Influence of amphibolite powder and Silvamix fertiliser on Norway spruce plantation in conditions of air polluted mountains

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ABSTRACT: The objective of the paper is to assess the effects of amphibolite powder (waste from a dust removing process in a rock pulveriser) and Silvamix slow release fertiliser on Norway spruce plantation in the harsh physical environment of the Jizerské hory Mts. The plantation characteristics such as mortality, annual height increment, stem base diameter, crown diameter and nutrient analyses are evaluated. A nine-year-long period of observation is summarised. The effects of both the forms of chemical amelioration seem to be positive and statistically significant. The benefits of the amelioration expressed in absolute figures have been easily observable until now. Recently, the importance of these benefits has decreased after the adaptation of planted trees to the mountain site and natural acceleration of their annual increment.

Keywords: Jizerské hory Mts.; Norway spruce; chemical amelioration; amphibolite powder; Silvamix fertiliser; plantation development

The Jizerské hory Mts. are border mountains in northern Bohemia. A vast forest decline occurred at the highest elevations of the Jizerské hory Mts. during the second part of the 1970s and in the 1980s. High concentrations of air pollutants and their subsequent deposition in soils were the main causes of this serious phenomenon. The SO_x generated in the past on a massive scale by thermal power stations should be mentioned in this connection first of all. There arose extensive clear-cut areas as a result of the forest decline in the Jizerské hory Mts., the reforestation of which was very difficult in the extreme mountain environment. The difficulty of this reforestation (heavy plantation losses, increment depression, etc.) initiated research on support of young tree plantations in such extreme conditions. The evaluation of effects of precisely applied chemical amelioration on prosperity of young trees in mountain clear-cut areas is one of the research themes (BALCAR, PODRÁZSKÝ 1995). The gist of this research is to assess to what extent the application of amendments could help young tree plantations to recover from a planting shock in harsh conditions ruling in the air-polluted mountain felling coupes. Basically, such amendments only with long-lasting and gradual ameliorative influence are desirable to be applied in order to respond to the physiological needs of young trees and reduce losses through leaching.

Two different slow acting fertilisers were chosen for the experiment evaluated in this paper. The amphibolite powder is a cheap and traditional material used for purposes of soil amelioration. Nevertheless, this material has to be applied in relatively high dosage to achieve a reasonable soil improving effect. Therefore the costs related to its transport and application are relatively high. On the other hand, Silvamix is a modern slow release fertiliser widely used in the Czech forestry. This fertiliser can be easily transported and applied, but it is considerably more expensive in terms of purchase costs.

MATERIAL AND METHODS

The planting experiment was established in the Central Ridge of the Jizerské hory Mts. (Lat. 50°49´N, Long. 15°21´E) at an altitude of 960 m a.s.l. in 1994. The mean annual air temperature is 5.2°C and the mean annual precipitation is 1,089 mm (BALCAR 2002). The bedrock is biotitic granite, the soil type is determined as mountain humus podzol (Ferro-humic Podzol according to the FAO terminology). The average air SO_2 concentration is 11 $\mu g/m^3$ and that of air F is 0.18 $\mu g/m^3$ (KUC 2000).

The experimental plantation was established in 1994. It consists of Norway spruce trees (*Picea abies* [L.] Karst.), which were positioned in 9 independent subplots (10 × 10 m). Each subplot contained 50 trees at the spacing of 1 × 2 m. The young spruces were 4 years old in 1994. They originate from the Beskydy Mts. (north-eastern Moravia).

In addition to control (3 subplots), two alternative fertilised variants were established: amphibolite variant (3 subplots) and Silvamix variant (3 subplots).

In the amphibolite variant, the trees were fertilised during their plantation in 1994, i.e. 2 kg of amphibolite

