Soil Preparation for Forest Plantations in Former Farmland *Haplic Arenosols* with and without Plough-pan

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Abstract

The growth of pine, spruce and birch plantations as well as penetration of taproots into deeper soil layers were studied on former farmland soils with a formed plough-pan. The soil was prepared by deep plowing (60 cm), as well as by patch scarification and by complete soil plowing to the depth of 25-27 cm.

Normal plowing of light textured soils prevented the growth of vertical roots of spruce and birch, when soil density was over 1.6 gcm^{-3}. Deep plowing when compacted plough-pan turns out on soil surface provides more favourable conditions for the growth of taproots and increases their rooting depth. More favorable conditions for the root growth may significantly accelerate the growth of the above-ground part of trees.

Pine seedlings survived and grew better for the first 3 years on former farmland *Haplic Arenosols* without plough-pan in shallow furrows (8-10 cm depth), while in year 4 the maximum increment were in completely plowed soil.

Key words: abandoned farmland, soil compaction, soil preparation, deep plowing, patch scarification, complete plowing furrowing, root growth

Introduction

In Lithuania, the Ministry of Forestry and Forest industry started forest planting on poor soils of former agricultural land in 1957. By the year 2000, 114 thousand ha of abandoned land were reforested (Malinauskas and Verbyla 2003). Cultivated land area unsuitable for agriculture makes up to 610,000 ha in Lithuania (Kairiūkštis and Vaičys 1997). It is mostly *Haplic Luvisols* (sandy loam), slopes and other areas unsuitable for farming. Forest and agricultural soils differ from each other in fertility and in the amount of weed seeds and weed species composition. Agricultural soils also often have a plough-pan. Therefore usual soil preparation practices used in forest regeneration can be inappropriate on former agricultural land.

Former agricultural land contains large bank up to 50,000 per m^2 of germinable seeds, consisting mostly of seeds of pioneer weed species (Paatela and Erviö 1971, Kiirikki 1993). Seeds of pioneer weed species can remain viable for a long time, up to 20 years (Kiirikki 1993). Both arable and abandoned lands are usually more fertile than conventional forest sites because of changes in soil properties caused by agricultural practices (Hytönen and Wall 1997, Wall and Hytönen 2005). For these reasons vegetation on former agricultural lands is more vigorous and competes with tree seedlings for water, nutrients and light (Hytönen and Jylhä 2008).

Soil compaction is a global problem of high economic and ecological importance. Soil compaction has a deleterious effect on soil structure, hydrology and physiological processes and consequently adversely affects the growth and productivity of woody plants (Kozlowski 1999). Heavily compacted soils typically do not recover naturally for a very long time. Soils compacted by heavy vehicles in the boreal forests of Canada remained compacted for several decades (Corns 1988). Natural recovery of southern soils requires up to 60 years (Mitchell et al. 1982). The duration of natural recovery of soils varies with the depth of compacted layer. Recovery to the original compaction level of the surface soil layer (0-7.5 cm) of a sandy loam required 4.5-8.5 years, however, at the depths of 15-23 cm or 23-30 cm no recovery was evident after 8.5 years (Thorud and Frissell 1976).

Compacted plough-pans (depth of the compacted layer about 10 cm) may occur in all former farmlands, except meadows and pasturelands established on drained waterlogged soils with a 30-50 cm (or deeper) peat layer or on soils (meadows or pasturelands) which have not been ploughed for a long time (50 years or more) (Malinauskas et al. 2006). The density of plough-pan soil can be so high that this layer may retard the root elongation of most tree species (Malinauskas et al. 2006). Besides, in meadows and pasturelands the density of topsoil at the depth of 11-20 cm is considerably higher than in forest soils and can significantly retard the growth of roots.

A lot of experiments have been conducted to mitigate the harmful effect of soil compaction however, not all of them were successful (Pittenger and Stamen 1990). On compacted soils species tolerant to soil compaction have been planted, mycorrhizal inoculation applied, soil has been improved or replaced, drainage systems installed, seedlings fertilized, soil loosened and trenched (Ruark et al. 1982, Jim 1993, Gerik et al. 1987, Day et al. 1995, Velykis 1996, Ramoška 2002). In general, prevention of soil compaction before planting is much preferred over post – planting practices, because later it becomes costly, difficult to implement, sometimes inefficient, and the roots of plants may be injured (Howard et al. 1981).

The aim of this research was to investigate the effects of different soil preparation methods for growth and survival of Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* L. Karst) and silver birch (*Betula pendula* Roth) seedlings in former farmland *Haplic Arenosols* with and without plough pan.

