THE EFFECT OF AIR POLLUTANTS ON DIAMETER INCREMENT OF SCOTCH PINE AND AUSTRIAN PINE

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Abstract

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There were done 11 bore holes for Austrian pine and 51 bore holes for Scotch pine in the forest stand subjected to direct air pollutants effect. After dating and synchronization of increment curves their increment trends were equalled. Increment index was derived for each tree from these increment trends as a ratio of actual and supposed increment in the year 1992. Significance of differences between actual and supposed increments as well as between increment indexes of both pine trees was tested by statistical test. With equal damage of trees by air pollutants, being expressed by defoliation of crowns, Austrian pine had higher increment indexes by 20-25% than Scotch pine. Based on this knowledge we can evaluate Austrian pine as more resistant against air pollutants than Scotch pine.

Key words: Scotch pine, Austrian pine, air pollutants, increment

Introduction

Based on current knowledge air pollutants directly or indirectly affect and damage mainly the function of the assimilatory organs of trees. It results not only in reduction of assimilatory organs of trees but also reduction of tree increment as well as tree dieback after heavy and long-lasting damaging of trees. These processes are influenced mainly by the intensity of air pollutants impact, climatic and site conditions as well as tree species to mention the last but not the least. Studies carried out up to now were aimed mainly at coniferous species, particularly spruce, which is the most distributed tree species and the most easily influenced by air pollutants (the least resistant). It is necessary to say that especially with this tree species methodology of research was improved and respective increment and production losses were quantified. What regards methodology findings of Vinš (1962), Vinš, Mrkva (1972) but particularly of Schweingruber (1983) and Pollanschütz (1986) are valuable. Specially Kramer et al. (1988) summarized findings on increment and production losses of other tree species as fir, Scotch pine and Douglas pine. According to his comparisons Douglas pine has the highest volume increment with the same loss of needles, followed by fir, Scotch pine and spruce.

In comparison with other tree species spruce has only half values. Interesting results for spruce and Scotch pine were obtained in Estonia, namely by Ots, Rauk (2001).

In the Slovak Republic similar research was carried out later but there are currently available some interesting results. Following authors give partial results of experimental research for spruce – Priesol (1989, 1995), Scheer (1990), Ďurský (1992, 1994), Petráš et al. (1993), Ďurský, Šmelko (1994), Šmelko (1994), Šmelko et al. (1996), Riemer et al. (1997) and Oszlányi (1999). Petráš et al. (1999, 2000), Petráš, Mecko (2003) give in works increment reactions for Scotch pine or their comparison with spruce. It is obvious from the given list they were formed separately for each tree species and their comparisons can have also some shortcomings.

The aim of this work is to analyse and quantify the effect of air pollutants on diameter increment of the trees of Scotch pine and Austrian pine, which were growing together in one stand as well as to evaluate disposition of both tree species or their resistance for the growth in specific air pollution conditions.

Materials and methods

Empirical material is from the forest stand no. 358, which is situated in forest management unit Plešivec in limestone mountains Slovenský kras in southeastern part of Slovakia. This stand had in the time of measurement, it means in 1992 the area about 10 ha, south eastern exposure on limestone underlying rock with the slope aspect 40%, altitude 325 m, tree species composition – about 70% of spruce, 25% of Austrian pine and small proportion of hornbeam, locust and field maple. The age of stand was 95 years, stocking 0.8 and site class, being given by mean height at the age of 100 years, was 26. We can state that it is relatively good pine stand though on steep and stony slope but on relatively suitable site for both pine species. Information about the location of the stand in relation to emission source is very important. This source is namely plant for the production of calcium hydroxide in Gombasek, which is only 200 m to southeast from the stand. It means that with southeastern wind air pollutants directly affected the stand. According to longer-term observations this plant can be classified into small or medium-sized pollution sources especially due to solid (dust) substances in the air.

Respective empirical material is namely annual ring bore holes of radial increments on the stem of pine trees at the breast height. There were made 51 bore holes for Scotch pine and 11 bore holes for Austrian pine. Bore holes were made by Pressler increment borer only one on the stem from upper side of slope. Trees for taking bore holes were selected systematically and evenly in a whole stand. Besides taking bore hole also diameter and height of trees was measured, then tree class was determined according to Kraft as well as relative length of crown and its freedom was determined in relation to surrounding crowns and defoliation, it means defoliation of crown in % according to classification scale of international monitoring of forest condition (ICP Forest). Annual ring bore holes were measured on digital position meter, which was connected directly to personal computer. From measured data there were created curves of radial increments in relation to calendar years from which they were created. With regard to a possibility of error occurrence in identification as well as measurement of annual rings all increment curves were dated and synchronized. Their marked minimums and maximums as well as statistical tests of parallelism of increment trends according to Jačka (1989) were used.

