Growth of mountain pine (*Pinus mugo* Turra) in relation to the use of other tree species

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ABSTRACT: In summit parts of the Orlické hory Mts., massive dieback of forests occurred during an air pollution/ecological disaster in the 70s to the 80s of the 20th century. Destroyed stands were cut down and deforested areas were planted by more resistant species including mountain pine (*Pinus mugo* Turra). The aim of the paper was to assess effects of mountain pine on the prosperity of other tree species. Four localities with mountain pine stands were selected at altitudes from 1,000 to 1,115 m. In 2003–2005, growth analyses of shrubs were carried out there and basic parameters of stands were determined such as: height; cover of mountain pine, other tree species and herbs; radiation transmittance and temperature gradients. Results show the importance of the height of mountain pine stands in mitigating climatic changes in the ground layer of air, identification of the light compensation point for the mountain pine prosperity, the dependence of a growth type on outer and inner conditions of mountain pine including partly its age. Under given conditions, the present stands of mountain pine on top parts of the Orlické hory Mts. show their justification because they create a good protection for young seedlings, self-seeding and newly planted tree species. If forest spreads there, the markedly heliophilous mountain pine will recede similarly as in case of more than hundred-year-old mountain pine in the Sowie gory Mts. in Poland.

Keywords: mountain pine (*Pinus mugo* Turra); growth analysis; upright and ascending growth type; relative insolation; temperature gradient; heliophilous species; self-seeding species prosperity

The studied area is situated in Orlické hory Mts. in the Czech Republic (50°6´–50°22´N, 16°12´–16°37´E). It is built mainly of crystalline rocks – mica schists and paragneisses, the highest locations are covered with haplic podzols, the lower with entic podzols. Average annual temperature is about 4°C and the sum of precipitation is about 1,300 mm. The flora is composed of Central European mesotrophic or mountain species (Vacek et al. 2003).

The landscape of summit parts of the Orlické hory Mts. developed without any marked influences of man until the 13th century AD. Very intense impacts were documented as late as the 16th and 17th centuries when the majority of forests was felled for needs of Kutná Hora mines or for glassworks in the Orlické hory Mts. Particularly beech stands served as an important source of potash for the glassworks. However, cut down areas were not mostly regenerated and so even at the beginning of the 19th century, there were 640 ha of deforested areas on the mountain ranges (http://www.orlickehory.net/lesy.htm). One of the reasons of the reduction of forest areas was also livestock grazing developing in the following century. Cattle grazing right in the forest affected also the species composition of stands and thus the increasing proportion of spruce occurred. Norway spruce became the main species which was regenerated by seed on clear-felled areas, silver fir gradually disappeared from stands and also beech largely vanished (Kriesl 1971). The construction of a fortress line in 1936–1938 also affected the local territory and forest management. After World War II, spruce was

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planted again, unfortunately, its provenance was unsuitable (Vacek et al. 1998). Autochthonous stands have been preserved only in some reserves (e.g. National Nature Reserve Bukačka, National Nature Reserve Trčkov, Nature Reserve Sedloňovský vrch, Nature Reserve Pod Vrchmezím, Nature Reserve Komáří vrch etc.).

A striking negative impact on all stands (autochthonous and man-made) has been demonstrated by an air pollution/ecological disaster accompanied by unfavourable climatic conditions and other factors (Špinlerová et al. 2004). The polluted environment began to be evident after putting the Chvaletice thermal power plant into operation (the 80s of the 20th century) (Vacek et al. 2000). Mountain range stands (Norway spruce or Norway spruce/fir/beech stands) gradually disintegrated lastly being felled on large areas. In new plantings, original species were often replaced by other more resistant species such as blue spruce (*Picea pungens* Engelm.), Serbian spruce *Picea omorika* (Pančic) Purkyně, European larch (*Larix decidua* Mill.), lodgepole pine (*Pinus contorta* Loud.) and by mountain pine (*Pinus mugo* Turra), too (Lokvenc, Souček 2000). At present, we can encounter nearly closed stands of planted mountain pine (*Pinus mugo* Turra) on extensive areas (on ca. 126 ha) (Vacek et al. 2000).