Material and methods

The Utena and Veisiejai experiments

Scots pine and Norway spruce plantations were established in Utena Forest Enterprise (55° 31' N 25 43' E) and Scots pine, silver birch plantations in Veisiejai Forest Enterprise (54° 04' N 23° 39' E), in the spring of 2000 year. Two-year-old seedlings (2+0) were used on *Lamelli-Haplic Arenosols* with a formed plough-pan (Table 1) prepared by deep plowing (to the depth of 60 cm) and in the neighborhood by complete plowing (to the depth of 25-27 cm) or by scarified patch (removing 10 cm deep topsoil) Total size of the plantation in Utena forest enterprise 1.1 ha and in Veisiejai forest enterprise 2.1 ha. In each plantation were selected 4 sample plots (replications).

Table 1. Soil bulk density, g cm^{-3}

Forest enterprise	Soil preparation method	Depth of soil sample, cm		
		5-10	Plough-pan	60-65
Utena	25-27 cm deep complete plowing	1.34±0.03	1.57±0.03	1.57±0.02
	Deep plowing	1.33±0.03	1.33±0.0	1.57±0.02
Veisiejai	Scarified patch	1.46*±0.03	1.61±0.02	1.56±0.04
	Deep plowing	1.35±0.01	1.37±0.01	1.56±0.04

Soil density was measured by taking 200 cm^3 soil samples of undisturbed texture (with 10 replications) and weighting them after drying to oven-dry weight at 105^{0}C. Soil texture was determined according to ISO 11277-1997 method (Table 2).

Table 2. Plough-pan-soil texture, %

Forest enterprise	Gravel, 10 - 2 mm	Sand, 2 - 0.05 mm	Silt, 0.05 – 0.002 mm	Clay, < 0.002 mm
Utena	5.82	73.4	22.0	4.6
Veisiejai	5.85	72.5	22.8	4.7

A total of 100 8-year-old seedlings of each species were measured to estimate mean height of plantations. The root systems were studied by uncovering them at a radius of 30 cm around the studied trees to the depth of root penetration. In each soil preparation method, the roots of 4 to 8 of trees medium height have been uncovered.

The Anykščiai experiment

Scots pine plantations were established in Anykščiai Forest Enterprise (55° 26' N 25° 01' E) on *Haplic Arenosols* (without plough-pan) prepared by complete plowing (to the depth of 25-27 cm), by furrows (depth 8-10 cm, width 50 cm and depth 15 cm, width 70 cm) and in non-prepared soil. The soil preparation treatments were no soil preparation, complete plowing (to the depth of 25-27 cm) by making furrows (depth 8-10 cm, width 50 cm and depth 15, width 70 cm). The total size of the plantation is 1.2 ha. The soil was prepared in September 2004 with 4 replications per treatment and plantations were established the following spring. The plantations were established using two-year old Scots pine seedlings (2+0).

The survival of seedlings, height, height increment and diameter 10 cm high above the ground were assessed for 1, 2 and 4-year-old plantations. The biomass of weed vegetation was measured in the first and second year at the first half of September by severing it at the ground level 40x50 cm sized sampling plots (5 sampling plots for each replication). Shading class of the ground vegetation on each seedling was assessed as follows: 0 – no shading, 1 – one quarter, 2 – half, 3 – three quarter of the seedling in shade and 4 – fully shaded (Hytönen and Jylhä 2005). Seedlings of 3-rd and 4-th shading classes needed weed control.

Data analysis

Analysis of variance was used to test the statistical significance of the soil preparation methods, seedling survival, seedling growth and seedling shading class. Before conducting the analysis, the homogeneity of variance was tested. Transformation to homogenize variances was not necessary. The statistical reliability of difference between groups, for data that were expressed in direct measurement units or their ratio were evaluated using T-test, if data were nonparametric – F-test.

Results

In the Utena experiment, Scots pine and Norway spruce seedlings, planted in deep plowed soil grew considerably faster than the seedlings planted in completely ploughed soil. Mean height of 8-year-old Scots pine seedlings in deep plowed soil was 47% greater, and the height of Norway spruce seedlings 55% greater than the height of plantations established on soil ploughed to the depth of 25-27 cm (Table 3).

Table 3. Mean seedling height and root penetration depth in different soil preparation methods in 8-year-old plantations

Soil preparation method	Tree species	Height, m	Depth of root penetration, cm
	Utena forest enterprise		
Complete plowing, depth 25-27 cm	Scots pine	1.91±0.08	70-80
	Norway spruce	1.74±0.04	30-40
Deep plowing	Scots pine	2.81±0.08	95-105
	Norway spruce	2.69±0.14	65-75
	Veisiejai forest enterprise		
Scarified patch	Scots pine	3.34±0.05	100-115
	Norway spruce	3.34±0.14	20-40(120)
Deep plowing	Scots pine	3.50±0.06	105-120
	Norway spruce	4.46±0.13	150-160

In the Veisiejai experiment, the mean height of Scots pines seedlings in deep plowed and patch scarified soils was similar. However the height of silver birch on deep plowed soil was 34% greater than the height of seedlings planted in scarified patch. In deep plowed soil seedlings grew faster (Table 4). Statistically significant height increment for Scots pine and Norway spruce were observed during 3-8 and 2-8 growing seasons, respectively.

