LIMING OF SPRUCE PLANTATION ON THE TOP LOCALITY OF THE JIZERSKÉ MTS.

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The tree planting and ameliorative experiment has been established in the central part of the Jizerské Mts. at an altitude of about 960 m a.s.l. in 1990–1995. One of aims of the experiment was to test the liming effects on the growth and development of new Norway spruce (*Picea abies* Karst.) plantations. Two different ways of liming were tested: on the soil surface around the trees just after plantation and mixing with the soil in the planting point – in both cases 5 $t.ha^{-1}$ of fine dolomitic limestone. The short term effects on the Norway spruce plantation, on the soil and tree quality and growth were evaluated. Soil chemistry was positively affected as well as the plantation growth and state.

forest soils; amelioration; liming; spruce plantation; pedochemistry

INTRODUCTION

The Jizerské Mts. are regarded as one of the most air polluted regions in the Czech Republic. Forest stands died on large areas and severe forest decline can be observed in the rest of the forested land. The majority of declined and cut stands has been reforested – more than 6 000 ha of new plantations is in this mountain range at present. Both autochthonous and introduced (e.g. blue spruce) tree species have been used for the forest regeneration. But the new plantations do not show sufficient health state very often – the reasons are: extreme site conditions in the top mountain localities with air pollution load, and the unappropriated species and provenances composition of planted stock. Tree plantation experiments testing convenient species for regeneration of forest ecosystems have been established in the past as well as at present (Materna, Jirgle, 1983; Skuhrovec, 1983; Jirgle, 1985; Tichý, 1988; Balcar, Podrázský, 1994, 1996). One of these research plots was established for the testing of particular species, provenances, as well as for the testing of ameliorative treatments in the top part of the central mountain range in 1990. Research of the Norway spruce plantation liming is a part of this experiment.

Liming is a frequent treatment of reforestation systems applied in immission areas. It should neutralize the acid impact of air pollution on forest soils and improve the vitality of trees. But the results of its practical application are not always positive. Because of the bad technologies selected (aerial application of crushed coarse limestone and dolomitic limestone), the liming effect on soils was not often significant and the treatment failed (for summary of this theme see Podrázský, 1993). Some results of more effective liming application have been published recently (Podrázský, 1994, 1995). First results of the liming effects research on the spruce plantation and its environment in the top part of the Jizerské Mts. are presented in this report.

MATERIALS AND METHODS

Research plot is situated in the stand no. 257 B7 on the territory of the forest district Nové Město pod Smrkem nearly 1.5 km to the north of the Jizerka village. The altitude of the plot is around of 960 m a.s.l., aspect SW, forest type 8K2, immission threat zone B. Soil type was determined as a mountain humus podzol, some places changing to peat podzol (ÚHÚL classification), organozem podzol (MKSP classification), or Ferro-humic podzol to Histo-humic podzol (FAO classification – Hraško et al., 1987). Bedrock is formed of biotitic granite. Mean annual precipitation represents 1 476 mm, mean annual temperature is 4 °C, mean annual SO_2 concentration 25 9 $\mu g.m^{-3}$ and fluorine concentration 0,19 $\mu g.m^{-3}$.

Spruce plantation followed in the described experiment was established in the spring 1991 on the clear-cut area in the spacing 2 x 1 m. Square subplots 10 x 10 m were formed, containing 50 transplants. Comparison of three variants was performed in three replications (control variant 4 replications): K – control, P – application of 1 kg finely ground dolomitic limestone in the circle 50 cm around plants just after plantation, J – application of 1 kg of the same material in the planting hole. Limestone contained 21.5% Ca and 11.25% Mg. Granulometrically, the material was formed of 5.8% of particles with the diameter above 1 mm, 16.3% of particles was between 1 and 0.5 mm, 20.4% between 0.5 and 0.2 mm and 57.5% was less than 0.2 mm.

Soil samples for the comparison of soil on surface limed and control plots were taken in autumn 1994 in 2 replications on each subplot from F and H horizons of holorganic layer and from the A horizon (Ae to E character, uppermost 10 cm of the mineral soil) on each subplot. Sampling points were

selected randomly on the particular variants on undisturbed places, soil samples were analyzed individually.

