–2 June 1999

Instar	Development (days)	Average daily food consumption (mm²)	(mm³)	Average daily frass production (pcs)	(mm³)
1st	2.0	5.4	0.8	73.7	0.2
2nd	2.0	13.4	1.9	45.7	0.5
3rd	2.0	52.4	7.5	52.4	2.0
4th	2.5	178.1	25.5	61.0	11.2
5th	2.5	487.9	69.8	69.7	56.7
Total	11.0	150.7	21.6	60.8	14.5

their hatching from eggs until their retreat into earth at the laboratory temperature of 23–26°C was only 8.5 and not full 11 days, respectively (Fig. 16 and Table 1).

In EGGER's (1971) laboratory rearings, the larvae of the sawfly *N. pavidus* on the willow *S.* × *smithiana* moulted four times at intervals of 3 days (which means that they had 5 instars), and the grown-up larvae were from 12 to 18 (average 14) mm long. The total period of development of the sawfly from oviposition until cocoon formation was 17 days. A somewhat different opinion is that of SPAIĆ (1975), who found out that the male larvae of the 1st (spring) generation on *S. caprea* and *S. alba* need 4 instars to grow up (females over 5 instars). According to this author, the duration of particular instars gets gradually prolonged with the higher growth stages lasting from 2 to 6 days and the total period of development being 18 days.

The larvae of the 1st generation of the sawfly *N. melanocephalus* on the willow *S. fragilis* in the author's own laboratory experiments also developed over 4 and 5 instars, the total period of their development being 7–11 days (URBAN 1999). Nevertheless, the number, size and period of development of the particular instars of the male and female larvae of sawflies from the genus *Nematus* Panz. can be considerably affected in the laboratory by unnatural light, temperature and moisture conditions, and, therefore, the knowledge obtained from the laboratory experiments can considerably differ from the actual situation in the field.

Young and middle-aged larvae always eat together, only the larvae of the last instar sometimes spread on the leaves and then their eating is more or less separate. For nearly the whole period of feeding, the larvae sit with their thoracic part (or the front half) of the body dwelling on the leaf edge, holding "astraddle" at the leaf with their thoracic or abdominal legs. The body rear is usually slightly turned downwards. Feeling endangered, they suddenly raise their abdomen into an S shape and stay motionless in this defensive position until the danger is over again, or swing their abdomens up and down in a common rhythm, and only exceptionally release their hold on the leaves and fall on the ground. While doing so, they produce a characteristically smelling defensive

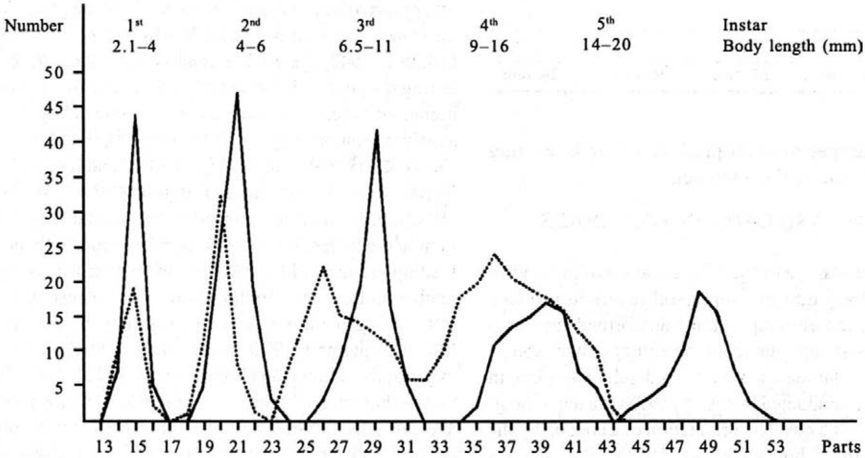

Fig. 18. Head shell width and body length in the larvae of particular instars of the 1st generation of the sawfly *N. pavidus* on brittle willow (*S. fragilis*) (solid line). Male larvae produced 4 (female 5) instars. Laboratory rearing, 18 May–2 June 1999. Dotted line for the head shell width of the 2nd generation of the male larvae of the 1st to 4th instars (1 part = 0.0357 mm). Laboratory rearing, 18 June–2 July 1999

Table 2. Hatching and death of adult sawflies *N. pavidus*. The adults were raised in the laboratory from eggs laid on 13 May 1999

Date	Males		Females	
	hatching	death	hatching	death
13 June	–	–	1	–
14 June	–	–	–	–
15 June	–	–	–	–
16 June	–	–	–	–
17 June	–	–	1	–
18 June	–	–	1	1
19 June	1	–	1	–
20 June	–	–	–	1
21 June	4	–	–	1
22 June	–	1	–	–
23 June	1	–	2	1
24 June	–	1	2	–
25 June	–	2	2	–
26 June	–	1	–	–
27 June	–	–	–	4
28 June	–	1	–	1
29 June	–	–	2	1
30 June	–	–	–	1
1 July	–	–	–	–
2 July	–	–	–	–
3 July	–	–	1	1
4 July	–	–	1	–
5 July	–	–	–	–
6 July	–	–	–	1
7 July	–	–	–	–
8 July	–	–	–	1
...	...	...	...	...
22 July	–	–	1	–
23 July	–	–	–	–
24 July	–	–	–	–
25 July	–	–	–	1
Number	6	6	15	15
Average	21 June	25 June	26 June	29 June

secret from the special smell-producing glands opening on the ventral side of the abdomen.

PUPATION AND HATCHING OF ADULTS

The grown-up larvae of the 1st generation of the sawfly *N. pavidus* retreat into the upper soil layers to produce cocoons in which eonymphs are transformed into pronymphs and these into pupae. In the author's own laboratory rearings the larvae cocooned at a depth of 1–4 cm, in the experiments conducted by SPAIĆ (1975) at a depth ranging between 2 and 5 cm. The production of a cocoon by the larva takes some 7 hours (EGGER 1971). The cocoons (Fig. 18) are oval, brown to blackish-brown. Male cocoons are on average 7 mm long and 3 mm wide. Female cocoons are on average 9.2 long and 4.2 mm wide. According to EGGER (1971), the average size of the cocoons (irrespective of the sex of the larvae) is 7.2 × 3.3 mm. The cocoon walls are dense and firm. Unlike the two-ply cocoons of *N. salicis*, *N. melanocephalus* and *N. miliaris*, the cocoons of *N. pavidus* and *N. melanaspis* have only one ply.

First adults from the 1st generation larvae which accomplished their feeding in the laboratory conditions towards the end of May and at the beginning of June 1999 hatched as early as about 13 June, i.e. 2 weeks after the retreat of the larvae into earth. However, the subsequent course of the hatching of imagoes was surprisingly very lengthy and the last adult hatched as late as on 22 July. According to the author's own study and in harmony with the results of SPAIĆ (1975), the length of the period of development of sawfly male and female individuals in the cocoons is identical. Nevertheless, regarding the fact that the male larvae grew up by about 3 days earlier, the male sawfly adults kept in the laboratory experiments hatched about 21 June while the female adults hatched about 25 June, i.e. by 4 days later. The average length of time after which the sawfly adults hatched from the cocoons was 24 days (Fig. 16, Table 2). A nearly identical period of development of the 1st (spring) generation of the sawfly *N. pavidus* in the cocoons (25 days) is also mentioned by SPAIĆ (1975). The adult imagoes leave the cocoons through irregular oval holes bitten out at the cocoon ends (Fig. 19). The total period of development of the sawfly in the laboratory, from oviposition to the hatching of male and female adults of the 1st generation was 37 days and about 41 days, respectively.

GENERATION RELATIONSHIPS

The development of *N. pavidus* is in principle modified by climatic conditions and by the actual course of the weather. This is why the opinions concerning the number of generations in a year considerably differ (similarly like in other plurivoltine species of sawflies from the genus *Nematus* Panz.). For example, according to BAER (1915) and ESCHERICH (1942), there is 1 or usually 2 generations developing during the year with 1 generation being presumable only at higher altitudes. The bivoltine developmental cycle of the sawfly is mentioned by e.g. ENSLIN (1918), HEDICKE (1930), ZHELOKHOVTSEV et al. (1955), LORENZ and KRAUS (1957), BENSON (1958), etc. According to PSCHORN-WALCHER (1982), there are 2 to 3 considerably overlapping generations at the lower altitudes of Central Europe, with the main feeding in June and July, August and September, or in September and October. In the laboratory rearings by EGGER (1971), 3 generations developed during the period from May to September 1970. The sawfly has three generations in a year for example in Croatia (SPAIĆ 1975). According to this author, the 1st (spring) generation develops in May and June, the 2nd (summer) generation develops in July and August, and the 3rd (autumn) generation develops in August and September.

In the riparian and accompanying stands in Brno, the sawfly *N. pavidus* produced 2 (in the laboratory 3) generations during the period from May to the beginning of

Fig. 19. Cocoons of the sawfly *N. pavidus*, left by the adults (male – top, female – bottom). Laboratory rearing, 28 June 1999

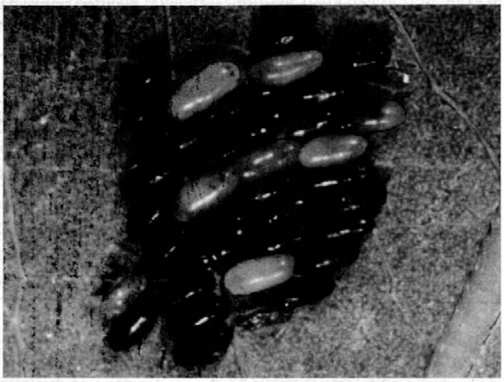

Fig. 20. A group of eggs of the 2[nd] generation of the sawfly *N. pavidus* on the abaxial face of the leaf of brittle willow (*S. fragilis*). All eggs (including the so far light eggs) are parasitized by the trichogramma *Trichogramma embryophagum* Htg. Komín (District Brno-City), 10 August 1999

September. It was unfortunately impossible to find out whether the generations were complete or incomplete. The 1[st] generation larvae occurred from about the 2[nd] half of May to the beginning of July, the 2[nd] generation larvae occurred from the beginning of July to the beginning of September. The adults from the even-aged cocoons of the 1[st] generation of the sawfly were hatching for an unusually long time (1.5 month) and small part of vital eonymphs did not further develop at all. A larger percentage of diapausing eonymphs occurred in the 2[nd] generation of the sawfly. It appears, therefore, that – similarly like in some other sawfly species from the genus *Nematus* Panz. – already the 1[st] generation of the sawfly *N. pavidus* may partially diapause. The occurrence of a facultative diapause in the 1[st] generation of the larvae and the more extensive diapausing of the larvae of the 2[nd] or even 3[rd] generations can considerably complicate the development relations of the sawfly so that it gets difficult for one to find the clue. Also, the unequivocally evidenced arrhenogenic parthenogenesis may further influence the generation relationships of the sawfly. The regular fluctuation of generation relations (as they are said to be seen for example in the sawfly *N. ribesii* Scop.) is, however, only hardly presumable due to the overlapping of the particular generations and the diapausing eonymphs.

ENEMIES

The larvae of the sawfly *N. pavidus* and those of related species (*N. salicis*, *N. melanocephalus*, *N. melanaspis* etc.) are characteristic of their relatively large size, typical texture and colour, and by their common feeding on the leaf edges and defensive reactions when disturbed. There is no doubt that the morphological and ethological adaptations are ecologically important for the survival of the larvae. Yet, there are sudden and considerable fluctuations occurring in the population density of the sawflies, their gradations being usually of local, and at all times markedly temporary (1–2 years) character.

BAER (1915) and many other authors after him have considered egg parasitoids to be the main controllers of the number of these sawflies, capable of being the cause of a rapid extinguishment of the gradations. There are many insect ecto- and endoparasitoids that were raised from the larvae of the sawfly *N. pavidus*. For example, OZOLS (1928) raised the ichneumon *Mesoleius opticus* Grav. from this sawfly. BERLAND (1947) mentions the larvae parasitoids *Rhorus extirpatorius* Grav., *Polyblastus palaemon* Sch., *Mesoleius opticus* Grav., and *Hypsantyx lituratorius* L. ZINNERT (1969) ranks with the main larvae parasitoids the following species: *R. extirpatorius*, *M. opticus*, *Eridolius lineiger* Thoms., *Hypamblys albopictus* Grav., and *Olesiacampe* sp. (family *Ichneumonidae*), and *Myxexoristops stolida* Stein, and *Hyalurgus lucidus* Meig. (family *Tachinidae*). According to this author, the secondary larvae parasitoids include *Lethades facialis* Brischke, *Smicroplectrus bohemanni* Hlgr., *Rhinotorus atratus* Hlgr., *Hyperbatus segmentator* Hlgr. (family *Ichneumonidae*) and *Bessa selecta* Meig. (family *Tachinidae*). There was also *Exenterus amictorius* Panz. (= *marginatorius* F.) (family *Ichneumonidae*) that hatched sporadically from the cocoons of the sawfly *N. pavidus* (EGGER 1971).

The trichogramma *Trichogramma embryophagum* Htg. (family *Trichogrammatidae*) was most responsible for the dramatic reduction of the sawfly *N. pavidus* population density in the riparian and accompanying stand along the Svratka River in the Brno region (det. H. Bírová, Bratislava) when the parasitoid exhibited a particularly heavy infestation (over 80%) of the 2[nd] generation of eggs (Fig. 20). The trichogramma females usually deposited a prevailing portion or all eggs in a group. The development of the trichogramma is very rapid with the adults leaving the

Table 3. Average leaf area of brittle willow (*S. fragilis*) (mm^2) damaged by particular developmental stages of the sawfly *N. pavidus* larvae, including average food consumption (mm^3). Laboratory rearing, 18 May–2 June 1999

Instar	Rearing 1		Rearing 2		Average		Average food consumption	
	Larvae	Average area	Larvae	Average area	Larvae	Average area	(mm^3)	(%)
1st	44	17.2	42	15.2	86	16.2	2.3	0.7
2nd	24	42.7	26	38.1	50	40.3	5.8	1.9
3rd	19	141.0	16	121.2	35	131.1	18.7	6.0
4th	15	546.7	14	522.1	29	534.4	76.4	24.4
5th	13	1,400.0	13	1,527.3	26	1,463.7	209.3	67.0
Total	–	2,147.6	–	2,223.9	–	2,185.7	312.5	100.0

eaten out sawfly eggs as soon as in 13 days from the oviposition (MARTINEK 1963). According to various authors, it can have 3–7 generations during the growing season. The parasitized eggs of the sawfly gradually darken at the time of the maturation of the trichogramma adults and in the end their colour is black. It is interesting that the collectivelly parasitized eggs in the same group went black very unevenly in the laboratory in about 4 days. The trichogramma *Trichogramma embryophagum* is also one of the most important natural enemies of the sawfly *N. melanaspis* Htg. (URBAN 1993). For example, in the salicarium of the arboretum of the then University of Agriculture (VŠZ) – at present Mendel University of Agriculture and Forestry in Brno – the trichogramma infected nearly 95% of eggs of the 1st generation (and 70% of eggs of the 2nd generation) of this sawfly.

Other killers of the larvae of the sawfly *N. pavidus* living in the field are insectivorous birds (according to EGGER 1971 for example the great tit *Parus major* L.) and numerous insect predators (e.g. heteropters, lady-birds and ants). The cocoon stages of the sawfly are being destroyed by many predators such as wireworms, ground beetles, mice, voles and shrews, and last but not least also by adverse abiotic factors (e.g. excessive moisture or drought) and originators of diseases (entomopathogenic fungi in particular). Concrete observations of the action of these mortality factors on the population dynamics of the sawfly *N. pavidus* are still missing, though.

FOOD CONSUMPTION AND UTILIZATION

The 1st generation larvae of the sawfly *N. pavidus* develop in the 2nd half of spring and at the beginning of summer and take in food for about 2 weeks (male and female larvae in the laboratory conditions for about 8.5 and 11 days, respectively). During this relatively short period of time the male and female larvae pass through 4 and 5 growth stages, respectively. The measurement of the consumed leaf area of the willow *S. fragilis* (average dry weight 38.9 g/m^2) revealed that the female larvae consumed in total nearly 22 cm^2 (i.e. about 312 mm^3) of leaves. The share of the 1st, 2nd, 3rd, 4th, and 5th instar larvae was 0.7, 1.9, 6.0, 24.4 and 67.0%, respectively (Table 3). The exact consumption of the male larvae was measured in the 2nd generation of the larvae raised from unfertilized eggs. The male larvae kept on the willow *S. fragilis* (average dry weight 40.9 g/m^2) consumed only 9.7 cm^2 (i.e. about 138 mm^3) of leaves, i.e. 2.3-times less than the female larvae. The share of the 1st, 2nd, 3rd, and 4th instar larvae was 1.7, 4.1, 19.2 and 75.0%, respectively (Table 4). During the feeding of the growing up larvae in the laboratory, a negligible portion of the consumed leaves falls onto the bottom of the rearing dishes in the form of small irregular remainders. This so called waste feeding amounts to max. 3% of the total leaf area consumed. EGGER (1971) estimates that one larva can eat in total 1.6 average leaf of the willow *S. × smithiana*. According to him, the larvae hatched from a group with the average number of eggs (35) eat (provided that their mortality is 0%) about 50 leaves (i.e. a shoot of about 1 m in length).

The male and female larvae of the last instars of the sawflies *N. pavidus* and *N. melanaspis* have about the same head shell width (male about 1.3 mm and female about 1.7 mm), and the grown-up larvae reach the about identical length (male about 13 mm and female about 16 mm). Also, the total food consumption is identical in these two sawfly species (URBAN 1993). In contrast, the male and female larvae of the sawfly *N. melanocephalus* reach a larger size. The average head shell width in the male larvae of the last instar is 1.44 mm and in the female larvae 1.9 mm, i.e. 1.11-times larger than in *N. pavidus* or *N. melanaspis*. The average body length of the male and female larvae of the sawfly *N. melanocephalus* is 15 mm and 20 mm, respectively, i.e. 1.25-times greater than in *N. pavidus* or *N. melanaspis*. The average food consumption of the male and female larvae of

Table 4. Average and total period of development and leaf area of brittle willow (*S. fragilis*) damaged by the 2nd generation larvae of the sawfly *N. pavidus*. Eggs were laid on 14 June 1999. Laboratory rearing, 18 June–2 July 1999

Instar	Average development (days)	Larvae	Food consumption (mm^2)	(%)
1st	3.0	50	16.0	1.7
2nd	3.0	37	40.2	4.1
3rd	3.0	30	186.7	19.2
4th	3.0	27	729.8	75.0
Total	12.0	–	972.7	100.0

Table 5. Average number, size (length/width in mm) and volume of frass produced by female larvae of the particular developmental stages of the sawfly *N. pavidus* on brittle willow (*S. fragilis*). Laboratory rearing, 18 May–2 June 1999

Instar	Rearing 1			Rearing 2			Average		
	number	L/W	(mm³)	number	L/W	(mm³)	number	L/W	(mm³)
1st	236	0.24/0.11	0.5	205	0.23/0.11	0.4	221	0.24/0.11	0.5
2nd	138	0.34/0.19	1.3	136	0.35/0.20	1.5	137	0.35/0.19	1.4
3rd	137	0.58/0.29	5.3	123	0.58/0.29	4.7	131	0.58/0.29	5.0
4th	187	0.90/0.51	34.4	178	0.93/0.50	32.5	183	0.91/0.51	33.5
5th	206	1.44/0.84	164.4	212	1.53/0.83	175.5	209	1.49/0.83	170.0
Total	904	–	205.9	853	–	214.6	881	–	210.4

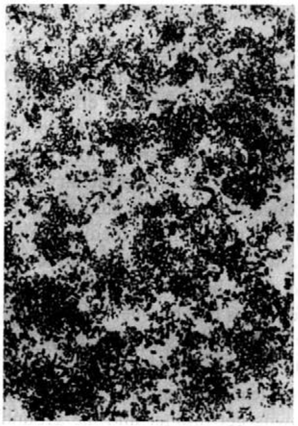

Fig. 21. Frass of the 1st instar larvae of the sawfly *N. pavidus*. The average length and width of the frass pieces is 0.24 mm and 0.22 mm, respectively. Laboratory rearing, 1999

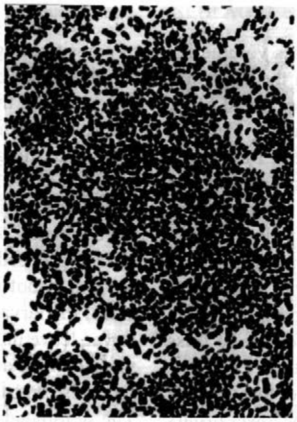

Fig. 22. Frass of the 3rd instar larvae of the sawfly *N. pavidus*. The average length and width of the frass pieces is 0.58 mm and 0.29 mm, respectively. Laboratory rearing, 1999

Fig. 23. Frass of the 5th instar larvae of the sawfly *N. pavidus*. The average length and width of the frass pieces is 1.49 mm and 0.83 mm, respectively. Laboratory rearing, 1999

the sawfly *N. melanocephalus* is, therefore, obviously higher (about 20 cm² and 45 cm² of the leaves of the willow *S. fragilis* of about the same dry weight in the male and female larvae, respectively) (URBAN 1999). In comparison with the sawflies *N. pavidus* and *N. melanaspis*, the food consumption of the sawfly *N. melanocephalus* is 1.9 to 2.0-times higher. The larvae of *N. salicis* reach even much larger dimensions; however, any closer details on their food consumption are not known so far.

The larvae are incapable of any longer starvation. According to SPAIĆ (1975), the 1st and 2nd instar larvae can live without food 1 day at a maximum. During the nearly continuous feeding, the larvae produce the brownish-black to black frass of spindle- to cylindrical shape. The average daily food consumption and frass production are presented in Table 1. While the frass of the 1st to 4th instars is released from the digestive tract separately, the frass of the 5th instar is normally defecated in the form of long (up to 60-fold) strangulated strings. For the whole period of feeding the male and female larvae produce about 670 and 880 frass pieces, respectively. The average size (length × width) and the total volume of the frass defecated by the larvae of both sexes are conspicuously growing from the first to the last instar (Table 5, Figs. 21–23). A minor growth of the frass size also occurrs during the feeding of the larvae of the same instar (Table 6). The frass of the growing up male and female larvae of the 4th instar is on average 0.89 mm long and 0.46 mm wide, while the frass of the growing up female larvae of the 5th instar is on average 1.49 mm long and 0.83 mm wide.