Table 4. The annual height increment (cm) of seedlings in soils prepared by deep plowing and by plowing to 25-27 cm deep. Comparison is performed using T-test. Significance levels: * $p < 0.05$; ** $p < 0.01$, *** $p < 0.001$

Season, years	Scots pine			Norway spruce		
	complete plowing	deep plowing	t-value	complete plowing	deep plowing	t-value
1st	4.3±0.9	7.7±0.8	2.75**	6.5±0.6	7.5±1.0	0.81
2nd	8.8±2.7	12.0±1.8	1.01	6.9±1.1	10.3±1.5	1.79*
3rd	7.9±1.9	21.3±2.1	4.71***	7.6±1.2	17.9±3.7	2.66**
4th	14.2±2.8	36.7±3.7	4.61***	9.2±1.5	22.8±4.2	3.06**
5th	27.4±1.1	42.3±4.5	1.66*	13.7±2.6	42.3±4.5	5.50***
6th	32.9±1.6	41.2±2.7	2.68**	34.6±3.1	52.1±6.6	2.62**
7th	42.4±1.6	60.3±2.6	5.89***	32.6±2.7	43.1±3.8	2.26*
8th	49.6±2.3	70.4±2.0	6.77***	49.9±3.1	63.0±3.7	2.72**

In Utena forest enterprise, the roots of studied Scots pines on completely ploughed and in deep ploughed soil reached the depth of 70-80 cm and 95-105 cm respectively. The roots of Norway spruce had reached the depth of 30-40 and 65-75 cm, respectively (Table 3). The taproots of Norway spruce failed to penetrate the plough pan having mean density 1.57g cm^{-3} (range from 1.45 - 1.68g cm^{-3}). The taproots of Norway spruce after reaching the plough-pan started growing horizontally or even upwards (Fig. 1). In some cases Norway spruce roots managed to penetrate the plough pan.

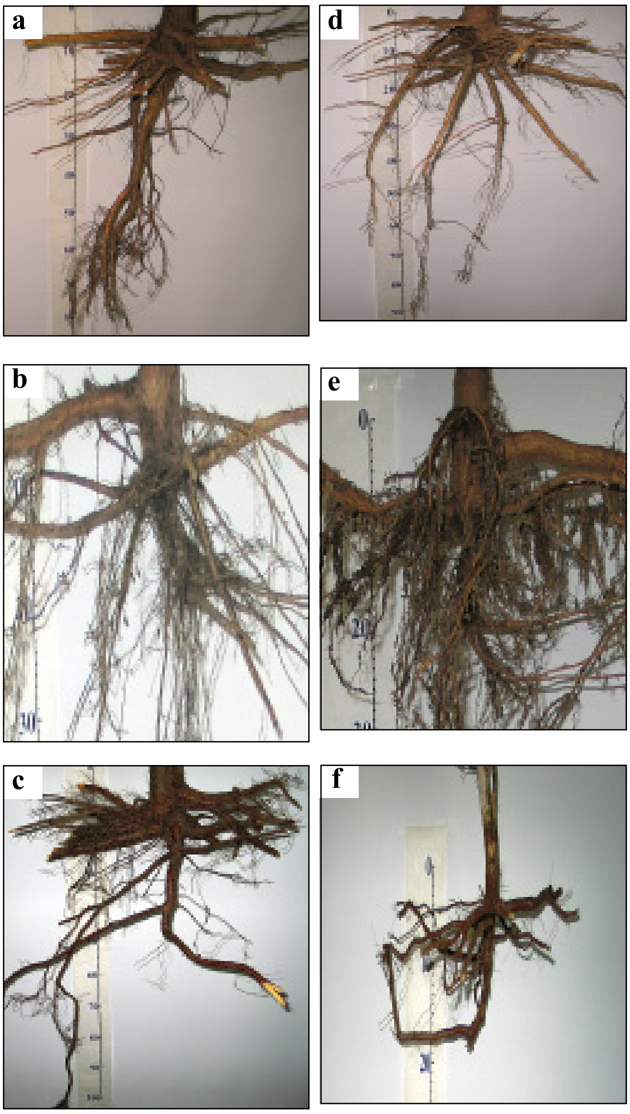

Figure 1 The root system of Scots pine (a), Norway spruce (b) and silver birch (c) in soil prepared by deep plowing and the root system of Scots pine (d) and Norway spruce (e) in soil prepared by complete plowing and silver birch (f) in soil prepared by patch scarification