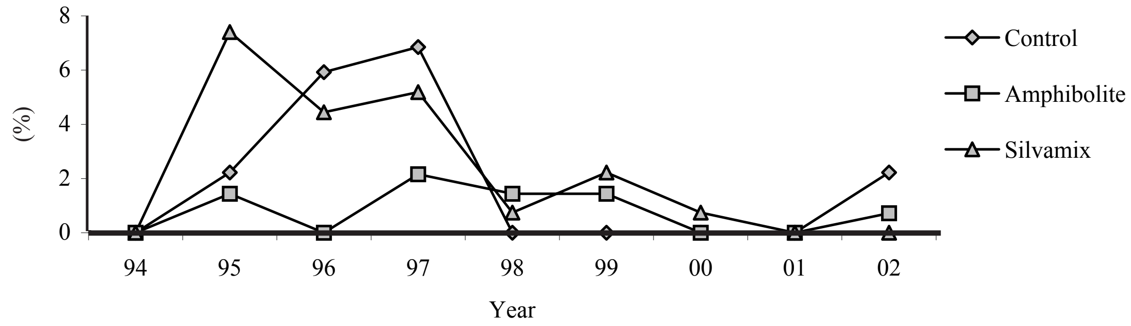

Fig. 1. Annual mortality development of particular variants

powder were mixed with soil in the space of planting hole (35 × 35 × 25 cm). The amphibolite powder originates from a quarry near Libodřice village (central Bohemia). It contains 7.90% of Ca, 4.82% of Mg, 0.82% of K and 0.13% of P. This powder consists of 5% of particles with the diameter over 0.25 mm, 53% of particles with the diameter between 0.25 and 0.05 (mm) and 42% of particles whose diameter was below 0.05 mm.

The Silvamix Forte fertiliser tablets were used in the Silvamix variant. The fertiliser consists of 17.5% of N, 5.4% of Mg, 8.7% of K and 7.7% of P. They were applied later – in 1997. A planting bar was used to position the tablets 15 cm under the soil surface. There were 4 tablets per each tree applied in this variant (i.e. 10 g of the fertiliser/tree). The tablets were positioned evenly in circle around a tree stem. The "application circle" diameter was approximately 60 cm.

The paper summarises the outputs of measurements that were made in the nine-year-long period of observations (1994–2002) including mortality, annual height increment, stem base diameter, crown diameter and nutrition of plantation. The mortality and annual height increment were measured annually, the other characteristics usually at longer intervals.

A scaled rod was used to measure tree height values and to determine crown diameters. The height values are measured to the nearest ± 1 cm and those of crown diameters to the nearest ± 10 cm. A calliper is used to measure stem base diameter to the nearest ± 1 mm.

Except for mortality, the results of the other abovementioned biometrical characteristics were statistically analysed using ANOVA, Homogeneity of Variance Test – Bartlett's Procedure, Multiple Comparisons + (in the case of variance heterogeneity) Kruskal-Wallis Analysis and Multiple Comparisons with *t*-distribution. The chosen confidence level was 95%. The statistically processed files consist of the data that belong only to the trees surviving in 2002. In the tables, different letter indexes at the values compared in pairs indicate statistically significant difference. The outputs of nonparametric analyses, which were used in the case of variance heterogeneity, are marked with asterisk.

The nutrition analyses are presented in percentages of macroelements (N, P, K, Ca, Mg, S) in dry matter of assimilatory tissues. Nutrition status of assimilatory tissues was evaluated in 1996, 1999 and 2001 (no detailed statistical analysis). Samples of needles were taken in off-season period (usually in the second half of October). A composite sample was formed for each variant and consisted of the newest needle generation. The sampled needles originated from annual shoots in the third whorl. The samples were analysed in the Tomáš Laboratory (FGMRI – Opočno Research Station) by standardised methods (ZBÍRAL 1994).

RESULTS

Plantation development

Mortality (Figs. 1 and 2)

The application of the amphibolite powder markedly reduced the mortality of young spruces in the period of observation (1994–2002). In contrast to control, there was no sharp upswing in the curve of annual mortality rate (A.M.) in the amphibolite variant during the first years after planting. The Silvamix fertiliser was applied in 1997. In the Silvamix variant, the annual mortality rate of spruces developed analogously to control before 1997. The plantations of all three variants stabilised by 1998 – the annual mortality rate did not exceed 2.5% since that year. In 2002, the total mortality rate (T.M.) indicated a positive effect of application of amphibolite powder on prosperity of young spruce plantation:

$\text{T.M.}_{\text{CONTROL}} = 17.0\%$; $\text{T.M.}_{\text{AMPHIBOLITE}} = 7.2\%$;
$\text{T.M.}_{\text{SILVAMIX}} = 20.7\%$.