Table 6. The increasing size of frass (mm) in the particular instars of the sawfly *N. pavidus* larvae during their feeding on brittle willow (*S. fragilis*). Laboratory rearing, 18 May–2 June 1999

Instar	Feeding – beginning length/width	Feeding – middle length/width	Feeding – end length/width
1st	0.21/0.09	0.24/0.11	0.26/0.14
2nd	0.32/0.17	0.35/0.19	0.38/0.21
3rd	0.54/0.25	0.58/0.29	0.61/0.32
4th	0.86/0.43	0.91/0.51	0.98/0.58
5th	1.38/0.83	1.49/0.83	1.56/0.84

Table 7. Average volume of frass (in total and from 1 mm² leaf) produced by the 1st to 5th instar female larvae of the sawfly *N. pavidus* on brittle willow (*S. fragilis*). The last but one column contains the per cent proportion of the frass volume from the volume of consumed food, and the last column contains the per cent of food utilization for body building and vital functions. Laboratory rearing, 18 May–2 June 1999

Instar	Frass volume (mm^3)	(%)	Frass volume from 1 mm^2 leaf	Coefficient	Frass volume (%) from intaken food	Percentage of food utilization
1st	0.5	0.2	0.031	1.0	21.7	78.3
2nd	1.4	0.7	0.035	1.1	24.1	75.9
3rd	5.0	2.4	0.038	1.2	26.7	73.3
4th	33.5	15.9	0.063	2.0	43.8	56.2
5th	170.0	80.8	0.116	3.7	81.2	18.8
Total	210.4	100.0	0.096	–	67.3	32.7

The food consumption and the total frass volume increase by the geometric progression with the transition of the larvae into the higher instars (Tables 3 and 5). A highly significant increase is also exhibited by the frass volume produced from the unit leaf area (e.g. 1 mm^2) destroyed by the larvae of the 1st to 5th instars (Table 7). For example, the female larvae of the 1st instar produced 0.031 mm^3 frass from 1 mm^2 leaf, while the 5th instar larvae produced 0.116 mm^3 (i.e. 3.7-times more) frass. The total frass volume of the 1st instar female larvae amounts to only 21.7% of the total food volume consumed by the larvae of this instar. However, the total volume of frass produced by the 5th instar larvae represents 81.2% of the total food volume consumed by the larvae of this instar. It follows from the above that the larvae of the lower instars of the sawfly *N. pavidus* (similarly like the larvae of the sawfly *N. melanocephalus* – URBAN 1999) utilize the intaken food for body building and various vital functions much more effectively than the larvae of the higher (and particularly the last) instars (Table 7).

HARMFULNESS AND CONTROL MEASURES

The sawfly *N. pavidus* is a polyphagous species living in Central Europe mainly on willows and less frequently also on poplars. Similarly like some other sawfly species from the genus *Nematus* Panz. (e.g. *N. salicis* L., *N. melanocephalus* Htg., *N. melanaspis* Htg., and *N. ferrugineus* Först.) it exhibits mass outbreaks from time to time, which result in considerable damage (ESCHERICH 1942). Its relatively greatest importance is in osier plantations and in willow shelterbelts (Zaddach, Brischke in ESCHERICH 1942, PSCHORN-WALCHER 1982, etc.). Its sudden population explosions at the same place last only 1 or 2 years after which the sawfly abundance retreats into a long-term latency that may last many years. Reasons to this fluctuation of the population density are not known in detail and according to the prevailing opinion they can be attributed mainly to the account of egg parasitoids.

In the natural conditions of the Czech Republic, the sawfly usually produces 2 generations in a year. The extent and intensity of the damage to woody species by the larvae of the 1st (i.e. mainly spring) generation of the sawfly depend primarily on the number and health condition of wintering eonymphs in the cocoons and on the percentage of parasitized eggs. The extent and degree of woody species defoliation by the larvae of the 2nd (i.e. mainly summer) generation of the sawfly are apparently most effectively controlled by the egg parasitoids. In the year of erruption gradation, the greatest losses of the assimilation organs usually occur as late as during growing up the larvae of the 2nd generation, i.e. towards the end of summer or at the beginning of autumn. At the common feeding which always proceeds on the woody species in the direction towards shoot ends (i.e. from beneath upwards or into sides) the larvae eat the leaves one by one. Growing up larvae leave intact only the leaf stalks with the main leaf vein (or with at least its basal and central parts), sometimes also with the adjacent leaf blade remainders (Fig. 14). The defoliated tree crowns get thinner and the ground under the infested trees gets covered with a layer of frass. The leaf remainders left on the woody species shed before their regular time.

The loss of the assimilation organs usually shows only in the reduced increment, in older trees sometimes also by a more rapid drying of branches in the crowns. Cooperating with other phylophagous insect pests, and particularly in a combination with the physiological weakening of the trees due to drought, the sawfly can sometimes contribute to the premature dieback of these trees. In the studied locality in Brno, the sawfly *N. pavidus* larvae ate 10% of the assimilation area of the willow *S. fragilis* at the most, and the affected woody species survived the partial defoliation with no evident consequences.

The sawfly *N. pavidus* is not definitely an important forest pest and its control is not, therefore, usually necessary. According to ILJINSKIY and TROPIN (1965), however, the defoliation of 10% is a signal that a control of the coming generation in the shelterbelts and willow and poplar plantations will be needed. If this coming generation is to be the spring generation, it is necessary to make a spring check of the health condition of the eonymphs in the cocoons. The larvae can be knocked down or in urgent cases killed using chemicals based on synthetic pyrethroids, or quinine production inhibitors, mentioned in the valid *List of Chemicals Permitted in Forest Protection* for the given year. The application must be made against the youngest larvae (1st to 3rd instar).

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Výsledky studia bionomie a škodlivosti pilatky *Nematus pavidus* Lep. (*Hymenoptera, Tenthredinidae*)

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ABSTRAKT: Práce pojednává o výskytu, vývoji a škodlivosti biologicky a lesnicky málo známé polyfágní pilatky *Nematus* (= *Pteronidea*) *pavidus* Lep., která se v roce 1999 přemnožila na vrbě křehké (*Salix fragilis* L.) v břehovém a doprovodném porostu kolem řeky Svratky na Brněnsku (okres Brno-město). Výskyt pilatky na jiných potenciálních hostitelských dřevinách nebyl zjištěn. Samičky kladly vajíčka od 10. května, a to do 1–2 skupin na abaxiální stranu listů. Počet vajíček ve skupinách činil 30–124 (průměrně 62) ks a v laboratoři 21–82 (průměrně 45) ks. Průměrná plodnost samiček byla 62 vajíček. Embryonální vývoj trval 9 (v laboratoři 4–5) dnů. Samčí housenice procházely během dvou týdnů čtyřmi (samičí pěti) instary. V laboratoři se samčí housenice vyvíjely při 23–26 °C pouhých 8,5 (samičí necelých 11) dnů. Dorostlé housenice zalézaly do země, kde si v hloubce 1–4 cm zhotovovaly jednovrstevné kokony. Průměrně za 24 dnů po odchodu do země se v laboratoři líhli dospělci 1. generace. Na vyšetřované lokalitě pilatka vytvořila během května až začátku září dvě (v laboratoři tři) generace a způsobila až 10% defoliaci napadených dřevin. Samčí housenice zkonzumují kolem 10 cm^2 (samičí kolem 22 cm^2) listů *S. fragilis*. Na celkové spotřebě samčích housenic se podílí 1. instar 1,7 %, 2. instar 4,1 %, 3. instar 19,2 % a 4. instar 75,0 %. Na celkové spotřebě samičích housenic se 1. instar podílí 0,7 %, 2. instar 1,9 %, 3. instar 6,0 %, 4. instar 24,4 % a 5. instar 67,0 %. Housenice nižších instarů využívají potravu efektivněji než housenice vyšších (a zejména posledních) instarů. Např. housenice 1. instaru vyprodukují z jednotky listové plochy (1 mm^2) 0,031 mm^3 trusinek, kdežto housenice 5. instaru 0,116 mm^3 trusinek, tj. třikrát více.

Klíčová slova: *Tenthredinidae*; *Nematus* (= *Pteronidea*) *pavidus*; výskyt; bionomie; spotřeba potravy

Pilatka *Nematus* (= *Pteronidea*) *pavidus* Lep. je biologicky málo známý, široce rozšířený evropský druh, který se občas lokálně přemnožuje na vrbách, případně topolech. V roce 1999 se tato pilatka velmi hojně vyskytla na vrbě křehké (*Salix fragilis* L.) v břehovém a doprovodném porostu kolem řeky Svratky na Brněnsku (okres Brno-město) a způsobila až 10% defoliaci napadených dřevin. Studiem jejího výskytu, bionomie a škodlivosti byly získány tyto hlavní výsledky:

1. V dotyčném porostu, tvořeném pestrou směsicí dřevin různého věku a velikosti, byla pilatka nalezena pouze na vrbě křehké. Její výskyt na ostatních potenciálních hostitelských dřevinách (např. na vrbě bílé – *S. alba* L., vrbě *S.* × *rubens* Schr., topolu černém – *Populus nigra* L. a olši lepkavé – *Alnus glutinosa* [L.] Gaertn.) nebyl prokázán. Housenice v laboratorních chovech normálně konzumovaly listy *S. alba*, *S.* × *rubens* a *P. nigra*, překvapivě však odmítaly žrát listy *A. glutinosa*.
2. Dospělci přezimující generace se na zkoumané lokalitě vyskytovali od 10. května. Brzy po výletu z kokonů se dospělci páří a kladou vajíčka. Pilatka se může rozmnožovat i partenogeneticky, přičemž se z neoplozených vajíček líhnou vždy jedinci samčího pohlaví (arrhenotokie). Sesterské páření je omezováno mírnou (v laboratoři asi čtyřdenní) protandrií.
3. Samičky nalepují vajíčka na abaxiální stranu listů do 1–2 skupin. Počet vajíček ve skupinách činil 30–124 (průměrně 62) ks a v laboratoři 21–82 (průměrně 45) ks. Celková fyziologická a ekologická plodnost samiček je kolem 62 vajíček. Nepřikrmovaní dospělci se v zajetí dožívali 2–6 (průměrně 4) dnů a za 1–2 dny po skončení rozmnožování hynuli.
4. Bezprostředně po vykladení jsou vajíčka 1,0 mm dlouhá a 0,4 mm široká. Embryonální vývoj trvá kolem 9 dnů (v laboratoři při 23–25 °C 4–5 dnů). Během embryonálního vývoje se rozměry vajíček v důsledku osmotického příjmu vody z okolního prostředí postupně zvětšují a těsně před líhnutím housenic dosahují délky 1,24 mm a šířky 0,59 mm. Z průměrně početné vaječné skupiny se housenice líhnou přibližně 2 h a 30 min.
5. Během vývoje na listech procházejí samčí housenice čtyřmi (a samičí pěti) vzrůstovými stupni. Housenice

1. instaru listy *S. fragilis* vždy děrují, aniž by přitom poškozovaly listové žilky. Housenice 2. instaru listy zčásti děrují, zčásti ožírají od okrajů. Housenice 3. až 5. instaru listy ožírají od okrajů. V laboratorních podmínkách (při 23–26 °C) se samčí housenice vyvíjely po vylíhnutí 8,5 dne a samičí necelých 11 dnů. Dorostlé samčí housenice 4. instaru mají hlavovou schránku širokou 1,3 mm a délku těla kolem 13 mm. Dorostlé housenice 5. instaru mají hlavovou schránku širokou kolem 1,64 mm a délku těla kolem 17 mm. Mladé a středně staré housenice žerou vždy pospolitě, housenice posledního instaru někdy i samostatně. Na nebezpečí reagují zaujetím obranného postavení nebo společnými rytmickými kmity zadečku, výjimečně pádem na zem.

6. Dorostlé housenice posledního instaru zalézají do země, kde si v hloubce 1–4 cm zhotovují jednovrstevné zámotky. Samčí zámotky jsou průměrně 7 mm dlouhé a 3 mm široké. Samičí zámotky jsou průměrně 9,2 mm dlouhé a 4,2 mm široké. Za 13–52 (průměrně 24) dnů po odchodu housenic do země se v laboratoři líhnou dospělci. Celková doba vývoje od vykladení vajíček až do vylíhnutí dospělců samečků je kolem 38 dnů a samiček kolem 41 dnů. Na vyšetřované lokalitě pilatka vytvořila během května až do začátku září dvě generace. U části eonymf se vyskytovala diapauza.
7. Nejvýznamnějším regulátorem početnosti pilatky je drobněnka *Trichogramma embryophagum* Htg. Tímto vaječným endoparazitoidem bylo zvlášť silně (více než z 80 %) napadeno druhé pokolení pilatky.
8. Housenice přijímají potravu průměrně dva týdny. Samčí housenice během této poměrně krátké doby spotřebují kolem 9,7 cm^2 listů (o hmotnosti sušiny kolem 40,9 g/m^2) a samičí housenice kolem 22 cm^2 listů *S. fragilis* (o hmotnosti sušiny kolem 38,9 g/m^2), tj. přibližně 2,3krát více. Na této celkové spotřebě se samčí housenice 1. instaru podílely 1,7 %, 2. instaru 4,1 %, 3. instaru 19,2 % a 4. instaru 75,0 %. Samičí housenice 1. instaru se na celkové spotřebě podílely 0,7 %, 2. instaru 1,9 %, 3. instaru 6,0 %, 4. instaru 24,4 % a 5. instaru 67,0 %.
9. Samčí housenice vyprodukují během žíru kolem 670 (samičí kolem 880) ks trusinek. Trusinky samčích housenic posledního (4.) instaru (a samičích housenic 4. instaru) jsou průměrně 0,89 mm dlouhé a 0,46 mm široké. Trusinky samičích housenic posledního (5.) instaru jsou průměrně 1,49 mm dlouhé a 0,83 mm široké. Objem trusinek vyprodukovaný housenicemi 1. až 5. instaru z jednotky plochy zkonzumovaného listu s přechodem do vyšších instarů vzrůstá. Např. housenice 1. instaru vyprodukují z 1 mm^2 listu 0,031 mm^3 trusinek, kdežto housenice 5. instaru 0,116 mm^3 trusinek, tj. 3,7krát více. Housenice nižších instarů využívají přijatou potravu ke stavbě těla a životním funkcím mnohem efektivněji než housenice vyšších (a zejména posledních) instarů.
10. Na území ČR pilatka *N. pavidus* rozhodně nepatří k lesnicky významným škůdcům, a proto proti ní obvykle není nutné bojovat.

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Model of volume production of damaged spruce stands

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ABSTRACT: An algorithm and particular formulas were proposed and tested in this paper with the aim to derive total production and its increments for stands damaged by defoliation. In constructing the model changes in volume production of these stands were distinguished due to damage to living trees as well as due to gradual decline of trees, it means reduction of its density. Variables of total production were derived by means of simulation from model data of yield tables for spruce and partial models for the reduction of increments of damaged trees and stands.

Keywords: spruce; damaged stands; production; increments

Despite the fact that an investigation was conducted in damaged forests and it was particularly aimed at growth and increments of stands, the efforts to solve all related issues, particularly total production and its increments, have failed. Only the issues of increments of damaged trees and stands have been solved on a relatively good level. It concerns particularly spruce. The most important knowledge is presented by POLLANSCHÜTZ (1986), SCHWEINGRUBER (1983) and KRAMER et al. (1988) who summarized results published on this subject into more important monographs. Within the European Forest Institute also SPIECKER et al. (1996) wrote a collection of papers on the development of increment trends in European forests. In the Czech Republic the oldest results on diameter increment of trees were processed by VINŠ (1962), VINŠ and MRKVA (1972). Later also POLENO (1984), KOUBA (1987) and KUPKA (1985, 1995) dealt with modelling the development of damaged stands. Also in Slovakia some results from experimental research are available as reported by PRIESOL (1989, 1995), SCHEER (1990), ĎURSKÝ (1992, 1994, 1995, 1996), ĎURSKÝ and ŠMELKO (1994), HLADÍK and ŠUŠKA (1996), ŠMELKO (1994), ŠMELKO et al. (1996), PETRÁŠ et al. (1993), PETRÁŠ and HALAJ (1993), RIEMER et al. (1997), RAČKO (1994), BUCHA et al. (1997) and BREZINA (1988, 1992). Also KOLENKA (1995) tried to estimate economic losses due to damage by air pollutants but without any concrete quantification.

Though the authors mentioned above have been investigating in detail increment reduction for respective trees and stands they do not deal with total production and its increments. The main fact is they would need long-term and detailed repeated observations and measurements on permanent research plots. The dynamics of the development of health condition of trees including the dead ones should be investigated on these plots in addition to keeping detailed records according to main stand and secondary crop. Even at the present time such measurements are very rare not only in Slovakia but abroad as well. Therefore we have proposed a model for simulating total production and its increments for spruce stands damaged by defoliation. By means of this model and on the basis of yield tables and increment indices of trees we have derived total production and increment indices for total current increment and total mean increment.

DERIVATION OF MODELS

For derivation of total production of stands the following general formula is valid:

$$CP_t = V_{2(t)} + \sum_{0}^{t} V_3 \quad (1)$$

where: CP_t – total production at age t,
$V_{2(t)}$ – standing volume of main stand at age t,
$\sum_{0}^{t} V_3$ – sum of secondary crop in the interval 0–t years.

For total production of damaged stands it is necessary to know not only their instantaneous condition but also their development up to certain age, it means the development of basic stand variables before damage as well as during the process of damaging. Basic underlying data for deriving total production of damaged spruce stands were namely models of the 3rd edition of yield tables by HALAJ and PETRÁŠ (1998). In deriving the total production the development of stands before damage was taken directly from the models of domestic yield tables but during damaging it was modelled according to simulated health conditions. In the construction of a model it is necessary to divide the changes in volume production of damaged stands according to causes into two groups as follows:

- reduction of volume production of stands due to damage to living trees,
- reduction of volume production of stands due to gradual decline of trees and reduction of their density.

MODEL OF THE REDUCTION OF STAND PRODUCTION DUE TO DAMAGE TO LIVING TREES

Total production of damaged stand is calculated according to the following formula:

$$CP_{p(t)} = \sum_{0}^{t} \frac{V_{2(t+5)} - V_{2(t-5)}}{10} \cdot 5 \cdot I_{IV2(t)} + \sum_{0}^{t} V_{3(t)} \cdot I_{IV3(t)} \quad (2)$$

where: $CP_{p(t)}$ – total production of damaged stand at age t,
$V_{2(t+5)}, V_{2(t-5)}$ – standing volume of main stand at age $t + 5$ and $t - 5$ years,
$I_{IV2(t)}$ – increment index of standing volume of main stand at age t,
$I_{IV3(t)}$ – increment index of standing volume of secondary crop at age t,
$V_{3(t)}$ – standing volume of secondary crop at age t.

Regarding formula (2) it must be noted that standing volume of secondary crop is here the increment of its total value, it means similarly to the increment of main stand in relation to its standing volume.

Providing we want to apply formula (1) or (2) to the calculation of total production of damaged stand not from its very establishment but from its higher age we must modify it as follows:

$$CP_{p(t)} = V_{2(tp)} + \sum_{0}^{tp} V_3 + \sum_{tp+1}^{t} I_{V2p} + \sum_{tp+1}^{t} V_{3p} \quad (3)$$

where: $CP_{p(t)}$ – total production of damaged stand at age t,
$V_{2(tp)}$ – standing volume of main stand at age tp,
tp – age of stand at the beginning of its damage,
V_{3p} – standing volume of damaged secondary crop,
I_{V2p} – current increment of standing volume of main stand with damage.

According to this formula the total production of damaged stands at age t is the sum of total production from its establishment up to the beginning of damage at age tp and the total of current increments of main stand and standing volume of secondary crop from the first year of damage. After its modification (formula 3) it is as follows:

$$CP_{p(t)} = CP_{tp} + \sum_{tp+1}^{t} \left(I_{V2p} + V_{3p}\right) \quad (4)$$

Increment of main stand and standing volume of secondary crop with damage I_{V2p} and V_{3p} were calculated as a product of increment of not damaged main stand and standing volume of secondary crop and of their increment indices according to the following formulas:

$$I_{V2p} = I_{V2n} \cdot I_{IV2} \quad (5)$$

$$V_{3p} = V_{3n} \cdot I_{IV3} \quad (6)$$

where: I_{V2p} – increment of main stand with damage,
I_{V2n} – increment of main stand without damage,
I_{IV2} – increment index of main stand,
V_{3p} – standing volume of secondary crop with damage,
V_{3n} – standing volume of secondary crop without damage,
I_{IV3} – increment index of secondary crop.

Increment indices of the standing volume of main and secondary crop I_{IV2} and I_{IV3} were derived by means of formulas given in detail by PETRÁŠ and HALAJ (1993). From derived total production of the stands that are being damaged according to formulas (2) and (4) total mean increment as well as total current increment were derived. Based on them increment indices were calculated as relative increment rates. Indices were calculated by means of the following formulas:

$$I_{CPP(t)} = \frac{CPP_{p(t)}}{CPP_{n(t)}} = \frac{\frac{CP_{p(t)}}{t}}{\frac{CP_{n(t)}}{t}} = \frac{CP_{p(t)}}{CP_{n(t)}} \quad (7)$$

$$I_{CBP(t)} = \frac{CBP_{p(t)}}{CBP_{n(t)}} = \frac{\frac{CP_{p(t+5)} - CP_{p(t-5)}}{10}}{\frac{CP_{n(t+5)} - CP_{n(t-5)}}{10}} = \frac{CP_{p(t+5)} - CP_{p(t-5)}}{CP_{n(t+5)} - CP_{n(t-5)}} \quad (8)$$

where: $I_{CPP(t)}, I_{CBP(t)}$ – indices of total mean (*CPP*) and total current increment (*CBP*) at age t,
$CPP_{p(t)}, CBP_{p(t)}$ – *CPP* and *CBP* of damaged stand at age t,
$CPP_{n(t)}, CBP_{n(t)}$ – *CPP* and *CBP* of not damaged stand at age t.