Another samples were taken directly from the planting points – from the root zone in the planting hole – a year sooner (in 1993). On each particular subplot, mixed samples taken by an auger to 10 cm depth were formed (10 individual samplings). Analyses were performed in the laboratory of the Forest Research Station Opočno by standard methods (Šmídová, 1991). The following characteristics were assessed: pH in water and in 1 N potassium chloride solution, characteristics of the soil adsorption complex by Kappen (S – bases content, H – hydrolytical activity, T – cation exchange capacity and V – base saturation), total C and N content by Springer–Klee, exchangeable acidity, aluminium and hydrogen in 1 N KCl solution, accessible nutrients in the citric acid solution and total nutrients in the holorganic layers (mineralisation with H_2SO_4 + Se and H_2O_2). Phosphorus content was then determined using spectrophotometric method by the Spekol 210, potassium content by the flame photometry and calcium and magnesium content by the AAS.

Biometrical measurements have been performed each autumn since 1992. Total height and foliage state were measured. Health state (defoliation and needle-colour) was assessed in two years' periods. The defoliation was estimated by using of 10% scale, and the colour changes along to 4-degrees scale: 1 – green needles, 2 – yellow-green, 3 – green-yellow, and 4 – yellow. The nutrition state on particular plots was determined in 1994, by the aid of leaf-analysis (mixed samples from 20 plants per plot). Sampling took place in November. Macronutrients were assessed in 1 year old needles, sulphur content was analyzed in 2 year old needles. Finally, the length of shoots (10 replications) and needles (10 pcs in 10 replications), as well as the mass of 10 shoots (10 replications) and needles (100 pcs in 1 replication) were determined.

Statistical programme STATGRAPHICS version 2.1 was used for data processing. The significance of differences was tested by the procedure analysis of variance on the 95% level. In tables, statistically homogeneous groups are identified by the same indexes, if significant differences occur. Indexes are omitted in the case of significant differences absence.

RESULTS AND DISCUSSION

Effects of liming on the intact soil state are given in the Tab. I. It is apparent, that after 4 vegetation seasons the liming resulted in considerable decrease of the holorganic layer thickness (F layer by 12% and H layer by 28%). This fact results in serious losses of the organic matter and within fixed nutrients, especially nitrogen. On the contrary, the soil reaction, expressed as

I. Surface liming effects on soil chemistry on the Jizerka locality (sampling 1994)

Characteristics	Control			Limed 5 $t.ha^{-1}$		
	Horizon					
	F	H	Aeh	F	H	Aeh
Thickness (cm)	6.4	7.9	10	5.6	5.7	10
pH (H_2O)	4.30	4.17	4.47	4.40	4.35	4.60
pH (KCl)	3.44	3.34	3.54	3.63	3.51	3.52
S mval/100 g	21.9	14.4	0.18	31.4	22.6	0.39
H mval/100 g	52.0	46.3	8.00	47.8	46.8	8.80
T mval/100 g	73.8	60.8	8.20	79.2	69.4	9.20
V %	29.3	23.5	1.7	32.4	31.1	3.3
$Acidity_{ex}$	144.1	112.2	44.7	97.5	98.3	43.2
H_{ex} mval/1 000 g	41.1	25.4	11.0	25.4	24.0	10.8
Al_{ex} mval/1 000 g	103.0	86.8	33.6	72.2	74.4	32.4
K_2O mg/100 g	27.1	19.2	2.8	22.6	17.6	2.6
P_2O_5 mg/100 g	28.3	32.6	9.1	25.7	22.2	6.8
CaO mg/100 g	168.8	82.7	11.3	175.4	167.9	17.8
MgO mg/100 g	121.5	52.8	7.2	121.9	135.6	12.5
N_T %	1.56	1.40		1.99	1.47	
P_T %	0.11	0.12		0.10	0.09	
K_T %	0.22	0.26		0.16	0.22	
Ca_T %	0.08	0.07		0.09	0.05	
Mg_T %	0.099	0.002		0.031	0.102	

Note: Identical letters indicate statistically homogeneous groups (differences between variants for particular horizons were tested)

pH (both in water and KCl solution), is more favourable on the limed plots. Differences are obvious in the whole surveyed profile, more pronounced in upper horizons yet.

Bases content is also elevated through liming, in the A horizon more than by 100%. Hydrolytical acidity is comparable on both plots, only in the uppermost horizon a slight decrease is visible. These tendencies resulted only in low increase of the cation exchange capacity and base saturation in absolute values, but due to extreme soil state even this little change represents a considerable improvement of the soil chemistry. Exchangeable acidity is

also remarkably decreased only in the F layer, deeper the effects are very slight only.