In the experiment in Veisiejai forest enterprise, the roots of Scots pine, independent of soil preparation method, reached a similar depth. Contrary to Scots pine, penetration depth of silver birch roots depended on soil preparation methods. The penetration depth of silver birch roots in soil prepared by deep plowing was 150-

160 cm and that of birches planted in scarified patch – 20-40 cm (Fig. 1). The taproots of silver birch did not penetrate the compacted plough pan with the average density of 1.61g cm^{-3} (range 1.51-1.69 g cm^{-3}).When the roots reached the plough-pan they started growing horizontally or even several centimeters upwards. Some trees in our experiment succeeded in penetrating through the plough-pan and then their roots reached the depth of 120 cm.

Anykščiai experiment

In non-prepared and completely ploughed *Haplic Arenosols*, the survival of Scots pine seedlings during the first growing season were only 32 and 36% respectively, while in 15 cm deep furrows 81% and in 8 to 10 cm deep furrows 91% (Fig. 2). Later the survival of seedlings decreased only insignificantly.

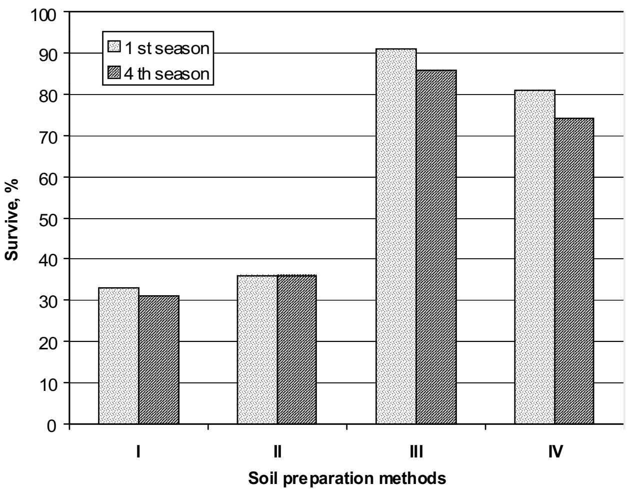

Figure 2 Scots pine seedlings survival in soils, prepared by different methods: I – no site preparation; II – complete plowing; III – 8 cm deep, 50 cm width furrows, IV – 15 cm deep, 70 cm width furrows

During the first 4 growing seasons, Scots pine seedlings planted in 8 to 10 cm deep furrows were highest and seedlings planted in non-prepared soil were shortest (Fig. 3). Scots pine seedlings planted in shallow furrows (depth 8-10 cm) was significantly taller than the seedlings planted in non-prepared or in completely ploughed soil (Table 5). Height increment of seedlings planted in 8 to 10 cm deep furrows was significantly higher, than the height increment of seedlings planted in non-prepared soil during the 1st, 2nd and 4th growing seasons (Table 6). During the first growing season, the height increment of seedlings planted in shallow furrows was significantly higher ($P < 0.05 – 0.001$) than that of seedlings, planted in completely ploughed and in soil with deep furrows. During the second growing season, the height increment of seedlings planted in shallow furrows was significantly higher than the growth of seedlings planted in completely ploughed soil ($P<0.001$). During fourth growing season, height was higher in shallow furrows than in 15 cm deep furrows ($P<0.01$).

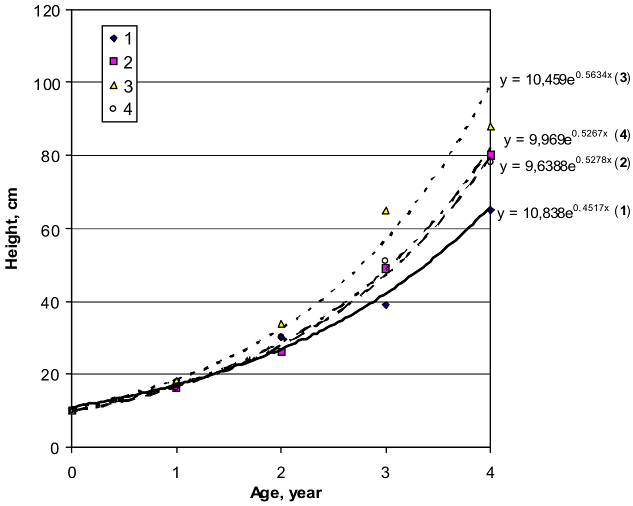

Figure 3 Scots pine seedlings height increment in soils, prepared by different methods: **1** – non-prepared; **2** – completely plowed to the depth of 25-27 cm; **3** – to the depth of 8 cm, 50 cm wide furrows, **4** – to the depth of 15 cm, 70 cm wide furrows