MODEL OF REDUCTION OF THE PRODUCTION OF STANDS DUE TO GRADUAL DECLINE OF TREES AND REDUCTION OF THEIR DENSITY

Damage to forest stands is usually manifested by gradual weakening of individual trees up to their dieback. Reduction of the number of productive trees in the stand then means also reducing its density which can be quantified objectively by stocking. Reduction in the stocking of stands must rightfully appear in the reduction of their total production. For its final quantification it is necessary to modify formulas (2) and (4) as follows:

$$CP_{p(t)} = \sum_{0}^{t} \frac{V_{2(t+5)} - V_{2(t-5)}}{10} \cdot 5 \cdot I_{IV2(t)} \cdot z_t + \sum_{0}^{t} V_{3(t)} \cdot I_{IV3(t)} \cdot z_t \quad (9)$$

$$CP_{p(t)} = CP_{tp} + \sum_{tp+1}^{t} \left(I_{V2p} + V_{3p}\right) \cdot z_t \quad (10)$$

where: z_t – stocking of stand at age t.

Formulas (9) and (10) differ from formulas (2) and (4) only in that the increment of main stand and standing volume of secondary crop are being reduced by stocking. Besides model data from yield tables both formulas contain also increment index and stocking of stand which depend on stand damage. As it is the calculation of total production not only damage intensity but also the age of stand, when the process of damaging has started, is significant.

For the stands with reduced stocking during their whole life total mean increment and total current increment were derived. Based on them their increment indices were derived according to the following formulas:

$$I_{CPP \cdot z(t)} = \frac{CPP_{p(t)} \cdot z_t}{CPP_{n(t)}} = \frac{\frac{CP_{p(t)} \cdot z_t}{t}}{\frac{CP_{n(t)}}{t}} = \frac{CP_{p(t)} \cdot z_t}{CP_{n(t)}} = I_{CPP(t)} \cdot z_t \qquad (11)$$

$$I_{CBP \cdot z(t)} = \frac{CBP_{p(t)} \cdot z_t}{CBP_{n(t)}} = \frac{\frac{\left(CP_{p(t+5)} - CP_{p(t-5)}\right) \cdot z_t}{10}}{\frac{CP_{n(t+5)} - CP_{n(t-5)}}{10}} = \qquad (12)$$

$$= \frac{\left(CP_{p(t+5)} - CP_{p(t-5)}\right) \cdot z_t}{CP_{n(t+5)} - CP_{n(t-5)}} = I_{CBP(t)} \cdot z_t$$

where: $I_{CPP \cdot z(t)}$, $I_{CBP \cdot z(t)}$ – indices of total mean (*CPP*) and total current increment (*CBP*) with reduced stocking at age *t*,
$CPP_{p(t)}$, $CBP_{p(t)}$ – *CPP* and *CBP* of damaged stand at age *t*,
$CPP_{n(t)}$, $CBP_{n(t)}$ – *CPP* and *CBP* of not damaged stand at age *t*.

The same indices were calculated for stands with reduced stocking only in a certain age interval:

$$I_{CPP \cdot z(t)} = \frac{CP_{tp} + \sum_{tp+1}^{t}\left(I_{V2p} + V_{3p}\right) \cdot z_t}{CP_{n(t)}} \qquad (13)$$

Regarding the fact that total current increment is derived only from a short segment of the curve for total production it is possible to use formula (12) for the calculation of increment indices of stands with reduced stocking in a certain age interval.

VOLUME PRODUCTION OF DAMAGED SPRUCE STANDS

For the verification of derived formulas (2)–(8) there were calculated indices of total mean increment and of total current increment of damaged spruce stands according to formulas (7) and (8) using the data from yield tables by HALAJ and PETRÁŠ (1998). The indices were simulated for yield classes 14–42 and initial age of damage 50–150 years with the grades of 10 years. Similarly damage to crowns was simulated and it is given by their mean and constant defoliation 20, 39 and 67%. This mean defoliation was derived for respective degrees of tree damage by PETRÁŠ and HALAJ (1993) as follows:

Degrees of tree damage	Mean defoliation (%)
0+1	20
2	39
3+4	67

For better illustration the calculated indices are presented in Figs. 1 and 2. In both figures the respective indices in dependence on the age of stand for yield classes 20 and 40 are given as well as mean defoliation of tree crown 20% and 67% and initial age of damage 50 and 100 years.

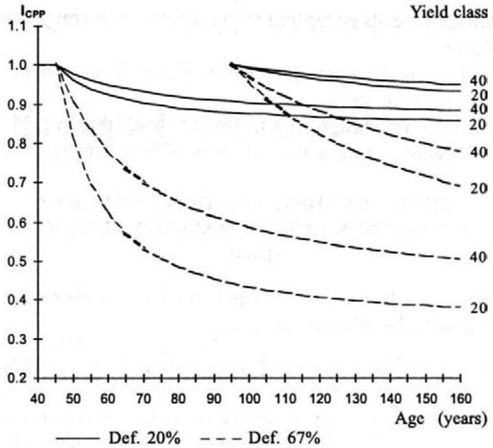

Fig. 1. The development of indices of total mean increment in dependence on age and yield class of spruce stands with crown defoliation 20 and 67%

We can see in Fig. 1 the highest index with the value 1.0 was reached for stands in the beginning of their damage. Starting from the point the indices of total mean increment are decreasing in hyperbola with higher age. Indices of total mean increment are decreasing with lower yield class but particularly with higher crown defoliation. It is obvious that the stand is subjected to damage for the longer period the lower is the index. In Fig. 1 we can also see that all presented factors, namely yield class, age of stand and initial age of stand damage as well as degree of

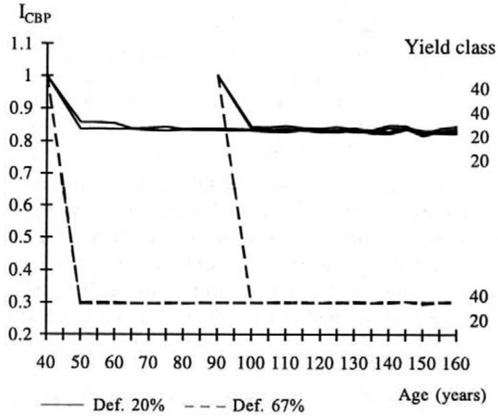

Fig. 2. The development of indices of total current increment in dependence on age and yield class of spruce stands with crown defoliation 20 and 67%

damage to tree crown affect each other. It is clear from the fact that for example the significance of yield class with 20% defoliation is different from that with 67% defoliation. Similarly the effect of yield class is differently significant in stands with the beginning of damage at 50 or 100 years. After evaluation of these effects we can express the dependence of total mean increment index according to the following general relation:

$$I_{CPP} = f(q,t,t_p,def) \tag{14}$$

where: I_{CPP} – index of total mean increment,
q, t – yield class and age of stand,
t_p – age of stand in the beginning of its damage,
def – damage to stand given by its defoliation (%).

In Fig. 2 illustrating indices of total current increment the course of indices is slightly different from that of indices of total mean increment. The indices of total current increment do not practically depend on age and yield class of stand nor on the age of stand when damage has started. The only significant factor which can be considered is damage to stand expressed by its defoliation. It is a similar case like with increment index of main stand as given by PETRÁŠ et al. (1993). After the evaluation of these effects we can give the dependence of total current increment index according to the following general and simple relation:

$$I_{CBP} = f(def) \tag{15}$$

where: I_{CBP} – index of total current increment,
def – damage to stand given by its defoliation (%).

Providing the stand also has lower stocking due to its damage then both increment indices depend directly on this stocking according to formulas (12) and (13). For the index of total current increment it is valid also in the case when lower stocking occurred at higher age. The index of total mean increment must be calculated in this case according to formula (13). We can make a conclusion from this analytical shape that stocking of stand will very significantly affect also the index of total mean increment.

DISCUSSION AND CONCLUSION

As for damage to forest stands it is very important to express not only the extent of damage and implementation of recovery measures but also to quantify the damage. Despite of about 30 years long research in Europe and about 10 years long research in this field performed in Slovakia there are not available any complex underlying data for objective quantification of production losses and increment reduction in damaged stands. Most of recent knowledge is namely the knowledge of increment in trees and stands.

In this work we proposed and tested an algorithm as well as concrete formulas for deriving total production and its increments for spruce stands damaged by crown defoliation. Variables of total production were derived by simulating from model data of yield tables and partial models for reduction of increments of damaged trees and stands. It is necessary to state that derived data were not compared with any empirical data or data of other authors. The reason in the first case is that for obtaining empirical data on total production there are needed detailed measurements not only of healthy but particularly of damaged stands, it means detailed observations and measurements on permanent research plots. It was impossible to implement all these measurements especially as they are very demanding on time. Currently there do not exist any authentic literary data for comparison.

We are aware that simulation of increments according to proposed formulas is relatively schematic and actual increments can vary in comparison with model increments. Also the size and direction of deviation can be predicted only with difficulties. Regarding the knowledge that with lower stocking the increments on remaining trees are usually increasing due to a release of these trees we can expect that also actual increments will be slightly higher than our model increments. Against this generalization we can argue that increment indices of damaged trees, which were used for simulation of stand increments, were derived from empirical material, it means from actual stands. These stands had mostly lower stocking. Based on that we can state that on average they represent relative increments regarding released canopy and stocking.

Taking into account the knowledge of increment indices in total production it is necessary to stress significance of multifactorial effects on the index of total mean increment. While for the index of total current increment only tree crown defoliation is significant that, for the index of total mean increment also yield class and age of stand are significant as well as the age of stand when damage started as well as the number of years the trees were subjected to damage. By consistently reviewing these differences it is necessary to state the total mean increment is not typical biological increment. It gives only the proportion of total production in relation to the age of stand. But it has an irreplaceable role and significance in production and forest management. Due to this reason it has its own importance also in quantification of increment reduction.

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Model objemovej produkcie poškodených smrekových porastov

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ABSTRAKT: V práci sa navrhol a odskúšal algoritmus, ale aj konkrétne vzorce na odvodenie celkovej produkcie a jej prírastkov pre porasty poškodené defoliáciou korún. Pri konštrukcii modelu sa rozlišovali zmeny v objemovej produkcii týchto porastov v dôsledku poškodenia žijúcich stromov a v dôsledku postupného odumierania stromov, teda znižovania jeho hustoty. Veličiny celkovej produkcie sa odvodili simuláciou z modelových údajov rastových tabuliek smreka a parciálnych modelov pre redukciu prírastkov poškodených stromov a porastov.

Kľúčové slová: smrek; poškodené porasty; produkcia; prírastky

I keď sa v poškodzovaných lesoch pomerne dlho skúmal ich rast a prírastok, nepodarilo sa túto problematiku doriešiť až po ich celkovú produkciu a jej prírastky. Je to hlavne preto, že k tomu sú potrebné dlhodobejšie a podrobné opakované pozorovania a merania na trvalých výskumných plochách. Na týchto plochách by sa mala dlhodobejšie sledovať dynamika vývoja zdravotného stavu stromov vrátane uhynulých, a to ešte s ich podrobnou evidenciou podľa hlavného a podružného porastu. Treba i v dnešnej dobe priznať, že takéto merania sú nielen na území SR, ale aj v zahraničí veľmi zriedkavé. Najmä z tohto dôvodu sme navrhli model na simuláciu celkovej produkcie a jej prírastkov pre defoliáciou poškodené smrekové porasty. Pomocou tohto modelu sa z podkladov rastových tabuliek a prírastkových indexov stromov odvodili celková produkcia a prírastkové indexy pre celkový bežný a celkový priemerný prírastok.

Základným podkladom pre odvodenie celkovej produkcie poškodených smrekových porastov sa stali modely 3. vydania rastových tabuliek (HALAJ, PETRÁŠ 1998). Pri jej odvodzovaní sa vývoj porastov pred poškodením prebral priamo z modelov týchto rastových tabuliek, ale počas poškodenia sa modeloval podľa simulovaného zdravotného stavu. Pri konštrukcii modelu sa zmeny v objemovej produkcii poškodených porastov rozdelili podľa príčin do dvoch skupín:

- zníženie objemovej produkcie porastov v dôsledku poškodenia žijúcich stromov,
- zníženie objemovej produkcie porastov v dôsledku postupného odumierania stromov a znižovania ich hustoty.

Celková produkcia poškodeného porastu sa tu vypočíta podľa vzorca (2). Keď by sa mal aplikovať vzorec (1) alebo (2) na výpočet *CP* poškodzovaného porastu nie hneď od jeho založenia, ale od neskoršieho veku, musí sa upraviť na tvar (3), podľa ktorého je celková produkcia poškodených porastov vo veku *t* súčtom celkovej produkcie od jeho založenia po začiatok poškodenia vo veku *tp* a úhrnu bežných prírastkov hlavného a zásoby podružného porastu od prvého roku poškodenia. Po jeho úprave má tvar vzorca (4). Prírastok hlavného a zásoba podružného porastu pri jeho poškodení I_{V2p} a V_{3p} sa vypočítali ako súčin prírastku nepoškodeného hlavného porastu a zásoby podružného porastu a ich prírastkových indexov podľa vzorcov (5) a (6). Prírastkové indexy zásoby hlavného a podružného porastu I_{IV2} a I_{IV3} sa odvodili pomocou vzorcov, ktoré podrobne uvádza PETRÁŠ, HALAJ (1993). Z odvodenej celkovej produkcie poškodzovaných porastov podľa vzorcov (2) a (4) sa odvodil celkový priemerný prírastok (*CPP*) a celkový bežný prírastok (*CBP*), z ktorých sa vypočítali aj ich prírastkové indexy ako relatívne prírastkové miery pomocou vzorcov (7) a (8).

Poškodzovanie lesných porastov sa obyčajne prejavuje postupným oslabovaním jednotlivých stromov až po ich odumretie. Zníženie počtu produkujúcich stromov v poraste potom znamená aj zníženie jeho hustoty, čo je možné objektívne kvantifikovať zakmenením. Zníženie zakmenenia porastov sa musí zákonite prejaviť aj v znížení ich celkovej produkcie. Pre jej konečnú kvantifikáciu sa upravili vzorce (2) a (4) na tvar (9) a (10), ktoré sa líšia od vzorcov (2) a (4) len tým, že sa prírastok hlavného porastu a zásoba podružného porastu redukujú zakmenením. Obidva vzorce obsahujú popri modelových údajoch z rastových tabuliek aj prírastkový index a zakmenenie porastu, ktoré sú závislé na jeho poškodení. Pretože sa jedná o výpočet celkovej produkcie, je pri poškodení porastu významná nielen jeho intenzita, ale samozrejme aj vek, od ktorého poškodzovanie začalo. Pre porasty so zníženým zakmenením počas celého života porastu sa odvodil celkový priemerný prírastok *CPP* a celkový bežný prírastok *CBP*, z ktorých sa odvodili aj ich prírastkové indexy podľa vzorcov (11) a (12). Rovnaké indexy sa vypočítali aj pre porasty, ktoré majú znížené zakmenenie, ale len od určitého veku podľa vzorca (13). Vzhľadom na to, že *CBP* sa odvodzuje len z krátkeho úseku krivky celkovej produkcie, je možné pre výpočet prírastkových indexov porastov, ktoré majú od určitého veku znížené zakmenenie, použiť vzorec (12).

Pre overenie odvodených vzorcov (2)–(8) sa na podklade údajov rastových tabuliek (HALAJ, PETRÁŠ 1998) vypočítali podľa vzorcov (7) a (8) indexy *CPP* a *CBP* poškodených smrekových porastov. Indexy sa simulovali pre bonity 14–42 a počiatočný vek poškodenia 50–150 rokov s odstupňovaním po 10 rokoch. Rovnako sa simulovalo aj poškodenie korún, ktoré je udané ich priemernou a konštantnou defoliáciou 20, 39 a 67 %. Ako je vidieť z obr. 1, najvyšší index s hodnotou 1,0 dosahujú porasty na začiatku ich poškodenia. Od tohto bodu indexy *CPP* s vyšším vekom porastu hyperbolicky klesajú. Indexy *CPP* rovnako klesajú s nižšou bonitou, ale najmä s vyššou defoliáciou korún. Je rovnako zrejmé, že čím je porast dlhšie poškodzovaný, tým má aj nižší index. Z obr. 1 je zrejmé aj to, že všetky uvádzané faktory, a to bonita, vek porastu a počiatočný vek jeho poškodenia ako aj stupeň poškodenia korún stromov, sa vzájomne ovplyvňujú. Po zhodnotení týchto vplyvov sa môže konštatovať, že index *CPP* závisí od bonity, veku porastu, ale aj od veku, keď začali imisie porast poškodzovať, a od stupňa tohto poškodenia vyjadreného percentom defoliácie. Z obr. 2 je vidieť, že indexy *CBP* prakticky nezávisia od veku a bonity porastu, ale ani od veku, kedy k poškodeniu došlo. Jediný významný faktor, s ktorým sa tu môže počítať, je poškodenie porastu vyjadrené jeho defoliáciou. Je to podobný prípad ako pri prírastkovom indexe hlavného porastu, ako ho uvádzajú PETRÁŠ, HALAJ (1993). V prípade, že má porast v dôsledku poškodenia aj menšie zakmenenie, potom obidva prírastkové indexy závisia priamo úmerne od tohto zakmenenia podľa vzorcov (12) a (13). Pre index *CBP* to platí aj v prípade, že zníženie zakmenenia nastalo v neskoršom veku. Index *CPP* je potrebné však pre tento prípad prepočítať podľa vzorca (13). Z tohto analytického tvaru je však možné usudzovať, že zakmenenie porastu bude veľmi významne ovplyvňovať aj index *CPP*.

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Production of biomass of beech (*Fagus sylvatica* L.) leaves and buds after cutting of various intensity

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ABSTRACT: The paper presents the results of leaf- and bud-biomass production for beech stands on plots with original stand density of various grades (0.3, 0.5, 0.7, 0.9). The plots resulted from cutting of various intensity by shelterwood cutting methods which represent the most wide-spread and typical way of natural regeneration. It follows from our results that the production of leaf dry-matter of the tested sample trees of the parent stand increased with increasing cutting intensity. It is true about each crown-third in the case of the codominant and subdominant trees. For dominant trees, the production dependence on stand density was proven only within the lower crown third. The production of buds was found to be distinctly dependent on cutting in the case of subdominant sample trees only. The production of the individual stands, calculated per 1 ha, decreased with increasing cutting intensity. This means that the opposite trend was found in the sample trees.

Keywords: European beech; biomass; leaves; buds; shelterwood cutting

Silvicultural treatments, namely tending (cleaning, thinning) and regeneration (clear cutting, shelterwood cutting, border cutting), represent a considerably important factor that enables us to control or to influence woodmass increment. Few are the papers dealing with the influence of the treatments on the dynamism of parent stand increment in the case when the treatments are performed only with mature trees as a regenerative process using an undergrowth form of shelterwood cutting.

Shelterwood cutting represents the most common and typical basic procedure of natural regeneration by means of cutting mature and non-desired trees on a given regenerated plot so that the stepwise lowering of canopy density and the influence of parent stand shelter can create favourable ecological conditions enabling the germination and survival of self-seeding desired tree species. The aim is to improve the wood production as well as the nonwood production function of a forest (GREGUŠ 1980; KORPEĽ et al. 1991).

In addition to thick pole as well as to small wood, assimilatory organs are the subject of interest to forestry, too. They are significant not only in view of bulk tree-phytomass production but also from the viewpoint of their commercial use. The data concerning leaf biomass of spruce, pine and beech can be found first of all in PETRÁŠ et al. (1985) and PETRÁŠ (1985); the results for oak, elm and hornbeam are given in VREŠTIAK (1989, 1990, 1991).

According to BURGER (1953), the production of 1 m^3 of wood of shaded subdominant beech and spruce requires nearly twofold more leaves or needles compared with well-lighted dominant trees. The same also holds good for the individual parts of the crown. The well-lighted part of the crown influences the result of assimilatory process considerably more distinctly than the shaded one. For Douglas fir and spruce no lowering of the increment has been observed after cutting of shaded branches.

There is a noticeable difference in the development as well as morphology of plants exposed to high intensity radiation and plants growing in conditions with low intensity radiation. This points to the ability of the plants as well as of their assimilatory organs to give different responses to different radiation conditions. This adaptive ability is related to specific changes in leaf structure, morphology and physiology (LARCHER 1988; MASAROVIČOVÁ 1991).

MATERIAL AND METHODS

The research was conducted in a beech stand at the Ecological Experimental Station (EES) Kremnické Vrchy Mts., Central Slovakia (48°38' N, 19°04' E). The beech stand at the EES is 100 years old and is situated on a western slope with gradient of 20% at an altitude of 470 m above sea level. The central association of EES is *Den-*

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Table 1. Data on stands on individual partial plots

PP*	Area (ha)	Year	Stem density (No./ha)	Basal area (m^2/ha)	Volume** (m^3/ha)	Stand density
I	0.35	1989	160	13.50	193.70	0.30
		1996	160	18.50	280.20	0.40
S	0.35	1989	243	18.60	256.80	0.50
		1996	229	23.80	353.40	0.62
M	0.35	1989	397	28.80	398.90	0.70
		1996	363	33.10	497.10	0.78
K	0.15	1989	700	40.90	571.20	0.90
		1996	633	41.20	619.80	0.87

*partial plot, **volume of thick pole – V_{7b} (> 7 cm)

tario bulbiferae-Fagetum Zlatník (1935), in some places the association *Carici pilosae-Fagetum* Oberd. (1958) is spread. The mean annual temperature is 8.2°C, the mean annual precipitation is 664 mm.

The individual partial plots (PPs) of the station differ in their stocking grade, i.e. in the ratio of the real to the so called native basal area of the stand which is given in the yield tables (HALAJ et al. 1987) for each individual yield class and age. The correctness of this method can also be verified in ASSMANN (1968). According to his opinion, natural basal area of the stand represents a significant site and ecological index.