Height growth (Table 1, Fig. 3)

The young spruces, irrespective of the variant, suffered a depression of height growth in their first years after planting. The spruces of the amphibolite variant and of the Silvamix variant got over the depression in 1997, the ones of the control got over the depression one year later in 1998. In terms of statistical analysis, the young trees of the amphibolite variant showed significantly higher values of the annual height increment than the control in the period from 1996 to 2000. The Silvamix fertilised spruces accelerated their height growth in 1997 when the fertiliser was applied. They got ahead of the control and, one year later in 1998, they overtook slightly but steadily

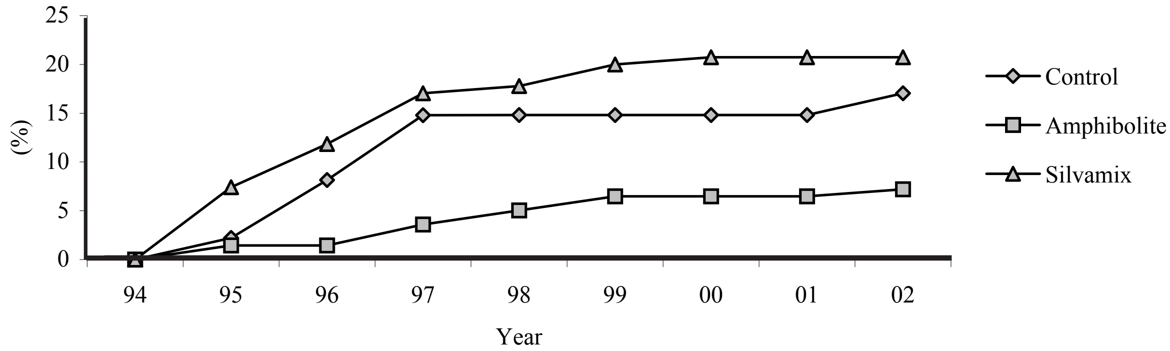

Fig. 2. Total mortality development of particular variants

Table 1. Development of annual height increment

Year		94	95	96	97	98	99	00	01	02	94–02
Bartlett's test value		10%	38%	–	–	14%	95%	–	48%	8%	56%
Control	*x* (cm)	**6.3a**	**2.4a**	**3.9a***	**5.9a***	**10.0a**	**11.4a**	**10.2a***	**18.6a**	**30.1a**	**11.0a**
	s (cm)	4.15	2.81	3.10	6.46	6.98	7.16	7.76	10.86	14.02	4.66
Amphibolite	*x* (cm)	**5.9a**	**2.8a**	**5.7b***	**8.3b***	**12.6b**	**12.0b**	**13.5b***	**20.3a**	**32.3a**	**12.6b**
	s (cm)	3.56	3.19	4.61	7.93	8.14	6.97	9.69	11.47	17.23	5.14
Silvamix	*x* (cm)	**5.4a**	**2.4a**	**3.9a***	**7.4ab***	**14.3b**	**12.3b**	**13.7b***	**20.3a**	**34.4a**	**12.7b**
	s (cm)	3.43	3.07	2.99	6.61	8.35	7.00	10.03	12.21	16.20	4.96

Different letter indexes at the values compared in pairs indicate statistically significant difference. The outputs of nonparametric analyses that were used in the case of variance heterogeneity are marked with asterisk

also the trees of the amphibolite variant. The Silvamix fertilised spruces showed a significantly faster pace of height growth than control in the period from 1997 to 2000. In spite of a slight difference, there was no statistical significance between the amphibolite and Silvamix variant during the whole period of observation. The benefits of fertilisation by amphibolite as well as by Silvamix tablets, expressed in form of annual increment advantage, ceased to be statistically significant in 2000. The periodic annual increment P.A.I. (94-02) can be used for the variant comparison.

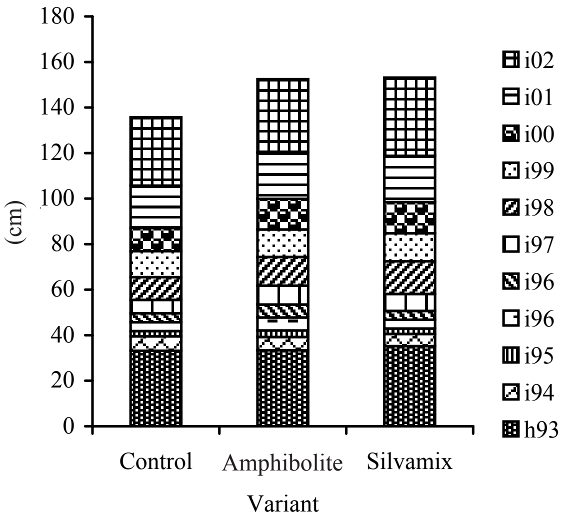

Fig. 3. Development of average plantation height

$$\mathrm{P.A.I.}_{\mathrm{AMPHIBOLITE}} = 114.5\%\ \mathrm{P.A.I.}_{\mathrm{CONTROL}}$$
$$\mathrm{P.A.I.}_{\mathrm{SILVAMIX}} = 115.5\%\ \mathrm{P.A.I.}_{\mathrm{CONTROL}}$$

