Farmland Afforestation: the Plantations of Birch *Betula pendula* Roth. on Different Soils

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Birch *Betula pendula* Roth., which under the conditions of Latvia is fast-growing, easy for establishment, and yields high-quality wood, is one of the most suitable species for farmland afforestation. On the basis of trials established all over the country for investigating afforestation uses of birch the field data are analysed for the survival, growth and increment of birch and stem quality in different soils, planting densities, changes in the farmland vegetation after establishing forest, plantation tending, fertilisation, and protection.

Key words: farmland afforestation; birch *Betula pendula* Roth.; soil types; annual increment in height and diameter; stem quality; crown height; survival; forest plantation tending, fertilisation and protection.

Introduction

Rational land use is currently in focus not only in Latvia but also elsewhere in the world. Because of economic considerations, vast farmland areas are laid fallow – mostly low-value, bogged or lean sandy, as well as heavy clayey sites.

The total land area in Latvia is 6.495 m ha, including 2.882 m ha of forest land and 2.829 m ha of farmland. According to the data of the Latvian Institute of land Survey and Development (1999-2001), about 430,000 ha or 17 % of farmlands are out of use at present. Following the estimates of the possible developments in land use in Latvia made by the Ministry of Environmental Protection and Regional Development (MEPRD), the amount of agricultural lands suitable for afforestation is about 400-500 thousand ha. According to estimation of some researchers (Daugaviete 2001) 580,000 ha will stay economically disadvantageous for agriculture after entrance in EU.

One of using alternative such lands is afforestation. The support of afforestation of abandoned lands is accepted by Forest Policy of Latvia accepted by the Council of Minister on April 28, 1998.

Afforestation or plantation cultivation of forest is among the alternative uses of similar lands all around the world. Considerable afforestation experience is gained in the EU (Germany, Denmark, France, Finland, Sweden, Italy, Spain etc.), the USA and Canada, as well as in the former Soviet block countries, Hungary, Romania, Poland, Estonia, Lithuania, Latvia etc.

As birch is fast-growing, easily adapts to different climatic and growing conditions, and yields high quality wood, its cultivation is increasing not only in northern and southern Europe (common birch *Betula pendula* Roth., hairy birch *Betula pubescens* Ehrh.) but also in North America and Japan (*Betula platyphylla* Sukacz., *Betula papyrifera* Marsh., *Betula alleghaniensis* Britt., *Betula maximovicziana* Regel in DC).

The research work on birch covers a variety of aspects: provenance selection following their performance and growth, crossing the best progeny of different species, cultivation methods to stimulate growth and improve wood quality, etc. (Cameron 1996, Borecki, Nowakovska 1995, Karlsson, Albrektson, Sonesson 1997, Karlson 1996, Erken 1972, Ferm 1991, 1993, Keltikangas, Seppala 1977, Raulo 1997, Hoyle 1965, 1975, 1984; Parviainen 1985, Dimitri *et al.* 1990, Lehonkoski 1940, Appelroth, Lappi-Sappala 1946, Cevedaev 1950, Hedemann-Gade 1964, Gunzl 1971, Braide 1985, Bergman *et al.* 1986, Raulo 1979).

The number of methods for plantation establishment, including direct sowing of birch in a prepared site and planting out a variety of stock at different times, with the ball-rooted one found to be the most efficient was tested in Finland and in other countries in the temporary zone (Raulo, Lahde 1976, Willoughby, Kerr, Jinks, Gosling 1996). Research is done also on plantation establishment, including site preparation, planting patterns and techniques, juvenile tending and protection, cultivation to get definite end-use assortments. For instance, P. Niemisto (1998) has found that for veneer logs the stand density cannot exceed 1,600 stems/ha. In cultivating pulpwood the density is up to 2,000 stems/ha, while at 3,000-4,000 stems/ha by the age of 10 the end-use assortment would be fit for fuelwood only. In southern Finland the best birch plantations yield 500 m^3/ha, a half of which is top grade veneer logs.

The German, Finnish and Swedish scientists recommende cultivation of hairy birch in medium moist, loose, humus-rich loamy and sandy loam soils too. According to German researchers the wood of hairy birch is the best raw material for veneer (Cameron 1996; Helinska-Raczkovska, Fabisiak 1995 etc.).

Ample research on birch is conducted also in Austria, Germany, Sweden and elsewhere (Gunzl 1971, Hoyle 1975, Keltikangas, Seppala 1997, Karlsson *et al.* 1996, Otto 1996). To get the birchwood of special texture and properties required in furniture making and finishing (e. g. cross-grained wood, "flaming" wood) the emphasis is on *Betula verrucosa* syn. *Pendula* (Johinsson, Junger 1962). Selected for breeding are birches showing special features of stem; the progeny of elite specimens are obtained by *in vitro* techniques, etc. (Kleinscmidt 1998).

In the CIS countries birch is considered suitable for plantation cultivation in the steppe/forest steppe zone to protect the soils against erosion (Popov 1965, Danko 1978, Usoltsev 1985, Pavlovskii, Akhtyamov 1986, Grechushkin 1978, Pisarenko 1980, Cevedaev 1950, *etc.*).