The EES consists of 5 PPs. In February 1989, several cuttings of various intensity were performed in such a way that individual PPs represented the stages of shelterwood cutting with the aim to adjust tree species as well as stand density grade on the individual plots. The original stand density (0.9) was changed as follows: 0.3 – PP I (intensive cutting), 0.5 – PP S (medium intensive cutting), 0.7 – PP M (low intensive cutting). One PP was cleared PP H – stand density 0.0 and PP K was left without cutting – stand density 0.9 – PP K (control). The first cutting was to remove all dying trees, diseased trees and the trees of very poor quality to make the beech a principal species. The data concerning the development trends of mensurational variables after cutting in 1989 compared with the data observed in 1996 are given in Table 1.

DETERMINATION OF BIOMASS AMOUNT, SAMPLING AND PROCESSING OF THE MATERIAL

The process is divided into the following three steps: 1. selection of sample trees, 2. analysis of sample trees, 3. calculation of biomass amount (for individual biomass categories) per whole experimental plot or per unit area (1 ha).

1. Each of the samplings followed after tree inventory. All trees with diameter d.b.h. > 7 cm were graded as acceptable. The sampling was performed so that the sample trees represented the mean stand diameter for each PP and tree class. The social status order was determined according to the Kraft classification scheme of tree social status. According to OSZLÁNYI (1983) it is a method of dominant, codominant and subdominant mean trees (3 sample trees for each PP). The research concerning the response of the beech crown to cutting intensity was performed in a total of 12 sample trees selected according to the tree classes and PPs. The cutting of sample trees started only after the prolongation of shoots had been completed and physiological maturity of leaves had been reached (23 July–10 September in the years 1996, 1997).
2. The analysis of the crown biomass was performed by the following steps:
   - division of the crown into thirds from the top to the bottom,
   - separation of the biomass of branches with the diameter of 0–1.5 cm from the biomass of the stem (seems to work more appropriately with annual shoots),
   - sampling of twigs with leaves (at an amount of about 2–3 kg – OSZLÁNYI 1986) to determine the ratio of the weight of leaves to the weight of twigs and water content in the biomass.
3. Biomass weight for the individual categories was determined as a relative value with respect to the number of dominant, codominant and subdominant trees per 1 ha.

LABORATORY ANALYSIS

Dry weight was determined in 0.2 kg samples of live leaves and branches taken from sample trees containing 0–1.5 cm thick branches after preliminary removal of the leaves. Having determined the amount of dry weight, the buds were separated and their weight percentage was calculated.

The fresh as well as dry weight of the samples was computed relatively to the whole crown of the tree or to 1ha area of the plot using a highly precise scale (METTLER) with 0.01 g accuracy. In the laboratory, the specimens were dried to a constant weight at a temperature of 80°C (THIEBAUT, COMPS1990; DYKYJOVÁ et al. 1989).

The weight of the fresh biomass of the individual crown parts was determined by weighing them immediately. The dry weight was computed multiplying the fresh weight by the appropriate percentage of dry weight represented as the weight ratio of the fresh to the dry specimens.

RESULTS

DOMINANT TREES

Table 2 gives the values of the percentage content of dry weight for the analysed individual parts of the crown biomass (in this table as well as in the following parts the mean expresses the arithmetical mean). It is obvious from the table that the percentage of dry weight of leaves decreases from the top to the lower third of the crown, i.e. the crown water content increases, except the sample tree on PP S. There is an opposite trend in buds and branches. The lower the position in the crown, the higher the proportion of dry weight and amount of water. Comparing the values for the individual PP it can be stated that there is no relationship between the percentage of dry weight of leaves in the upper third of the crown and the stand density and cutting intensity. In the middle and lower third the value of dry weight of leaves increases with increasing cutting intensity. The percentage values of dry weight of buds and branches in the upper third do not show any dependence on the intensity of cutting. In the lower third they decrease with increasing intensity of cutting.

The biomass values of fresh and dry weight as well as their percentage distribution in the crown are shown in Table 3. It is obvious from the results that the sample trees on PP I has the minimum value of dry weight of leaves (7.40 kg) only in the lower third of the crown while in the middle and the lower parts the value is maximum (5.74 kg and 3.20 kg) compared with the other sample trees. The relation of leaf biomass production to the stand density (PPs) is evident only in the lower third of the crown. This relation can be explained by a change in microclimate site conditions on the individual PPs due to the cutting 9 years ago. The influence is at present evident only in the lower third of the crown (this observation on PP I and S correlates with the length increments of branches). The following applies to the weight values of dry buds: the more intensive the cutting, the higher the production. The values observed on PP K do not follow this trend.

CODOMINANT TREES

It is obvious from Table 2 that the percentage of dry weight of leaves decreases down the crown (with the exception of the sample tree on PP I). In the case of buds and branches, a similar dependence on the position in the crown (the corresponding third), like that observed for the dominant trees, is evident only for values determined for PP K and M. Within PPs the percentage of leaf dry weight in the upper third of the crown is approximately the same. Nevertheless, there is a decreasing tendency of the dry weight percentage with increasing stand density in the middle and the lower third. It follows that the higher the stocking grade the higher the moisture content in the leaves. This trend is also supported by data for the whole crown. The values of the percentage of dry weight of

Table 2. Dry-weight percentage of leaves, buds and branches on individual PPs according to the crown third and social status

Social status	Type of biomass	Partial plot															
		I				S				M				K			
		Third of crown															
		upper	middle	lower	mean	upper	middle	lower	mean	upper	middle	lower	mean	upper	middle	lower	mean
Dominant	leaves	44.18	43.13	41.13	43.18	47.28	42.86	45.31	46.37	43.94	41.67	39.48	42.73	47.51	41.94	36.29	44.81
	buds	50.27	50.00	52.63	50.53	54.92	59.38	55.00	55.75	54.02	55.00	60.00	54.46	55.37	56.52	57.14	55.75
	branches*	50.32	49.69	53.35	50.63	55.06	58.59	56.01	56.03	55.90	56.38	57.85	56.27	55.32	56.84	56.06	55.88
Codominant	leaves	48.88	50.72	50.00	49.66	46.97	45.06	42.01	45.69	47.48	40.60	43.14	44.94	46.04	41.13	39.87	44.02
	buds	58.72	58.62	50.00	58.48	62.69	64.71	57.90	62.14	59.70	55.56	62.50	58.33	52.69	55.26	55.56	53.57
	branches	56.02	56.41	58.14	56.28	56.51	59.69	57.50	57.64	58.30	56.11	60.47	57.83	53.02	55.14	57.85	54.31
Subdominant	leaves	42.25	40.03	39.18	40.32	45.70	42.48	42.00	43.90	41.29	39.19	41.20	40.69	40.81	38.28	38.04	39.24
	buds	52.78	57.14	55.56	54.94	57.89	55.56	60.00	57.57	60.00	60.00	62.50	60.87	57.14	60.00	50.00	56.25
	branches	52.63	53.55	55.50	54.05	57.69	54.97	57.39	56.80	59.37	58.33	59.65	59.21	54.96	56.21	57.29	56.05

*thickness cathegory 0–1.5 cm

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Table 3. Weight proportion and percentage of leaf and bud biomass in individual crown thirds (the values are given in kg and %)

Social status	Biomass		I upper	I middle	I lower	I sum	S upper	S middle	S lower	S sum	M upper	M middle	M lower	M sum	K upper	K middle	K lower	K sum
Dominant	leaves	fw*	16.75	13.30	7.78	37.84	34.22	7.49	4.48	46.19	17.32	9.12	3.47	29.91	18.90	10.49	2.48	31.87
		(%)	44.26	35.15	20.59	100.00	74.08	16.22	9.70	100.00	57.91	30.49	11.60	100.00	59.30	32.92	7.78	100.00
		dw**	7.40	5.74	3.20	16.34	16.18	3.21	2.03	21.43	7.61	3.80	1.37	12.78	8.98	4.40	0.90	14.28
		(%)	45.29	35.13	19.58	100.00	75.54	14.98	9.48	100.00	59.55	29.73	10.72	100.00	62.89	30.81	6.30	100.00
	buds	fw	1.83	0.60	0.38	2.81	1.22	0.32	0.20	1.74	0.87	0.20	0.05	1.12	1.21	0.46	0.07	1.74
		(%)	65.13	21.35	13.52	100.00	70.12	18.39	11.49	100.00	77.68	17.86	4.46	100.00	69.54	26.44	4.02	100.00
		dw	0.92	0.30	0.20	1.42	0.67	0.19	0.11	0.97	0.47	0.11	0.03	0.61	0.67	0.26	0.04	0.97
		(%)	64.79	21.13	14.08	100.00	69.07	19.59	11.34	100.00	77.05	18.03	4.92	100.00	69.07	26.81	4.12	100.00
Codominant	leaves	fw	10.74	7.67	0.82	19.23	13.52	5.77	3.69	22.98	11.12	5.69	1.97	18.78	6.82	2.48	1.58	10.88
		(%)	55.85	39.89	4.26	100.00	58.83	25.11	16.06	100.00	59.21	30.30	10.49	100.00	62.68	22.80	14.52	100.00
		dw	5.25	3.89	0.41	9.55	6.35	2.60	1.55	10.50	5.28	2.31	0.85	8.44	3.14	1.02	0.63	4.79
		(%)	54.98	40.73	4.29	100.00	60.48	24.76	14.76	100.00	62.56	27.37	10.07	100.00	65.55	21.20	13.15	100.00
	buds	fw	1.09	0.58	0.04	1.71	0.67	0.17	0.19	1.03	0.67	0.45	0.08	1.20	0.93	0.38	0.09	1.40
		(%)	63.74	33.92	2.34	100.00	65.05	16.50	18.45	100.00	55.83	37.50	6.67	100.00	66.43	27.14	6.43	100.00
		dw	0.64	0.34	0.02	1.00	0.42	0.11	0.11	0.64	0.40	0.25	0.05	0.70	0.49	0.21	0.05	0.75
		(%)	64.00	34.00	2.00	100.00	65.62	17.19	17.19	100.00	57.14	35.72	7.14	100.00	65.33	28.00	6.67	100.00
Subdominant	leaves	fw	4.71	7.07	6.10	17.88	3.37	2.26	1.50	7.13	2.01	1.48	1.99	5.48	1.47	1.28	0.92	3.67
		(%)	26.34	39.54	34.12	100.00	47.26	31.70	21.04	100.00	36.68	27.01	36.10	100.00	40.05	34.88	25.07	100.00
		dw	1.99	2.83	2.39	7.21	1.54	0.96	0.63	3.13	0.83	0.58	0.82	2.23	0.60	0.49	0.35	1.44
		(%)	27.60	39.25	33.15	100.00	49.20	30.67	20.13	100.00	37.22	26.01	36.77	100.00	41.67	34.03	24.30	100.00
	buds	fw	0.36	0.28	0.27	0.91	0.19	0.09	0.05	0.33	0.10	0.05	0.08	0.23	0.07	0.05	0.04	0.16
		(%)	39.56	30.77	29.67	100.00	57.58	27.27	15.15	100.00	43.48	21.74	34.78	100.00	43.75	31.25	25.00	100.00
		dw	0.19	0.16	0.15	0.50	0.11	0.05	0.03	0.19	0.06	0.03	0.05	0.14	0.04	0.03	0.02	0.09
		(%)	38.00	32.00	30.00	100.00	57.89	26.32	15.79	100.00	42.86	21.43	35.71	100.00	44.45	33.33	22.22	100.00

Column headings: Partial plot (I, S, M, K); Third of crown (upper, middle, lower, sum).

*fresh weight, **dry weight

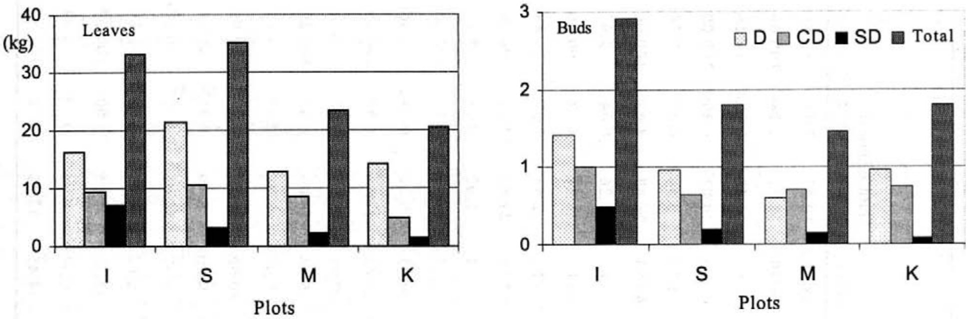

Fig. 1. Dry weight of leaves and buds in the studied sample trees according to tree classes (D – dominant, CD – codominant, SD – subdominant)

buds and branches do not decrease with the stand density on the PPs I, S and M. On the other hand, an evident decrease was noted on the PP K.

In the upper third of the crown (Table 3) the most substantial production of the leaf biomass is evident on the sample tree from the PP S. The values of PP I (5.25 kg) and M (5.28 kg) are approximately the same and the values from PP K are the lowest ones. The dependence on the stand density is evident in the middle and the lower third of the crown. The influence of the stand density on bud production was not manifested. It was detected only on PP I with considerable crown thinning. The sample trees from PP I had the highest values (1.00 kg). The other values were lower and more or less equal (PP S – 0.64 kg, PP M – 0.70 kg, PP K – 0. 75 kg). For the middle and the lower third of the crown it is valid that the bud biomass values are directly proportional to the cutting intensity with exception of the lower third of the crown on the PP I.

SUBDOMINANT TREES

The dry weight of leaves decreases corresponding to the decreasing third of the crown for dominant, codominant as well as subdominant trees (Table 2). For the buds and branches such dependence was found only for the branches from PP I and K. A slight decrease of the percentage amount of dry weight of leaves with increasing stand density grade was observed on the PPs with the exception of the PP S with these values higher than PP I. The values of dry weight of buds and branches show increasing tendency with increasing stand density on the plots after cutting.

The sample trees of this tree class (Table 3) show for each crown third the dependence of leaves and buds biomass production on the stand density. That means that the more intensive the cutting the more rich the production of the leaf mass.

PRODUCTION OF SAMPLE TREES ON INDIVIDUAL PARTIAL PLOTS

Based on the comparison between the values of the total production of the sample trees it was concluded that the production of leaf and bud biomass is the most intense in the case of dominant trees and the least intense for the subdominant trees (Fig. 1). The influence of cutting on the leaf biomass production was detected for the codominant and subdominant trees. The influence of cutting on the bud biomass production was observed in the dominant and subdominant trees except the PP K. It is also obvious from the figure that in the case of the dominant and codominant trees the highest production of dry weight of leaves was on the sample from the PP S and in the case of the subdominant trees on the PP K. The highest values of bud biomass production were observed on the PP I for all the tree classes. The lowest values for dominant trees were found on the PP M, for codominant trees on the PP S and for subdominant trees on the PP K.

STAND PRODUCTION VALUES ON THE INDIVIDUAL PARTIAL PLOTS

Based on the up-to date results it is evident that the biomass production is higher in the stands with more intensive cutting but the living trees are less numerous. That is why it is very important from the point of view of the total production to compare the relative values per 1 ha.

The total production of all beech trees on the PPs was determined by multiplying the sample values by the actual number of beech trees in the individual tree classes per 1 ha. The highest production of leaves and buds was found on the PP K. Only within the codominant trees the highest amount of leaves was produced on the PP M.

These values do not have sufficient accuracy for the comparison of the stand production values between the individual PPs. The reason is that, in addition to beech, also other tree species (PP I 7.0%, PP S 10.0%, PP M 19.7%, PP K 5.3%) are present on the given PPs. So to improve the comparison between the production values requires us to adapt the obtained values according to the percentage of beech present in the individual tree-classes. The values are given in Fig. 2. However the opposite trend is obvious for the production of sample trees selected from the same PPs (Fig. 1). The lowest biomass production was detected in the stand on the PP I while the highest was detected on the PP K.

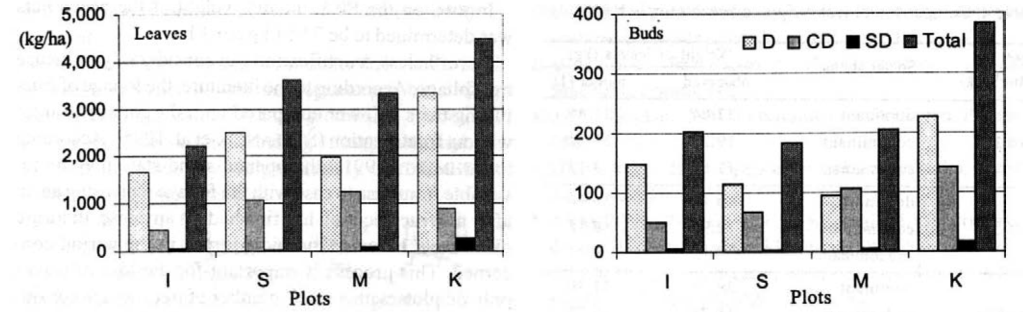

Fig. 2. Biomass production of leaves and buds calculated per 1 ha according to tree classes and PP (D – dominant, CD – codominant, SD – subdominant)

DISCUSSION

Having no opportunity to compare our results with the literature (as far as we know there are no research works evaluating the leaf- and bud-biomass production for beech trees in dependence on the stand density), we compared them with the results obtained in stand conditions most similar to the EES Kremnické Vrchy Mts.

DRY WEIGHT PERCENTAGE

The data given in Table 2 indicates that the values of the leaf dry weight range from 36.29% (PP K, dominant tree) to 50.72% (PP I, codominant tree). According to PETRÁŠ et al. (1985) the mean dry weight of leaves makes 36.5% for different tree classes of beech stands with the stand density 0.7–1.0. According to VYSKOT (1989), this value for 40-years-old beech trees is 44.2%. OSZLÁNYI (1986), evaluating 12 samples of beech logs with mean diameter from a stand with density 1.0 determined the mean content of dry weight of leaves to be 45.2%. The dry weight percentage was higher for the branches below 1.5 cm in diameter. The values of branch dry weight determined within the EES ranged from 50.63% (PP I, dominant tree) to 59.21% (PP M, subdominant tree). The above-mentioned authors confirm the dry weight of 40.1%, 59.0% and 45.2% in the sample trees. We can see that there is an accordance between the data in spite of their fair variability. The fresh weight of the leaves is considerably dependent on climatic conditions during sampling (season, etc.). That is why it is more appropriate to compare the value of biomass in dry state.

PRODUCTION OF BIOMASS OF LEAVES AND BUDS

After cutting in February 1989, the vacant area of different size was obtained for growing trees on the individual PPs. Following the canopy opening the trees allowed increased light increments which was well-observable with beech. This reaction was evaluated on the basis of increased production of the biomass of branches – or leaves and buds (corresponding to the actual state every year). According to BURGER (1939, 1947 in ŠEBÍK, POLÁK 1990) the fresh weight of the beech leaves is as follows: for the diameter of 20 cm it is 9 kg, for 30 cm – 19 kg and for 40 cm – 34 kg.

On the EES, the samples of dominant trees had diameters about 40 cm, the samples of codominant trees about 30 cm and those of subdominant trees a little below 20 cm. Thus they were comparable with the above-mentioned values. Nevertheless, the more accurate approach is to compare the determined production of beech leaves with the values calculated from the regression model of leaf biomass given by PETRÁŠ et al. (1985) and PETRÁŠ (1985):

$$m = b_1 \cdot (d + 1)^{b2} \cdot h^{b3} \qquad (1)$$

where: m – fresh biomass of leaves (kg),
d – tree diameter 1.3 m above the ground,
h – height of tree (m),
b_1–b_3 – regression coefficients.

The respective model was developed using 285 beech samples taken from stands with density of 0.7–1.0.

The values of leaf biomass (Table 4) determined on the EES and calculated according to model (1) are in better accord in the case of the PP K and M than in the case of the PP S and I. It is caused by the fact that the calculation according to model (1) uses the values of stand density 0.7–1.0 corresponding to the density values on PP K and M. With a lower density, the actual production of beech-leaf biomass is higher compared with the computed value.

The determined values indicate that the more intensive the cutting, the higher the production. Nevertheless, the number of remaining trees is decreasing. Therefore, it is necessary to compare the production of individual trees as well as of the whole stands on the PPs using the values computed relatively per 1 ha area.

According to BURGER (in ASSMANN 1968), 98 years old beech trees produced 2.8 t of dry leaves per 1 ha. OSZLÁNYI (1986) gives for a 74 years old mature beech stand with basal area 41.39 m^2/ha, the volume production 603.9 m^3/ha and density of trees 630 individuals per ha, the amount of 3.22 t/ha leaves in dry state. The calcu-

Table 4. Comparison of leaf weight in beech sample trees

PP* (stocking)	Social status	Weight of leaves (kg)	
		observed	model (1)
I (0.3)	dominant	37.84	31.45
	codominant	19.23	17.22
	subdominant	17.88	8.17
S (0.5)	dominant	46.19	36.46
	codominant	22.98	18.18
	subdominant	7.13	4.83
M (0.7)	dominant	29.91	31.30
	codominant	18.78	15.30
	subdominant	5.48	6.14
K (0.9)	dominant	31.87	30.32
	codominant	10.88	13.21
	subdominant	3.67	5.44

*partial plot

lation of beech leaf weight per 1 ha can be performed also using the above-mentioned model (1) according to the relation:

$$M = N \cdot m \qquad (2)$$

where: M – fresh weight of leaves of the beech stand per 1 ha,
N – number of trees per 1 ha,
m – fresh weight of leaves of an average tree (PETRÁŠ 1985).

After multiplying the results by the percentage of dry weight I found for the PPs of the EES the following values: PP I 1,929 kg, PP S 2,500 kg, PP M 3,165 kg and PP K 3,540 kg of dry weight per 1 ha.

The actual values determined by the analysis of samples of the EES are as follows: PP I 2,206 kg, PP S 3,616 kg, PP M 3,339 kg and PP K 4,496 kg of dry weight of leaves per 1 ha. These values are higher than the corresponding theoretical values. Only in the case of PP M was the identity of this value observed. Comparison of the stand production values requires to involve several other factors influencing this process such as the substrate nature, soil depth, moisture content, site class, etc.