The aim of the paper was to assess effects of mountain pine on possibilities of the reuse of other possibly autochthonous tree species. We wanted to detect, if this shrub has negative influence on other species or if it can support their growth and development.

MATERIAL AND METHODS

The study was focused on mountain pine from localities selected on top parts of the Orlické hory Mts. at altitudes from 1,000 to 1,115 m (50°14´ to 50°20´N, 16°23´ to 16°27´E). It referred to localities under the top of Velká Deštná – plots Pod Kioskem and Nad Kioskem, under Šerlich – Masarykova chata locality and plots in the vicinity of peat bogs near Nature Reserve Jelení lázeň and Nature Monument U Kunštátské kaple. The selected localities were represented by stands from older plantings, i.e. age about 70–80 years and from plantings after an air-pollution disaster, i.e. age 18–23 years. At the localities Nad Kioskem, Pod Kioskem, Kunštátská kaple a Jelení lázeň, there were selected sample plots (10 × 10 m) which represented the typical cover of the stands. At the locality Masarykova chata were found only few shrubs, which covered area less then referential one. For reference purposes, selected shrubs of mountain pine were measured (age 130 years) at a locality Lesní unikát in the Sowie gory Mts., Poland (altitude 980 m, 50°40´N, 16°28´E) and also mountain pine plantings in the urban environment were studied. With respect to the objective of the paper attention was paid to the relationship between the growth type of mountain pine, stand density and possibilities of the prosperity of other tree species. The study was carried out in 2003 to 2005.

Mountain pine and its stands were studied in 3 different ways:

1. The research was focused on the whole mentioned plots. For each of the plots, following parameters were recorded: the cover of mountain pine, the cover of all trees in the stand, and the cover of herbs (everything in % of the total area) (Moravec et al. 1994). Moreover, radiation transmittance was measured 10 times under canopy and on fully insolated areas at the same time (by means of radiometry using an ALAI 02 instrument, expressed as relative insolation) (Larcher 2003). Through a manual infrared thermometer Omega (accurate to ± 1% measured value) temperatures were recorded of the surface of mountain pine shrubs at various levels of stands and of soil surface temperatures as compared with air temperatures (measured at a height of 2 m by a mercury thermometer covered by an aluminium foil). These temperatures were measured in May (on a clear day and calm) during 1.5 hours shortly after midday on plots Nad Kioskem and Pod Kioskem. In all cases, measurements were repeated 10 times (at 10 places during short time).
2. On each of these plots, 33 shrubs were randomly selected. It was measured their height (i.e. the length of a vertical line from a terminal shoot to the soil surface), increments of the main axis of branches in particular years and length of a typical branch (the sum of lengths of these increments). On the basis of results for each of the plots following values were calculated: mean, minimum and maximum height and length of branches, variability of values and standard errors. Relationships between the branch length and height expressed the lodging rate of the shrub growth.
3. Then the growth of mountain pine was analysed in detail on particular average branches selected from sample shrubs from each of the plots (one branch from every one plot). These branches were documented photographically and by schematic drawings and then cut into shoots (annual growth moduli). The shoots were further classified to sections according to the spatial position on a branch (S, SN, N) and at the same time, according to the year when their elongation growth was realised (by

