Biological and chemical amelioration effects on the localities degraded by bulldozer site preparation in the Ore Mts. – Czech Republic

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ABSTRACT: Biological and chemical (fertilising, liming) amelioration are among the principal tools used to restore degraded sites. These techniques were also used on the Ore Mts. plateau on plots prepared by bulldozing. We evaluated the impact of these amelioration techniques by measuring tree species primary production and humus form restoration. Begun in 1983–1985, this project studied growth reaction of forest stands by measuring height and diameter increment, for the following species (blue spruce *Picea pungens* Engelm., European larch *Larix decidua* Mill., lodgepole pine *Pinus contorta* Dougl., Eastern white pine *Pinus strobus* L., alder *Alnus incana* Moench., European beech *Fagus sylvatica* L.) during the period 1994–2000. The growth potential by species decreases in the following order: larch, alder, lodgepole pine, white pine, blue spruce. Beech was almost exterminated by red deer browsing and the harsh climate; pines suffered heavily from browsing and bark stripping. Hologanic horizons were measured and basic soil chemical and mechanical characteristics were determined – pH, soil adsorption complex characteristics (using Kappen's methodology), content of the humus and total nitrogen, exchangeable acidity and plant available macronutrients, granulometric composition of mineral soil horizons. Our results confirmed the relatively long-lasting effects of soil amendments, as well as the amelioration effects of alder, and the relatively inhibiting effects of larch and blue spruce.

Keywords: Ore Mts.; preparatory stands; tree species growth; site preparation; fertilisation; liming; humus forms; site restoration

Large areas of forest in the Czech Republic deteriorated due to air pollution resulting from extensive industrial development. On background of the pollution-caused degradation, subsequent damage resulted from poor forestry practices including frequent bulldozing as a site preparation method. Legislative mandates created pressure for reforestation and ignored the impacts of poor technologies, resulting in approximately 10,000 ha of bulldozed plots with intense degradation (PODRÁZSKÝ et al. 2001). Precise evidence of the extent of this forestry practice is missing. Although these techniques were criticised very early on (JIRGLE 1984), they continued to be employed for a long time during the 70's–80's, in some cases on into the 90's. Humus removal and nutrient cycle interruption were the main causes of the degradation effects of this treatment, intended as site preparing originally. Many research projects commenced during this time, but little data resulted, largely due to poor research administration. Only a few research plots and plantations were conserved to the present for testing of particular silvicultural and amelioration treatments in the region of the Ore Mts. Their evaluation is a matter of prime importance for the future forest ecosystems management. The aim of this presentation is so to summarise briefly the growth potential of the particular tree species on experimental plot Boleboř and to study the amelioration effects 16 years after application on the one relatively well conserved plot in the area of interest.

METHODS

The Institute of Applied Ecology and Ecotechnology of the Czech University of Agriculture in Prague, in co-operation with the Technical University of Dresden, established the research plots in 1983. The experimental plots are located on the plateau of the Ore Mts. in the altitude 850 m a.s.l., near the road between the villages Boleboř and Kalek. The site is characterised by the dominance of Cambisols and 7th vegetation (spruce-beech) altitudinal zone: typical for the large areas of bulldozed plots and the localities of the mountain plateau of this region. The objective of this project was to evaluate the reforestation of sites heavily damaged by air-pollution. We especially focused on the use technical, chemical and biological

The presented study is part of the Project MSM 414100009 *Restoration of Functioning Forest Ecosystems of the Krušné hory (Ore) Mts*. Results are prepared also for presenting at the XII World Forestry Congress in Québec, Canada 2003.

amelioration treatments in site restoration (ČÍŽEK 1985; MELZER et al. 1980). The plot was prepared in 1983, tree planting and fertilisation were conducted in 1984, and the sowing of *Lupinus polyphyllus* occurred in 1985.

The site amelioration treatments were:
- bulldozer soil preparation,
- broadcast fertilisation before soil preparation (4 t/ha $CaCO_3$, 0.5 t/ha K_2O+MgO, 0.2 t/ha P_2O_5),
- site preparation, fertilisation after soil preparation (1 t/ha $CaCO_3$, 0.1 t/ha P_2O_5),
- post-planting sowing of *Lupinus polyphyllus*.