As fast-growing and having excellent assimilation properties, birch readily absorbs atmospheric CO_2 (Rey, Jarvis, Proctor 1997, Rey, Jarvis 1997, Gulidova 1960).

Research also proves that in highly industrialised areas birch efficiently absorbs soil pollutants (Ermakov 1986, Gazuzullin 1991, Korotaev 1992, Ocvirek, Orlic 1994, Kaar 1959, Gurth 1986, Ferm, Polet 1991, Ferm 1993).

Many researchers now recognise that in a situation of increasing wood consumption birch can be successfully plantation-cultivated in the temperate climate zone. Although on a per cu. m. basis the costs are higher as compared to spruce, birch, due to a variety of efficient uses, should be given priority in farmland afforestations and forest plantations.

In Latvia, the research done so far shows birch cultivation in farmlands to hold promise because of high economic returns it offers. In line with the Program for Rural Development and the Latvia's international commitments (Rio, Helsinki and Lisbon declarations) the LFRI "Silava" is conducting research on birch breeding (J. Gailis) and the models for farmland afforestation, including plantation cultivation of birch (Daugaviete *et al.* 1997, 1998, 1999, 2000, 2001).

Under the Latvia's conditions common birch *Betula pendula* Roth. and hairy birch *Betula pubescens* Ehrh. are of high commercial value. The available data show that hairy birch, though yielding less wood as compared to common birch, is suitable for cultivation in peaty soils on occasionally overflowing sites.

Latvian scientists (Maike 1947) had managed the investigations for birch performance on different soil types: clay, loam, sandy loam, peat and with different densities: from 1250 (1.3x1.3 m) up to 5917 (2.1x4.0 m) stems/ha. The investigations show, if the historical density of the birch stand is very large, the larger is the selfthining gait. The density of the artificial birch stands reduce to density of the natural stands during growing time.

The performance of the artificial birch stands on the agricultural lands is remarkably slower than in the natural stands in the first 5 years, but already at age 20 years the performance of artificial stands remarkably exceeds that of natural stands.

The maximum increment in height on the artificial birch stands on the agricultural lands culmination received between year 10-15, but approximately in the age of 20 the increment fell under increment of natural stands (the culmination point is between 8-20 years).

The yield of natural birch stand in Latvia at age 60 years on average is 300-350 m^3/ha. Annual increment of birch stands is 6.1 m^3/ha.

Research projects (since 1994) had carried out by Latvian Research Institute "Silava" covered the following investigations:

- models for the afforestation of abandoned farmlands,
- regularities governing the change of field biocenoses into those of forest
- monitoring of performance of different tree species in different soils

In this article the results of longterm investigations (satarted in 1994) for establishing and cultivating birch in farmlands are disccussed:

- survival, growth and increment of birch, and stem quality in different soils
- planting densities
- changes in the farmland vegetation and soils after establishing forest
- appropriate tending practises
- fertilisation effect on birch in lean soils
- protection of birch plantations.

Materials and methods

The present paper is based on the study of the survival, growth and increment, stem quality, fertilisation effect on the birch, effectiveness of the management on the growth and development of birch, efectiveness of different type of protection the trees, as well as the results of some research conducted on the changes in agrochemical properties of the soil and on the changes of vegetation cover in the 14 birch plantations spreaded all over Latvia (56-58°N; 21-28°E), covering different agroclimatic regions and soil types (Table 1).

In Latvia, average temperatures range from 16.8 °C – 17.6 °C in July to -5 °C – -7.5 °C in February. Maximum temperature can rise to 33.3 °C – 36.4 °C in summer and fall to -32.9 °C – -43.2 °C in winter.

Table 1. Trial plantations in farmland afforestation by birch

No.	Agroclimatic region/ trial location (administrative region/community/farm/ area, ha)*	Soil type	Planting density, stem/ha (planting sheme)
Coastal agroclimatic region			
1.	Liepāja/Grobiņa/Bērzpurvi/ 1.4 ha	**POi**- typical podzol	3300 (1.5x2.0 m), 2500 (2.0x2.0 m)
2.	Dobele/Auri/Mežanši/ 1.2 ha	**PVv**- sod podzolic soil	3300 (1.5x2.0 m), 2500 (2.0x2.0 m)
3.	Jelgava/Sidrabene/ Medņi/ 3 ha	**PVv**-sod podzolic soil	3300 (1.5x2.0 m), 2500 (2.0x2.0 m)
4.	Bauska/Iecava/Skujenieki/ 0.8 ha	**Alv**-alluvial sod-gley soil	3300 (1.5x2.0 m), 2500 (2.0x2.0 m)
5.	Bauska/Iecava/Gaiļi/ 3.5 ha	**VKt**-typical sod-calcareous soil	2500 (2.0x2.0m)
Kurzeme (western) agroclimatic region			
6.	Kuldīga/Padure/Rūmnieki/ 2.71 ha	**VKt**-typical sod-calcareous soil	10 000 (1.0x1.0 m) 5 000 (1.0x2.0 m) 2 500 (2.0x2.0 m) 1667 (2.0x3.0 m) 1111 (3.0 x 3.0 m)
7.	Tukums/Vāne/Aizļoļas /2.65 ha	**VKg** -sod calcareous gleysolic soil	3300 (1.5x2.0 m), 2500 (2.0x2.0 m)
Latgale (eastern) agroclimatic region			
8.	Jēkabpils/Sauka/Lejas Palsāni/1.78 ha	**BRn** - brown base unsaturated soil	3300 (1.5x2.0 m), 2500 (2.0x2.0 m)
9.	Jēkabpils/Mežāre/Pāķi/ 3.5 ha	**VKg** -sod calcareous gleysolic soil	2500 (2.0x2.0 m)
10.	Gulbene/Litene/Sopuļi/ 2.4 ha	**Alv**- alluvial sod-gley soil	3300 (1.5x2.0 m), 2500 (2.0x2.0 m)
11.	Rēzekne/Malta/Bitītes/ 2.9 ha	**PVv**-sod podzolic soil	10 000 (1.0x1.0 m) 5 000 (1.0x2.0 m) 2 500 (2.0x2.0 m) 1667 (2.0x3.0 m) 1111 (3.0 x 3.0 m)