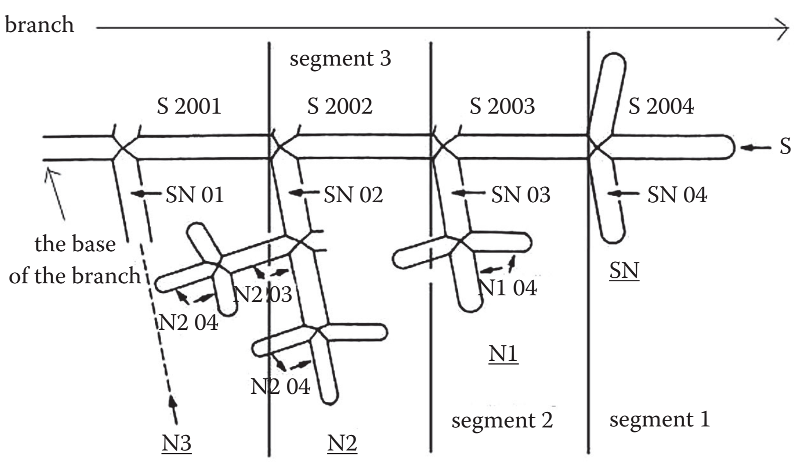

Fig. 1. Schematic depicting of shoots (stems) on a branch according to Lichtenthaler (1985 in Hanisch, Kilz 1990). S – increments of the first order branch, SN – lateral shoots of the main axis (adjacent to the main axis), N – other shoots growing from SN

Lichtenthaler 1985 in Hanisch, Kilz 1990) (Fig. 1). After drying to constant weight (at 105°C), following parameters were measured in shoots: shoot length (cm) accurate to 1 mm; dry matter (DM) of needles (g) – determined by means of the Kern 822 electronic balance accurate to 0.001 g and the area of an average pair of needles (cm^2) – measured by means of the ImageTools program accurate to 0.01 cm^2. The needle area is the area of the projection of a horizontally laid needle (Evans 1972).

On the basis of initial values measured on particular growth moduli summary values were found of parameters for particular segments (Fig. 1) of the main axis of the branches: total branch length (m), total shoot number (pc/segment), needle dry weight (g/segment) and needle dry weight per area (g/m^2/segment) – i.e. reciprocal vocal to SLA (Evans 1972). The processing of results was carried out according to methods tested by various authors (Evans 1972; Hager, Štěrba 1985; Barták et al. 1993; Larcher 2003; Martinková 1990, 1992; Martinková et al. 1996; Grabařová, Martinková 2000).

RESULTS AND DISCUSSION

Field measured biometric characteristics of the sampled branches of mountain pine

The highest stand with longest branches was on a plot Pod Kioskem where the mean height of branches exceeded that in other plots nearly by 65% and the length of branches by 54%. This site differed markedly from the others. There occurred statistically significant differences between some other plots, but such differences were very small (Fig. 2).

Relationship between the total branch length and their height was almost linear in most smaller branches (Fig. 3 – ranges of individual sites were marked by circles), but it started to change with in-

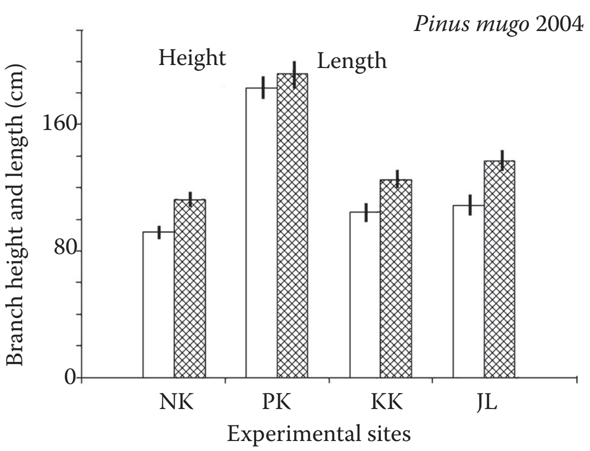

Fig. 2. Comparison of height and length of the 33 sample branches of mountain pine (mean values and standard errors) from 4 sample plots Nad Kioskem (NK), Pod Kioskem (PK), Kunštátská kaple (KK) and Jelení lázeň (JL)

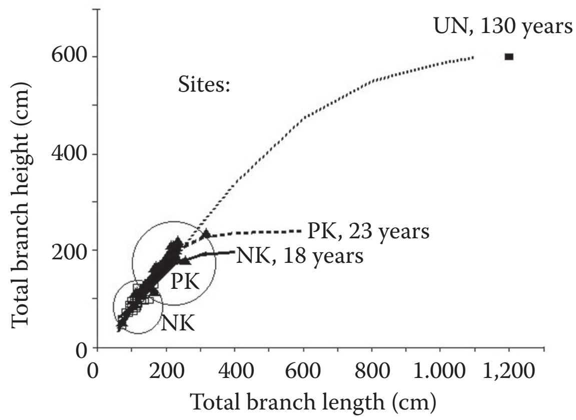

Fig. 3. Relationship between the total height and length of sampled branches on research plots of different age Nad Kioskem (NK), Pod Kioskem (PK) and of sample shrub branch from locality Lesní unikát (UN). Plots Kunštátská kaple (KK) and Jelení lázeň (JL) are not shown here to prevent overlapping of points at the figure, but they are almost identical with NK. The curves indicate probable development with age