Accessible nutrients (in the citric acid solution) are a little lower in the whole profile in the case of potassium and phosphorus, on the contrary, considerably higher for calcium and magnesium, even in the mineral soil. Total nutrient content is slightly elevated for nitrogen, indicating relative enrichment due to accelerated mineralization of the humus, and depressed for phosphorus and potassium. This represents considerable losses, which may be serious in the further development. Total calcium content is slightly lower on limed plots (so deeper horizons are influenced only by dissolved calcium and not by incorporated particles) in the H layer, in the F layer is lower also the magnesium content. Total Mg content increased considerably on the limed plots in the H layer.

Favourable effects correspond with the results of other authors and experiments (e.g. Derome, 1985; Evers, 1984; Gussone, 1983; Podrázský, 1993, 1995). Also in these cases the changes of soil chemistry, corresponding with determined development of followed soil characteristics on the plot Jizerka, were confirmed. The depression of the phosphorus and potassium contents seems to be dangerous for the further plantation nutrition development. It was confirmed by other authors only in certain cases (Seibt, Reemtsma, 1977; Podrázský, 1993). As to the phosphorus, this situation may be caused by the microbial immobilization (Binkley, 1986) and for the second macronutrient mentioned by the cation antagonism and monovalent bases leaching (e.g. Seibt, Reemtsma, 1977). The nitrogen dynamics needs further research, these preliminary results indicate the development suggested by Popovic (1984) for poorer localities: in the 1st phase the relative enrichment and fixation by the soil microbiota and ground vegetation were observed. This is connected with the intense ectohumus mineralization and organic matter losses. The surface humus net mineralization and nutrients content decrease have not been observed before the Czech conditions in (Podrázský, 1995). This phenomenon on the Jizerka locality is probably caused by the site extremity – clear-cut area, low vegetation and plantation vitality.

Qualitative effects of liming were more visible in the planting holes, without buffering effects of the surface humus (Tab. II). The pH-value (in water) increased by 1.5 unit on the surface liming plots and by 2.1 units on the plots with mixing of the limestone in the planting substratum. The pH-value in the KCl showed similar proportion changes. Adsorption complex characteristics exhibited drastic changes, an increase for S, T, and V characteristics and decrease for the last one. Also the characteristics representing the exchangeable acidity decreased very sharply, indicating favourable effect of the lime-

II. Effects of the liming on the soil chemistry in the rooting zone of plantations in the year 1993

Variable	Variant		
	K	P	J
pH H_2O	4.25 a	5.75 b	6.38 c
pH KCl	3.41 a	4.90 b	5.66 c
S[1]	16.2 a	70.4 b	83.5 c
H[1]	28.8 a	15.4 ab	6.6 b
T[1]	45.0 a	85.8 a	90.0 a
V %	34.6 a	82.2 b	96.8 b
$Acidity_{ex}$[2]	77.4 a	22.1 b	13.9 b
H_{ex}[2]	27.9 a	11.0 a	7.3 a
Al_{ex}[2]	49.6 a	11.1 b	6.6 b
C_T %	18.5	12.6	12.6
N_T %	0.73	0.51	0.73
C : N	25	28	21

Note: [1] – adsorption complex characteristics in mval/100 g of fine earth, [2] – exchangeable acidity components (aluminum, hydrogen and total acidity) in mval/1 000 g of fine earth, the same letters indicate statistically homogeneous groups (differences between variants)
Variant K – control, P – surface liming, J – limestone mixed with soil in the planting hole

stone application on the scarified surface (P-variant) and mixing of the ameliorative matter with the soil (J-variant).

Total carbon (humus) content, indicating (again) accelerated mineralization, was lower on the limed plots and the same trend was on the superficially limed soil for the total nitrogen content. This resulted in more favourable C : N ratio on the J-variant and less favourable one on the P-variant, but actually all three variants had not favourable state of this characteristic.

Treatment of the same kind – the mixing of ameliorative material into the soil of the planting point was widely used in the plantation on very poor and degraded sites in Bohemia (Němec, 1950; Materna, 1963; Lhotský et al., 1987). The pedochemical changes, if mentioned, are of the similar trend and size as our results. This treatment needs further study, some results (Tesař, 1986) indicate the exhaustion of nutrients in the planting hole and bad root development in this zone in later stages. Concerning comparable results in other countries, we have not found any information about this type of amelioration.