Increment losses were derived from the development of increment curves before and after damage by air pollutants. Knowledge from the research on air pollutants effect on trees, generalized by Pollanschütz (1986), was used for determination of the border between these two states. Based on the knowledge air pollutants effect and subsequent crown defoliation annual diameter increments resulted not only in a marked drop but also in their smaller variability. Particular increment losses were expressed in relative units, it means by increment index, which is the ratio of actual annual increments of trees after damage by air pollutants and increments supposed for a tree if air pollutants do not damage it. These supposed increments were derived by extrapolation of increment trends from equalled increment curve before damage.

Results and discussion

Curves of radial increments, it means 51 curves of Scotch pine and 11 of Austrian pine were synchronized as first. Model increment curve, being necessary for synchronization of increment curves of individual trees, was constructed as a mean from the sample of the most healthy and vital trees, for which no disturbances in regular formation of annual rings were supposed. For the selection of such trees statistical tests of significance were used. Percent of parallelism of increment trends according to Jačka (1989) was tested. First step in the construction of model curve was calculation of the percent of parallelism between the pairs of curves for all studied trees. As from studied trees there were not taken equally long increment bore holes, parallelism of radial increments was assessed only for last 50 years. After the first assessment of increment curves parallelism but also after their graphical illustration and mutual comparison some curves of trees with high defoliation of crowns and lower tree class were excluded from the choice for model increment curve. From remaining curves an average curve was calculated which represents a certain increment model for whole stand. Then all individual increment curves were compared with this model curve. Credibility and accuracy of each increment curve was judged according to the percent of parallelism of its increment trends as well as according its graphical comparison with model curve. In case individual curve showed low parallelism the reason was searched for after their graphical illustration. After studying all increment curves we can state that for Austrian pine a disturbance occurred in one of 11 curves and for Scotch pine in 8 of 51 curves. The reason was missing out annual ring in measurement or non-formation of annual ring in some year.

In accordance with generalized findings of Pollanschütz (1986) an age, at which permanent drop of increments occurred, was determined from all radial increment curves and at the same time these increments have also a smaller variability. For most of trees it was in 1982. Also our increment curves of one Scotch pine tree and one Austrian pine tree document that. They are illustrated in Fig. 1. All increment curves until this year were equalled by regression function, which reflected the best their declining age trend. According to this function radial increments for the years 1982–1992 were calculated, when air pollutants effect had already appeared on the studied trees and real increments had markedly lower values. For the quantification of increment losses of trees relative rate was used, namely increment index as the proportion of real and supposed increment of damaged tree according to the equation

$$I_{ir} = \frac{i_r}{i_r},$$

where I_{ir} – index of radial increment at breast height of trees
i_{rr} – real radial increment of damaged tree
i_{rs} – supposed radial increment of damaged tree.

For detailed analysis of increment losses of the studied pines increment indexes, calculated according to eq. (1), were selected only for the last year 1992. The reason was that only in that year we knew besides radial increment also other studied parameters as for example tree crown defoliation. Fig. 2 illustrates the values of increment indexes in

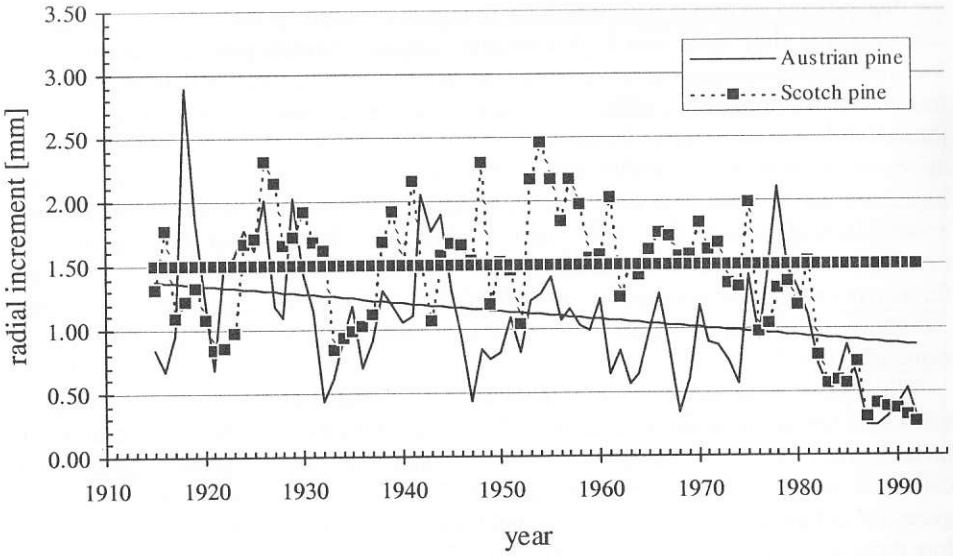

Fig. 1. Empirical and equalled values of radial increments of one tree of Scotch pine and Austrian pine with typical drop of increment after their damaging since 1982.