creasing length, which was not further followed by height (i.e. growth of shaded branches in height relatively decreased, because stems were usually more leaning, longer and longer part of stems occurred close to the ground). The oldest sampled shrub from the site of Lesní unikát (i.e. 130 years old, base girth of branch about 91 cm), had the leaning part of branch (almost laying on the ground) 6 m long and then turned strictly upright up to 6 m.

On the plot Pod Kioskem, we can speak on the mountain pine of a different growth type (upright) unlike other plots the stands of which were similar in their height and the growth of mountain pine was rather procumbent, ascending only in distal parts (Fig. 2). Different "growth habits" of *Pinus mugo*, were described in Orlické hory Mts., which were related to different provenances of the planting stock (Lokvenc, Souček 2000). On the other hand, Štursa (1966) and Lukáčik (2001) suppose that there is a question to which extent the growth types (or forms) are affected by external or internal factors. It means, that a growth type need not be steady and can change in relation to these internal and mainly external conditions. The differences, which we observed between the site Pod Kioskem and other young sites, must not be strictly limited by age differences only, but mostly by external conditions which are supporting the tree growth form.

Non-linear relationship between total branch length and height indicated that branches were more leaning with increasing age. There were rather small differences in age between the intensively studied plots, that is why we included one shrub of substantially (5×) higher age, although the curve is only approximated there. However curves characterising the relationship are evidently similar and show certain tendency of development at illuminated or shaded conditions (Fig. 3).

Shoot and needle distribution along mountain pine branches

More detail biometric analysis of branches gave additional characteristics. Needles, i.e. foliated parts of stems occurred further from the ground and not on branches parts leaning closely to the ground surface. This was not so pronounced in younger (up to about 23 years old) and smaller (up to about 2 m long) branches, but appeared clearly in longer and older ones – this was markedly visible e.g. in 80 years old branches at the experimental site Masarykova chata (MCh) (Fig. 4).

Age and branch length determines changes in branch form in mountain pine. Branches of older individuals of *Pinus mugo* are increasingly more leaning if they were shaded. Needles cannot grow in the oldest parts of branches close to the ground, where is too dark and also other unfavourable growing conditions (Fig. 4). The determined trend of growth generally corresponded to an "S" curve (Luxová 1965; Kramer, Kozlowski 1960) – its beginning represents a "lag" phase, then a logarithmic phase follows and after it, the generation of further biomass varies in growth waves.

Crown density (expressed as number of shoots per segment along branches) is one of the parameters characterising growth habit. The results indicate that all individuals showed a similar growth strategy: they culminated their biomass in certain "waves" (or peaks), i.e. roughly groups of segments (= years of growth) along their branches. However the amplitude was higher in larger branches (sampled shrubs Pod Kioskem and Masarykova chata) and lower in others (Fig. 5).

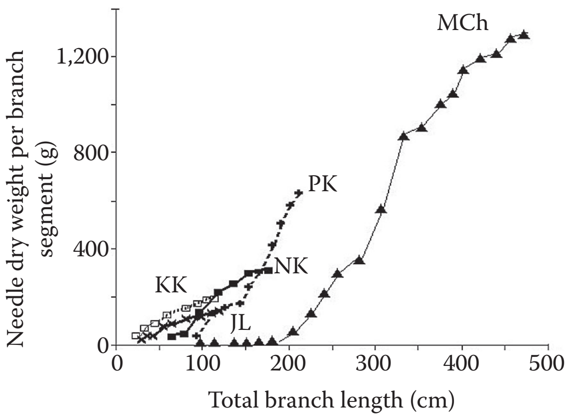

Fig. 4. The relationship between the needle dry weight per branch segment and total branch length of 5 sample shrub branches from sample plots Nad Kioskem (NK), Pod Kioskem (PK), Kunštátská kaple (KK), Jelení lázeň (JL) and Masarykova chata (MCh)