Crown diameter (Table 2***)***

The average crown diameter of the spruces was influenced by fertilisation relatively late and slightly. There was no marked difference between the particular variants in 1999. As late as in 2002, statistically significant differences were registered in the average crown diameter values. However, in terms of forestry practice, these differences are not of crucial importance in spite of the statistical significance. The average crown diameter of the amphibolite variant was 14% larger than that of the control and the average crown diameter of the Silvamix variant was 9% larger than that of the control in 2002.

Table 2. Development of average crown diameter

Year		99	02
Bartlett's test value		86%	26%
Control	*x* (cm)	**48a**	**104a**
	s (cm)	18.3	31.9
Amphibolite	*x* (cm)	**54a**	**119b**
	s (cm)	18.7	36.6
Silvamix	*x* (cm)	**51a**	**113ab**
	s (cm)	17.8	32.7

Different letter indexes at the values compared in pairs indicate statistically significant difference

Table 3. Development of average stem base diameter

Year		1999	2002
Bartlett's test value		44%	16%
Control	x (cm)	**1.6a**	**4.0a**
	s (cm)	0.56	1.22
Amphibolite	x (cm)	**1.9b**	**4.4ab**
	s (cm)	0.63	1.38
Silvamix	x (cm)	**1.8ab**	**4.5b**
	s (cm)	0.63	1.46

Different letter indexes at the values compared in pairs indicate statistically significant difference

Stem base diameter (Table 3)

The effect of fertilisation on stem base diameter was already detectable in 1999, however, nowise markedly. The average stem base diameter of the amphibolite variant was the largest one in 1999. In 2002, nevertheless, the Silvamix fertilised spruces got ahead of the spruces of amphibolite variant in terms of this parameter. In both the above-mentioned years, there was no significant difference between the amphibolite and Silvamix variant. The average stem base diameter of the control was slightly but statistically significantly lower than those of the ameliorated variants. In 2002, the average stem base diameter of the amphibolite variant was 10% larger than that of the control. The average stem base diameter of the Silvamix variant was 12.5% larger than that of the control at that time.

Average needle length and length of annual shoots (Figs. 4 and 5)

The potential impact of fertilisation on the average needle length and the average length of annual shoots positioned in the third whorl was also quantified in 1999 and 2002. There was not detected any marked difference between the variants.

Nutrition of plantations (Fig. 6)

Nitrogen. The N supply of the plantations of all three variants seems to be sufficient for the time being. Irrespectively of the variant, the N content showed a slight upward trend. The application of neither amphibolite powder nor Silvamix fertiliser influenced detectably the N content in the assimilatory tissues.

Phosphorus. The P supply also seems to be sufficient in all three variants during the period of observation. In the amphibolite variant, there is detectable a slowly diminishing impact of rock powder on spruce nutrition, which has the form of a gradual P proportion decrease to the level of the control. The relatively high P content in the assimilatory tissues of the Silvamix variant was detected in 1999. This could be a reaction to the application of the fertiliser which was realised in 1997.

Potassium. The K proportion in the assimilatory tissues is normal irrespectively of the variant. It fluctuates within the range of moderate level.

Calcium. The Ca content indicates the influence of applied amphibolite powder on nutrition of young trees. In 1996, the Ca proportion in the needles of the spruces belonging to the amphibolite variant was markedly higher than the proportions registered in the control and Silvamix variant. In 1999 and 2001, the Ca content value, however, dropped to the level that is only slightly above the values registered in control and Silvamix variant. This could indicate a process of diminishing of amphibolite effects.