* Only the name of the farm is given hereinafter

The mean annual precipitation varies from 617 to 743 mm.

The above-mentioned plantations of silver birch were established in the spring of 1995-1997. In the establishing plantations, mainly one-two-year old bare rooted seedlings were used. The soil ploughing was not done. On the chosen sites correct moowing of grass and marking of the planting beds were done.

In each trial plantation there is a permanent observation plot where 200 stems are measured on a regular basis: tree height, cm; annual increment, cm; stem diameter at the root collar (at 5 cm above groung level) in the first three years after planting, mm; stem diameter at the breast level (1.3 m above ground level) started by 4 - year plantations, cm; crown closure.

For the respective management models in each trial plantation observation plots (500 m^2; 125 stems in each) were delineated.

For each tending alternative there are 60 observation plots, comprising 300 planting spots.

The following tending alternatives are considered:

- mowing (about 1 m^2) around the crop stems so that grass does not outcompete the trees: 2-3times in 1997; 3-4 times in 1998; 1-2 times in 1999-2001
- soil loosening (hoeing) within a radius of 25 cm around the trees (as required)
- herbicide application over 1 m^2 around each tree (Roundup: 3 l/ha; MCPA: 2 l/ha plus Roundup 1 l/ha; timing as by the herbicide technical specifications; in 1997-1998 - twice, in 1999–2001 - once)
- mulching by black polyethylene film (25 cm on each side of the tree) or by sawdust (once in 2-3 years)
- control (no tending).

The tending efficiency is evaluated in terms of tree growth (height and diameter of trees, anuall increment) and survival.

The fertilisation trials were established on sites with poor soils (*Bērzpurvi*, *Laubītes*; plot size 100 m^2 each, planting sheme: 1.5x2.0 m; total number of trees tested for each fertilising spot -500). Fertiliser doses were calculated to achieve the optimum N, P, K content.

Tests for protecting birch against wildlife were, in 1997-2000, laid on eight sites *(Bērzpurvi, Aizļoļas, Skujenieki, Laubītes, Lejas Palsāni, Rūmnieki, Bitītes, Birzes*: 3 sample plots 10x10 m, 25 stems in each, the total number of trees tested for each protection method - 125) by using two methods:

- repellents *Fitorodents* (the product of A/S "Biolat") and *Alcetals* (LFRI "Silava")
- enclosing the tree in plastic tubing
- control (no protection).

In all plantations one characteristic soil pit (down to a depth of 1,0 m) was prepared and soil type was determined according to the FAO-UNESCO (FAO-UNESCO 1994,), but with amendments in accordance with Latvia conditions (Karklins 1995). Soil samples were analysed for pH_{KCl}, total Kjeldahl nitrogen, available phosphorus- P_2O_5 (photometric method by Kirsanov), available potassium- K_2O (photometric method by Maslova), NH_4 (photometric method by Nestler).

Accounting the vegetation cover carried out by W.Berthold's method established the constant sample plots by size 1 m^2- 10 plots for each experimental plot. The first accounting was carried out in 1997, but second- after 4 years – in 2001.

Analysis of variance and T-test were used in statistical analysis ($P<0.05$).

Results and discussion

To achieve high-yield birch stands on farmlands a proper plantation establishment method matching the requirements of the given species is of paramount importance. In many countries great effort is devoted to identify the suitability of different soils for cultivating birch (Kinnaird 1970, Kleinsmith 1998, Korotaev 1992, Lopusiewicz 1987, Kaunisto 1973, Karlsson, Albrektson, Sonesson 1997, Ocvirek, Orlic 1994, *etc.*). However, the field data show the performance of birch in the first years after planting to differ considerably even for a single soil type and the basic substrates. The establishment, survival and growth rates are primarily determined by other factors as planting stock quality, site preparation, soil moisture, and juvenile tending. In this respect the data of foreign researchers very well agree with those of the given study.

Changes in soil agrochemical properties

The trials were established in different soil types, with the assessment made at different stages:

- overall assessment before establishing plantation to determine soil suitability for the research objectives (1996)
- identifying the soil type and soil analyses (1997)
- repeated collection of soil samples for agrochemical analyses (autumn of 2000).