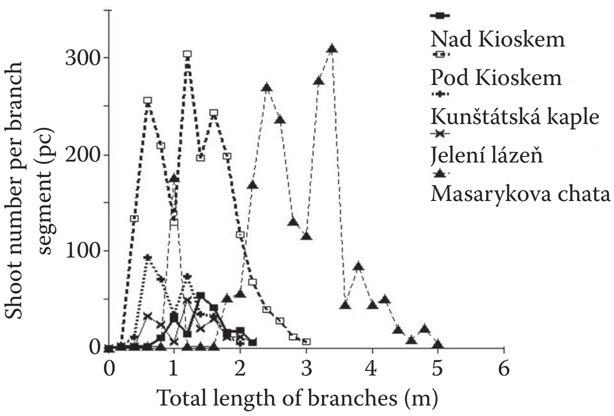

Fig. 5. Crown density expressed as number of shoots per segment along branches sampled in different experimental plots

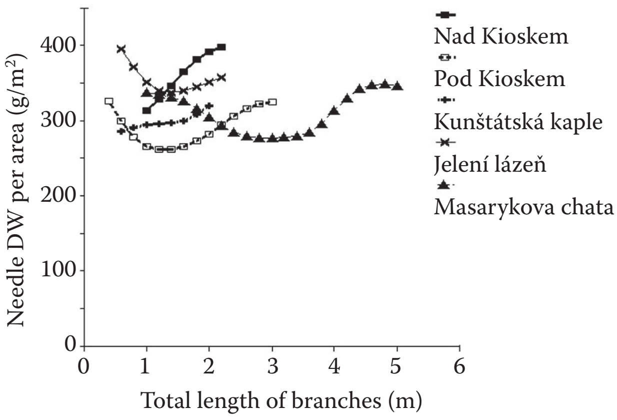

Fig. 6. Needle dry weight per area along sampled branches from 5 experimental plots

Somewhat similar trend as in crown density occurred also in needle dry weight per area. The "waves" were of different length and usually two of them appeared. This was true in almost all sampled branches of analysed shrubs. Little differences (not so pronounced peaks) seems to occur only in younger sampled shrubs Nad Kioskem (Fig. 6).

It is known, that relationship between leaf dry mass and leaf area in general reflects conditions of illumination in broadleaf as well as coniferous species (Šesták et al. 1985; Martinková et al. 2001; Martinková, Gebauer 2004). More illuminated crown parts with higher needle density (i.e. also higher needle dry weight per area) along stems impose more shade on crown parts beneath them, which is reflected by lower needle dry weight per area. Such situation is clearly visible on our results (Figs. 5 and 6). Naturally it is again more pronounced in longer stems and sometimes not so clear in shorter stems (Fig. 6).

Critical bioclimatic stand properties – radiation transmittance and temperature

The highest transmittance of radiation was found in the plot of Kunštátská kaple, reaching about 60% more than in other sites. There was also the highest herb cover there (80%), but no other woody species. The relative transmittance under stand was similar in all other plots (lower than on Kunštátská kaple). On the plot Nad Kioskem it ranged about 8%, on the plot Pod Kioskem about 10% and Jelení lázeň about 11%. The cover of the herb layer ranged from 45 to 60%. Other tree species, either from planting or self-seeding, were also not found like on Kunštátská kaple except the plot Pod Kioskem, where the cover of other tree species (some individuals from self-seeding) was about 7% (Fig. 7).

The radiation transmittance through various types of stands is related to the spatial distribution of branches (shoots). The minimum radiation transmittance of mountain pine stands decreased sporadically to 3 to 2% of radiation at the open area (or above stands), it is a critical value nearly for all vascular species of plants (Larcher 2003). Mean values from 8 to 11% represented already a dysphotic space where needles of mountain pine died back. The minimum requirement of this studied heliophilous species amounted to about 12% relative insolation, what is a value of the light compensation point. According to Vaňková and Martinková (2003), there are conditions from 6 to 12% radiation transmittance suitable for germination, emergence and prosperity of the majority of tree species in early stages of their ontogenesis. These light conditions were found on the plots Pod Kioskem and on the peaty plots Kunštátská kaple and Jelení lázeň. It is important to consider, that under conditions of comparable canopy, only on the plot Pod Kioskem (with shrubs of upright growth form) there were found other broadleaf tree species as from planting or self-seeding (Fig. 7).