Magnesium. Though the applied amphibolite powder contained 6.4% of Mg, the proportion of this element in

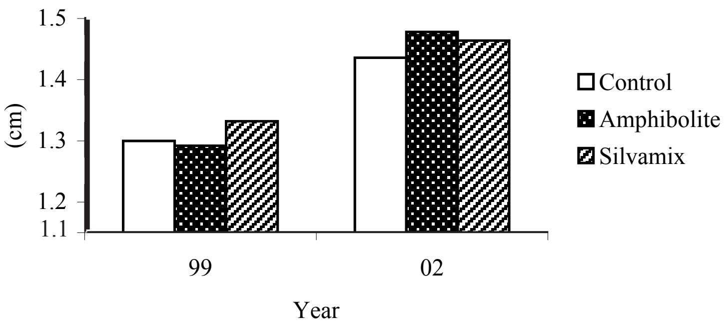

Fig. 4. Development of average needle length in particular variants

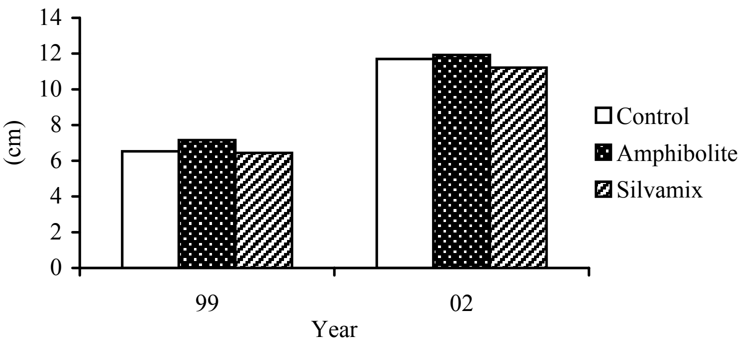

Fig. 5. Development of average length of annual shoots positioned in the third whorl