By separation of leaves from branches, fructification was observed on several samples. It is interesting that fructification occurred only in the case of samples taken from dominant and codominant trees on the PP I where the cutting was the most intensive and the beech crowns were sufficiently opened even 8–9 years after the cutting. This fact agrees with the results of ŠTEFANČÍK and CICÁK (1993), who detected the highest number of fructifying trees after the cutting every year also on PP I.

The dry mass of the collected beech nuts was as follows:

- the dominant sample tree produced in the upper third of the crown 0.32 kg of beech nuts (no fructification was observed in the middle and the lower third),
- the codominant sample tree produced 0.64 kg nuts in the upper third, 0.34 kg in the middle and 0.02 kg in the lower third of the crown.

In total on the PP I, the dry weight of the beech nuts was determined to be 72.51 kg per 1 ha.

Nevertheless, fructification can considerably influence tree foliage. According to the literature, the foliage of fructifying trees is lower compared with the foliage of trees without fructification (ŠTEFANČÍK et al. 1995). According to SCHMIDT (1991), the opened stand state may be reversible from case to case with the foliage increasing again after the fructification has finished. In any case, there are differences between individual trees in the period concerned. This process is important for the loss of leaves only on plots with a small number of trees where considerable fructification on beech arises. During a very productive year up to 20% decrease of leaf production can be observed. That is why the production values for beech crowns on the PP I can be influenced also by this fact.

The variability in the production of various beech stands is documented also by the results of DUVIGNEAUD (1988), who gives the values of primary production for 145 years old grass-beech stands of high site class with canopy closures. To the biomass of leaves making 3,256 kg/ha, of beech nuts 224 kg/ha and of small wood 50,300 kg/ha corresponded the production of 15.6 t of dry weight per ha/year. The author follows with evaluating the production of a slightly younger beech stand growing on richer soil (17.8 t/ha per year) and of two younger ones – the first growing on rich soil (20 t/ha per year) and the second on poor soil (10.6 t/ha per year). According to the author – there is an important factor of production – the nutrient availability in the soil, the appropriate herb layer being a bio-indicator of this abundance and production volume.

For the production of bud biomass on the EES (Fig. 2) it holds true that the weight values for its individual stands' PPs influenced by cutting of various intensity are approximately the same (PP I 201 kg/ha, PP S 181 kg/ha, PP M 205 kg/ha), while being distinctly higher only on the control plot (383 kg/ha). It follows that in addition to the growing conditions, the number of trees has a decisive influence on the final bud production.

CONCLUSION

By means of the sample analysis the influence of cutting intensity on the production of beech leaves and buds was investigated. Based on the complex evaluation of the results, we can conclude:

The percentage of dry weight (Table 2):

- in all the tree classes the percentage of leaf dry weight decreased from the upper third of the crown to the lower,
- the percentage of dry mass of branches increased from the upper third of the crown (i.e. the water content decreased),
- the percentage of leaf dry weight in the individual thirds of the crown increased with increasing cutting intensity (except the upper third of the crown of dominant trees),
- in the case of branches and buds the trend was opposite – the more intensive the cutting, the lower the percentage of dry weight.

Production of biomass of leaves and buds (Table 3):

Dominant trees

- production of leaf biomass in the upper and middle third of beech crowns showed no dependence on cutting intensity. In the lower third the production of leaf dry weight increased with increasing cutting intensity,
- production of bud dry weight slightly increased with increasing cutting intensity.

Codominant trees

- production of leaf weight increased in each of the thirds with increasing cutting intensity,
- the influence of cutting on bud dry weight production was observed only in the stand with intensive cutting (PP I) in the upper and middle third of the crown.

Subdominant trees

- dry-weight production of leaves and buds is considerably dependent on cutting intensity. In all the thirds of the crown as well as within the whole crown it increased with cutting intensity.

Sample production for all tree classes (Table 2, Fig. 1)

- the highest production of leaf and bud biomass was observed in dominant trees and the lowest in subdominant trees,
- significance of the influence of cutting intensity on production increased with decreasing tree-class order.

Production of plants on PPs (Fig. 2)

- production of leaf and bud dry weight in the stands on PPs (per 1 ha) decreased with increasing cutting intensity, having in such a way the opposite trend compared with the production of the observed samples.

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Produkcia biomasy listov a púčikov u buka (*Fagus sylvatica* L.) po ťažbovom zásahu rôznej sily

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ABSTRAKT: V práci sú prezentované výsledky produkcie biomasy listov a púčikov bukových porastov na plochách s rôznym počiatočným zakmenením (0,3, 0,5, 0,7, 0,9). Plochy vznikli po ťažbovom zásahu rôznej sily, podrastovou formou, clonným rubom. Je to najrozšírenejší a najtypickejší základný spôsob prirodzenej obnovy. Z výsledkov vyplýva, že produkcia sušiny listov na skúmaných vzorníkoch materského porastu rastie so silou ťažbového zásahu. Platí to pre každú tretinu koruny úrovňových a podúrovňových stromov. U predrastavých stromov závislosť produkcie od zakmenenia bola zistená iba v dolnej tretine koruny. Na produkcii púčikov sa vplyv ťažbového zásahu výrazne prejavil u podúrovňových stromov. Produkcia jednotlivých porastov – po prepočte na hektár – so silou ťažbového zásahu klesala, mala teda opačný trend ako pri vzorníkoch.

Kľúčové slová: buk lesný; biomasa; listy; púčiky; clonný rub

Práca sleduje vplyv ťažbového zásahu na produkciu materského porastu, keď sa zásah uskutočnil v rastovej fáze kmeňoviny v obnovnom procese podrastovej formy clonným rubom.

Clonná obnova je najrozšírenejší a najtypickejší základný spôsob prirodzenej obnovy, pri ktorom sa postupne na obnovovanej ploche ťažia zrelé alebo nežiadúce stromy materského porastu tak, aby sa postupným znižovaním zápoja a vplyvom clony materského porastu vytvárali na rúbani vhodné ekologické podmienky pre vznik a prežitie náletu žiadúcej dreviny, aby sa zvýšila hodnota drevnej produkcie a zlepšili mimoprodukčné účinky polesa (GREGUŠ 1980; KORPEĽ et al. 1991).

Ekologicko-experimentálny stacionár (EES) Kremnické vrchy sa skladá z piatich čiastkových plôch (ČP). Vo februári 1989 boli uskutočnené ťažbovo-obnovné zásahy rôznej sily tak, aby jednotlivé ČP EES reprezentovali fázy clonného rubu. Cieľom bolo upraviť drevinové zloženie a zakmenenie na jednotlivých ČP. Pôvodné zakmenenie porastu (0,9) sa zmenilo na: 0,3 – ČP I (intenzívny zásah), 0,5 – ČP S (stredne intenzívny zásah), 0,7 – ČP M (mierne intenzívny zásah). Jedna ČP sa vyrúbala naholo (ČP H – 0,0) a ďalšia zostala bez zásahu, teda s pôvodným zakmenením 0,9 (ČP K – kontrola). Zámerom bolo odstrániť predovšetkým stromy odumierajúce, choré a veľmi nekvalitné, aby dominantnou drevinou bol buk.

Pre výskum bolo vybratých 12 vzorníkov. Výber bol robený tak, aby vzorníky reprezentovali strednú hrúbku porastu pre každú ČP a stromovú triedu. Stromová trieda bola určená podľa Kraftovej klasifikačnej schémy sociálneho postavenia stromu. Podľa OSZLÁNYIHO (1983) je to metóda stredných stromov nadúrovňových, úrovňových a podúrovňových (tri vzorníky z každej ČP). Ťažba vzorníkov sa začala až po ukončení predlžovacieho rastu výhonkov a fyziologickom dozretí listov (23. 7.–10. 9. 1996, 1997).

V tab. 2 sú uvedené hodnoty percentuálneho obsahu suchej hmotnosti jednotlivých analyzovaných častí biomasy korún. Z nej vidno, že percento suchej hmotnosti listov klesá s klesajúcou tretinou koruny skúmaného vzorníka (horná, stredná, dolná tretina koruny), tzn. že obsah vody rastie (s výnimkou predrastavého vzorníka z ČP S a úrovňového vzorníka z ČP I). V púčikoch a konároch tento trend nemá vždy jednoznačný priebeh a je opačný ako pri listoch – čím nižšie v korune, tým je viac suchej hmotnosti a menej vody. Ak porovnáme hodnoty medzi jednotlivými ČP, zistíme, že percento obsahu suchej hmotnosti listov v hornej tretine koruny predrastavých a úrovňových stromov nevykazuje žiadnu závislosť vo vzťahu k zakmeneniu – k sile ťažbového zásahu. V strednej a dolnej tretine koruny percento suchej hmotnosti listov rastie so silou ťažbového zásahu. To znamená, že čím bolo vyššie zakmenenie (menšia sila ťažbového zásahu), tým viac vody sa nachádzalo v listoch. Závislosť percenta suchej hmotnosti púčikov a konárov od sily ťažbového zásahu nebola jednoznačne zistená na všetkých vzorníkoch.

Hodnoty biomasy čerstvej a suchej hmotnosti ako aj percentuálne rozloženie v rámci tretín korún sú uvedené v tab. 3. Z výsledkov pre predrastavé stromy vidíme, že vzorník z ČP I iba v hornej tretine koruny vykazuje v porovnaní s ostatnými vzorníkmi najmenšiu hodnotu sušiny listov (7,40 kg), v strednej a dolnej tretine najväčšiu (5,74 kg a 3,20 kg). Závislosť produkcie biomasy listov od zakmenenia (podľa ČP) vidíme iba v dolnej tretine koruny (produkcia rastie so silou zásahu). Dá sa to vysvetliť tým, že deväť rokov po ťažbovo-obnovnom zásahu sa rastové podmienky na jednotlivých ČP zmenili tak, že tento vplyv je zreteľný už len v dolnej tretine korún (tento poznatok bol zistený aj pri dĺžkových prírastkoch konárov). Pre hodnoty suchej hmotnosti púčikov platí: čím silnejší ťažbový zásah, tým väčšia produkcia. Tomuto trendu sa vymykajú hodnoty z ČP K.

V hornej tretine koruny úrovňových stromov, podobne ako u predrastavých, skúmané vzorníky nevykazujú závislosť produkcie biomasy listov od sily ťažbového zásahu, resp. zakmenenia. Závislosť od zakmenenia je viditeľná v strednej a dolnej tretine koruny. Ani vplyv zakmenenia na produkciu púčikov v hornej tretine sa neprejavil, resp. bol zistený iba na ČP I pri silnom presvetlení, pretože najväčšie hodnoty sú na vzorníku z ČP I (1,00 kg), ostatné boli nižšie a vyrovnané (ČP S – 0,64 kg, ČP M – 0,70 kg a ČP K – 0,75 kg). V strednej a dolnej tretine koruny platí, že hodnoty biomasy púčikov rastú so silou ťažbového zásahu. Výnimkou je dolná časť koruny z ČP I.

U podúrovňových vzorníkoch vidieť v každej tretine koruny závislosť produkcie biomasy listov a púčikov od zakmenenia. To znamená, že čím silnejší bol ťažbový zásah, tým bola väčšia produkcia listovej hmoty.

Z porovnania celkovej produkcie vzorníkov vidíme, že najväčšiu produkciu biomasy listov a púčikov majú predrastavé stromy a najmenšiu podúrovňové (obr. 1). Vplyv ťažbového zásahu na produkciu biomasy listov bol zistený pri úrovňových a podúrovňových stromoch a na produkciu biomasy púčikov pri podúrovňových a predrastavých, okrem ČP K. Z obrázku vidieť, že najvyššia produkcia sušiny listov pri predrastavých a úrovňových stromoch je na vzorníkoch z ČP S, pri podúrovňových stromoch na ČP I. Najmenšia produkcia pri predrastavých stromoch je na ČP M, pri úrovňových a podúrovňových na ČP K. Pri produkcii biomasy púčikov najvyššie hodnoty boli zaznamenané na ČP I pri všetkých stromových triedach. Najnižšia produkcia pri predrastavých stromoch bola na ČP M, pri úrovňových na ČP S a pri podúrovňových na ČP K.

Z výsledkov je zrejmé, že na porastoch so silnejším ťažbovým zásahom stromy produkujú viac biomasy, avšak počet zostávajúcich stromov je menší. Preto je z hľadiska celkovej produkcie dôležité porovnať hodnoty prepočítané na hektár.

Produkcia všetkých bukov na ČP bola vypočítaná vynásobením zistených hodnôt vzorníkov skutočným počtom bukov v jednotlivých stromových triedach a prepočítaná na hektár. Hodnoty sú zobrazené na obr. 2. Vidieť tu opačný trend ako pri produkcii vzorníkov z tých istých ČP (obr. 1). Najnižšiu produkciu biomasy vykazuje porast na ČP I a najväčšiu porast na ČP K.

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The influence of physiological activity on the rate of electrolyte leakage from beech and oak planting stock

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ABSTRACT: This study describes the influence of physiological activity of unstressed planting stock on the rate of electrolyte leakage within two experiments. The test material was represented by bare-rooted plants of beech (*Fagus sylvatica* L.) and oak (*Quercus robur* L.). In the first experiment, plants were lifted from the forest nursery once a month during one year. Immediately after lifting the electrolyte leakage of root and shoot material was measured. In the second experiment the plants in dormancy were placed in growth chamber in two-days interval. Then, 21 days after the first seedlings were placed into growth chamber, the electrolyte leakage from taproot, shoots and terminal buds was measured. The analysis of results showed that the physiological activity influences the rate of electrolyte leakage. However, it is possible to determine whether an increase of the electrolyte leakage rate from taproot is caused by physiological damage or by the physiological activity of planting stock.

Keywords: beech and oak planting stock; physiological activity; physiological quality; taproot; electrolyte leakage

The plant stock quality and correct afforestation procedures play a decisive role for artificial regeneration. After afforestation the planting stock is under shock and therefore it is necessary to use only good quality planting stock. But it is very difficult to define the term plant quality and accordingly the existing methods of determining the actually initial survival potential or field performance as they have been changing and developing.

Generally, the plant quality is a complex of genetic, morphological and physiological traits. The genetic quality of planting stock must be ensured by the use of proper seed and plants. The second part of general planting stock quality is morphological quality. According to Standard 48 2211 (ON Semenáčiky a sadenice lesných drevín – Seedlings and Woody Plants) from the year 1988 it is possible to use for transplantation and afforestation only planting stock which corresponds to biometrical requirements of this standard. On the other hand, Standard 48 2115 from the year 1998 (ČSN Sadební materiál lesních dřevin – Planting Stock of Woody Plants) does not impose to use biometrical characteristics.

The third part is physiological quality. According to MARTINCOVÁ (1990) the physiological quality is a complex of different factors which separately and in their interaction influence the planting stock survival and growth after planting.

Achievement and control of morphological and genetic quality of planting stock are common in forestry practices. It is namely the definition of seed zone for mainly forest trees and observation of the rules of horizontal and vertical transfer of seeds and plants. The morphological quality is defined mainly according to relations between shoots and roots, quality of root system, diameter of root collar and proportion of fine roots. The determining of physiological plant quality is the most complicated part of total plant quality. The physiological damage (root desiccation, extreme temperature, frost) tends to internal tissue, which is rarely evident during visual inspection (MCEVOY, MCKAY 1997a,b). Besides plant damage the physiological quality is influenced also by other factors. These factors highly significantly influence key traits of planting stock quality. The nursery practises (undercutting, transplantation) have a marked influence on root growth potential, different regimes of cold storage influence water content in plant tissues and the end and beginning of dormancy play a very important role. All these factors affects mitotic index and chlorophyll fluorescence.

Therefore, most methods for determining the physiological quality of planting stock may be used only under specific stress conditions (measurement of water content to discover drought injury or to detect wrong cold storage). The methods which could provide information on the vigour of planting stock (measurement of root growth potential, vitality test according to Oregon State University) are very demanding for time, the interpretation of the results of tests is very complicated and some methods are costly.

The method of measurement of electrolyte leakage from the root system is quick and provides solid results about the physiological quality of planting stock. This method

Table 1. The biometrical characteristics and age of tested planting stock

	Beech	Oak
Age	2 + 1	1 + 0
Height ± s_x (cm)	47 ± 8.4	21 ± 7.5
Root length ± s_x (cm)	20 ± 4.9	19 ± 3.4
Stem diameter ± s_x (mm)	9.5 ± 1.3	4.5 ± 1.9
Root diameter ± s_x (mm)	15.2 ± 2.0	7.2 ± 2.2

Annex 1

Structure of substrate used in growth chamber:

peat	50%
bark substrate	30%
woody compost	10%
clay	5%
green compost	5%
Flory 73 (adjustment of pH – 5.5)	20g/m^3
NP 26/14	1 kg/m^3

was used for determining frost and drought injury, incorrect mode of cold storage of bare-rooted and containerized coniferous and broadleaved planting stock (BURR et al. 1990; KERR, HARPER 1994; MCEVOY, MCKAY 1997a; MCKAY 1991, 1992a,b, 1994, 1998; MCKAY, MASON 1991; MURRAY et al. 1989; SARVAŠ 1999a,b; SCHÜTE, SARVAŠ 1999; TINUS 1996).

The aim of this study was to describe the influence of physiological activity of unstressed beech and oak planting stock on the rate of electrolyte leakage within two tests. The attention was concentrated on the state of dormancy. If the beginning of dormancy can increase the rate of electrolyte leakage, it could lead to misinterpretation of the results.

MATERIALS AND METHODS

Beech (*Fagus sylvatica* L.) and pendulate oak (*Quercus robur* L.) bare-rooted seedlings which had been produced in a nursery of the Lower Saxony Forestry Institute (360 m above sea level, annual precipitation 800 mm, in vegetation period 400 mm, mean annual temperature 7.6°C) were used in this study. The biometrical characteristics and age of tested planting stock are given in Table 1.

This study was carried out during a scholarship stay at Lower Saxony Forestry Institute (Department of Forestry Breeding in Escherode). The Institute participated in EU project *A European approach to assessing: regrowth potential of woody plants: parameters for plant vitality and dormancy of planting stock.* Duration of the project: 1. 3. 1996–1. 9. 1999. The scientific objectives of the project are as follows:

- to identify morphological and physiological and molecular parameters for predicting the survival and growth rate of woody planting stock and to define criteria for the development of reliable and simple plant quality assessment that can be standardized and used in practice,
- to show how regrowth potential can be improved by cultural and/or storage methods,
- to build a model for (re)growth potential.

In the first experiment the process of electrolyte leakage from unstressed oak and beech planting stock was determined. The plants were lifted from the forest nursery once a month (in spring in two weeks intervals) during one year. Immediately after lifting the electrolyte leakage from roots and shoots was measured in twenty unstressed oak and beech plants.

In the second experiment the plants from the same nursery bed (as in the first experiment) after lifting (end of November) were stored in cold (temperature 2°C, air humidity 90–92%). At the end of February the plants were placed to growth chamber boxes in two days intervals. The boxes 0.85 m long, 0.2 m wide and 0.25 m high were made of 0.5cm tin. These boxes were put to water bath and the bath temperature was automatically maintained at 25°C. The lamp with photosynthetic active light (350 μmol/m^2/s) was installed over the boxes. The light period was 16 hours/day. After 21 days, the electrolyte leakage from taproot, shoots and terminals buds was measured.

The electrolyte leakage from fine roots, taproot and shoots was assessed according to the method described by MCKAY (1992a). Plant material was washed in cold tap water to remove soil and rinsed in deionized water to remove surface ions. Samples of fine roots < 2 mm in diameter were taken randomly from the root system of each plant. The fresh weight was 100 mg. The sample length from taproot and shoots was 2 cm (taproot sample was taken directly under root collar and shoot sample from 3/4 height of plant). Individual samples were put in 40ml universal glass bottles containing 30 ml deionized water of conductivity < 3 μS/cm. The bottles were capped and left at room temperature for 24 h. The bottles were shaken (5×) and the conductivity of bathing solution was measured using the conductivity meter LF 320 with built-in temperature compensation (25°C). The conductivity of 0.01 mol/l solution KCl at 25°C is 1,413 μS/cm. Then the samples were killed in a pressure cooker at 110°C for 10 min. The second conductivity measurement was made 24 h after treatment in the pressure cooker. The total conductivity was:

$$\text{REL/SEL (\%)} = \frac{\textit{conductivity after 24 h}}{\textit{conductivity 24 h after autoclaving}} \cdot 100$$

where: REL – root electrolyte leakage,
SEL – shoot electrolyte leakage.

RESULTS

PROCESS OF ELECTROLYTE LEAKAGE DURING ONE YEAR

Beech

Samples from fine roots, taproot and shoots were used. The electrolyte leakage from fine roots ranged from 23 to 47% during year. The maximum values of electrolyte leakage were detected in May and August (47%). The 23–26% rate of electrolyte leakage was measured in autumn and

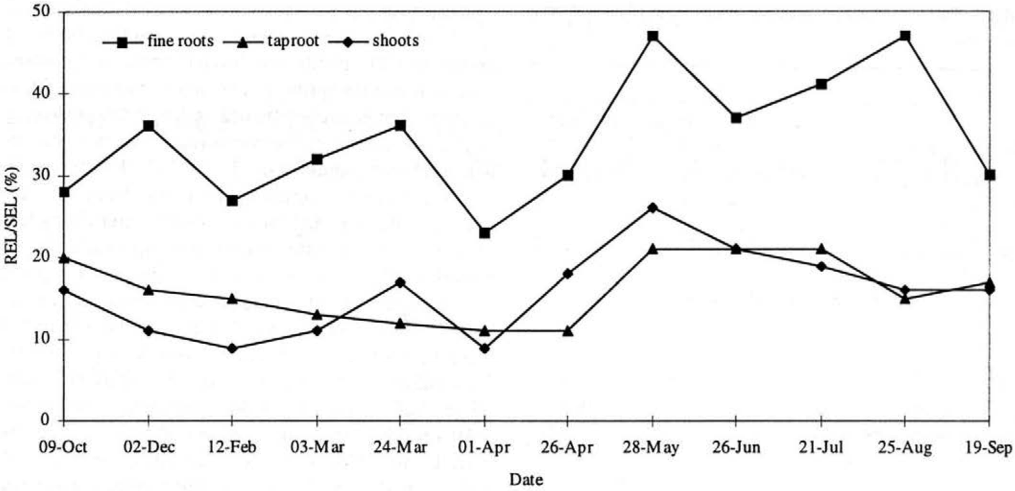

Fig. 1. Electrolyte leakage from beech planting stock during one year

winter. But it is very problematic to determine a universal trend of electrolyte leakage because the values of leakage from fine roots had large amplitudes (Fig. 1).