Table 5. The mean height increment of 4 years old Scots pine seedlings at Anykščiai in soils, prepared by different methods. Comparison is performed using T-test. Significance levels: * $p < 0.05$; ** $p < 0.01$

Site preparation method	No. site preparation	Complete plowing	Furrow depth, 8-10 cm, width 50 cm
Complete plowing	-0.932		
Furrow depth 8-10 cm, width 50 cm	-2.898**	-1.822*	
Furrow depth, 15 cm, width 70 cm	-1.304	-0.337	1.490

Table 6. Comparison of height increment of Scots pine seedlings using T-test between un-prepared soil and other soil preparation methods.
Significance levels: * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Site preparation methods	1st season	2nd season	4th season	1,2,4th season
Complete plowing	1.013	1.065	-3.115**	-0.973
Furrow depth 8-10 cm, width 50 cm	-2.146*	-3.162**	-4.030***	-3.257***
Furrow depth, 15 cm, width 70 cm	-0.381	-2.440**	-0.528	-1.117

The highest weed biomass (134 g m^{-2}) during the first growing season was in non-prepared soil and during the second growing season in completely plowed soil (167 g m^{-2}) (Table 7.). In soil prepared by furrows, the biomass of weeds was 2-3 times lower. The shading of competing vegetation depends on its biomass (density), height and height of the seedlings. The highest seedling shading class during the 1st growing season was defined in non-prepared soil (2.69), and during the 2nd growing season – in completely plowed soil (2.18). Significantly lower shading class was observed in soil prepared by furrows. Similar to shading class varied the need of weed control. In completely plowed soil during the second growing season, 25% of seedlings needed weed control, while planted in furrows significantly smaller number of seedlings, only 7-13% needed weed control. Weed control was not necessary for Scots pine seedlings planted in non-prepared soil during the second growing season because of the low weed size.

Table 7. Weed biomass, shading class and percentage of seedlings needing weed control after the 1st and 2nd year in different soil preparation treatments.
Significance levels: * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Soil preparation methods	Oven-dry biomass[1], gm^{-2}		Shading class[2]		The need of weed control, %	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
No site preparation	134	98	2.69	1.58	58	0
Complete plowing	108**	167***	2.31*	2.18***	54	25
Furrow depth 8-10 cm width 50 cm	37***	71***	0.83***	1.58	4	13
Furrow depth, 15 cm, width 70 cm	50***	67***	1.32**	1.158***	16	7

Comment: 1. The significance of soil preparation methods on weed biomass was calculated as difference using T-test between unprepared and other soil preparation treatments.
2. Significance level of shading class calculated using F-value comparing shading class in soils prepared by different methods with shading class in non-prepared soil

Discussion

The growth of Scots pine, Norway spruce and silver birch seedlings planted in deep plowed soil with the exception of Scots pines in Veisiejai experiment, was much faster and their taproots penetrated considerably deeper than in the soil prepared by other methods. The significantly faster growth of seedlings planted on deep plowed soil, as compared to other soil preparation methods, could result from small amount of competing ground vegetation during the first 3-4 years and better soil conditions for the growth and development of root systems. Soil prepared by deep plowing or loosening has lead to a considerably faster growth of taproots and also accelerated the development of seedling height. This has been in several other studies as well. For example in New Zealand, the taproots of 8-year-olds *Pinus radiata* on soil loosened to the depth of 100 cm had reached the depth of 153 cm, while in the control (skin- deep loosened soil) the roots had penetrated only to 93 cm depth (Balneaves and De la Mere 1989). In soil loosening was performed to the depth of 70-80, 50-60 and 30-40 cm without turning over the topsoil rooting depth in 10-year-old plantations on soils loosened to a maximum depth comprised 130-140 cm, while in those loosened to a minimal depth – 90-100 cm (Toropogrickij 1987). The height of plantations growing on soils with maximally deep loosening was by 84.6 cm, while the diameter was by 1.8 cm greater than in soils scarified to a minimal depth. Deep (60-70 cm) preparation of dry infertile soils ensures not only high survival and growth rate of pine plantations in the first year after planting, but it also increases the long-term (up to 15 years) growth of plantations (Golovchanskij and Govorova 1977). Tuszynski (1984) conducted studies in Poland on the influence of complete plowing to the depth of 25, 50 and 70 cm on the growth and on the development of Scots pine, Norway spruce, silver birch, aspen, Pedunculate oak and Douglas fir. In this study complete plowing had a positive effect on the survival and healthiness of plantations. At two sites in Sweden, Karlsson (2002) investigated the possibility of establishing silver birch on abandoned fields and prepared five methods (no soil preparation, rotary cultivation, deep plowing, soil inversion and removal of topsoil). The tallest seedlings were found on sites with topsoil retained within the soil profile (Karlsson 2002). The conclusion is that deep plowing was also found to be essential for good growth on poplar sites in Bulgaria when four different methods were compared (Kalchev 1983).