Four average soil samples were obtained in 5 probings. Totally 1,600 probings were made, yielding 320 average soil samples used in analyses.

As it follows from Table 2, the humus content at the depth 0-30 cm has increased in all trials. It may partly be explained by the fact that the sites were fallow before establishing forest and the grass was regularly mown and left to decay. At this stage the role of birch litter is insignificant.

The soil analyses for active nutrients can be summarised as follows:

Table 2. Changes in the soil humus content in birch trial plantations, 1997-2000

Trial	Soil type	Humus content (0-30cm), % 1996yr.	2000yr.	Changes: +,-
		Sod podzolic soil		
Mežanši	PVv	1.98	2.95	+
Bitītes	PVv	2.22	3.04	+
Laubītes	PVv	2.16	2.50	+
Birzes	PVv	2.52	2.81	+
		Typical podzol		
Bērzpurvi	PO1	2.42	3.17	+
		Alluvial soil		
Skujenieki	Alv	2.81	3.41	+
Sopuļi	Alv	3.58	4.74	+
		Calcareous soil		
Rūmnieki	VKt	3.17	4.49	+
Zariņi	Vki	2.60	3.31	+
Aizļoļas	VKg	2.13	3.15	+
		Brown based saturated soil		
Lejas Palsāni	BRn	2.43	3.02	+

Table 3. Content of active nutrients in the upper 30 cm soil layer, mg/100 g

Trial/soil type	N nitrogen		P2O5 phosphorous		K2O potassium		PH KCl pH of 1 ml KCl suspension	
	1996	2000	1996	2000	1996	2000	1996	2000
				Sod podzolic soil				
Mežanši/PVv	1.5	2.1+	6.1	5.2-	5.2	5.6+	6.0	6.5+
Laubītes/PVv	1.1	2.8+	2.0	2.3+	6.4	6.4±	5.0	5.4+
Birzes/PVv	1.2	2.3+	6.6	5.6-	7.1	7.9+	5.4	5.5+
Bitītes/PVv	1.2	2.0+	13.2	12.3-	8.1	9.0+	5.2	5.2
				Typical podzols				
Bērzpurvi/ PO1	1.1	3.0+	1.9	2.2+	1.7	3.7+	5.6	6.0+
				Calcareous soils				
Rūmnieki/ VKt	1.1	3.6+	4.1	5.0+	6.3	11.5+	5.7	6.1+
Aizļoļas/ VKg	1.1	2.5+	2.8	1.8-	17.4	17,3-	7.0	6.5-
Zariņi/Vki	1.2	3.0+	6.7	5.5-	6.9	7.2+	5.0	4.9-
				Alluvial soil				
Sopuļi/Alv	1.1	1.6+	6.6	6.2-	8.0	8.3+	6.1	6.5+
Skujenieki/ Alv	1.4	2.8+	11.8	9.2-	5.0	5,5+	6.4	6.7+
				Brown based saturated soil				
Lejas Palsāni/ BRn	1.2	2.5+	6.0	4.5-	11.4	13.6+	5.1	5.8+

- the N content increased on the average by 30.8%
- the active nutrients(P,K) content without essential changes during four years (or variations were within the error admissible)
- soil acidity remained virtually unchanged (or the variations were within the error admissible).

The literature sources report on similar soil nutrient changes after planting deciduous, and birch in particular (Bezkorovainaya, Vshkayakova 1996, Ivanov 1987).

The investigations of changes in herbaceous cover in the afforested areas shows that the changes after four-year establishment of birch plantations are without essential remarks.

Survival and growth of birch

As it follows from the field data, common birch performs best on naturally dry sites, rich in mineral nutrients (Fig. 1, Table 4 and Fig. 2 below). The increment in height and survival are notably higher for the planting stock of the average height 50-60 cm and the root collar diameter 6-8 mm.

According to the field data (Table 4; Fig. 1 and 2), birches in fertile nutrient-rich soils of stable hydrological regime (Alv- alluvial sod-gley; BRn-brown base unsaturated; PVv-sod podzolic) reached essentially greater height and root collar diameter than in

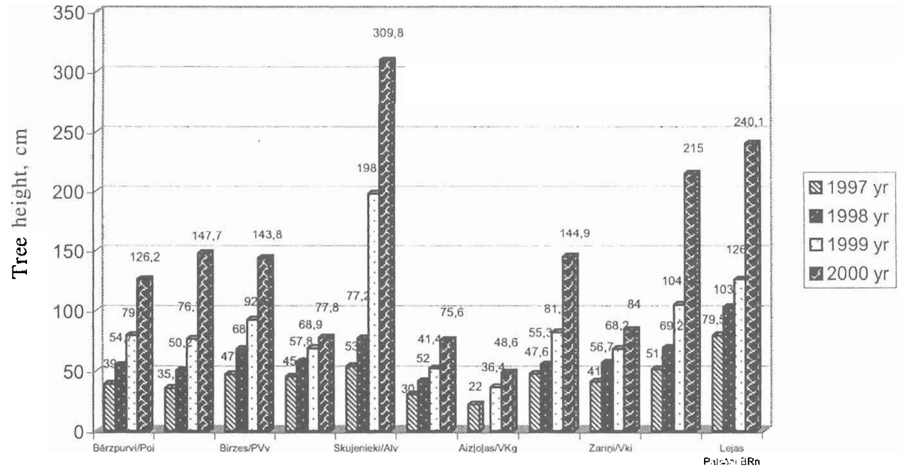

Figure 1. The birch height in different soil types, 1997-2000, cm

Table 4. Survival percent and root collar diameter increment for birch, mm, x±Dx, 1997-2000