The planting technology consisted of:
- strip plough soil preparation,
- row planting with the distance between rows of 2 meters.

We evaluated four species mixes ("variants"):
1. Mixed stand (*Picea pungens* Engelm., *Larix decidua* Mill., *Pinus contorta* Dougl., *Pinus strobus* L.) at 5,000 plants per ha. In addition, speckled alder (*Alnus incana* Moench.) was planted at a density of 1,667 plants per ha on the ameliorated sites. Particular species were planted in mono-specific lines.
2. European beech (*Fagus sylvatica* L.) at a spacing of 2.0 × 0.6 m (8,333 per ha) in mixture with speckled alder (*Alnus incana* Moench.) at 2,000 plants per ha.
3. European beech (*Fagus sylvatica* L.) at a spacing of 2.0 × 0.6 m (8,333 per ha) in a mixture with European larch (*Larix decidua* Mill.), at a spacing of 2.0 × 2.0 m (2,500 plants per ha). All sites are without alder.
4. Blue spruce (*Picea pungens* Engelm.) at a spacing of 2.0 × 1.0 m (5,000 plants per ha), in mixture with speckled alder (*Alnus incana* Moench.) at 1,667 plants per ha on the ameliorated sites only.

Each species mix was replicated four times: two replications on the ameliorated blocks and other two on the control ones. 16 experimental plots were thus created, each 60 × 25 m or 0.15 ha in size. Thirteen plots were fenced to reduce deer browse. The complete inventory (measurements of tree height and diameter at breast height) was done in 2000. Statistical analysis of the growth dynamics of each species and evaluation of the amelioration effects were done on the basis of the analysis of variance at the 95% confidence level.

Sampling of humus forms was restricted only on parts (subplots) with simple species composition. Samples of the humus form layers were taken in September 2001 using a 25 × 25 cm iron frame. We sampled four replications, so we might quantify the holorganic layers. Horizons were distinguished: L + F_1 and F_2 + H. The Ah mineral horizon was sampled too, but not quantitatively. The bulk samples were prepared by mixing the substrates directly in the field. We used standard analytical methods for soil analyses: dry matter amount (105°C), pH, soil adsorption characteristics by Kappen, exchangeable acidity, total humus and nitrogen content by the combustion method and Kjeldahl method, plant available nutrients by Mehlich III procedure.

RESULTS AND DISCUSSION

The biomass production potential (tree growth – Fig. 1) confirm the different growth development and dynamics of the particular tree species on the experimental plots. European larch (*Larix decidua* Mill.) is the species with the best growth rate of all selected tree species. It reached the highest mean height and diameter at breast height on all plots. Speckled alder (*Alnus incana* Moench.) grew very fast too, but only on one plot. On other plots where we planted this species, there was no survival.

On the other hand, beech (*Fagus sylvatica* L.) was the worst of species for reforestation of the degraded plots, because it is frequently frost-damaged and almost eliminated by deer browsing. Although introduced pines, particularly lodgepole pine (*Pinus contorta* Dougl.) showed