Deep plowing enhances root penetration and increases the rooting volume of the soil. It is highly important for the uptake of water and nutrients (Hetsch et al. 1981). Deep plowing improves soil water relations by improving permeability and preserving moisture in the buried humus material during dry periods (Buchholz and Neumann 1964).

The taproots of Norway spruce in Utena and those of silver birch in the Veisiejai experiment did not penetrate or hardly penetrated the compacted plough pan. According to our results high soil bulk density retards or hinders rooting downwards and are in agreement with earlier results from Wästerlund (1985). In his study, the growth of roots of Scots pine and Norway spruce depended on soil density after growing 16 days in compacted soil. Also in agreement with our study the growth of spruce roots was disturbed more than that of pine (Wästerlund 1985). The upper limits of bulk density at which roots do not penetrate wet fine-textured soils vary from about 1.4 to 1.6 g m^{-3}, while that of coarse textured soil is about 1.8 g cm^{-3}. However, this critical limit of bulk density does not prevent penetration of roots in all soils (Cassel 1983). The rooting ability of different tree species in compacted soils differs. According to Korotayev (1992), the roots of Pedunculate oak in clay loam may grow until its density reaches 1.9 g cm^{-3}, those of Siberian larch and silver birch – 1.8 g cm^{-3}, Scots pine – 1.7 g cm^{-3}, Norway spruce and small-leaved lime – 1.6 g cm^{-3}. Our data supports the findings of Korotayev (1992) in the case of Scots pine and Norway spruce. The difference in the results of silver birch could be explained by different soil texture (clay loam and fine sand).

Choice of soil preparation methods affects the amount of competing vegetation and thus the success of plantation. In our study, sparse ground vegetation on soil prepared by deep plowing allowed avoiding weed control during the first years after planting. Also according to Tuszynski (1984) deep (70 cm) or medium (50 cm) soil plowing allows avoiding the weed control for 3-4 years after the establishment of plantation. Deep plowing or inversion suppressed competing vegetation, compared with topsoil at the surface also in the study of Karlsson (1996).

In *Haplic Arenosols* soils during the first 4 growing seasons, the maximum height was reached by seedlings, planted in shallow furrows (8-10 cm deep). At the initial plantation growth stage this type of soil preparation ensured the best moisture and nutrients supply, as well it was effective diminishing the competing vegetation. Best growing conditions in terms of seedling survival were in small furrows as compared with other soil preparation methods. However, during the 4th growing season the highest height increment (31.3±1.2 cm) was measured in completely plowed soil, while in soils prepared by other methods seedlings height increment was 14-27% lower. Favourable conditions for seedlings develop in completely plowed soil when seedlings grow taller and thus the influence of competing vegetation diminishes and roots reach deeper soil layers ensuring good moisture availability. Soil preparation by elimination the topsoil diminishes the amount of competing vegetation around the seedlings, but the effect is short-termed (Bärring 1962; Söderström et al. 1973). Results from experiments on former agricultural land in Poland show that the best growing conditions were in completely plowed soil (Jakubowski and Sobczak 1999).

Conclusions

1. The light textured plough-pan compacted to 1.6gcm^{-3} retards the growth of Norway spruce and silver birch taproots downwards. However, Scots pine taproots were able to penetrate trough the plough-pan and it did not retard the taproots growth.

2. Deep plowing with plough-pan inversion provides favourable conditions for the growth of taproots and increases rooting depth. The growth of roots depended on the rooting conditions and thus more favourable rooting conditions may considerably increase the growth of the above-ground part of the tree.

3. In former agricultural *Haplic Arenosols* soils without plough-pan, survival and growth of Scots pine seedlings for the first three growing seasons were the best in soils prepared in shallow furrows, while during the 4th growing season the completely plowed soil gave best height growth.

References

Balneaves, J.V. and De la Mere, P.J. 1989. Root patterns of *Pinus radiata* on fine ripping treatments in a Canterbury Forest N.Z.J. *Forest Science* 19 (1): 29-40.

Bärring, U. 1962. Studies of methods for planting spruce and pine on old fields in southern and central Sweden. *Studia Forestalia Suecica*, 50 pp.

Buchholz, F. and Neumann, E. 1964. Der Einfluss der Bodenbearbeitung und Dūngung auf den Wasserhaushalt und die Durchwurzelung sandiger Waldböden Brandenburgs [The influence of tillage and fertilization on the water resourse and root penetration in the sandy forest soils in Brandenburg]. *Albrecht-Thaer-Archiv* 8: 525-536 (in German).