The electrolyte leakage from taproot and shoots reached their maximum also in vegetation period. The minimum leakage from taproot was found in April (11%) and maximum in summer (21%). The process of electrolyte leakage from shoots was the same as from taproot.

Oak

The same measurements as for beech plants were carried out for oak plants. A small difference was in a part of samples from the root system. The samples from root caps instead of fine roots (lack of fine roots) were used.

The same trend as beech was detected for all three samples (root caps, taproot, shoots – Fig. 2). The maximum value for taproot was 23% and for shoots 21%. The minimum values of electrolyte leakage for shoot (12%) and taproot (11%) were measured on 1 April. The electrolyte leakage from root caps had large amplitudes during one year (12–27%).

CHANGES OF ELECTROLYTE LEAKAGE IN RELATION TO PHYSIOLOGICAL ACTIVITY OF PLANTING STOCK

It is evident from the latter experiment that the physiological activity of planting stock influences the rate of

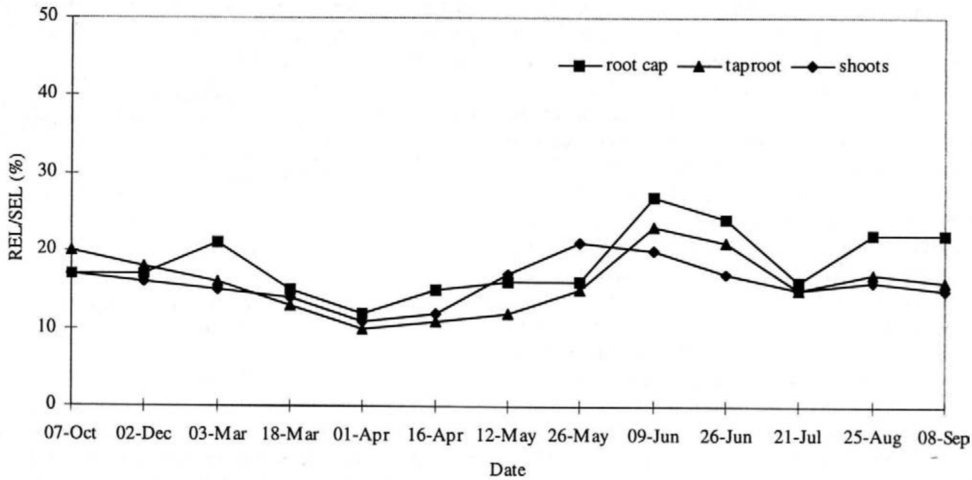

Fig. 2. Electrolyte leakage from oak planting stock during one year

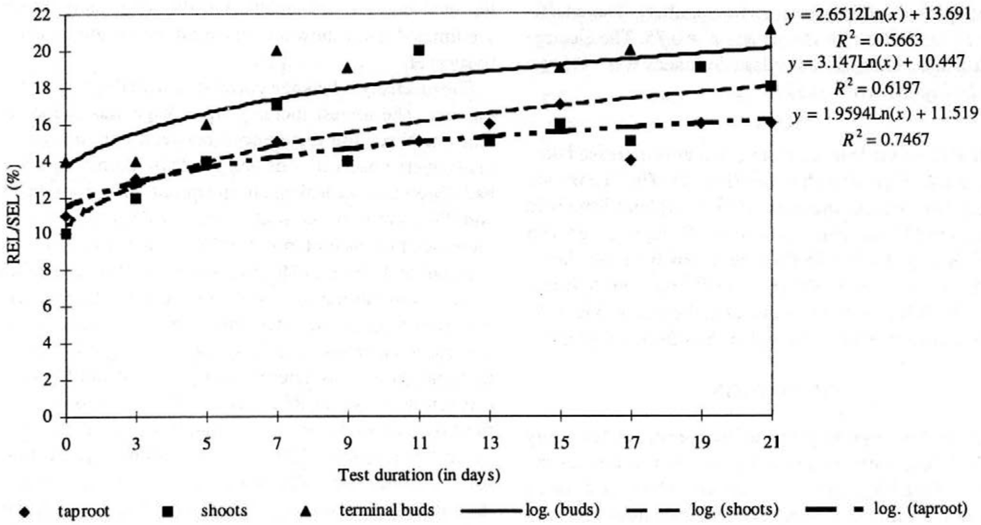

Fig. 3. Electrolyte leakage from beech planting stock placed in to growth chamber for a different time

electrolyte leakage. Therefore another experiment was carried out. The plants were transplanted in to growth chamber in two days intervals and after 21 days the electrolyte leakage was measured. The electrolyte leakage from taproot, shoots and terminal buds was examined.

Beech

The values of electrolyte leakage increased for all three plant parts during the test (Fig. 3).

The correlation between planting stock placed in growth chamber and the values of electrolyte leakage was evaluated by non-linear regression. Very close correlation was found for all parts. The electrolyte leakage from taproot (REL) not placed in growth chamber was 11% and REL after 21 days from samples placed in chamber increased to 16% (coefficient of correlation $r^2 = 0.75$). The value of electrolyte leakage from shoots (SEL) increased from 10% (plants not placed in growth chamber) to 18%

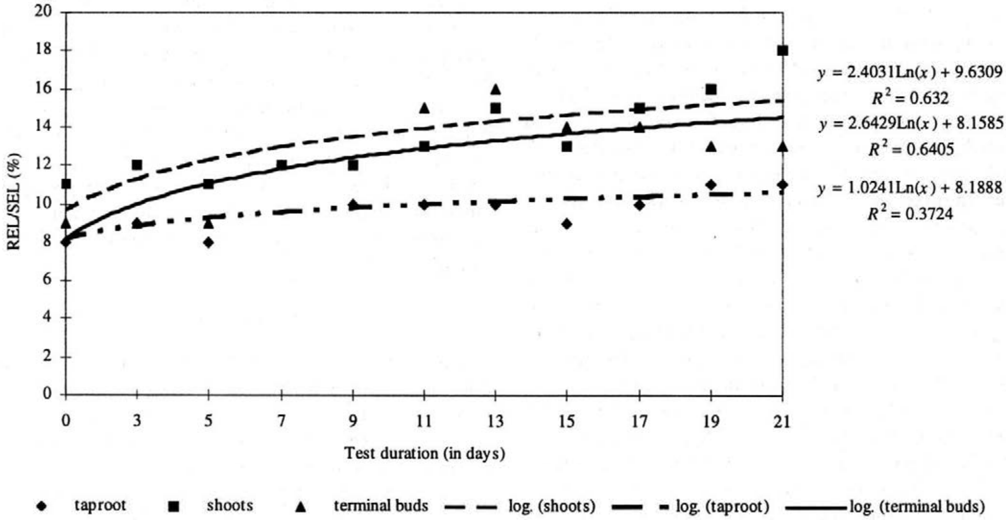

Fig. 4. Electrolyte leakage from oak planting stock placed in to growth chamber for a different time

(plants placed 19 days in growth chamber). The coefficient of correlation for shoots was $r^2 = 0.75$. The electrolyte leakage from terminal buds in dormancy was 14% and after 21 days 21% ($r^2 = 0.57$).

Oak

The electrolyte leakage from oak plants increased during the test in growth chamber (Fig. 4). The electrolyte leakage from taproot increased from 8% (plants from cold storage) to 11% for plants placed for 21 days into growth chamber ($r^2 = 0.37$). The electrolyte leakage from shoots was between 11 and 18% ($r^2 = 0.64$) and from terminal shoots 9–13% ($r^2 = 0.63$). Generally, the electrolyte leakage from beech plants was higher than from oak plants.

DISCUSSION

The trials of physiological quality are changed not only due to different stress factors. The weather influences the growth of seedlings in a forest nursery. The conditions of cold storage affected water content, nutrition and root growth potential (MATTSSON 1997). Therefore the aim of this study was to observe the effect of dormancy on electrolyte leakage from undamaged planting stock.

Electrolyte leakage from unstressed beech and oak planting stock was measured from September 1996 to September 1997. Maximum values of electrolyte leakage for both species were observed in summer. The beech fine roots reached maximum amplitudes of electrolyte leakage (23–47%).

This fact was not caused only by physiological activity. Probably, own prepared fine roots samples for electrolyte leakage measurement could cause their damage and extreme values of electrolyte leakage. On the other hand, this is not a problem with damage of samples when using the samples from taproot. MCEVOY and MCKAY (1997b) described a high rate of electrolyte leakage from fine roots of ash after desiccation. It could be mean a high physiological damage of ash plants. But establishment problems after planting with this species was uncommon in this experiment. Possibly ash and other broadleaved tree species may rely more on the taproot than the fine roots after planting.

The values of electrolyte leakage from taproot increased with the beginning of vegetation period. The planting stock in dormancy reached 11% electrolyte leakage for both species. The maximum values were detected in summer (21%). The process of electrolyte leakage from shoots was the same as from taproot, but generally the values were higher.

These results verify the fact that electrolyte leakage is lowest for planting stock in dormancy and the beginning of physiological activity increases a leakage rate. The beginning and end of vegetation period depend on temperature and therefore there are different annual amplitudes.

In the second experiment, the unstressed planting stock after cold storage was transplanted to growth chamber in two-day intervals and after 21 days the electrolyte measurements from taproot, shoots and terminal buds were carried out. At the same time, the physiological activity of planting stock was visible. The growth of new roots was observed after 12 days and after 18 days the burst of terminal buds in oak plants. On the other hand, beech seedlings did not show any discernible physiological activity at all.

The electrolyte leakage correlated with the duration of the test. The lowest increase of leakage was found for taproot. Next, the differences between oak and beech plants were observed. The oak plants (in dormancy state) had 8% electrolyte leakage from taproot, 11% from shoots and 9% from terminal buds. After 21 days these values increased to 11% for taproot, 18% for shoots and 13% for terminal buds. SCHÜTTE and SARVAŠ (1999) determined negative correlation ($r^2 = -0.97$) between electrolyte leakage from taproot and later regrowth of terminal shoots. The assessed relation of REL and later regrowth of the terminal shoots was determined by 15 frost and 12 desiccation tests. Next, the REL-value of 10–12% was found as the basic values for unstressed planting stock in dormancy. In this range 85–100% of the seedlings are flushing from terminal buds. The analysis of results showed that the physiological activity influence the rate of electrolyte leakage, however the values of electrolyte leakage did not increase significance for oak plants after 21 days in growth chamber. On the other hand, the plants showed visible physiological activity (growth of new roots, buds burst). In this case, handling with planting stock is not recommended.

CONCLUSION

The physiological quality of planting stock plays a very important role for survival and later regrowth of plants. Determination of physiological damage is problematic as it is rarely evident during visual inspection.

These results confirm that it is possible to determine whether the increase of electrolyte leakage rate from taproot is caused by physiological damage or by the physiological activity of planting stock. The increase of electrolyte leakage was slow for taproot. The electrolyte leakage from unstressed oak planting stock began after bud burst. Probably, it is connected with the beginning of photosynthesis. The method of measuring the electrolyte leakage can be used to determine the physiological quality of planting stock. The test can provide precise results within two days. Moreover it is relatively simple, initial and running costs are low, and the method is not very sensitive to changes of the physiological state of undamaged plants.

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Vplyv fyziologickej aktivity na rozsah straty elektrolytu zo sadbového materiálu buka a duba

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ABSTRAKT: V práci bola venovaná pozornosť v dvoch testoch vplyvu fyziologickej aktivity na výšku straty elektrolytu z nestresovaného sadbového materiálu buka (*Fagus sylvatica* L.) a duba (*Quercus robur* L.). V prvom teste bol sadbový materiál vyzdvihovaný v mesačných intervaloch počas jedného roka. Následne po vyzdvihnutí bola zisťovaná strata elektrolytu z koreňového systému a stonky. V druhom experimente bol sadbový materiál presadzený v dvojdňových intervaloch do rastovej komory. Strata elektrolytu bola následne zisťovaná z hlavného koreňa, stonky a terminálneho púčika 21 dní po umiestnení prvej vzorky do rastovej komory. Rozbor dosiahnutých výsledkov preukázal vplyv fyziologickej aktivity na rozsah straty elektrolytu. Bolo však možné určiť, či zvýšenie straty elektrolytu z hlavného koreňa bolo zapríčinené fyziologickým poškodením alebo fyziologickou aktivitou sadbového materiálu.

Kľúčové slová: dubový a bukový sadbový materiál; fyziologická aktivita; fyziologická kvalita; hlavný koreň; strata elektrolytu

Kvalita sadbového materiálu spolu s dodržaním technologických postupov zalesňovania má rozhodujúcu úlohu pri úspešnosti obnovy lesa. Sadbový materiál po vysadení trpí šokom z presadenia, a preto je potrebné používať pri zakladaní a obnove lesa len vysokokvalitný sadbový materiál. Samotné určenie pojmu kvalita sadbového materiálu je ale problematické a taktiež sa menia a neustále vyvíjajú metódy a spôsoby jej zisťovania.

Vo všeobecnosti je možné rozumieť pod pojmom kvality sadbového materiálu súhrn genetických, morfologických a fyziologických znakov. Splnenie a kontrola genetickej a morfologickej kvality je prepracovaná na prevádzkovej úrovni. Pri genetickej kvalite je to vylíšenie jednotlivých semenárskych oblastí a dodržiavanie zásad horizontálneho a vertikálneho prenosu semena a sadeníc. Morfologická kvalita sa určuje hlavne na základe pomeru nadzemnej a podzemnej časti, vyspelosti koreňového systému a podielu jemných koreňov. Určenie fyziologickej kvality predstavuje najkomplikovanejšiu zložku celkového určenia kvality sadbového materiálu. Fyziologické poškodenie nie je možné určiť vizuálne a vo väčšine prípadov sa prejaví až po výsadbe.

Ďalším problémom je, že na ukazovatele fyziologickej kvality vplývajú okrem rozsahu samotného poškodenia aj ďalšie faktory (stupeň dormancie, spôsob skladovania, výživa atď.). Preto je možné väčšinu metód určených na zisťovanie fyziologickej kvality sadbového materiálu použiť len pri špecifických stresových podmienkach (meranie obsahu vody – zistenie poškodenia suchom, nesprávny režim skladovania v klimatizovanom sklade). Metódy, ktoré poskytujú informácie o celkovej vitalite (metóda rastového potenciálu koreňov, test vitality podľa OSC), sú časovo veľmi náročné, vlastná interpretácia výsledkov je komplikovaná a na uskutočnenie týchto testov je potrebné mať k dispozícii dostatočne vybavené laboratórium.

Cieľom práce bolo overiť vplyv fyziologickej aktivity na presnosť metódy merania straty elektrolytu pri drevinách buk a dub. Pozornosť sa kládla na to, či ukončenie, respektíve nástup dormancie môže zvýšiť výšku straty elektrolytu, čo by mohlo viesť k nesprávnemu diagnostikovaniu úrovne kvality sadbového materiálu.

Na testovanie sa použil voľnokorenný sadbový materiál buka a duba. Počas jedného roka sa v mesačných intervaloch (v jarnom období v dvojtýždňových) uskutočnilo meranie straty elektrolytu z 20 kusov nestresovaného voľnokorenného sadbového materiálu priamo po vyzdvihnutí zo záhona lesnej škôlky. V druhej časti pokusu bol sadbový materiál v jesennom období (koncom novembra) uskladnený do klimatizovaného skladu (teplota 2 °C, vlhkosť vzduchu 90–92 %) a koncom februára bolo v dvojdňových intervaloch presadených 20 sadeníc do rastovej komory. Teplota v komore bola automaticky udržiavaná na úrovni 25 °C, vlhkosť vzduchu bola 75 % a fotoperióda 16 h s fotónovou hustotou 350 μmol/m^2/s. Následne sa 21 dní po presadení prvej vzorky do rastovej komory uskutočnilo meranie straty elektrolytu z hlavného koreňa, stonky a terminálneho púčika. Na testovanie bola použitá výberová vzorka z rovnakého materiálu, aký bol použitý pri predchádzajúcom pokuse.

Strata elektrolytu bola určovaná z koreňových vláskov (hmotnosť 1 g), hlavného koreňa (2 cm, odobratý pod koreňovým krčkom), zo stonky (2 cm z hornej tretiny stonky) a z terminálneho púčika. Pre nedostatok koreňových vláskov pri dube boli použité vzorky z koreňovej čiapočky. Z dosiahnutých výsledkov merania straty elektrolytu počas roka pri prvom teste je zrejmé, že fyziologická aktivita sadbového materiálu vplýva na vyšší rozsah straty elektrolytu. Maximálne hodnoty straty elektrolytu boli zaznamenané v letnom období – *buk*: koreňové vlásky 47 %, hlavný koreň 21 % a stonka 26 %, *dub*: koreňová čiapočka 27 %, hlavný koreň 23 % a stonka 21 %. Naproti tomu minimálne hodnoty boli namerané pri oboch drevinách 1. apríla – *buk*: koreňové vlásky 23 %, hlavný koreň 11 % a stonka 9 %, *dub*: koreňová čiapočka 13 %, hlavný koreň 11 % a stonka 12 %.

Na základe výsledkov dosiahnutých pri druhom teste so sadbovým materiálom umiestneným rozdielne dlhý čas v rastovej komore je možné konštatovať, že k prudkému zvýšeniu straty elektrolytu z hlavného koreňa dochádza až po dlhšom časovom období (11 % sadbový materiál buka v dormantom stave, 16 % sadbový materiál po 21 dňoch v rastovej komore a pri dube sa strata elektrolytu zvýšila z 8 % pri sadbovom materiáli v dormantnom stave na úroveň 11 % pri materiáli po 21 dňoch v rastovej komore). Pri dube bolo možné pozorovať po 21 dňoch optické prejavy fyziologickej aktivity (pučanie a rast nových koreňov). Sadenice buka neprejavili viditeľné znaky ukončenia dormancie.

Tieto výsledky ukazujú, že je možné určiť, či na zvýšenú stratu elektrolytu z hlavného koreňa má vplyv fyziologické poškodenie sadbového materiálu alebo jeho aktivita. Metóda založená na meraní straty elektrolytu z koreňového systému (hlavného koreňa) je rýchla, jednoduchá a finančne nenáročná, nie je vo veľkom rozsahu senzitívna na zmeny vo fyziologickom stave nestresovaného materiálu testovaných drevín a jej použitím je možné určiť fyziologické poškodenie sadbového materiálu.

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Qualitative and value structure of timber from salvage fellings in protective forests

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ABSTRACT: Methodology of qualitative and quantitative analysis of timber from salvage felling is presented on sample trees. The results of analysis by means of mathematico-statistical methods were generalized in the model of the distribution of diameter classes and assortment structure. Input parameters are namely diameter $d_{1.3}$, volume and tree species composition. Estimation of the assortments and orientation calculation of the costs and profit is a part of the work in the case of timber processing within stand sanitation.

Keywords: protective forests; diameter classes; mathematico-statistical methods; value analysis

Protective forests are usually situated at exposed sites and timberline and thus they are subjected more to wind and snow calamities. Recently they have been attacked locally by bark beetles as the upper isotherm of regular occurrence of bark beetles has been rising due to global warming. It is about 1,400–1,500 m above sea level at present.

Management and technical-management measures are planned for protective forests only minimally and they are not planned in nature reserves at all. In compliance with valid legislation the human activities in national nature reserves and natural reserves are limited to some exceptions permitted after judgement and acceptance in commission.

Resulting situation must be judged not only from ecological aspects but also from time aspects and spatial technological-economic aspects. Unprocessed timber from salvage felling, particularly a greater volume of timber, restricts fulfilment of other functions of protective forests and it can be a potential source of infestation which can endanger also adjacent forest complexes.

Methods of qualitative and quantitative analysis of salvage felling timber, analysis of the structure of assortments, valuation of assortments and extrapolation of the results for the whole estimated volume of salvage felling timber are presented on sample trees. Orientation calculation of costs and profit in the case of timber monetization within stand sanitation is also presented.

DESCRIPTION OF RESEARCH PLOTS AND METHODS

In solving the problems within the research of Grant project *Theoretical and Practical Presuppositions of the Intensification of Cableways Utilization in the Forestry of Slovakia* 1/7050/20 (GL 1020) three research plots were established in the National Nature Reserve Poľana, particularly in the area of Zadná Poľana and Hrončekov grúň at the altitude 950–1,250 m. The plots are border zones of a great disaster that occurred in Čierny Balog in 1996. Description of stands on particular plots, mensurational indices and tree species composition are given in Tables 1 and 2.

The plots of the size 25 × 25 m or 50 × 50 m were considered formerly. As the trees were thrown in various directions and crossed over each other it was impossible to make accurate demarcation of these plots. Therefore a sample tree method was used with the proportional number of sample trees according to estimated tree species composition.

Lying trees from calamity were fully callipered and timber volume and frequencies in diameter classes were determined. These data were used as a basic set for comparison with the model of sample tree method.

The number of sample trees was determined according to the formula:

$$n = (z_{\alpha} \cdot s_x / \Delta)^2$$

where: n – number,

z_{α} – for $\alpha = 0.05$ it equals 1.96,

s_x – expected variation range of the proportion of assortments is 90% – interval < 5; 95 >, then we can estimate $s_x = 15$,

Δ – required accuracy 5%.

Then $n = (1.96 \cdot 15/5)^2 = 35$ sample trees.