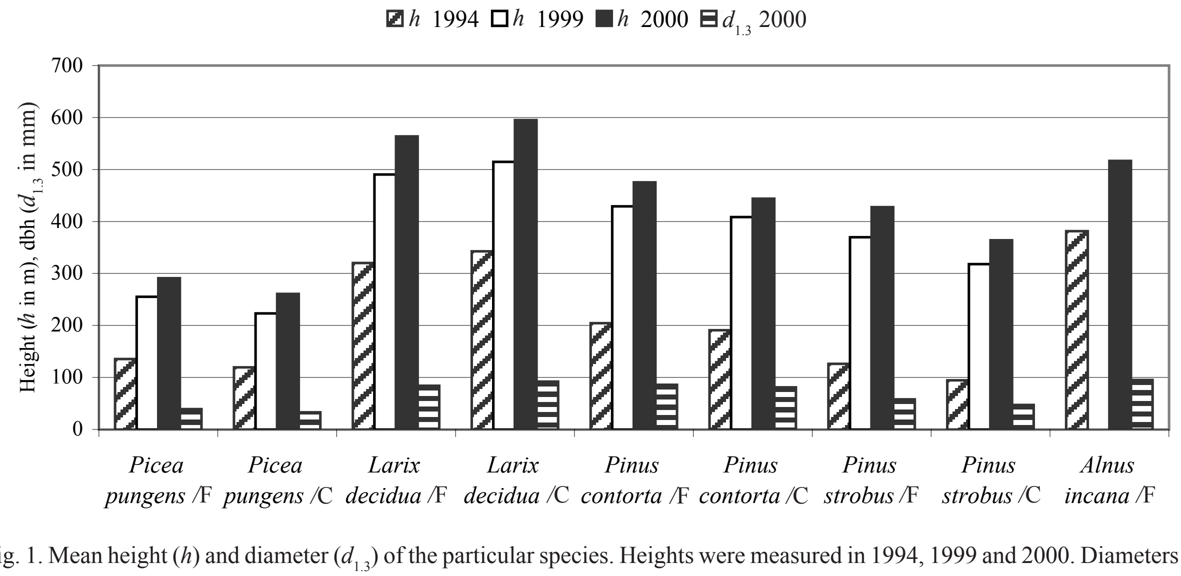

Fig. 1. Mean height (*h*) and diameter ($d_{1.3}$) of the particular species. Heights were measured in 1994, 1999 and 2000. Diameters were measured in 2000. F – fertilised, C – control variants

Table 1. Basic pedochemical characteristics and characteristics of exchangeable acidity in stands of different tree species on the Boleboř research plot

Site	Fertilised	Horizon	pH H_20	Acidity ex	Al ex	S base content	T cation exchange capacity	V base saturation
				(mval/kg)		(mval/100 g fine earth)		(%)
Alder	+	L + F_1	7.1	22.6	22.5	61.1	68.1	89.7
		F_2 + H	7.1	8.6	8.6	51.0	57.3	89.0
		Ah	6.5	5.0	4.7	39.6	46.5	85.1
Blue spruce	–	L + F_1	5.9	34.6	31.3	39.6	48.8	81.2
		F_2 + H	5.8	26.0	25.2	21.8	41.3	52.7
		Ah	5.6	56.0	55.9	5.8	20.3	28.3
*Blue spruce	+	L + F_1	6.2	33.5	30.6	56.7	67.7	83.8
		F_2 + H	6.7	11.6	10.6	65.8	74.7	88.1
		Ah	7.0	6.0	6.0	45.6	48.1	95.0
*Blue spruce	–	L+ F + H	5.9	30.7	30.6	24.1	47.0	51.3
		Ah	5.2	65.5	64.6	6.2	22.4	27.5
*Larch + blue spruce	+	L + F_1	6.2	49.5	49.4	68.5	86.0	79.7
		F_2 + H	6.7	17.5	16.6	68.5	78.1	88.1
		Ah	6.8	4.6	4.5	38.3	41.2	93.1
Larch + beech	+	L + F_1	6.5	25.0	24.9	72.1	87.8	82.1
		F_2 + H	5.8	35.4	35.3	22.5	43.2	52.0
		Ah	5.5	71.8	71.4	4.8	20.3	23.9
Larch + beech	–	L + F_1	6.3	29.5	29.4	67.2	80.0	84.0
		F_2 + H	5.7	22.1	19.0	28.5	61.7	46.2
		Ah	5.2	70.0	69.8	5.7	22.2	25.4

*amelioration by speckled alder, which lately declined and now is not present on the stand

good growth, unfortunately these species were heavily damaged by deer browse and bark stripping. Hoofed game (red deer – *Cervus elaphus*) is the limiting factor of the future development of the experimental plots in the Ore Mountains, as well as limiting factor for practical reforestation. Chemical amelioration showed minor, but clearly visible effects on the tree species growth, with the exception of larch.