Cassel, D.K. 1983. Effects of soil characteristics and tillage practices on water storage and its availability to plant roots. In Raper C.D., Jr. & Kramer P.J. (Eds.). Crop relations to Water and Temperature stresses in Humid temperate Climates. Vestview Press, Boulder, CD, p. 167-186.

Corns, G.W. 1988. Compaction by forestry equipment and effect on coniferous seedling growth on four soils in the Alberta foothills. *Canadian Journal of Forest Research*: 18: 75-84.

Day, S.D., Bassuk, N.L. and van Es, H. 1995. Effects of four compaction remediation methods for landscape trees on soil aeration, mechanical impedance and tree establishment. *Journal Environement and Horticulture.* 13: 64-71.

Gerik, T.J., Morrison, J.E. and Chichester, F.W. 1987. Effects of controlled traffic on soil physical properties and crop rooting. *Agronomy Journal* 79: 434-438.

Hetsch, W., Kramer, W. and Wessels, W. 1981. Bodenkundliche und waldbauliche Auswirkungen einer kombinierten Meliorationsmassnahme im Forstamt Syke [Soil and forest structural effects of a combined Melioration in Forestry Syke]. *Der Forst-und Holzwirtshaft* 36(21): 548-554 (in German).

Hytönen, J. and Wall, A. 1997. Summary: Nutrients amounts of afforested peat fields and neighbouring peat land forests. *Suo* 48 (2): 33-42.

Hytönen, J. and Jylhä, P. 2005. Effects of competing vegetation and post-planting weed control on the mortality, growth and vole damages to *Betula pendula* planted on former agricultural land. *Silva Fennica* 39 (3): 365-380.

Hytönen, J. and Jylhä, P.F. 2008. Fifteen-year response of weed control intensity and seedling type on Norway spruce survival and growth on arable land. *Silva Fennica* 42(3): 355-358.

Howard, R.F., Singer, M.J. and Frantz, G.A. 1981. Effects of soil properties, water content and compactive effort on the compaction of selected California forest and range soils. *Soil Science Society American Journa.* 45: 231-236.

Jakubowski, G. and Sobzak, R. 1999. Mozliwosci intensiwnej uprawy sosny i brzozy na gruntach porolnych [Possibilities of pine and birch trees establishment on abandoned agricultural land]. Prace Instytutu Badawczego Lesnictwa, Serie A. No 878/883, p. 61-93 (in Poland).

Jim, C.Y. 1993. Soil compaction as a constraint to tree growth in tropical and subtropical urban habitats. *Euvironement Conservation.* 20: 35-49.

Kairiūkštis, L. and Vaičys, M. 1997. Lengvai pažeidžiamų ir žemdirbystei nepalankių žemių vieta Lietuvos ekologinio tvarumo sistemoje [The place of vulnerable to adverse farming lands on the eco-system of Lithuania]. Ekologiškai jautrių ir nepalankių žemės ūkiui žemių naudojimo Lietuvoje mokslinės, socialinės ir gamybinės problemos integruojantis į Europos Sąjungą. V., p. 37-49 (in Lithuanian).

Karlsson, A. 1996. Initial seedling emergence of hairy birch and silver birch on abandoned fields following different site preparation regimes. Swedish University of Agricultural Sciences, Departament of Silviculture. 11 (2): 93-123.

Karlsson, A. 2002. Site preparation on abandoned fields and early establishment of planted small – sized seedlings of silver birch. *New Forest* 23 (2): 159-175.

Kiirikki, M. 1993. Seed bank and vegetation succession in abandoned fields in the Karkali Nature Reserve, Southern Finland. *Annaels Botanici Fennici* 30: 139-152.

Kozlowski, T.T. 1999. Soil compaction and Growth of Woodly Plants. *Scandinavian Journal of Forest Research* 14: 596-619.

Malinauskas, A., Suchockas, V. and Urbaitis, G. 2006. Dirvožemio tankis žemės ūkiui naudotuose plotuose ir galima jo įtaka miško želdiniams [Soil density on former agricultural lands and its possible influence on forest plantations]. *Žemės ūkio mokslai* 2: 51-59 (in Lithuanian).

Malinauskas, A. and Verbyla, V. 2003. Miško želdinimas nevalstybinio fondo žemėse [Forest plantations on non-state land fund]. Lietuvos miškų metraštis XX a. p. 255-260 (in Lithuanian).

Mitchell, M.L., Hassan, A.E., Davey, C.B. and Gregory, J.D. 1982. Loblolly pine growth in compacted greenhouse soils. *Transamerican Society Agriculture and Enginering* 25: 304-307.