The spruce nutrition (Tab. III) was affected only in the case of the nitrogen, indicating higher accessibility of this nutrient after liming of both types, especially of the surface one. The difference between K-variant and P-variant is statistically significant. There are no further differences in the foliar nutrition of spruce plants on all three variants. The spruce nutrition is not deficient in any case (Bergmann, 1988).

More favourable soil chemistry and nitrogen nutrition changes on the treated plots are reflected by the faster plantation growth (Tab. IV A). The mixing of the soil with the ameliorative matter seems to be more effective in the first stage of plantation development, but there is a possibility of the reverse of this favourable trend several years (5–10) later (Tesař, 1986). This author documented more rapid plantations growth and development in the first period after liming but, on the other hand, bad outgrowth of roots from the ameliorated planting hole into the neighbouring extremely acid soil. For this reason, the plantation experiment needs further observations. Mentioned possibility is not topical on the surface limed plots. The positive effect of limestone application on the spruce plantation growth was described also by other authors (e.g. Jirgle, 1986).

The foliage state (Tab. IV B) was favourably affected by the liming too. The significant difference in the foliage state between plantation variants was observed in the course of the third year after planting (1993). The defoliation decreases in the order: K-variant (control), P-variant, and J-variant. From 1993 to 1995, defoliation did not change markedly. The foliage colour was also positively affected by liming. Slight difference between treated and untreated plantations was observed even in the year of planting (1991). The most distinct difference in colour was observed in the third year after planting. In accordance with the last observation (1995), very good needle colour on all tested plantations was noticed, without any significant differences.

III. Nutrition state of spruce plantations in 1994

Variant	N	P	K	Ca	Mg	S
	%					
K	1.37 a	0.130 a	0.59 a	0.40 a	0.226 a	0.160 a
P	1.53 b	0.130 a	0.60 a	0.42 a	0.204 a	0.165 a
J	1.44 ab	0.145 a	0.60 a	0.41 a	0.214 a	0.172 a

Note: Identical letters indicate statistically homogeneous groups (differences between variants were tested)

IV A. Reaction of spruce plantation on the Jizerka locality on the liming – growth reaction

Variant	Height (cm)	Increment (cm)					Increment (%)
	1990	1991	1992	1993	1994	1995	1991–1995
K	24,6 a	7,3 a	3,7 a	2,8 a	4,8 a	5,6 a	100
P	26,5 b	7,9 a	5,0 b	5,2 b	7,6 b	10,4 b	149
J	26,2 ab	7,9 a	6,6 c	7,3 c	8,4 b	11,9 b	174

Note: Identical letters indicate statistically homogeneous groups (differences between variants were tested)

IV B. Reaction of spruce plantation on the Jizerka locality on the liming – foliage state

Variant	Total foliage state (%)			Foliage colour		
	1991	1993	1995	1991	1993	1995
K	85,0 a	80,1 a	78,2 a	1,6 a	2,5 a	1,2 a
P	88,3 a	87,9 b	86,5 b	1,4 b	1,7 b	1,2 a
J	87,8 a	93,2 c	90,7 c	1,3 b	1,7 b	1,2 a

Note: Identical letters indicate statistically homogeneous groups (differences between variants were tested)

The growth parameters of the foliage apparatus (Tab. V) were positively affected, both by the shoot as well as the needle size. The results obtained have revealed, that this treatment influenced very favourably the plantation growth and health state. Preliminary results were summarized and generalized for the forest practice (Š a c h et al., 1995).

It has to be mentioned, that the liming of clear-cut areas is considered as risky for its environmental impacts. It is not recommended abroad (E v e r s, 1984; G u s s o n e, 1983, 1987) and its application is a specific Czech problem. This is one of reasons, why the information concerning clear-cut areas and plantation liming is missing in the foreign literature.