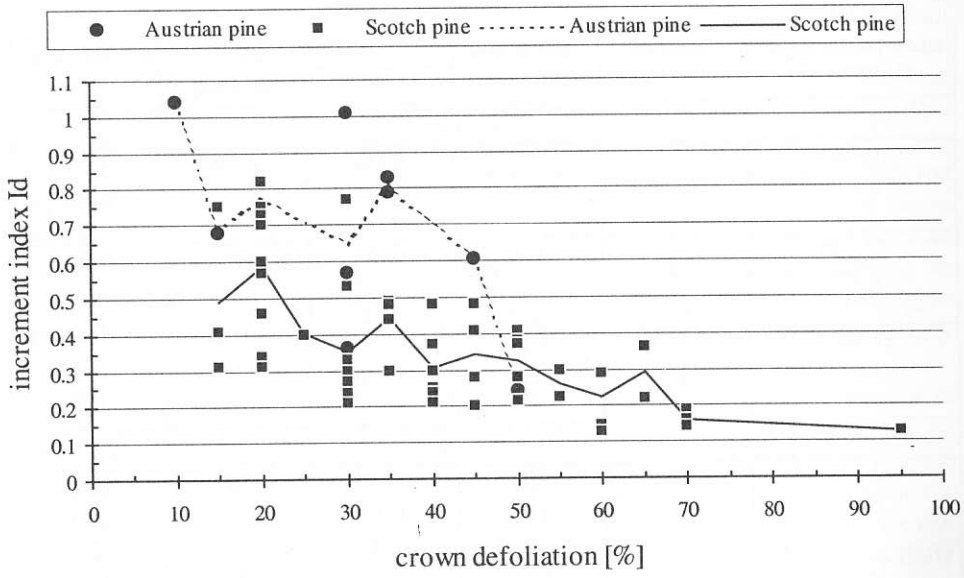

Fig. 2. Individual and mean values of the increments of indexes of Scotch pine and Austrian pine in the dependence on crown defoliation.

the dependence on crown defoliation for both pines. Based on their first assessment we can state that they have very high variability, equally Scotch pine and Austrian pine. Variability of increment indexes can have several reasons, but we confirmed similarly to many other authors only defoliation of tree crowns as the most important one. Though the variability of increment indexes is considerable, we can suppose from the figure their approximate non-linearly declining dependence on crown defoliation. As we can see in Fig. 2 average indexes of Scotch pine have almost for the whole range of defoliation by about 0.02 units lower values than Austrian pine. It would mean that the same air pollutants effect causes greater increment loss for Scotch pine than Austrian pine. Given difference in average values must not be actually significant difference with relatively high variability of individual values. Therefore we evaluated their significance by means of statistical tests.

With regard to the fact there were available only 11 radial increments for Austrian pine the whole set of increment indexes was divided according to defoliation of crowns into three degrees with interval 0-30%, 31-50%, 51% and more. Table 1 presents basic statistical characteristics of radial increments and their increment indexes according to these three groups of defoliation. For Austrian pine defoliation above 50% has not occurred and therefore there are only two groups. Statistical significance of differences between arithmetical

Table 1. Basic statistical characteristics of radial increments and their indexes of Scotch pine and Austrian pine

Interval of defoliation of crowns [%]	Statistical characteristic	Defoliation of crowns [%]	Increment [mm]		Increment index
			real	supposed	
Scotch pine					
0 – 30	$\bar{x}$	22.6	0.359	0.758	0.488
n = 19	s_x	5.5	0.187	0.233	0.204
	s_x%	24.2	52.1	30.8	41.9
31 – 50	$\bar{x}$	42.6	0.203	0.584	0.353
n = 21	s_x	5.7	0.082	0.177	0.101
	s_x%	13.4	40.4	30.3	28.7
51 – 100	$\bar{x}$	65.9	0.135	0.612	0.218
n = 11	s_x	10.6	0.091	0.281	0.072
	s_x%	16.1	67.2	45.9	33.0
Austrian pine					
0 – 30	$\bar{x}$	22.5	0.698	0.943	0.741
n = 6	s_x	8.0	0.257	0.193	0.238
	s_x%	35.7	36.8	20.5	32.1
31 – 50	$\bar{x}$	43.0	0.460	0.859	0.538
n = 5	s_x	6.8	0.250	0.334	0.258
	s_x%	15.8	54.4	38.9	48.0