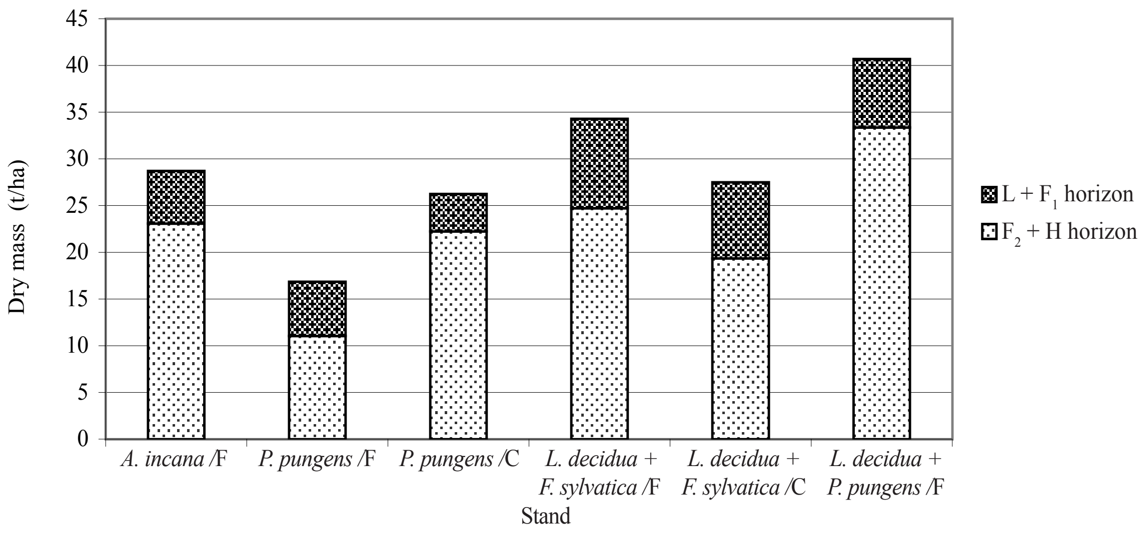

Fig. 2. Some species influence to the surface humus accumulation (dry mass t/ha) on the Boleboř research plots. F – fertilised, C – control variants

Table 2. Content of humus and plant available nutrients (Mehlich III) in stands of different tree species on the Boleboř research plot

Site	Fertilised	Horizon	Humus	N Kj	P	K	Ca	Mg
			(%)		(mg/kg)			
Alder	+	L + F_1	55.5	2.37	116	1,576	5,400	1,472
		F_2 + H	29.2	1.01	71	558	5,200	1,024
		Ah	15.7	0.59	16	168	4,120	806
Blue spruce	–	L + F_1	57.6	1.56	289	3,240	2,400	824
		F_2 + H	30.6	0.81	61	688	680	306
		Ah	12.4	0.31	6	156	120	36
*Blue spruce	+	L + F_1	51.9	1.52	196	2,200	4,440	1,192
		F_2 + H	36.3	1.00	55	800	5,800	1,312
		Ah	17.4	0.43	22	168	5,080	814
*Blue spruce	–	L+ F + H	35.7	1.42	75	752	1,420	520
		Ah	15.4	0.39	7	179	205	74
*Larch + blue spruce	+	L + F_1	49.2	1.76	151	1,440	5,400	1,608
		F_2 + H	29.6	1.16	87	624	6,000	1,280
		Ah	15.7	0.59	19	179	4,160	751
Larch + beech	+	L + F_1	40.4	1.47	124	1,240	3,940	1,236
		F_2 + H	28.2	0.92	51	444	1,080	400
		Ah	11.7	0.33	7	124	70	37
Larch + beech	–	L + F_1	50.6	1.60	178	2088	4,100	1,352
		F_2 + H	37.6	1.22	88	780	1,640	536
		Ah	16.1	0.37	16	179	140	39

*amelioration by speckled alder, which lately declined and now is not present on the stand

Favourable impacts on humus form restoration were especially noticeable in the stands with larch and alder with fertilisation, both from the qualitative as well as quantitative point of view (Fig. 2, Table 1). Beech was not an important component, largely due to deer browse, as in all mixtures where it occurred (REMEŠ , KRATOCHVÍL 2001). Larch demonstrated considerable litter production, whereas spruce produced the least amount of litter.