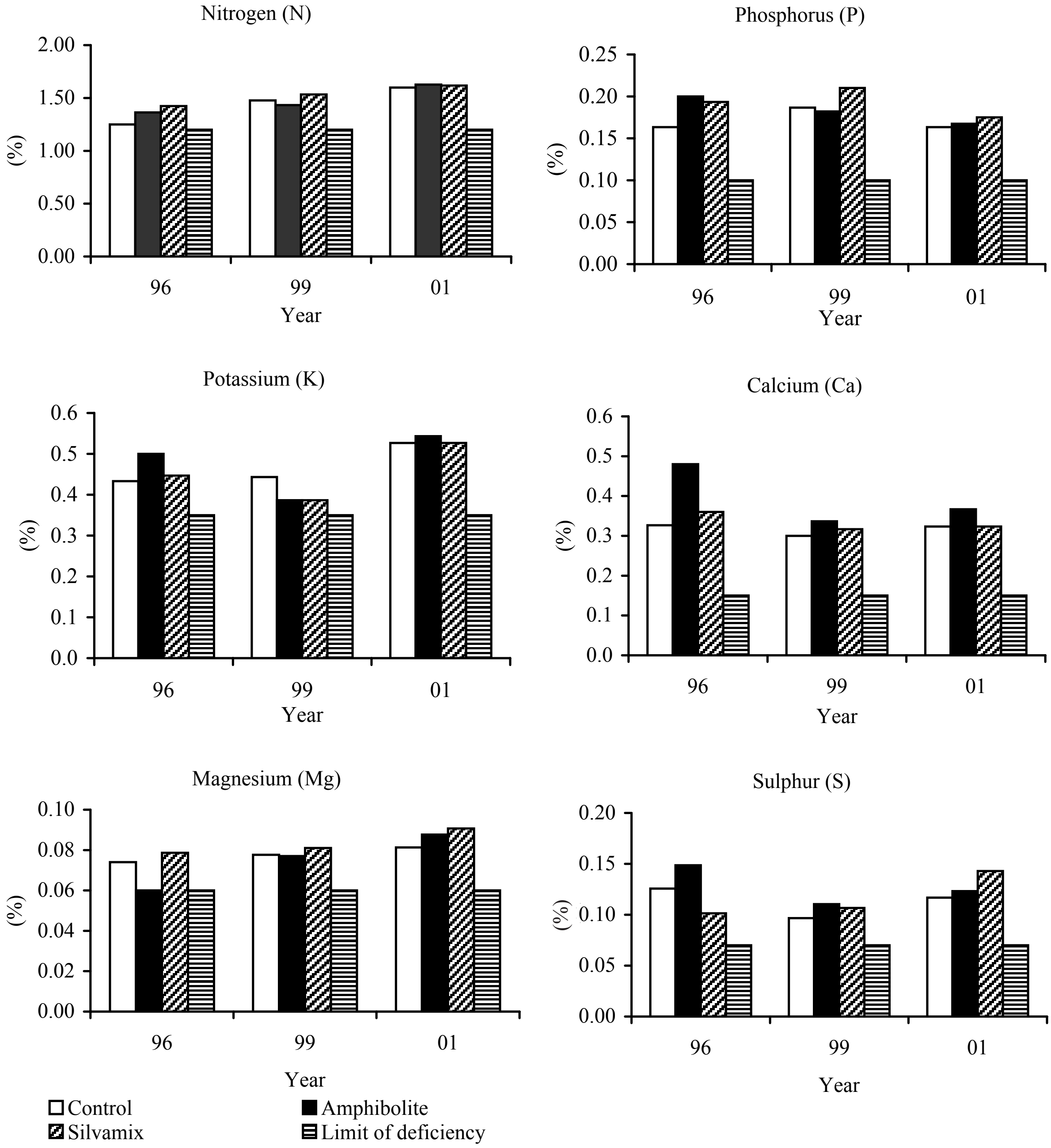

Fig. 6. Nutrition status of assimilatory tissues

the assimilatory tissues of the trees belonging to the amphibolite variant was very low in 1996 – the lowest one within the variant confrontation at that time. In 1999, however, the Mg proportion increased and stabilised in assimilatory tissues of the trees of the amphibolite variant. Except for the Mg anomaly of the amphibolite variant from 1996, the Mg supply of the spruces of all three variants seems to be sufficient and stabilised.

Sulphur. The sulphur contents are fluctuating. Though the values registered in 1999 were hopefully low, the ones registered in 1996 and 2001 are indicative of the remaining pollution impact.

DISCUSSION

There are many issues related to the chemical soil amelioration and forest fertilisation in mountain conditions. Many discrepant conclusions were presented by many authors as to its applicability (ŠRÁMEK 2003; PODRÁZSKÝ 2003; LEPŠOVÁ 2003; PALÁTOVÁ, MAUER 2003; PELC 1997; MATERNA, SKOBLÍK 1988, etc.). In fact, soil amelioration or fertilisation could be motivated by various aims and applied in various forms under various circumstances. In mountain conditions of the Czech Republic, liming and fertilisation are prosecuted to compensate detrimental impacts of air pollution on soils. Basically, the two most frequent goals should be achieved by these measurements: either to stabilise the existing forest stands or to support the newly established plantations. In Czech forestry practice, the application of the ameliorative substratum to a relatively large area is usual. This way of application is convenient for amelioration of existing and sufficiently vital forest stands or stabilised plantations with closing canopy of their crowns. However, in the clear-cut areas induced by air pollution, this way of application could be very risky from the viewpoint of long-term site development (PODRÁZSKÝ 2003). The process of humus mineralisation is frequently intensified due to the absence of forest cover at sites of such type. The non-point application of ameliorative substratum could result in further intensification of mineralisation process and in losses of organic matter including nutrients.

Therefore, the "spot amelioration" is tested to support young plantations in the mountain clear-cut areas induced by air pollution. The ameliorative substratum is applied precisely to the trees (to their vicinity) or directly mixed with soil in the planting hole during the plantation. The young trees can thus utilise the advantages of "spot amelioration" while the potential risks connected with organic matter losses are limited to a relatively small proportion of soil.

This contribution summarises outputs of the experiment that is aimed at "spot amelioration" in the extreme conditions. The young trees from a nursery are not usually fully adapted to such a poor and extreme site as mountain clear-cut area induced by air pollution impact. The young spruces therefore suffered a "planting shock", which resulted in the annual increment depression (all three variants) and in the increased mortality rate (control and Silvamix variant). The planting shock lasted 4 years in this particular instance: from 1994 to 1997.

The application of amphibolite powder reduced the mortality rate of young spruces significantly, which is probably the most important benefit of soil amelioration in this experiment. It is presumable that the Silvamix tablets could have had an analogous effect if they had been applied in the course of plantation and not three years later in 1997. Similar effects are also observed in other conditions and different tree species (PODRÁZSKÝ 2000).

The benefits of both the forms of amelioration (amphibolite and Silvamix) expressed in absolute figures of annual height increment have been easily observable until now. However, the relative importance of the amelioration effects decreased rapidly after the adaptation of the planted trees to the mountain site and acceleration of their annual increment. The benefits in the form of annual increment advantage ceased to be statistically significant in 2000.

One important conclusion could be drawn as to the support of newly planted young trees in mountain glades: the sooner after plantation the ameliorative substratum is applied, the more significant the profit that can be expected.