The described properties of mountain pine stands do not refer only to studied localities in the Orlické hory Mts. Self-seeding and taking roots of various species of trees (*Sambucus nigra* L., *Fraxinus excelsior* L., *Acer campestre* L., etc.) were also observed in ornamental mountain pine plantings in towns, parks, etc.

In the stand Nad Kioskem, constituted by lower (procumbent) shrubs of mountain pine, there were temperatures of insolated needles about 18°C, shaded low-placed needles 17.4°C and shaded soil surface 17.9°C. The temperature of old grass (*Ca-*

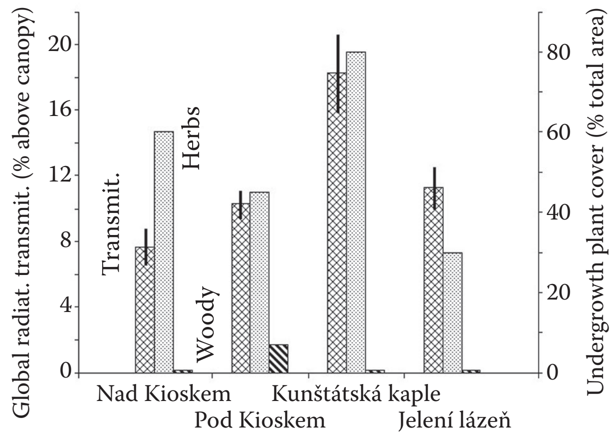

Fig. 7. Radiation transmittance and udergrowth plant cover of woody and herbaceous species in the mountain pine stands of four experimental plots in Orlické hory Mts.

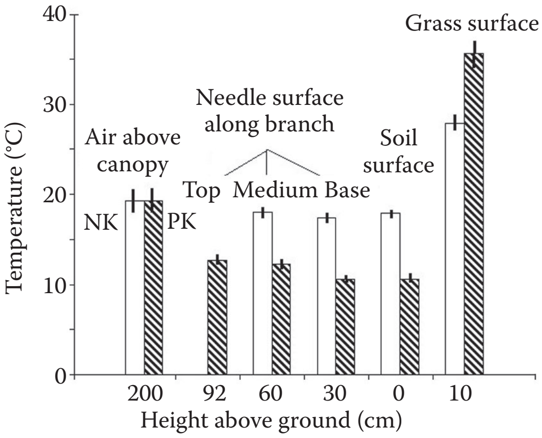

Fig. 8. Changes in temperatures of mountain pine, soil surface and grass surface (*Calamagrostis villosa*) in "solar windows" on two chosen different plots Nad Kioskem (NK) and Pod Kioskem (PK) in Orlické hory Mts.

lamagrostis villosa [Chaix] Gmel.) was about 28°C with a maximum 31.5°C. On the plot Pod Kioskem (with the upright growth) the temperature of insolated needles was about 12.2°C; in shaded low-laid needles about 10.6°C and shaded soil surface also 10.6°C. In the opened area the average temperature of the insolated old grass surface reached a value of 35.6°C with a maximum up to 42°C. The air temperature ranged from 18.5 to 20°C in course of time of all temperature measurements (Fig. 8).

Experimental plots Nad Kioskem and Pod Kioskem were the most contrasting in height and structure (if considering sites of similar age), which determined most environmental factors for undergrowth plants. Therefore more detail measurements of temperature was performed there. In the low stand Nad Kioskem, temperatures of the surface of mountain pine and soil surface were similar to the air temperature. On the other hand, in a high stand with upright growth Pod Kioskem (with comparable cover like Nad Kioskem – about 70%) the surface temperatures were lower by more than 5°C and therefore the gradient of temperatures was very marked too (Fig. 8). This showed an evidence of the important effect of a plant cover on the temperature regime (Čermák et al. 1955; Tesař et al. 2004; Šír pers. commun.).