Paatela, J. and Erviö, L.-R. 1971. Weed seeds in cultivated soils in Finland. *Annaels Agriculture Fenniae* 10: 144-152.

Pittenger, D.R. and Stamen, T. 1990. Effectiveness of methods used to reduce harmful effect of compacted soil around landscape trees. *Arboriculture Journal* 16(3): 55-57.

Ramoška, E. 2002. Podirvio gerinimo poveikis dirvožemio struktūrai ir vandens laidumui [Subsoil Improvement effect on soil structure and water conduction]. *Žemdirbystė* 79: 30-40 (in Lithuanian).

Ruark, G.A., Mader, D.L. and Tattar, T.A. 1982. The influence of soil compaction and aerationon the root growth and vigor of trees – aliterature review. Part I. *Arboriculture Journal* 6: 251-265.

Söderström, V., Jansson, V. and Byfalk, R. 1979. Optimal site preparation patch size for planting. Skogshögskolan, Inst.f. Skogsskötsel, Interna Rapporter 2.

Thorud, D.B. and Frissell, S.S. 1976. Time changes in soil density following compaction under an oak forest. Minnesota Forestry Research Note 257.

Tuszynski, M. 1984. Wplyw sposobu przygotowania gleby na wzrost i rozwoj upraw lesnych [Influence of the soil preparation on growth and development of forest plantations]. *Sylwan* 128 (11): 1-11 (in Polish).

Velykis, A. 1996. Gilaus purenimo įtaka negatyvioms suslėgimo pasekmėms pašalinti sunkaus priemolio dirvožemiuose [The influence of deep hoeing on negative consequences of a severe compression loam soils]. Daktaro disertacijos santrauka. Dotnuva-Akademija. 23 pp. (in Lithuanian).

Wall, A. and Hytönen, J. 2005. Soil fertility of afforested arable land compared to continuously forested sites. *Plant and Soil* 275 (1-2): 245-258.

Wästerlund, J. 1985. Compaction of till soils and growth tests with Norway spruce and Scots pine. *Forest Ecology and Management* 11: 171-179.

Головчанский, И. Н. and Говорова, Т.Т. 1977. О продолжительности последействия глубокой обработки песков при создании лесокультур [Duration of the influence of deep soil preparation on forest plantations]. *Лесоводство и агролесомелиорация* 49: 77-80 (in Russian).

Калчев, П. 1983. Растеж на тополовите култури в зависимост от начина на предварителната обработка на почвата [The growth of poplar plantations, depending on the preparation of the soil]. *«Горскостопство наука»* 20 (5): 67-73 (in Bulgarian).

Коротаев, А.А. 1992. Влияние плотности почвы на рост корневых систем саженцев древесных пород [The influence of soil density on the root systems of seedlings]. *Лесоведение* 4: 74-78 (in Russian).

Торопогрицкий, Д. П. 1987. Влияние глубокой подготовки почвы на рост культур сосны на песках (Effect of deep soil preparation on the growth of Scots pines on the sandy soils). *Лесное хозяйство* 8: 28-32 (in Russian).

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ПОДГОТОВКА ПОЧВЫ ПОД ЛЕСНЫЕ КУЛЬТУРЫ НА ВЫШЕДШИХ ИЗ ПОД СЕЛЬХОЗПОЛЬЗОВАНИЯ, СО СФОРМИРОВАВШЕЙСЯ ПЛУЖНОЙ ПОДОШВОЙ И БЕЗ НЕЕ *HAPLIC ARENOSOLS*

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Резюме

Проведены исследования роста деревьев в высоту и проникновения вертикальных корней сосны, ели и березы на более глубокие слои почвы в лесных культурах, созданных на вышедшых из под сельхозпользования со сформировавшейся плужной подошвой почвах. Почва под лесные культуры была подготовлена глубокой вспашкой (глубина вспашки 60 см), сплошной вспашкой (25-27 см) и площадками.

Установлено, что уплотненная плужная подошва на почвах легкого гранулометрического состава препятствовала росту вертикальных корней ели и березы. Глубокая вспашка с вывертыванием на поверхность уплотненного подпахотного слоя создает благоприятные условия роста и проникновения вертикальных корней деревьев на более глубокие слои почвы. Рост надземной части деревьев прямолинейно зависит от условий роста корней. Более благоприятные условия роста корней деревьев могут значительно ускорить рост надземной их части.

На вышедшых из под сельхозпользования без сформировавшейся плужной подошвы *Haplic Arenosols* в первые три года после посадки наилучший рост и сохранность культур сосны установлен на неглубокими бороздами подготовленной, а на 4-ом году наибольший прирост по высоте был на сплошной вспашкой подготовленной почве.

Ключевые слова: лесные культуры, плужная подошва, подготовка почвы, рост корней