In general terms, the actual effect of amelioration applied in this experiment is detectable but not substantial at all. An interesting comparison suggests itself: KUNEŠ (2003) summarises outputs of an amelioration experiment that was established at the same locality. A striking positive impact of "spot application" of limestone powder was registered on young Norway spruce plantation at that case.

The different effectiveness of amelioration could result from different ameliorative medium as well as from microclimate, tree provenience, soil conditions, etc. This difference shows how difficult it is to generalise in such severe conditions. Therefore, in the mountain clear-cut areas, it is desirable to limit the soil proportion in direct contact with ameliorative substratum to an indispensable minimum. The "spot application" of ameliorative substratum ("spot amelioration") could better respond to the variable and vulnerable environment of the mountain clearings than the broadly applied one.

CONCLUSIONS

The positive effect of amelioration applied in this experiment is detectable but not substantial at all.

The Silvamix Forte fertiliser could have influenced the plantation prosperity much more effectively if it had been applied immediately after plantation.

As far as the chemical amelioration is used as a support of young plantations, it is possible to assert: The sooner after plantation the ameliorative substratum is applied, the more significant the profit that can be expected.

It is possible to presume that the "spot application" of ameliorative substratum ("spot amelioration") could be more acceptable than the broadly applied one in the mountain clear-cut areas.

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Vliv aplikace amfibolitového odprašku a hnojiva Silvamix Forte na prosperitu smrkové výsadby v podmínkách hor s imisní zátěží

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ABSTRAKT: Příspěvek vyhodnocuje účinky aplikace amfibolitového odprašku a pomalu rozpustného hnojiva Silvamix Forte na výsadbu smrku ztepilého v ekologicky značně nepříznivých podmínkách Jizerských hor. Je v něm vyhodnocen vývoj mortality, výšky a výškového přírůstu, průměru koruny, tloušťky kmínku a některých dalších parametrů. Pozornost je věnována také chemickým analýzám asimilačního aparátu. Vyhodnocení shrnuje devítileté období po výsadbě mladých smrků na imisní holinu. Pozitivní účinky obou způsobů chemické meliorace jsou v číselných hodnotách dosud zřetelné a statisticky signifikantní. V poslední době – po adaptaci výsadeb na horské stanoviště a po přirozeném oživení jejich přírůstu – však již účinek meliorace i její význam pro další vývoj výsadeb ustupují.

Klíčová slova: Jizerské hory; smrk ztepilý; chemická meliorace; amfibolitový odprašek; hnojivo Silvamix; vývoj smrkových výsadeb

Možná pozitiva i rizika hnojení a chemické meliorace jsou dostatečně známa. Co ale současná lesnická praxe postrádá, to jsou přesnější informace o tom, za jakých okolností k těmto opatřením přistoupit a jakým způsobem je provádět, aby byla minimalizována možná rizika a zároveň posílena pravděpodobnost projevu jejich pozitivních účinků. Výsadbový pokus, o němž informuje příspěvek, je součástí širšího projektu, který byl iniciován právě touto problematikou.

Výsadbový experiment, o němž informujeme, byl založen v roce 1994 na pokusné ploše Jizerka a sleduje vliv aplikace jemného amfibolitového odprašku a hnojivých tablet Silvamix Forte na prosperitu mladé smrkové výsadby.

Oplocená plocha se nachází na imisní holině v nadmořské výšce 960 m na Středním Jizerském hřebeni. Stanoviště je řazeno do lesního typu kyselá smrčina třtinová (8 K 2), hospodářského souboru 721 a pásma imisního ohrožení B. Průměrná roční teplota stanoviště je 5,2 °C a celkové roční srážky asi 1 089 mm (měřeno na výzkumné ploše). Horninové podloží je tvořeno biotitickou žulou, půdním typem je horský humusový podzol. Průměrná koncentrace SO_2 ve vzduchu je 11 μg/m^3, u F pak činí 0,18 μg/m^3 (měřeno v osadě Jizerka asi 1 500 m od výzkumné plochy).

Pokusná výsadba sestává z devíti čtvercových plošek (100 m^2), přičemž na každou z nich bylo vysázeno 50 čtyřletých sazenic smrku ztepilého (*Picea abies* [L.] Karst.) ve sponu 2 × 1 (m).

Vedle kontroly byly založeny dvě přihnojené varianty. Jedná se o amfibolitovou variantu, kde byly při výsadbě kultury na každou sazenici použity 2 kg amfibolitového odprašku a promíseny s půdou v jamkách. Velikost jamek byla přibližně 35 × 35 × 25 cm. Druhou přihnojenou variantou je silvamixová varianta. U silvamixové varianty bylo hnojivo aplikováno později, v roce 1997.