Examining fertilisation and soil chemistry, the amelioration effect was clearly visible despite the passage of two decades since establishing the experiment. Larch and spruce-dominated stands had the highest decrease in pH. The lowest pH values were recorded in the blue spruce stand without fertilisation, only with the basic amendment. The same trend was even more pronounced with base content (S – value) and base saturation (V – value). This was quite different from the situation observed at the surface liming application on the other research plots, in both the magnitude of the change and the longevity (PODRÁZSKÝ et al. 2001; ULBRICHOVÁ et al. 2001). The results reflect the relatively high amounts of fertilisers that were applied, their incorporation into the soil and probably the aerial liming applied over the entire study area (the last time in 2001).

Total humus content (Table 2) was very similar in the holorganic as well as mineral horizons of all stands with alder and fertilisation, whereas the dominance of conifers caused its decline. This observation probably reflects the slower transformation of the conifers' litter. In the case of mineral A horizon, the absence of amelioration was reflected by reduced mixing of organic and mineral soil compounds, especially in blue spruce stands. We supposed that, due to the limited thickness of the holorganic layers, there could been some mineral particles in the samples. This species was repeatedly documented as not greatly adding to the soil function; a conclusion supported by other studies (PODRÁZSKÝ 2000; REMEŠ et al. 2002).

Plantations with alder showed increased nitrogen content in humus and mineral soil horizons, whereas the opposite was documented in the larch and blue spruce stands, even on those sites with amelioration (Table 2). The use of liming and the presence of alder depressed the exchangeable acidity, as evidenced by the exchangeable aluminum content (Table 1).

Examining levels of the plant-available nutrients (Table 2), no significant differences were observed in the phosphorus and potassium contents, with the sole exception of the non-amended blue spruce plantation. Plant-available magnesium and calcium were affected positively, whereas the dominance of conifers resulted in a considerable decrease of these bioelements. Due to the pre-bulldozed site mechanical preparation, changes were evident at depths up to 20 cm in the mineral soil horizon. Also the humus horizons, which are usually created after the tree species plantation, had been visibly influenced by amelioration treatments. Alder had a positive effect on the upper soil layers even without the previous chemical nutrient site improvement.

Our previous survey determined that the sites were quite homogeneous (REMEŠ, PODRÁZSKÝ 2002), which we concluded based on examination of ground vegetation, terrain type and soil morphology. Other work confirms the negative impacts of bulldozing on forest ecosystems, in general (e.g. BINKLEY 1986). This treatment causes increased soil erosion (BURGER 1983; ŠACH 1995), soil structure degradation (BALLARD 1988; ŠACH 1995) and stand nutrition degradation due to the severe disturbance of the humus layer. Soil remediation consists mainly of restoration of the humus layer (BENGTSON 1981; JIRGLE 1984; VITOUSEK, MATSON 1985). In this aspect, alder was confirmed as the best "site-restoring" species, whereas larch formed a lower quality of humus. Blue spruce was not an efficient producer of humus, while other species were suppressed in their function by unfavourable abiotic as well as biotic factors. We found that chemical and biological site amelioration could be used on such plots with a high degree of success.

CONCLUSIONS

Growth potential, as an expression of biological primary production, determines the functional effectiveness of particular tree species as tools of site preparation. Main restoration effect consists in the biomass production and the humus layer restoration. Larch and alder are autochthonous species with the greatest revitalisation potential (larch in terms of quantity, alder in terms of quantity and also the quality of the bio- and necromass). Soil amelioration also plays an important role, as unfavourable site conditions are limiting factors of soil and humus restoration.