Field works

- reconnaissance of terrain and sighting of plot, estimating salvage felling timber volume;
- determination of basic mensurational indices – tree spe-

Table 1. Description of forest stands

Research plot	1		2	3	
Forest stand	224 a	225 a	106	300	301
Forest management unit	55	55	55	55	55
Operating unit	511 22	411 22	511 22	513 22	511 22
Stand area (hectare)	11.45	16.6	14.99	15.89	14.11
Storey age – I.st./II.st. (years)	160/55	165/65	160/60	135	125
Slope (%)	45	55	65	35	8
Stand density – I.st./II.st.	7/3	5/3	6/2	7	5
Skidding distance (m)	300	550	440	500	500

cies composition, stocking, diameter and height of stand on a plot affected by disaster and surrounding stand;

- full callipering – all lying trees were fully callipered at breast height;
- selection of sample trees, accurate sighting of the diameter and length for the determination of the volume of assortments. Sample trees should cover tree species and diameter structure. Assortments were determined particularly on the basis of external errors, place of fictitious cut was marked with chalk on the tree. Stems were cut only when the assortments could not be sorted unanimously (minimization of anthropogenic activity in a national nature reserve). The length was measured with 10 cm accuracy, diameter $d_{1/2}$ with 1 cm accuracy. In the determination of assortments the incipient fungal attack of timber was not considered as the measurements were conducted one year after the calamity. For stem length and the length of the first cut the part of stem cut at a safe distance from the rootball was not considered.

Office works

- drawing the plot into the map and determining the area;
- determining the volume of growing stock – callipered trees according to weight curves, assortments according to volume tables;
- calculation of the proportion of the volume of assortments in per cent;
- data processing by mathematico-statistical methods: regression analysis, analysis of variance, frequencies and correlation coefficients.

DATA ANALYSIS AND RESULTS

SMOOTHING THE PROPORTIONS OF ASSORTMENTS BY REGRESSION ANALYSIS

The proportions of assortments in per cent were processed by regression analysis. The procedure was similar to the construction of assortment tables (PETRÁŠ, NOCIAR 1991). At first the proportion of assortments was smoothed according to diameter $d_{1.3}$ in quality class I, then quality class I and II together, then together I, II and IIIA, I, II, IIIA and IIIB, I, II, IIIA, IIIB and V. The rest is class VI. Equations of the respective classes II, IIIA, IIIB and V are differences between corresponding aggregate equations.

Note: examples of logs in quality classes:

I – wood for sounding-boards, sliced veneer logs, minimal top diameter 40 cm – spruce, fir, 35 cm – pine, larch, Douglas fir.

II – rotary veneer logs.

III – hardwood and softwood sawlogs, A – high quality, B – low quality.

IV – mining timber, groundwood.

VI – fuelwood.

Following types of regression equations were used:

$$y = a_0 + a_1 . x \quad (1)$$

$$y = a_0 + a_1 . x^{a2} \quad (2)$$

Regression coefficients of equations and correlation indices – R, of linear functions are presented in Table 3 and coefficients and indices of power functions in Table 4a,b.

Table 2. Mensurational data of timber from salvage felling

Research plot	Tree species	Mensurational data				
		Ø $d_{1.3}$ (cm)	distance d_{min}–d_{max} (cm)	Ø height (m)	Ø volume (m³)	composition (%)
1	beech	56	29–86	36	5.16	52
	fir	68	49–93	40	6.54	20
	maple	49	33–68	32	3.32	28
2	beech	52	22–77	34	3.99	50
	fir	60	38–89	36	4.62	50
3	ash	43	26–67	29	3.39	100

Table 3. Coefficients of linear regression equations

Quality classes	beech a_0	beech a_1	beech R	fir a_0	fir a_1	fir R	maple a_0	maple a_1	maple R	ash a_0	ash a_1	ash R
I										−12.97	0.472	0.75
II	13.01	−0.180	0.52							32.74	−0.243	0.82
IIIA	32.97	−0.212	0.87	37.38	−0.385	0.92	15.35	0.164	0.76	30.65	−0.207	0.85
IIIB	22.56	0.250	0.77	47.60	0.372	0.87	26.24	0.246	0.89	4.46	0.374	0.97
V	22.27	0.235	0.94	7.32	0.084	0.58	51.71	−0.338	0.92	37.48	−0.311	0.84
VI	9.20	−0.093	0.93	7.70	−0.071	0.94	6.69	−0.073	0.94	7.64	−0.085	0.97
Σ	100.00	0.000		100.00	0.000		100.00	0.000		100.00	0.000	

The trend of the assortments in per cent in dependence on diameter $d_{1.3}$ smoothed by linear regression functions is given in Figs. 1–4. For comparison the dependence of beech smoothed by power function is given in Fig. 5.

The proportion of high quality assortments is decreasing with increasing diameter (volume of tree is growing more quickly than the volume of high quality assortments). Subdominant or suppressed trees have better cleaning of stems in comparison with co-dominant and dominant trees, less overgrown burls, rot and ingenuine heartwood. All tree species have the core of assortments in quality classes II and IIIB.

It is obvious from the coefficients of regression equations and correlation indexes as well as from visual assessment in Figs. 1 and 5 that there is no difference between linear regression functions and power regression functions. With the following analyses it is possible to use the results of linear equations without statistically significant distortion.

The greatest difference between linear and power function – ash IIIA is shown by the testing statistic $F = (RSE_l - RSE_m) / (RSE_m / (n-2)) = (37.77-31.12)/(31.12/(17-2)) = 3.21$ lower than $F_{0.005} = 4.54$

where: RSE_l – residual sum of the squares of linear equation,
RSE_m – residual sum of the squares of power equation,
n – 17 sample trees,
$RSE_m/(n-2) = \sigma^2$ of power equation.

DETERMINATION OF FREQUENCIES IN DIAMETER CLASSES

The distribution of frequencies in diameter classes is mostly left-sided for the stands. In the case of calamity or when the whole variation range of diameters is not observed, it can be replaced by normal distribution (in calamity thinner and very thin trees of the second or third storey remain to stand or they are not important in view of timber monetization).

Actual and hypothetical frequencies are given in Table 5. Distribution agreement was tested by means of statistical characteristics (KLEIN et al. 1998):

$$\chi^2 = \sum \frac{(ns_i - nn_i)^2}{nn_i} \qquad (3)$$

where: ns_i – actual frequency in diameter class i,
nn_i – normal (hypothetical) frequency in diameter class i.

Beech $(\chi^2_{calc} = 7.40) < (\chi^2_{0.05} = 15.5)$
Fir $(\chi^2_{calc} = 3.44) < (\chi^2_{0.05} = 12.6)$
Maple $(\chi^2_{calc} = 6.50) < (\chi^2_{0.05} = 7.8)$
Ash $(\chi^2_{calc} = 7.76) < (\chi^2_{0.05} = 9.5)$

The distribution of frequencies can be considered normal for all tree species with 95% probability. The course of distribution is illustrated in Fig. 6. Visual effect has appeared mainly for tree species with higher proportions, with total number over 30. Maple has U distribution but

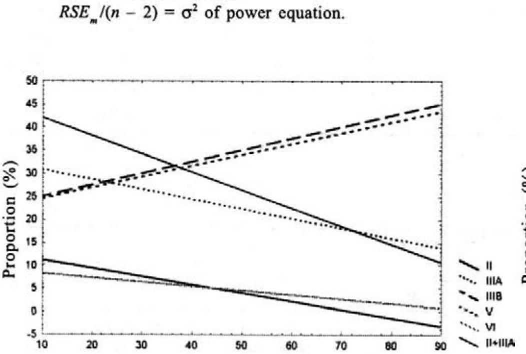

Fig. 1. Relationship between the proportion of assortments in per cent and diameter $d_{1.3}$ – beech
Note: Assortments with qualitative parameters of class II, diameter $d_{1.3} > 70$ cm, are included in class IIIA according to the standard

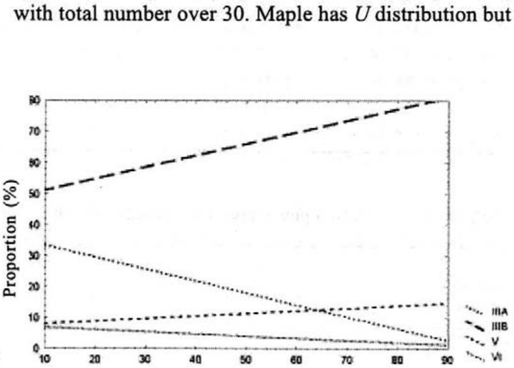

Fig. 2. Relationship between the proportion of assortments in per cent and diameter $d_{1.3}$ – fir

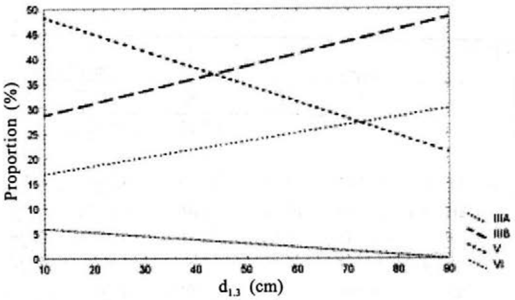

Fig. 3. Relationship between the proportion of assortments in per cent and diameter $d_{1.3}$ – maple

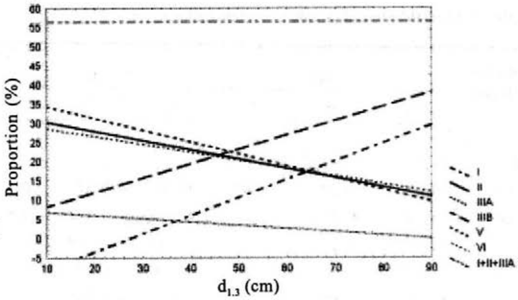

Fig. 4. Relationship between the proportion of assortments in per cent and diameter $d_{1.3}$ – ash

Note: Assortments with qualitative parameters of class I, diameter $d_{1.3} < 30$ cm, are included in class II according to the standard and assortments with qualitative parameters of class II with diameter $d_{1.3} < 20$ cm are included in class IIIA according to the standard

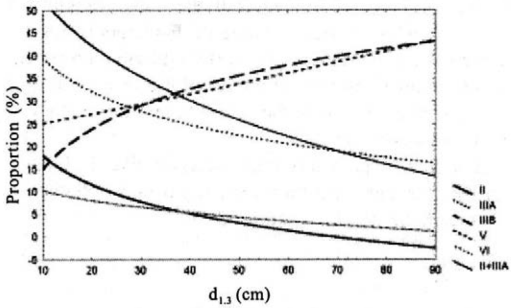

Fig. 5. Relationship between the proportion of assortments in per cent and diameter $d_{1.3}$ – beech

low frequencies that would also be very probably visually normal with higher total number.

VALUE ANALYSIS

Timber from salvage felling is more damaged, can be processed with greater difficulties and there are objective problems with its sale and setting market price (supply higher than demand). Maximally unfavourable situation was considered for valuation and broadleaved assortments of quality class I, II and IIIA were grouped together and valued as assortments of quality class IIIA.

Table 4a. Coefficients of power regression equations (beech, fir)

Quality classes	Tree species							
	beech				fir			
	a_0	a_1	a_2	R	a_0	a_1	a_2	R
I								
II	4,783.57	–4,743.622	0.00195	0.54				
IIIA	–1,833.54	1,897.252	–0.00569	0.87	77.94	–13.968	0.37209	0.93
IIIB	–3,788.06	3,773.813	0.00335	0.79	–2,623.46	2,599.969	0.00868	0.88
V	23.53	0.132	1.11481	0.94	8.41	0.008	1.50771	0.61
VI	18.10	–3.448	0.35217	0.94	–80.18	103.872	–0.05336	0.95

Table 4b. Coefficients of power regression equations (maple, ash)

Quality classes	Tree species							
	maple				ash			
	a_0	a_1	a_2	R	a_0	a_1	a_2	R
I					–24.44	124.181	–0.29052	0.77
II					–266.29	331.784	–0.03743	0.83
IIIA	–2,302.40	2,294.397	0.00352	0.77	4,035.07	–3,978.346	0.00235	0.88
IIIB	10.84	5.046	0.43726	0.89	6.07	0.223	1.10899	0.97
V	23.18	2,893.674	–1.43448	0.94	–47.18	148.129	–0.19663	0.86
VI	–343.93	360.825	–0.01008	0.94	–222.94	241.342	–0.01651	0.97

Table 5. Distribution of frequencies in diameter classes

Diameter classes		Tree species											
Class	Distance (cm)	beech			fir			maple			ash		
		nn_i	ns_i	*dif.*	nn_i	ns_i	*dif.*	nn_i	ns_i	*dif.*	nn_i	ns_i	*dif.*
1	10–19	1	–	–1	–	–	–	–	–	–	–	–	–
2	20–29	2	4	2	–	–	–	–	–	–	3	4	1
3	30–39	6	8	2	1	1	0	3	6	3	11	12	1
4	40–49	11	11	0	4	7	3	6	3	–3	18	12	–6
5	50–59	14	11	–3	8	8	0	6	4	–2	11	11	0
6	60–69	11	10	–1	9	7	–2	3	5	2	3	7	4
7	70–79	6	6	–0	8	6	–2	–	–	–	–	–	–
8	80–89	2	4	2	4	5	1	–	–	–	–	–	–
9	90–99	1	–	–1	1	1	0	–	–	–	–	–	–
Σ		54	54		35	35		18	18		46	46	

Note: only 6 classes are used for timber sorting, diameters above 60 cm are included in class 6

A negative difference in the price of assortments IIIA in comparison with I and II with their relative low proportion in total volume is insignificant in contrast with possible devaluation of timber in connection with the mentioned objective problems in the sale of ash and beech assortments of quality class I and II.

The proportions of assortments calculated from the model structure are given in Tabs. 6 and 7. They correspond with the proportions given in stand assortment tables.

For the illustration only some characteristic examples are given:

Beech, age 160 years, $d_{1.3}$ 54 cm, quality of stand 100% B, damage 30%				
Quality classes	I + II + IIIA	IIIB	V	VI
% according to model	25	36	35	4
% according to assortment tables	24	35	39	2
Beech, age 160 years, $d_{1.3}$ 60 cm, quality of stand 100% B, damage 30%				
Quality classes	I + II + IIIA	IIIB	V	VI
% according to model	30	33	32	5
% according to assortment tables	33	31	34	2
Fir, age 160 years, $d_{1.3}$ 60 cm, quality of stand 20% B, 80% C, damage 40%				
Quality classes	I + II + IIIA	IIIB	V	VI
% according to model	15	70	12	3
% according to assortment tables	15	71	13	1
Fir, age 160 years, $d_{1.3}$ 40 cm, quality of stand 20% B, 80% C, damage 40%				
Quality classes	I + II + IIIA	IIIB	V	VI
% according to model	22	62	11	5
% according to assortment tables	25	59	16	1

A higher proportion of assortments in quality class VI is typical of calamity, particularly of split and broken parts of stems.

A price list for timber 052 – products of timber felling valid since 1 January 1998 in the state enterprise Stredoslovenské lesy Banská Bystrica was used for valuation. The prices correspond to mean prices of realized sales of raw timber for the I[st] quarter of 1999 (BREZINOVÁ 1999).

CALCULATION OF PRICE, COSTS AND PROFIT PER 1 M^3

A. Calculation of mean price in SKK/m^3 according to tree species, proportion of assortments in diameter classes (analytical from regression equations – Table 3 and 6) and distribution of frequencies in diameter classes (Fig. 6, Table 7).

Tree Ø $d_{1.3}$	Indexes of the proportions of assortments in classes / Price of assortments in SKK/m^3				
	I + II + IIIA	IIIB	V	VI	Ø SKK/m^3
Beech	0.25	0.36	0.35	0.04	
Ø $d_{1.3}$ = 54 cm	1,900	1,650	780	450	1,360
Fir	0.15	0.70	0.12	0.03	
Ø $d_{1.3}$ = 60 cm	2,100	1,550	780	260	1,500
Maple	0.24	0.38	0.35	0.03	
Ø $d_{1.3}$ = 50 cm	2,250	2,200	780	450	1,660
Ash	0.51	0.20	0.25	0.04	
Ø $d_{1.3}$ = 40 cm	2,250	2,000	780	450	1,760

B. Estimation of maximal total costs of timber processing at given localities and estimation of net profit per 1 m^3. As the calamity occurred in the territory of a national nature reserve, more friendly processing is considered as well as the use of combined technology – cable system + wheeled forest tractor for skidding.

Working phase	Ø costs in SKK/m^3
Felling	70
Cableway skidding	340
Hauling by forest wheeled tractor	200
Transport	60
Handling at log yard	30
Together	700 SKK/m^3

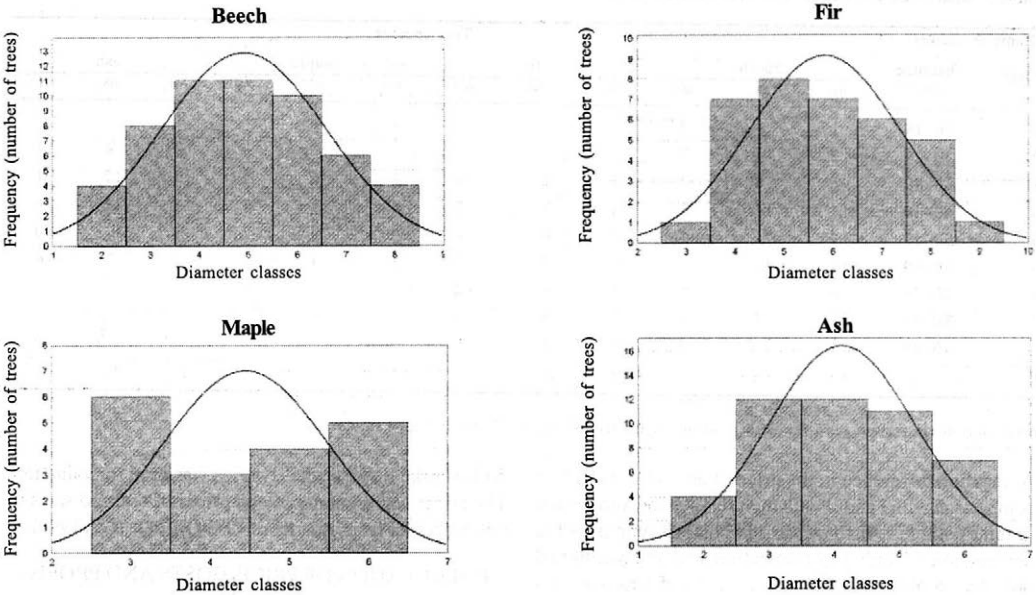

Fig. 6. Distribution of frequencies in diameter classes

Table 6. The model of assortment qualitative classes distribution

Diameter (cm)	Beech				Fir			
	qualitative classes distribution (%)				qualitative classes distribution (%)			
	II+IIIA	IIIB	V	VI	IIIA	IIIB	V	VI
10	42.06	25.06	24.62	8.27	33.53	51.32	8.16	6.99
20	38.14	27.56	26.97	7.34	29.68	55.04	9.00	6.28
30	34.22	30.06	29.32	6.41	25.83	58.76	9.84	5.57
40	30.30	32.56	31.67	5.48	21.98	62.48	10.68	4.86
50	26.38	35.06	34.02	4.55	18.13	66.20	11.52	4.15
60	22.46	37.56	36.37	3.62	14.28	69.92	12.36	3.44
70	18.54	40.06	38.72	2.69	10.43	73.64	13.20	2.73
80	14.62	42.56	41.07	1.76	6.58	77.36	14.04	2.02
90	10.70	45.06	43.42	0.83	2.73	81.08	14.88	1.31
100	6.78	47.56	45.77	0.00	0.00	85.92	15.72	0.60
Diameter (cm)	Maple				Ash			
	qualitative classes distribution (%)				qualitative classes distribution (%)			
	II+IIIA	IIIB	V	VI	IIIA	IIIB	V	VI
10	16.99	28.70	48.33	5.96	50.64	8.20	34.37	6.79
20	18.63	31.16	44.95	5.23	50.86	11.94	31.26	5.94
30	20.27	33.62	41.57	4.50	51.08	15.68	28.15	5.09
40	21.91	36.08	38.19	3.77	51.30	19.42	25.04	4.24
50	23.55	38.54	34.81	3.04	51.52	23.16	21.93	3.39
60	25.19	41.00	31.43	2.31	51.74	26.90	18.82	2.54
70	26.83	43.46	28.05	1.58	51.96	30.64	15.71	1.69
80	28.47	45.92	24.67	0.85	52.18	34.38	12.60	0.84
90	30.11	48.38	21.29	0.12	52.40	38.12	9.48	0.00
100	31.75	50.84	17.31	0.00	52.62	41.86	5.52	0.00

Table 7. The model of frequency distribution in diameter classes

Frequency distribution in diameter classes around $d_{1.3}$ (%)				
$d_{1.3}$ (cm)	beech	fir	maple	ash
–40	1.9	0.0	0.0	0.0
–30	3.7	2.9	5.0	2.1
–20	11.1	11.4	9.8	6.3
–10	20.4	22.9	19.5	25.0
$Ød_{1.3}$	25.8	25.6	34.1	33.2
10	20.4	22.9	19.5	25.0
20	11.1	11.4	9.8	6.3
30	3.7	2.9	5.0	2.1
40	1.9	0.0	0.0	0.0

Higher costs of processing, particularly logging and skidding by cableway, are also included, in the estimate of costs.

Net profit according to tree species: beech – 660 SKK/m^3, fir – 800 SKK/m^3, maple – 960 SKK/m^3, ash – 1,060 SKK/m^3.

The estimate of net profit in SKK/m^3 is minimal and real as minimal sale prices and maximal costs of timber processing were considered.

C. Comparison of the results of models with exact calculation. Regarding the range of works the results are processed in tables. Exact volume, structure of assortments and optimal application of their prices are given in Table 8, estimate according to the model in Table 9.

Estimated prices are lower than for optimal monetization of timber assortments, total loss is about 16% and it is caused mainly by unification of potential ash assortments of quality class I, II and IIIA into estimated volume of quality class IIIA. From practical aspects it is difficult to realize the sales of the assortments of quality class I and II purposefully or immediately (ad hoc) whereas timber can be devalued by storing or waiting for a more advantageous situation at the market.