In a suitable complex of abiotic conditions for tree form growth, mountain pine achieves such growth form, which moderates changes in temperature and provides a prosperity of self-seeding tree species anywhere. Mountain pine is unsuccessful in light competition and dies back (Musil et al. 2002; Jankovská 1997). The locality of Lesní unikát (Sowie gory Mts., Poland) is the example of described development. There were mountain pines planted out ca. 130 years ago. Presently, mountain pine stand is failing in health because of shading by ingrowth of Norway spruce and rowan trees. The similar situation becomes in urban parks and other areas. For maintaining of planted mountain pine as decorative greenery it is necessary to systematically remove all self-seeding woody plants.

CONCLUSIONS

It is possible to say that present stands of mountain pine in the devastated summit parts of the Orlické hory Mts. have their substantiation. Under abiotic conditions, which allow a suitable growth and canopy structure (vertical growth about 1.5–2 m, cover up to 70%), the mountain pine stands can fulfil the function of the temperature treatment of the harsh mountain climate in ground layers of air being good protection for germinating plants, self-seeding and newly planted tree species. Thanks to the protective function of mountain pine, these species thrive better than those on the open area. As a heliophilous shrub (light compensation point was found at 12% transmited global radiation), mountain pine can be gradually shaded by others species and spontaneously suppressed as documented by disappearing planting of mountain pine on the near Sowie gory Mts. in Poland (locality Lesní unikát).

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Růst kosodřeviny (*Pinus mugo* Turra) ve vztahu k uplatnění jiných druhů dřevin

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ABSTRAKT: Na vrcholových částech Orlických hor došlo k masivnímu odumírání lesa během imisně-ekologické katastrofy v 70. až 80. letech 20. století. Za použití těžké techniky byly zničené porosty vykáceny a odlesněné plochy zalesněny odolnějšími dřevinami včetně kleče (*Pinus mugo* Turra). Cílem práce bylo posoudit vliv kosodřeviny na prosperitu dalších druhů dřevin. Byly vybrány čtyři lokality v nadmořských výškách 1 000 až 1 115 m s klečovými porosty. Zde byla v letech 2003 až 2005 provedena růstová analýza keřů a zjištěny základní parametry porostů, jako jsou výška; pokryvnost kleče, jiných dřevin a bylin; propustnost záření a teplotní gradienty. Z výsledků vyplývá význam růstového typu a výšky klečových porostů při zmírňování klimatických výkyvů v přízemní vrstvě vzduchu, identifikace kritické hodnoty ozářenosti pro prosperitu kleče, závislost růstového typu na vnějších a vnitřních podmínkách kleče včetně jejího věku. Za daných okolností mají současné porosty kleče na vrcholových částech Orlických hor své opodstatnění, neboť vytvářejí dobrou ochranu pro klíční rostliny, nálety i nově vysazené druhy dřevin. Pokud se zde rozšíří les, bude výrazně světlobytná kosodřevina ustupovat podobně, jako je tomu v současnosti se stoletou výsadbou kleče na Sovích horách v Polsku.

Klíčová slova: borovice kleč (*Pinus mugo* Turra); růstová analýza; vzpřímený a vystoupavý růstový typ; relativní ozářenost; teplotní gradient; světlobytnost; prosperita náletových dřevin

Na vrcholových částech Orlických hor došlo k masivnímu odumírání lesa během imisně-ekologické katastrofy v 70. až 80. letech 20. století. Zničené porosty byly vykáceny a odlesněné plochy zalesněny odolnějšími dřevinami včetně kleče (*Pinus mugo* Turra). Cílem práce bylo posoudit vliv kosodřeviny na prosperitu dalších druhů dřevin. Byly vybrány čtyři lokality s klečovými porosty o nadmořských výškách 1 000 až 1 115 m s odlišnými stanovištními podmínkami (dvě z nich rašeliništního typu). Zde byla v letech 2003 až 2005 provedena růstová analýza keřů a zjištěny základní parametry porostů. Mimo území Orlických hor byla orientačně zkoumána 130letá výsadba kosodřeviny na lokalitě Lesní unikát v Sovích horách v Polsku a pozorovány výsadby kleče v městské zástavbě.