Our results confirmed the favourable effects of both chemical and biological amelioration treatments on the soil and humus forms. They can be summarised as follows:

– The impact of soil amendments is observable for at least two decades, reflected in increased soil reaction, bases content, base saturation and macronutrients content.
– The effect of alder to the site is very positive. This species contributes to efficient nutrient cycling and forms a considerable amount of surface humus of favourable character.
– The restoration of the structure and quality of the humus layer represents a basic condition of forest ecosystem revitalisation.
– European larch creates considerable amount of humus of lower quality. Its high biomass production, especially in mixed stands, could be used for humus layer recovery, leaving all the formed biomass for spontaneous decay and transformation.
– Blue spruce is a site degrading species with minimal positive impact upon site potential.

Our recommendations to forest managers would include the use of chemical amendments to improve productivity, and the incorporation of alder to rapidly improve the quality and quantity of the humus layer. European larch might improve the quantity, but not the quality of the humus. Soil disturbing activities, such as bulldozing, must be avoided at all costs. Control of deer browsing will accelerate the restoration of the site

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Received for publication January 13, 2003
Accepted after corrections February 27, 2003

Revitalizace stanovišť s využitím postupů biologické a chemické meliorace na lokalitách degradovaných buldozerovou přípravou v Krušných horách

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ABSTRAKT: Postupy biologické a chemické (hnojení, vápnění) meliorace patří k základním postupům při revitalizaci lesních porostů v imisně postižených oblastech včetně vrcholové části Krušných hor na stanovištích po tzv. buldozerové přípravě. Jejich účinnost lze dokumentovat na základě změn v primární produkci lesních porostů a v rychlosti obnovy humusové vrstvy. Experiment popisovaný v příspěvku byl založen v letech 1983–1985, růstová reakce porostů smrku pichlavého *Picea pungens* Engelm., modřínu opadavého *Larix decidua* Mill., borovice pokroucené *Pinus contorta* Dougl., borovice vejmutovky *Pinus strobus* L., olše černé *Alnus incana* Moench. a buku lesního *Fagus sylvatica* L. byla studována v letech 1994 a 2000: celková výška, výškový přírůst, výčetní průměr. Růstový potenciál klesal v pořadí: modřín, olše, borovice pokroucená, vejmutovka, smrk pichlavý. Buk byl téměř úplně zlikvidován zvěří a stanovištními podmínkami imisní holiny, borovice silně trpěly vytloukáním, okusem a loupáním. Dále byla stanovena zásoba nadložního humusu a pedochemické charakteristiky jednotlivých vrstev humusových forem: půdní reakce, charakteristiky sorpčního komplexu podle Kappena, obsah humusu a celkového dusíku, výměnná acidita a obsah přístupných živin. Výsledky potvrdily poměrně dlouhodobé účinky melioračních zásahů a příznivé účinky olše, na druhé straně pak degradační vliv modřínu a smrku pichlavého.

Klíčová slova: Krušné hory; přípravné dřeviny; růst; příprava stanoviště; hnojení; vápnění; humusové formy; regradace

Obnova plně funkčních lesních ekosystémů v Krušných horách představuje dlouhodobý a komplexní problém. Lesní hospodářství se musí vypořádat s následky dlouhodobé kyselé depozice a nevhodných hospodářských postupů. Opatření chemické a biologické meliorace pak představují základ pro komplexní revitalizaci stanovišť. Dosud je pak k dispozici jen minimum relevantních údajů umožňujících výběr optimálních melioračních postupů. Dříve založené výzkumné plochy byly často ztraceny, neboť rychle se měnící priority výzkumu neumožňují dlouhodobý koncepční výzkum. Vyhodnocení zachovaných ploch tak představuje mimořádně cennou příležitost dlouhodobých sledování. Jednou z nich je i trvalá výzkumná plocha Boleboř na typické lokalitě připravené tzv. buldozerovou přípravou v Krušných horách. Plocha byla založena v letech 1983–1985 v nadmořské výšce 850 m. Půdní typ je charakterizován jako kyselá kambizem, plocha se nachází v 7. LVS (SLT 7K). Cílem bylo sledovat vliv různé dřevinné skladby a melioračních opatření na revitalizaci lesních ekosystémů těchto poloh.