Trial/soil type	Survival percent	Root collar diameter, mm 1997	2000	Increment, mm
Bērzpurvi/ POi	84% No survival in small wet hollows	5.9±2.4	13.9±0.7	8.0± 0.2
Mežanši/ PVv	85% No survival on small dry knolls	5.5±0.2	15.3±0.6	9.8± 0.4
Birzes/ PVv	29% Birch on hilltop nearly destroyed by frost	5.8±1.2	12.2±0.5	6.4± 0.2
Bitītes/ PVv	94% Establishment is very slow (gravel/pebbles)	2.8±1.4	7.6±0.4	4.8± 0.24
Skujenieki/ ALv	93% Excellent survival, diebacks due to no soil uniformity	10.3±0,5	39.9±1.2	29.6± 0.2
Sopuļi/ ALv	27% Nearly no survival due to floods, (river 30 m away)	4.5±2.0	7.2±0.3	2.7± 0.3
Aizļoļas/ VKg	78% No rooting in heavy clay soil	3.3±1.2	7.2±0.2*	3.8± 0.2
Rūmnieki/ VKt	93% Excellent survival, diebacks by bad tending	4.4±1.7	18,9±0.7	14.5± 0.4
Zariņi/ VKi	94% Good survival	4.7±0.7	9.5±0.6	4.8± 0.1
Gaiļi/ VKt	90% Good survival, diebacks by bad tending	5.5±1.7	15.8±0.6	10.3± 0.15
Lejas Palsāni/ BRn	100% Excellent survival	8.1±1.7	27.0±1.0	18.9± 0.3

* planted in 2000

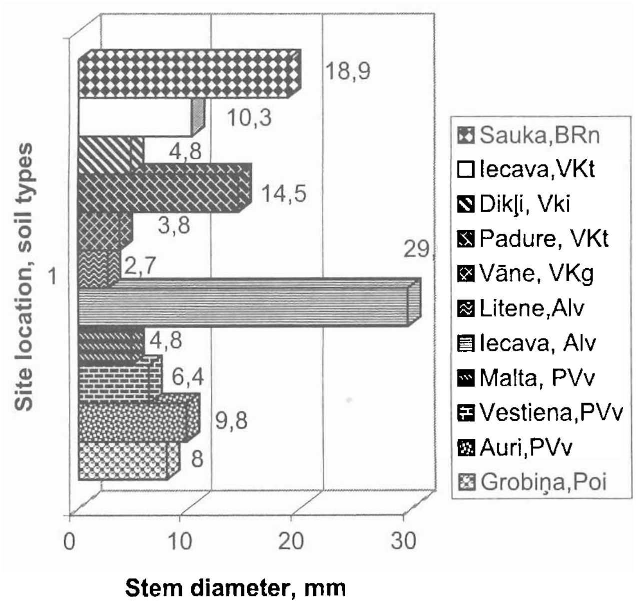

Figure 2. The root collar diameter for birch in different soil types, yr./mm, 1997-2000

lean soils. The poorest performance was on wet, occasionally overflowing sites regardless of the soil value affixed to it during the land cadastral evaluation. However, at *Bitītes* and *Zariņi* birch established itself slowly, yet the survival percent was high and the stem quality – good. As to survival, the difference between the *Sopuļi* and *Skujenieki* sites (Alv-alluvial sod-gley in both) is due to the former occasionally overflowing and water sometimes staying for 10 days. At *Sopuļi* the average height for birch - 77.8 cm (cf. 309 at *Skujenieki*) is because of beating up (in the autumn of 1999 1/3 of the beatings-up died back again).

The influence of planting density to birch growth did't apeared, because the crowns of trees are not closed.

The rooting of birch is also difficult in heavy clayey soils. Thus, at *Aizļoļas* the average tree height is only 48.6±1.0 cm, the increment in height – 12.2±1.0 cm/yr., the survival – 78%. The critical soil density for birch is known to be 1.84, although birch can adapt itself to difficult site conditions. If the soil is compact in lower horizons, the root system spreads out in the topsoil layer (Korotaev 1992; etc.). Many researchers also point to the importance of planting stock dimensions: a higher plant with a well-developed stem would be stronger against competing vegetation and show better juvenile increment (Clausen 1963; etc.). It is also confirmed by the present study: at *Lejas Palsāni, Skujenieki* and *Gaiļi* already in the first year of growth the increment in height for the stock of initial height 50 cm was 20 cm (Fig.1).

Notice that in a number of sites *(Medņi, Pāķi, Gaiļi)* birch reached the maximum height 6.5-7.0 m; d.b.h – 5.5-6.0 cm. The stem quality and the height of live crown are also evaluated on the mentioned sites (Table 5).