CONCLUSIONS

Liming in the extreme site and strong pollution conditions on the Jizerka locality has positive effects on the soil chemistry – pH, soil acidity, adsorption complex, Ca and Mg contents. Also the plantations show better height growth, assimilatory apparatus amount and parameters and better nitrogen nutrition. On the contrary, the soil nitrogen content and soil phosphorus and

V. Length and weight of shoots and needles of the particular variants

Variant	Mj (100)	Ml (10)	Lj (10)	Ll (1)
	g	g	mm	mm
K	0.147 a	0.544 a	101.5 a	46.0 a
%	*100*	*100*	*100*	*100*
P	0.161 a	1.165 b	119.5 b	74.6 b
%	*110*	*214*	*118*	*160*
J	0.181 a	1.239 b	119.7 b	76.0 b
%	*123*	*228*	*118*	*163*

Note: Identical letters indicate statistically homogenneous groups (differences between variants were tested)
Mj (100) – weight of 100 pcs of needles
Ml (10) – weight of 10 pcs of shoots
Lj (10) – length of 10 pcs of needles
Ll (1) – length of 1 shoot

potassium dynamics were affected slightly negatively. These trends may represent potential hazard for the next development. It may be prevented by the appropriate preparatory species management, fixing nutrients in the ecosystem and relatively enriching the topsoil. The detailed liming effects research, especially of ecological risks, rests as an important object for the next period.

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Vápnění smrkové kultury v hřebenové partii Jizerských hor.

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Jizerské hory patří k oblastem s nejvyšším poškozením lesních porostů v České republice. Na rozsáhlých plochách lesní porosty odumřely a zbylé jsou z velké části výrazně poškozeny. Převážná část odumřelých a vykácených ploch byla již opět zalesněna – v současné době se v regionu Jizerských hor nachází přibližně 6 000 ha nezajištěných kultur. K výsadbě byly použity domácí náhradní dřeviny, dále exoty (zejména smrk pichlavý) a na značné části plochy byl k výsadbě použit opět smrk ztepilý. Byly a stále jsou zakládány pokusné výsadby testující vhodné dřeviny pro obnovu jizerskohorských lesů. Nové výsadby však velmi často nevykazují uspokojivý zdravotní stav. Pro výzkum odolnosti různých druhů lesních dřevin a k testování vlivu opatření chemické meliorace půd na kultury lesních dřevin byla v roce 1990 založena výzkumná plocha ve vrcholové části Středního hřebene Jizerských hor. Její součástí se v roce 1991 stal experiment s vápněním smrku ztepilého při výsadbě. Předložená práce uvádí vliv vápnění na stav půd, přírůst a zdravotní stav kultur smrku.

Byly testovány dvě varianty vápnění: povrchová aplikace v množství 5 $t.ha^{-1}$ jemně mletého dolomitického vápence a aplikace 1 kg téhož materiálu do jamky při výsadbě. Každá dílčí plocha zahrnovala 50 sazenic ve sponu 2 x 1 m na ploše 10 x 10 m. Vápněné varianty byly založeny v počtu opakování tři, kontrola měla čtyři opakování. Vápnění příznivě ovlivnilo stav půdního chemismu. Na nenarušených místech došlo v důsledku povrchové aplikace ke zvýšení půdní reakce (aktivní i výměnné), obsahu bází, nasycení sorpčního komplexu bázemi a obsahu vápníku a hořčíku v celém sledovaném profilu (tab. I). Na druhé straně byl doložen pokles obsahu fosforu a draslíku, pravděpodobně v důsledku mikrobiální imobilizace (P) a antagonismu jedno- a dvojmocných bází (K). Mocnost holorganických horizontů byla značně snížena, což indikuje mineralizaci a ztráty humusu, obsah dusíku byl mírně zvýšen. Změny půdního chemismu byly ještě výraznější v případě analýz půdy z míst výsadby (jamek) – tab. II.

Výživa výsadeb vápněním výrazně ovlivněna nebyla (tab. III), pouze došlo k mírnému zvýšení obsahu dusíku v asimilačních orgánech vápněných variant. Půdní změ-

ny se odrazily především ve zvýšeném přírůstu sazenic (tab. IV A), dále ve zlepšení stavu asimilačního aparátu (tab. IV B) a v nárůstu velikosti i hmotnosti letorostů a jehlic (tab. V). V extrémních stanovištních a imisních podmínkách Jizerských hor je tedy stanovištně odpovídající vápnění vhodným prostředkem ke zvýšení vitality výsadeb. Nebezpečí negativních dopadů tohoto opatření vyžaduje další sledování výsadeb, lze je však výrazně zmírnit pěstováním porostů přípravných dřevin.

lesní půdy; meliorace; vápnění; smrkové kultury; půdní chemismus

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