Ke každému smrku byly sazečem umístěny čtyři tablety (tj. 10 g hnojiva na stromek) do hloubky asi 15 cm pod povrch půdy. Rozmístění tablet bylo po obvodu kruhů o průměru 60 cm se středy v osách stromků.

Hlavním cílem experimentu bylo zodpovězení otázky, zda může hnojení cíleně aplikované k jednotlivým mladým stromkům v extrémních podmínkách horské imisní holiny pozitivně ovlivnit vitalitu výsadby. To znamená, zda může mladým smrkům pomoci překonat šok z přesazení do extrémně nepříznivých podmínek a urychlit jejich vývoj v odrostlejší a odolnější jedince.

Aplikace amfibolitového odprašku snížila celkovou mortalitu mladých smrků v období 1994 až 2002. Zabránila totiž razantnímu vzestupu hodnot meziroční mortality, který obvykle v prvních letech po výsadbě provází mladé kultury v extrémních podmínkách imisní holiny a je jedním z projevů tzv. „šoku z přesazení“. V roce 2002 tak vykazovaly výsadby přihnojené amfibolitem jen 7% celkovou mortalitu, zatímco celková mortalita u kontroly činila 17 %. V případě silvamixové varianty se pozitivní vliv hnojiva spočívající v omezení mortality projevit nemohl, protože tablety byly aplikovány až v roce 1997, tedy v době, kdy již výsadby prodělaly nejkritičtější období s nejvyššími ztrátami a docházelo k postupné stabilizaci a odeznívání „šoku z přesazení“. Mortalita u silvamixové varianty je tak v roce 2002 ještě mírně vyšší než u kontroly a dosahuje necelých 21 %.

Přihnojení se u obou testovaných variant pozitivně projevilo i na výškovém přírůstu. Jeho stimulační efekt na přírůst nicméně nebyl přes statistickou průkaznost až tak výrazný a význam měl především v první polovině sledovaného období. I když si přihnojené varianty v absolutních hodnotách běžného ročního výškového přírůstu stále zachovávají určitý náskok, význam tohoto náskoku poklesl poté, co se výsadby na stanovišti aklimatizovaly a oživily tempo svého odrůstání. Pokles významu melioračního stimulu pro další vývoj výsadeb se odrazil i v tom, že v posledních dvou letech se hodnoty běžného ročního přírůstu u všech tří variant od sebe přestaly statisticky průkazně lišit. Určitou statisticky stále signifikantní výhodu si však obě přihnojené varianty dosud zachovávají u průměrné výšky výsadeb.

Hnojení se pozitivně projevilo i na průměru korun a tloušťce báze kmínku. Náskok přihnojených výsadeb v těchto parametrech lze statisticky podchytit, ale není nijak výrazný.

Zásobení výsadeb jednotlivými živinami dosud zatím nepokleslo ani u jedné ze sledovaných variant pod hranici deficitu. Snad kromě obsahu vápníku v jehličí výsadeb amfibolitové varianty v roce 1996 nelze konstatovat, že by aplikované hnojivé substráty nějak výrazněji zvýšily zastoupení některé ze sledovaných živin v asimilačním aparátu mladých smrků.

Z dosavadních výsledků pozorování výsadeb lze vyvodit následující závěry:

Chemická meliorace v tomto experimentu pozitivně ovlivnila prosperitu a odrůstání výsadeb. Její stimulační efekt nicméně nebyl zdaleka tak výrazný jako u dalšího melioračního pokusu na dané lokalitě, o němž informuje KUNEŠ (2003).

Dá se předpokládat, že hnojivo Silvamix Forte mohlo ovlivnit prosperitu smrkové kultury podstatně efektivněji, kdyby bylo aplikováno ihned po výsadbě.

Pokud má přihnojení napomoci překonat výsadbám první nejkritičtější období po výsadbě na imisní holinu, pak lze konstatovat, že čím dříve je hnojivý substrát aplikován, tím efektivněji může být mladou výsadbou využit.

Z dosavadních poznatků o chemické melioraci se zdá, že na horských imisních holinách by „bodová“ nebo pomístná cílená aplikace hnojivých či melioračních substrátů mohla být podstatně akceptovatelnější než jejich velkoplošný rozptyl.

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