Byla aplikována meliorační opatření:

– buldozerová příprava plochy,
– celoplošné hnojení před pomístnou přípravou půdy (4 t/ha $CaCO_3$, 0,5 t/ha K_2O + MgO, 0,2 t/ha P_2O_5),
– příprava půdy, hnojení po ní (1 t/ha $CaCO_3$, 0,1 t/ha P_2O_5);

technologie výsadby:

– liniová příprava pluhem,
– řadová výsadba ve vzdálenosti 2 m.

Varianty:

1. Smíšený porost (*Picea pungens* Engelm., *Larix decidua* Mill., *Pinus contorta* Dougl., *Pinus strobus* L.) v počtech 5 000 ks/ha. Olše lepkavá (*Alnus glutinosa*) byla vysázena v počtu 1 667 ks/ha na meliorované ploše. Směs byla liniová.
2. Buk (*Fagus sylvatica* L.) v počtu 8 333 ks/ha, spon 2,0 × 0,6 m ve směsi s olší v počtu 2 500 ks/ha.
3. Buk (*Fagus sylvatica* L.) v počtu 8 333 ks/ha, spon 2,0 × 0,6 m ve směsi s modřínem (*Larix decidua* Mill.) v počtu 2 500 ks/ha a sponu 2,0 × 2,0 m.
4. Smrk pichlavý (*Picea pungens* Engelm.) v počtu 5 000 ks/ha, spon 2,0 × 1,0 m ve směsi s olší v počtu 1 667 ks/ha pouze na meliorovaných částech.

Každá varianta měla čtyři opakování, dvě s meliorací a dvě bez ní, celkem tak vzniklo 16 dílčích ploch o velikosti 60 × 25 m (0,15 ha), 13 z nich bylo v bloku oploceno na ochranu proti zvěři. Zhodnocení plochy bylo provedeno v roce 2000, měřeny byly výšky a výčetní průměry. Statistická hodnocení růstové dynamiky jednotlivých dřevin byla prováděna analýzou variance na 95% stupni spolehlivosti.

Vzorky ke zhodnocení stavu humusových forem byly odebírány v září 2001 pomocí železného rámečku 25 × 25 cm ve čtyřech opakováních, pro hologanické horizonty kvantitativně. Zvlášť byly odebírány horizonty L + F_1 a F_2 + H, minerální horizont Ah byl odebírán pouze ke kvalitativním analýzám. Přímo v terénu byly připravovány směsné vzorky. Pro pedochemické analýzy byly použity standardní laboratorní metody: půdní reakce, hodnoty sorpčního komplexu podle Kappena, výměnná acidita, obsah celkového humusu a dusíku podle Kjeldahla a přístupné živiny podle metody Mehlicha III.

Výsledky (obr. 1 a 2 a tab. 1 a 2) potvrdily příznivý vliv jak chemické, tak i biologické meliorace. Mohou být stručně shrnuty takto:

– Vliv aplikace melioračních materiálů je patrný alespoň dvě desetiletí, je znatelný ve zvýšené půdní reakci, obsahu bází, nasycení sorpčního komplexu bázemi a obsahu makroelementů.
– Vliv olše je vysoce pozitivní; tato dřevina zajistila efektivní koloběh živin, formovala příznivou humusovou formu o vysoké kvalitě a kvantitě.
– Obnova kvalitní humusové formy v odpovídající zásobě organické hmoty je základem revitalizace podobných stanovišť.
– Modřín přispěl k vytvoření značné zásoby nadložního humusu, ale o nižší kvalitě. Vyznačoval se tvorbou značného množství biomasy, která může být využita ve smíšených porostech k obnově nadložní organické hmoty při ponechání přirozenému rozpadu.
– Smrk pichlavý je dřevina degradující stanoviště s minimální funkční hodnotou, buk pak vyžaduje ochranu proti zvěři stejně jako použité druhy borovic.

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