According to Table 5, the stem quality depends not only on the plant genetic properties but also on the soil, site location, and tending. For instance, hornet *Vespa crabro*, favouring old-growth oak, lime *etc.* in Gr *Aegopodiosa* forests, may peel the outer bark off the young shoots (up to 2-10% of damage) (Daugaviete *et al.* 1998). On the given sites the damage induced by roe deer is 10%, the diebacks due to inadequate tending – 10-15%. A low proportion of straight top quality stems (no more than 25% at *Pāķi* and *Gaiļi*) points to poor genetic properties of the planting stock could be caused by poor genetic properties of planting stock (planting material was wildings) or by insufficient management (influence of vegetative cover). It means that breeding genetically improved birch, especially regarding stem straightness and correct management of birch plantation in the first 2-3 years after planting, is a must. The data for the height of live crown suggest that in fertile soils on essentially dry sites in 6-7 year old plantations the average height of the first live branch is 0.3-0.6 m, at the stand density 2,500-3,300 stems/ha.

Our investigations have shown, that in 5-6 years the changes in the overall vegetation pattern are for

Table 5. Birch stem quality and the crown height, 2001

Trial	Number of trees evaluated	Stem quality				Tree height,m, x±Δx	Crown height,m x±Δx	Height of the first live branch,m x±Δx
		Straight no damage , %	Hornet damage %	Roe deer browsing, %	Bad tending, %			
Medņi	500	80	12	8	-	4.5± 0.35	3.9±0,25	0.6± 0.15
Gaiļi	500	25	28	12	15	4.3±0.2 0	3.85±0,2 0	0.45± 0.14
Pāķi	500	25	-	-	-	4.3± 0.25	3.8±0.15	0.5± 0.08

the most part insignificant, while in fertile soils the total vegetation mass remains high, which may also adversely affect the stem quality in the future (Daugaviete *et al.* 1998).

Efficiency of tending

Because of higher fertility, the height and mass of competing vegetation in agricultural soils is greater, affecting the performance of trees planted there. Since the composition and compactness of competing vegetation depend on the soil type and its fertility, the economically most feasible tending practices that match the soil type are of great importance.

As birch is highly sensitive to root competition, the site preparation and juvenile tending are of special importance (Borecki, Nowakowska 1995, Tuszynski 1983, 1984, Kaunisto 1987, Lopusiewicz, Szczupak 1987, Daugaviete, Krūmiņa, Lūkins 1999, *etc.*). Literature sources quote a variety of mechanical vegetation control techniques, analysing their efficiency and feasibility (Tracy, Nelson 1991). For instance, German scientists have concluded that continuous mowing of grass all over the site is less efficient than trampling, while mulching by sheets of board favours the multiplication of mice. Research on mulching by plastic foil is done in Denmark, the UK, Sweden, Finland, *etc.*

Herbicide application in forest plantations has been studied in the EU, the USA and elsewhere (Ferm, Hytonen, Lilja, Julha 1994, Britt, Smith 1996, Hjeljord 1994, *etc.*). The tendency is towards reducing it. Instead of continuous treatment spot treatment only is now advocated (Reinecke 1991). The same refers to the herbicides effective only against the *Calamagrostis, Holcus, Agrostis*, as well as *Deschampsia caespitosa* species, which form a strong continuous turf, suppressing tree growth (Fulisade 2000, *etc.*). Proper timing of herbicide application (normally between mid April and early June) reduces the grass competition considerably.

Different agrotechnical practices are likewise recommended. The German specialists, for instance, suggest that rape should be grown for two years on the sites to be afforested, with a different dose of additional N, P, K fertilisation (Gunzl 1971). As a result the trees grow faster with no need for early tending. Besides, in Germany there is a special sequence of crops practised on farmlands to be transformed into forest (Gurth 1986, *etc.*). According to Swedish scientists, inter-row cultivation is the best tending practice in the first two years of tree growth. It suppresses not only weeds, improves soil moisture conditions and aeration, but also reduces the mice population (Karlsson, Albrektson, Sonesson 1997).

In trial plantations 3 tending methods were tested: mechanical (mowing and mulching), chemical (herbicide application), and agrotechnical (hoeing). Herbicide application and mulching by a special plastic foil are found to be the most efficient methods for vegetation control in the immediate vicinity of crop trees. Right after establishing (1997) the difference in tree height between the tending scenarios was insignificant, while already after four years in intensively tended plots it significantly surpassed the control (Table 6).

Table 6. Management effect on birch height/increment in height, the average for all trials, 1997-2000, %.

Year	Hoeing	Mowing	Herbicides	Mulching	Control
1997	98	108	122	133	100
1998	108	110	128	125	100
1999	105	107	144	137	100
2000	116	109	182	146	100
Tending effect average for all period	107	110	144	135	100

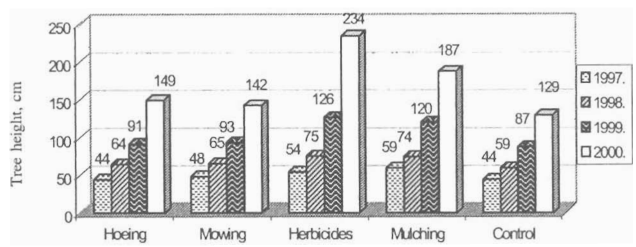

Figure 3. Management effect on birch height, the average for all trial plantations, yr./cm, 1997-2000; hoeing; mowing; herbicides; mulching; control.