Table 2. Statistical tests of the significance of diffrences between arithmetical means of radial increments and their indexes for Scotch pine and Austrian pine

Interval of defoliation of crowns [%]	Scotch pine			Austrian pine			t-value	
	n	$\bar{x}$	s_x	n	$\bar{x}$	s_x	calculated	critical $t_{0.05}$
Real increment								
0 – 30	19	0.359	0.187	6	0.698	0.257	3.37	2.07
31 – 50	21	0.203	0.082	5	0.460	0.250	3.71	2.06
Supposed increment								
0 – 30	19	0.758	0.233	6	0.943	0.193	1.69	2.07
31 – 50	21	0.584	0.177	5	0.859	0.334	2.50	2.06
Increment index								
0 – 30	19	0.488	0.204	6	0.741	0.238	2.44	2.07
31 – 50	21	0.353	0.101	5	0.538	0.258	2.46	2.06

means of the increments of Scotch pine and Austrian pine was assessed by Student t-test whereas it was supposed that tested values are independent and their dispersions are equal. Differences between real and supposed increments as well as between increment indexes of both pine species were tested separately. From the comparison of calculated and critical t-values given in Table 2 we can state that with 95% probability Austrian pine has statistically more significantly higher real and supposed increments and increment indexes than Scotch pine. The only exception are supposed increments with defoliation 0-30%, where this different was not confirmed by statistical test. Particularly for crown defoliation within 30% (on average 23%) Scotch pine has average increment index 0.488 and Austrian pine 0.741, it means by 0.253 higher. With trees crown defoliation in the interval 31-50% (on average 43%) Scotch pine has increment index 0.353 and Austrian pine 0.538, it means higher by 0.185. It follows from this comparison unanimously that Austrian pine has with the same defoliation relatively higher increments that Scotch pine. After generalizing we can state that with damage and trees crown defoliation within 50% Austrian pine has higher increments by about 20-25% than Scotch pine. This difference is with 95% probability statistically significant.

After summarizing the obtained results we can state that our results correspond with known results of several authors. It is mainly dependence of increment losses on damage of trees by crown defoliation. A new finding is different effect of air pollutants and crown defoliation on radial increment of Scotch pine and Austrian pine. Our finding documents higher resistance of Austrian pine against air pollutants effect than of Scotch pine. We can add to our current knowledge on broad ecological scale of Austrian pine and particularly its unrivalled adaptability in extreme site conditions also a new finding on its higher resistance against damage of crown by air pollutants and reduction of wood increment.

Conclusion

The effect of air pollutants on diameter increment of Scotch pine and Austrian pine was studied on increment bore holes of radial diameter increment of their stems at the height 1.3 m aboveground. In the forest stand, which was directly subjected to air pollutants effect from close plant for the production of calcium hydroxide 11 bore holes were taken for Austrian pine and 51 for Scotch pine. After dating and synchronizing the curves of radial increments their increment trends were equalled. Based on them increment index was derived for every tree as a ratio of actual and supposed increment in the year 1992. The significance of differences between actual and supposed increments as well as between increment indexes of both pine trees was tested by statistical test. With the same damage to trees by air pollutants, which was expressed by defoliation of crown, Austrian pine had statistically higher increments and increment indexes than Scotch pine. Within defoliation 0-50% it represents 20-25%. On the basis of knowledge we can classify Austrian pine among tree species more resistant to air pollutants.

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Petráš R., Mecko J., Nociar V.: **Vplyv imisií na hrúbkový prírastok borovice sosny a borovice čiernej.**

V lesnom poraste pod priamym imisným vplyvom sme odobrali 11 sond pre borovicu čiernu a 51 sond pre borovicu sosnu. Po datovaní a synchronizácii prírastkových kriviek sa vyrovnali ich prírastkové trendy, z ktorých sme pre každý strom odvodili prírastkový index ako pomer skutočného a predpokladaného prírastku v sledovanom roku 1992. Významnosť rozdielov medzi skutočnými a predpokladanými prírastkami, ale aj medzi prírastkovými indexmi obidvoch borovíc sme testovali štatistickým testom. Pri rovnakom imisnom poškodení stromov, ktoré sme vyjadrovali defoliáciou korún, mala borovica čierna o 20-25% vyššie prírastkové indexy ako borovica sosna. Na základe týchto poznatkov hodnotíme, že borovica čierna je voči imisiám odolnejšia ako borovica sosna.