DISCUSSION AND CONCLUSION

Processing of timber from salvage felling in a national nature reserve is a very frequently discussed issue by the professional community. At the beginning it is stated that there is a discrepancy between strict interests of nature protection and ecology, and possible negative consequences of not processing the calamity for the sanitary and health conditions and functions of surrounding forest complexes. At present biosystems and ecosystems are subjected to heavy anthropogenic activities that in the case of damage by biotic or abiotic agents require the assistance of man, it means investments of human energy for their further development (BORTEL 1999; KOREŇ 1997).

Methodology of estimating the volume and structure of salvage felling assortments on the basis of the selection of sample trees by means of standard mathematico-statistical methods is presented. Volume and proportions of assortments were determined on sample trees. The distribution of qualitative classes of assortments was defined by means of regression analysis in relation to diameter $d_{1.3}$. The diameter has a statistically significant effect on the proportion of all assortments in each tree species. As the improvement of testing criteria of nonlinear equations is insignificant in comparison with linear equations and as both types of equations have practically the same course in the interval of $d_{1.3}$ values that are important for timber evaluation and processing, linear equations were used in the models.

Model structure of the density of frequency distribution in diameter classes with normal distribution $N(d_{1.3}, s_x^2)$ was derived from the diameter $d_{1.3}$ and dispersion s_x^2. Possibility of replacement of left-sided distribution by normal distribution is reasoned in part *Determination of frequencies in diameter classes.*

The mentioned model has input data or parameters as follows:

– tree species composition,

– $Ød_{1.3}$, $Øh$, $Ød_{1/2} \Rightarrow Ø$ m^3/stem.

(As mentioned above, the data will be obtained by selection methods on sample trees.)

The distribution of qualitative classes of assortments will be calculated (Table 6) according to $Ød_{1.3}$ (Table 3). Indexes of the proportion of assortments in qualitative classes will be determined by means of the model of relative frequencies in diameter classes in dependence on $Ød_{1.3}$ (Table 7). Estimated price according to tree species in SKK/m^3 is as follows:

Table 8. Exactly calculated volume and price of assortments

	Beech		Fir		Maple		Ash		Total	
	(m^3)	SKK	(m^3)	SKK	(m^3)	SKK	(m^3)	SKK	(m^3)	SKK
I	0.00	0	0.00	0	0.00	0	19.62	175,392	19.62	175,392
II	4.50	18,718	0.00	0	0.00	0	33.95	182,501	38.45	201,219
IIIA	48.48	85,293	19.88	41,944	14.38	30,123	32.60	71,598	115.34	228,958
IIIB	94.85	158,409	140.35	210,427	23.52	50,773	38.78	75,508	297.50	495,117
V	93.95	73,467	25.85	20,059	20.05	15,684	35.11	27,456	174.96	136,666
VI	9.63	4,403	4.82	1,267	1.53	696	5.21	2,376	21.19	8,742
Σ	251.41	340,290	190.90	273,697	59.48	97,276	165.27	534,831	667.06	1,246,094

Table 9. Estimated volume and price of assortments

	Beech	Fir	Maple	Ash	Total
Tree volume (m^3)	4.73	5.55	3.49	3.48	
Number of trees (pcs)	54	37	18	47	
Total volume (m^3)	255	206	63	164	687
Costs/m^3 (SKK/m^3)	1,360	1,500	1,660	1,760	
Total costs (SKK)	347,371	308,269	104,153	288,109	1,047,902

$$Co_j = \Sigma (I_{ij} . Ca_{ij}) \qquad (4)$$

where: I_{ij} – index of the proportion of *i*-th quality class of *j*-th tree species,

Ca_{ij} – actual price of the assortments of *i*-th quality class of *j*-th tree species (SKK/m^3),

i – is 1 (for quality classes I, II, III, IIIA), 2 (for quality class IIIB), ...

j – tree species number 1, 2, ...

The difference in actual prices within quality classes in dependence on diameter classes will be determined by calculating the weighted mean price of quality class of the respective tree species where relative frequencies are weights.

The volume of total timber from salvage felling according to tree species can be estimated from the number of trees and their volume (for smaller disasters) from tree species composition, estimated area of salvage felling and mensurational indices of mean stem according to the tables of the number of trees per hectare or from growth tables.

The estimate of total sales according to tree species in SKK is as follows:

$$\Sigma (V_j . C_{oj}) \qquad (5)$$

where: V_j – total volume of *j*-th tree species (m^3),

Co_j – estimated price of *j*-th tree species (SKK/m^3),

j – tree species number 1, 2, ...

It is necessary to consider also the market mechanism of supply and demand for estimation (part *Value analysis*). In the case of disaster the prices of consumers will probably be lower than in a standard situation.

Finally, we can state that the construction of the model verified by exact measurements and by the calculation of prices is relatively very simple. It creates preconditions for its broad application in practice. It is quite exact for balancing the costs and sales in processing the timber from natural disaster. Another advantage is modularity of the system of processing model parameters. The model is less dependent on the structure of input data, which extends possibilities of model application to solve analogous problems.

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Kvalitatívna a hodnotová štruktúra dreva z kalamít v ochranných lesoch

ABSTRAKT: V práci je uvedená metóda kvalitatívneho a kvantitatívneho rozboru drevnej hmoty z kalamity na vybraných vzorníkoch. Výsledky analýzy matematicko-štatistickými metódami sa zovšeobecnili ako model rozdelenia hrúbkových tried a štruktúry sortimentov. Vstupné parametre modelu sú priemerný $d_{1,3}$, objemovosť a drevinové zloženie. Súčasťou práce je aj odhad ocenenia sortimentov a orientačná kalkulácia nákladov a zisku v prípade zhodnotenia drevnej hmoty v rámci sanácie porastu.

Kľúčové slová: ochranné lesy; hrúbkové triedy; matematicko-štatistické metódy; hodnotová analýza

Možnosť spracovania kalamity v národných prírodných rezerváciách a prírodných rezerváciách (NPR a PR) je problematická otázka vzhľadom k rozporu medzi záujmami ochrany a ekológie a možnými negatívnymi dôsledkami nespracovania kalamity na hygienu a zdravotnú a funkčnú kondíciu okolitých komplexov lesa. V súčasnosti sú biosystémy a ekosystémy natoľko poznačené antropogénnou činnosťou, že si v prípade poškodenia biotickými, resp. abiotickými činiteľmi vyžadujú pomoc človeka, t.j. vloženie ľudskej energie do ich ďalšieho vývoja.

V práci je uvedená metodika odhadu objemu a štruktúry sortimentov dreva z kalamity na základe výberu vzorníkov pomocou štandardných matematicko-štatistických metód. Počas výskumu boli založené tri výskumné plochy v NPR Poľana v nadmorskej výške 950–1 250 m n. m. Ide o okrajové pásma veľkej kalamity na Čiernom Balogu z roku 1996. Na vybratých vzorníkoch sa určili objemy a podiely sortimentov. Regresnou analýzou sa definovalo zastúpenie kvalitatívnych tried sortimentov vo vzťahu k priemeru – $d_{1,3}$. Priemer má štatisticky významý vplyv na podiel všetkých sortimentov u každej dreviny, indexy korelácie jednotlivých rovníc $f(d_{1,3})$ sú v intervale < 0,52; 0,97 >. Pretože zlepšenie testovacích kritérií nelineárnych rovníc oproti lineárnym je nevýznamné a preto, že v intervale hodnôt $d_{1,3}$ dôležitých z hľadiska posúdenia a spracovania drevnej hmoty majú obidva typy rovníc prakticky rovnaký priebeh, ďalej sa v modeloch použili lineárne rovnice.

Z priemeru $d_{1,3}$ a rozptylu s_x^2 sa odvodila modelová štruktúra hustoty rozdelenia početností v hrúbkových stupňoch s normálnym rozdelením $N(d_{1,3}, s_x^2)$. Zhoda rozdelení sa testovala štatistickou charakteristikou:

$$\chi^2 = \sum \frac{(ns_i - nn_i)^2}{nn_i}$$

kde: ns_i – skutočná početnosť v i-tej hrúbkovej triede,
ns_i – normálna (hypotetická) početnosť v i-tej hrúbkovej triede.

Model má nasledujúce vstupné údaje, resp. parametre: drevinové zloženie (zastúpenie drevín), Ø $d_{1,3}$, Ø h, Ø $d_{1/2}$, ⇒ Ø m³/kus, objemovosť (Ø m³/kus), kde kus znamená jeden kmeň.

Podľa Ø$d_{1,3}$ sa z rovníc (tab. 3) vypočítajú zastúpenia kvalitatívnych tried sortimentov (tab. 6). Ďalej sa použitím modelu relatívnych početností v hrúbkových triedach v závislosti od Ø$d_{1,3}$ (tab. 7) určia indexy podielu sortimentov v kvalitatívnych triedach. Odhadnutá cena podľa drevín v Sk/m³ je potom:

$$Co_j = \Sigma (I_{ij} \times Ca_{ij})$$

kde: I_{ij} – index podielu i-tej kvalitatívnej triedy j-tej dreviny,
Ca_{ij} – aktuálna cena sortimentov i-tej kvalitatívnej triedy j-tej dreviny (Sk/m³),
i – 1 (pre kvalitatívnu triedu I, II, IIIA), 2 (pre kvalitatívnu triedu IIIB), ...
j – číslo dreviny 1, 2, ...

Rozdiel aktuálnych cien v rámci kvalitatívnych tried v závislosti od hrúbkových tried sa zohľadní vypočítaním váženej priemernej ceny kvalitatívnej triedy danej dreviny, kde váhami sú relatívne početnosti.

Objem celkovej kalamity podľa drevín možno odhadnúť z počtu kusov stromov a ich objemovosti (pri menších kalamitách), alebo z drevinového zloženia, odhadnutej plochy kalamity a taxačných charakteristík stredného kmeňa podľa tabuliek počtov stromov na ha, alebo z rastových tabuliek.

Odhad celkových tržieb podľa drevín v Sk je:

$$\Sigma (V_j \times Co_j)$$

kde: V_j – celkový objem j-tej dreviny (m³),
Co_j – odhadnutá cena j-tej dreviny (Sk/m³),
j – číslo dreviny 1, 2, ...

Pri odhade je potrebné uvažovať aj s trhovým mechanizmom ponuky a dopytu, v prípade kalamity budú ceny odberateľov pravdepodobne nižšie ako v štandardnej situácii.

Na záver možno konštatovať, že model overený presnými meraniami a výpočtom cien je relatívne jednoducho konštruovaný, čo vytvára prepoklady pre jeho širšie praktické aplikácie, a je dostatočne presný na bilancovanie nákladov a tržieb pri spracovaní kalamity. Ďalšou výhodou je modularita systému spracovania parametrov modelu, čím sa stáva menej závislým na štruktúre vstupných dát a rozširujú sa možnosti jeho použita pri riešení analogických problémov.

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INFORMATION

The 21st World Congress of IUFRO

The 21st Congress of the International Union of Forest Research Organizations was held in Kuala Lumpur, Malaysia on 7–12 August 2000.

The IUFRO is a voluntary non-governmental union of the organizations which dedicate their efforts to forestry research and forestry sciences. The Union was founded in 1892. The aim of the Union is to support international cooperation in forestry research. The Union structure is under permanent changes according to the actual needs but the strategy is always the same.

The International Council (IC) is the supreme authority regulating the affairs of the Union and guiding its Executive Board (EB). Each country in which IUFRO has a member organization has one delegate and an alternate member in the IC, irrespective of the number of the member institutions. The IC meets in practice only when a World Congress is in session and acts as a general assembly of the Union. The International Council decides basic questions of IUFRO policy and strategy. The IC approved the Resolutions (see bellow) of the IUFRO World Congress, addressed to all member organizations and governmental authorities responsible for the forest affairs in IUFRO countries.

The other body of the Union is Executive Board which guides the Union between the IC sessions.

The structure of divisions which are the real frames for research activities, is relatively flexible. Working groups which are the part of divisions could be quite easily created or canceled depending on the research needs of the institutions. At present there are eight divisions (the names of division coordinators are also given):

1. Silviculture (John Parrotta, USA),
2. Physiology and Genetics (Ladislav Paule, Slovakia),
3. Forest Operations and Techniques (Dennis Dykstra, USA),
4. Mensuration, Growth and Yield (Klaus von Gadow, Germany),
5. Forest Products (Cathy Wang, China),
6. Social, Economic, Information, and Policy Sciences (Niels Elers Koch, Denmark),
7. Forest Health (Kazuo Suzuki, Japan),
8. Forest Environment (Alain Franc, France).

Each division has working groups which usually have few or many working parties. The Union has actually 65 working groups and 203 working parties. There are many scientific conferences and workshops held under the Union (about 70 each year) documented by the published proceedings. There are also projects under the Union guidance. First of all the Special Programme for Developing Countries (SPDC) which started after the IUFRO Congress in Kyoto in 1981, responding to the request of developing countries to pay more attention to forest problems of those countries.

SILVAVOC is a IUFRO project which is dedicated to forestry terminology. The other IUFRO project is Global Forest Information Service.

The others activities of IUFRO are Task Forces. Probably the most important is Task Force on Environmental Change established in 1995 to promote interdisciplinary research. The Task Force is the third in a series established first at the Montreal World Congress in 1985 and continued in 1990. The Task Force has gradually expanded in scope. In the period of 1985–2000, it was solely concerned with air pollution impacts on forests. The second Task Force (1990–2000) covered all aspects of change as they affect forests, including air pollution and climate change, but also including political, social and economic change.

The actual list of Task Forces is as follows:

- Environmental change (John Innes, UK/Canada),
- Forests in Sustainable Mountain Development (Martin Grosjean, Switzerland),
- Management and Conservation of Forest Gene Resources (Per Stahl, Sweden),
- Water and Forests (Rob Vertessy, Australia),
- Science/Policy Interface (Richard Guldin, USA),
- Public Relations in Forest Science (Max Krott, Germany).

The noticeable activities of a Finnish delegation at the Congress resulted in impressive representation at different level of IUFRO organs. Their delegation was the largest one with the exception of Malaysian as the organizing country. This effort ended with the election of Risto Seppala from Finland as the IUFRO President for the next five years of the Union.

The Congress venue was chosen appropriately as the representative tropical country. The area of Malaysia is about 33 mil. ha of which 61% is covered by forests not counting the plantation areas of palms and gum-trees which represent another 15%. Malaysia is one of the largest producers of tropical timber and it is very active in International Tropical Timber Organization (ITTO). Nowadays Malaysia has diminished its felling especially on Borneo island following the ITTO recommendations. The forest management system is very similar to the other tropical countries, i.e. they have a concession system. The concession is usually for 25 years and the concessionaire is responsible for the situation of the forest in the hired area. Malaysia has declared that at least 50% of the area will remain covered by forests and pronounced that area as Permanent Forest Estate. It does not mean that these forests would remain untouched by felling but it means that the cut will be done in sustainable way. The sustainability in tropical Malaysian conditions means 7–12 trees cut down per hectare. The system is called "selective harvesting system" and it is supposed to conserve the conditions for renewal of tropical forests.

A great interest in Malaysia is devoted to the sustainability of forest management. There is a clear conception plan which is monitored through permanent plots. The process is controlled by Forest Research Institute of Malaysia (FRIM) which guaranteed the organization of IUFRO Congress as well.

The Forest Research Institute of Malaysia (FRIM) was founded in 1929 (the actual name comes from 1985). FRIM has experimental forests with an area of 1,528 ha situated only 15 km north of Kuala Lumpur. The actual staff is about 500 employees and the institute produces two internationally referred scientific journals. FRIM is a member of the Association of Pacific Asian Forest Research Institutions (APAFRI). The other forestry research organization in Malaysia is Putra University which works in the field of agriculture and forestry research. The University was founded in 1931 and it includes the Forestry Faculty as well. The Putra University has actually 13 faculties and 4 institutes.

The 21st Congress was opened on Monday 7th of August at 10 a.m. The venue was Putra World Trade Center, splendid and luxury building in the center of Kuala Lumpur. The opening ceremony was planned for the Prime Minister, who was replaced in the last minute by the Minister for Primary Industries. The following keynote addresses by renowned speakers were by Dr. Abdul Razak Mohd. Ali, director of FRIM, President of IUFRO Prof. Jeffrey Burley etc. Then started plenary and subplenary sessions and later on scientific conferences on different topics organized by IUFRO working groups.

All subplenary sessions and the abstracts of other papers and posters were included in the CD-ROM and paper proceedings that were given to the participants at the start of the Congress. The representatives of the Czech Republic – mainly the teachers of both forestry faculties in Prague and Brno were present and they were very active at many conferences there.

Congress Resolutions of the 21st Congress of the International Union of Forestry Research Organizations:

CONSIDERATIONS:

– Role of forests and trees in human welfare

- Recognizing the great contributions made by forests, trees, industries and the forestry profession to human environmental, economic and socio-cultural welfare,
- further recognizing the contributions to poverty alleviation, the stimulating of development and reversing environmental decline,
- further recognizing the importance of cultural diversity,
- further recognizing that research is undertaken at different intensities depending on the geographical extent of a problem, the level at which it is approached, and the inter-relationships with other problems,

RESOLUTIONS:

- IUFRO should continue and expand its stimulation and support for research, and provide the knowledge necessary to achieve sustainable forest management within differing physical and social landscapes; it should seek to reconcile conflicting demands for wood and non-wood products, environmental services and social benefits; IUFRO should also seek appropriate knowledge, particularly from indigenous people.

CONSIDERATIONS:

– Attention by policy-makers

- Noting the increasing attention paid to forests by international and national agencies, international NGOs, commercial enterprises and academic institutions, and the need for reliable information by decision-makers in such organizations,

RESOLUTIONS:

- research should be increasingly directed towards forest policy-related issues in the major environmental and social conditions including urban, mountain and dry environments; IUFRO has a major role in enhancing the interface of science, policy and industry, aiming at better provision of all forest benefits, goods and services.

CONSIDERATIONS:

– Role in inter-governmental processes

- Being aware of the place of forestry in the considerations of several inter-governmental processes, and of IUFRO's unique capacity to mobilize a broad range of individual and collective expertise,

RESOLUTIONS:

- IUFRO should strengthen its contributions to international debates and political processes, specifically those relating to: genetic resources and biotechnology; biodiversity; sustainable forest management; climate change and carbon sequestration; soil; water; fire; deforestation, forest degradation and desertification. It should promote the transfer of socially acceptable, environmentally sound techniques.

CONSIDERATIONS:

– Research and the impacts of forestry activities

- Considering the public concern for the possible impacts of forestry activities on global and local environments, social welfare and biodiversity, and remembering that IUFRO's research traditionally focusses and progresses in major disciplines,

RESOLUTIONS:

- research should increase within single disciplines while simultaneously moving towards an inter-disciplinary, problem-solving approach; IUFRO should seek closer collaboration with other research organizations, while bringing its experience and networking powers to assist other research networks and consortia.

CONSIDERATIONS:

– **Information**

– Appreciating the research undertaken and the forest and forest products technologies developed, especially by IUFRO member institutions and individual scientists,

– realizing that much of this information is available in scattered sources and forms,

– observing the rapid development and availability of information technologies,

RESOLUTIONS:

– existing information should be made available in accessible and appropriate forms for the wide range of users; forest research institutions should strive to divulge their research results; use of the IUFRO Net, and development of the Global Forest Information Service led by IUFRO, should be intensified and IUFRO research units should continue to disseminate statements of the current state of knowledge in their specific fields.

CONSIDERATIONS:

– **Research capacity**

– Believing that forest research capacity is low in countries with developing and emerging economies, and that women scientists are under-represented and insufficiently supported in forest research,

RESOLUTIONS:

– IUFRO should expand its collaboration with other organizations that seek to enhance biophysical and social research capacity in countries with developing and emerging economies; it should encourage the role of women and disadvantaged researchers in forest sciences.

When looking at these resolutions we could find many stimulating considerations for our future research.

Doc. Ing. IVO KUPKA, CSc.,
prof. Ing. JAROSLAV SIMANOV, CSc.

INSTRUCTIONS TO AUTHORS

The journal publishes original results of fundamental and applied research from all fields of forestry related to European forest ecosystems. An article submitted to Journal of Forest Science must contain original work and must not be under consideration for publishing elsewhere. Manuscripts should not exceed 25 pages (A4 size) including tables, figures, references, abstract and summary. A PC diskette with the paper text and graphical documentation should be provided with the paper manuscript, indicating the used editor program. Papers should be clear, concise and written in English. Correct English is the responsibility of the author. Manuscripts should be typed on standard paper of A4 size. They must fully conform to the organization and style of the journal. Two copies of the manuscripts should be provided.

Text

Manuscript should be preceded by a title page comprising the title, the complete name(s) of the author(s), the name and address of the institution where the work was done, and the telephone, fax numbers and e-mail of the corresponding author. Each paper must begin with an Abstract of no more than 90 words, and keywords. The Introduction should be concise and define the scope of the work in relation to other work done in the same field. As a rule, it should not give an exhaustive review of literature. In the chapter Materials and Methods, the description of experimental procedures should be sufficient to allow replication of trials. Plants must be identified by taxonomic and common name. Abbreviations should be used if necessary. Full description of abbreviation should follow the first use of an abbreviation. The International System of Units (SI) and their abbreviations should be used. Results should be presented with clarity and precision. Discussion should interpret the results. It is possible to combine Results and Discussion in one section. Literature citations in the text should be by author(s), and year. If there are more than two authors, only the first one should be named in the text, followed by the phrase et al. They should consist of reviewed periodicals. References should include only publications quoted in the text. They should be listed in alphabetical order under the first author's name, citing all authors.

Tables

Tables should be numbered consecutively and have an explanatory title. Each table, with title, should be on a separate sheet of paper.

Figures

Figures should be referred solely to the material essential for documentation and for the understanding of the text. Duplicated documentation of data in figures and tables is not acceptable. All illustrative material must be of publishing quality. Figures cannot be redrawn by the publisher. Photographs should exhibit high contrast. All figures should be numbered consecutively with arabic numerals. Both line drawings and photographs are referred to as figures. Each figure should contain a concise, descriptive legend.

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