The herbicide application is found to be the most efficient method for suppressing the root competition between birch and the herbaceous, making soil nutrients available for the former. Finnish scientists had determined the changes in the content of mineral substances in birch foliage, bark, and branches, depending on the mass of surrounding vegetation (Ferm, Hytonen, Lilja, Julha 1994). An increase in surrounding vegetation considerably reduces the content of N, P, K, Cu, and trace elements in birch foliage, which also affects its growth (Britt, Smith, 1996, etc.). Besides, lack of vegetation control in birch plantations favours bark necrosis and the multiplication of mice (Ferm, Hytonen, Lilja, Julha 1994).

The results of the given study show that hoeing is feasible on pre-prepared sites only. In abandoned pasturelands and meadows it is of no avail. Mowing is not the best tending practice in plantations on fertile farmlands: if first done early in June, when the grass is growing most intensively, repeated mowing may be necessary already in a couple of weeks or so. In 2000, the survival percent for all trial plantations for different tending practices on average was the following: hoeing – 98%; mowing – 88%; herbicides – 88%; mulching – 97%; control – 41%.

Fertilisation efficiency

Absence of soil microflora suitable for forest crops is also among the factors affecting the establishment and performance of trees on farmlands. The same is true for soil acidity (pH 6.0-6.5 for deciduous; 4.0-5.0 for conifers; in farmlands the same index is normally 7.0-8.0), resulting in no availability of P for uptake. The research shows that in farmland afforetation trees start gaining in vigour only after a layer of mycorrhiza has covered the feeding roots, that helps convert soil mineral substances into compounds suitable for uptake (Fleming, Deacon, Last, Donaldson 1984, Hjeljord 1992, Manson 1984).

Research on fertiliser application in poor soils shows that at juvenile age (till 10-12 years) it positively affects the performance of birch (Goto, Hasegava 1981, Kaunisto 1987, Slapokas 1991, Hjeljord, Barzdajn, Ceitel, Sienkiewicz, Zientarski 1992, Ingestad 1988, Lumme 1988, Hytonen, Ecola 1993, *etc.*). An increase in the availability of P and K has the most benevolent effect on birch. The experiments on fertilising birch by wood ashes indicate that the best results are obtained by working ashes into the depth of 10 cm as well as 60 cm (the ratio 1:1) (Slapokas 1991).

The trials for determining the response of birch to fertiliser application on lean soils were staged in the autumn of 1997 at *Bērzpurvi* (POi) and *Laubītes* (PVv), when the samples were taken for N, P, K analyses to determine the fertiliser dosing. The fertilisers were applied at the end of April: ammonia saltpetre (34% NH_4); superphosphate (20% P_2O_5); potassium salt (45% K_2O). In 1998-2000, the doses in g per planting spot were the following: N – 5; P – 25; K – 5. The fertilisation data are summarised in Fig. 4.

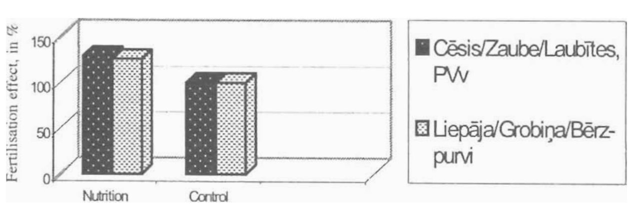

Figure 4. Fertilisation effect on birch height and diameter increment, %, in 2000

As it follows from Fig 4, fertilisation of 4-year birch on poor podzolic soils gave an increment in height by 28-35% surpassing the control *(Bērzpurvi)*. Since there is no significant difference between fertilisation and only herbicide application, herbicides can successfully substitute fertilisers in afforestation tending. Selective fertilising (the root zone of crop trees only) during 2-3 years after planting is recommended on sites with poor soils to achieve an optimum content of soil mineral substances: P (P_2O_5)- 8-10 mg/100g of soil; K (K_2O) – 11-15 mg; N (NH_4) – 5 mg, respectively (Mangalis, Kāposts 1971). Till the age of 5 years fertilisers should be applied to planting spots only, thus saving 70% of the costs as compared to fertilising the site as a whole. Moreover, spot application has no effect on the grass between the rows of trees. The average fertiliser consumption per 2,000 trees is, depending on the dose, between 50-70 and 100-200 kg/ha.