Porovnáním růstu porostů na plochách Nad Kioskem, Pod Kioskem, Kunštátská kaple a Jelení lázeň byl celkově nejvyšší porost na ploše Pod Kioskem, kde vztah mezi výškou a délkou větví charakterizoval typ růstu spíše vzpřímený proti růstu vystoupavému v porostech Nad Kioskem a Jelení lázeň. Kleč u Kunštátské kaple vykázala tendenci intermediární. U nejstaršího vzorníku z lokality Lesní unikát v Sovích horách v Polsku rostla 12 m dlouhá větev zprvu poléhavě (zřejmě v zástinu), poté, co větev dosáhla ozářeného prostoru, rostla vzpřímeně. Pak vztah mezi výškou a délkou větve byl charakteristický pro vystoupavý klečový růstový typ. Růstový typ tedy nemusí být ustálen a může projevovat změny ve vztahu k vnitřním i vnějším podmínkám.

Akumulace biomasy větví jedinců na jednotlivých lokalitách byla podmíněna jejich individuálním vývinem, věkem a podmínkami prostředí. Růst větví odpovídal typické „S“ křivce; v logaritmické fázi se projevilo zřetelné kolísání v „růstových vlnách“.

Struktura a výška kleče ovlivňovala vybrané faktory bioklimatu uvnitř porostu. V nízkém porostu Nad Kioskem byly teploty povrchu kleče a povrchu půdy podobné teplotě vzduchu. Naopak ve vyšším porostu se vzpřímenějším vzrůstem, avšak se srovnatelnou pokryvností (kolem 70 %) byl teplotní gradient velmi výrazný – od průměrné teploty vzduchu nad porostem po teplotu o téměř 50 % nižší na dně porostu. Oproti tomu na volné, nezastíněné ploše v rámci ozářeného „okna“ byly změřeny teploty o více než 100 % vyšší než průměrné teploty vzduchu. To potvrzuje významný vliv tohoto typu rostlinného krytu na teplotní režim.

Také propustnost záření různými typy porostů závisela na prostorovém uspořádání větví. Minimální propustnost porostů kleče činila 3 až 2 % záření dopadajícího na volnou plochu, což je kritická hodnota téměř pro všechny cévnaté druhy rostlin. Průměrné hodnoty od 8 do 11 % představovaly pro kleč již dysfotický prostor. Minimální požadavek této světlobytné dřeviny se ukázal kolem 12% relativní ozářenosti. Podmínky od 6 až 12% propustnosti záření jsou přitom vhodné pro klíčení, vzcházení a prosperitu většiny lesních stromů v časných fázích jejich ontogenie.

Za příznivých abiotických podmínek, které umožňují vhodný vzrůst a zápoj (vertikální typ o výšce kolem 1,5–2 m a pokryvnosti do 70 %) mohou klečové porosty plnit funkci temperování klimatu v přízemních vrstvách vzduchu, být dobrou ochranou pro klíční rostliny, nálety i nově vysazené druhy dřevin. Těmto dřevinám se zde daří lépe než na otevřených plochách, což je výhodné v horských podmínkách. Jak bylo zjištěno, jde o obecnou vlastnost kleče. Také v městských výsadbách tohoto odolného a zároveň okrasného druhu se uchycují náletové dřeviny; ty se však musí průběžně odstraňovat.

Z výsledků vyplývá, že současné porosty kleče na devastovaných vrcholových partiích Orlických hor mají své opodstatnění. Jejich budoucnost bude záviset na šíření a prosperitě druhů původního horského zapojeného lesa. Kleč jako dřevina vysoce náročná na ozářenost by mohla být postupným zastiňováním samovolně potlačena. Ukázku předpokládaného procesu lze vidět ve 130leté zanikající výsadbě kleče v blízkých Sovích horách v Polsku (lokalita Lesní unikát), do níž vrůstá smrk a jeřáb.

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