Protecting birch plantations

To get commercially valuable timber in plantation cultivation, not only the plantation as a whole, but also each individual tree requires tending and protection. As reported in the literature, birch suffers from a number of forest pests (weevils, may beetles, *june bugs)* especially foilivorous insects (Annila 1979, *etc.*). Rodents (mice, hare) in the first 2-3 years after planting may also cause heavy damage. Chewing off the tops of young trees by hare and roe deer is also common (Larsson 1976, Manson, Ostfeld, Canham 1998, *etc.*). Finnish researchers point to the damage by *birch sawfly (Agre pestoralis)* seriously affecting the stemwood quality: the damage in heartwood 4-6 cm wide may extend up the stem as high as 4 m (Annila 1979), impairing the timber value (Cameron, Dunham, Petty 1995, Hallaksela, Niemisto 1998, Hedemann-Gade 1964, Hoyle 1984). The damage by hornet was mentioned earlier. When the plantation is advancing in age, roe deer, red deer, wild boar start frequenting the site and inflicting damage.

Within the given research project the trials for the following protection methods were staged (1997): enclosing the stem to be protected in a plastic tube; applying repellents *Alcetals* and *Fitorodents*.

The investigations have shown, that protection of birch in the juvenile period are very essential in the agricultural lands on such soils than sod podzolic, sod calcareous, alluvial and brown base saturated.

A 4-year experience of enclosing tree stems in plastic tubes shows it to be highly efficient in averting wildlife damage (roe, hare) and improving tree performance. Because of favourable microclimate in the tube, the increment in height increases 30-40%. However, when the stem is enclosed, it tends to shoot up (the stem is 50% higher and its diameter is 30% less than for a similar stem in the open), and may break as soon as the tube is removed. That is why it is recommended to keep the stem enclosed for some 5-7 years till it extends well above the tube. To avoid shooting up, the tubing may be of plastic or wire mesh etc. Care must also be taken to suppress mice (by mowing the space between rows), lest they should live in the tubes. Tubing-in is a convenient but fairly expensive method for tree protection: the costs per ha (the number of stems 2,500) may run as high as 500-800 LVL.

The repellents *Fitorodents and Alcetals* are effective predominantly against hare and mice. Its consumption is 10-15 l/ha (2,500 stems, height 0.5 m), costs – 40-60 LVL/ha. As compared to the costs of beating-up, the margin is 70-80 LVL/ha (the survival with no protection is 44-60%). The plantations must be inspected 2 times during the growing season: early in spring in March and in autumn – middle of October to middle of November.

Conclusions

1. Soil analyses conducted on the 4 year period after establishing of the birch plantations on farmlands show no essential changes in the soil agrochemical properties, excluding the N content. In the active soil horizon (0-30 cm deep) the P, K content show no essential changes, the same shows the data on the soil acidity, it remained constant or varied within the admissible error, but the N content on average increased 30.8%.

2. Except occasionally overflowing sites, birch performs best in sod calcareous, sod podzolic, alluvial sod-gley, and brown base unsaturated soils on naturally dry or controlled soil moisture sites.

3. The soil moisture regime and tending practices are the basic factors, affecting the establishment and survival of birch in farmlands. In heavy clay and pebbly soils the growth is stunted while the survival is acceptable (78-94%). After 4 years the difference in the increment in height in such soils is 50% as compared to loose fertile ones.

4. In open places on heavy clay and pebbly soils birch is likely to suffer from frost due to difficult rooting (e. g. survival 29% at *Birzes*.) It implies that on similar difficult sites birch cannot be planted in autumn.

5. On naturally dry sod podzolic/sod calcareous soils and on alluvial soils of controlled soil moisture the crown closure for birch (density 2,500 stems/ha; 2x2 m) normally takes place in the 5th-6th year at the average height 4.3-4.5 m (max. 5.5-5.7 m) and the average d. b. h. 3-4 cm (max. 6 cm).

6. The crown height for 6-year-old birch is up to ¾ of the total height, with the first live branch at the height of 0.45-0.6 m.

7. Tending considerably improves the performance and quality of birch. Herbicide application and mulching by plastic foil in the immediate vicinity of crop stems are found to have the greatest effect, resulting in the increment in height by 46-81% surpassing the control.

8. Fertilisation favourably affects the performance of birch (height and diameter increment), especially on lean soils. Herbicide application in the root zone of crop trees has much the same effect as fertilisation (improvement by 25%).

9. The protection of crop trees in afforestation is a guarantee of high commercial value of end-use wood. The main types of damage are the bark chewing at the root collar (mice, hare), stripping young bark off the shoots by hornet, browsing of tree tops and shoots by cervidae. The protection may be by repellents, fencing-in, or enclosing each stem in a plastic tube till the age 6-7 years.

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РОСТ ОПЫТНЫХ ПОСАДКОК БЕРЕЗЫ (*BETULA PENDULA*) НА РАЗЛИЧНЫХ СЕЛЬСКОХОЗЯЙСТВЕННЫХ ПОЧВАХ

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Резюме

Одной из самых пригодных древесных пород для облесения малоценных земель в Латвии является береза (*Betula pendula* Roth), которая является быстрорастущей и дает ценную древесину. Береза хорошо аклиматизируется на открытых сельскохозяйственных площадях.

В статье обобщены данные по приживаемости и росту березовых посадок, качеству ствола, длины кроны в зависимости от возраста, технологии ухода, удобрения и защиты деревьев.

Ключевые слова: малоценные сельскохозяйственные земли, береза (*Betula pendula* Roth), приживаемость, рост, прирост, уход, защита посадок, удобрение.