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Height Growth of Four Fast-growing Deciduous Tree Species on Former Agricultural Lands in Estonia

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The present paper is based on the study of 21 plantations of deciduous trees growing on abandoned agricultural land in Estonia. For the establishment of the plantations, four fast-growing deciduous tree species (*Betula pendula* Roth., *Alnus incana* L. Moench., *Alnus hybrida* A. Br., *Populus x wettsteinii* Hämet-Ahti) were used as the planting material. Silver birch as the most important deciduous tree species in Estonia in the economic aspect grew well on *Glossic Podzoluvisol/Mollic Glossagualf, Calcaric Luvisol/Oxyaquic Argiudoll* and *Dystric Gleysol/Typic Endoaquent.* In comparison with silver birch and hybrid aspen, grey alder and hybrid alder appeared to grow faster on *Glossic Podzoluvisol/ Mollic Glossagualf.* Cultivation of silver birch on abandoned agricultural land proved highly effective with the use of polyethylene mulch. All studied fast-growing deciduous tree species are suitable for afforestation of abandoned agricultural lands in Estonia.

Key words: deciduous trees, former agricultural land, plantation, height growth, soil type, Estonia

Introduction

During the last decade the economic situation changed drastically in Estonia as well as in other post-socialist Eastern and Central European countries (Mander and Jongman 2000). The total area of Estonia is 4.5 million ha, including 2.2 million ha of forest land and 1.1 million ha of agricultural land. Due to socio-economic reasons the intensity of the use of agricultural land decreased significantly in Estonia, as a result of which at least 228 000 ha of abandoned agricultural land have come into existence (Meiner 1999). In the last decade a part of this area was already regenerated naturally with broadleaved pioneer tree species: alders, birches, aspens and willows. Unfortunately, the structure of the natural regeneration is highly variable and the economic value of naturally regenerated stands is low. Thus, afforestation of abandoned agricultural lands enables us to increase the stands' economic and ecological value.

The attention attracted by deciduous trees is the result of the increased need for energy and pulp, as well as of the possibility to afforest abandoned agricultural areas. Because of their low disease resistance, coniferous species are not recommended for afforestation of abandoned agricultural areas in Eastern and Northern Europe. Besides, broadleaved species have also become valued in sustainable forestry.

Very few studies have dealt with afforestation of abandoned agricultural land with deciduous tree species in the Estonian conditions. Therefore, experimental plantations of grey and hybrid alder (*Alnus incana* L. Moench., *Alnus hybrida* A. Br), silver birch (*Betula pendula* Roth.) and hybrid aspen (*Populus x wettsteinii* Hämet-Ahti) were established and monitored in 1995-2002. The parental species of hybrid alder (*Alnus incana* L. Moench., *Alnus glutinosa* L. Gaertn.) are widely distributed throughout Europe (Evans 1984). They have commonly high production capacity (Pregent and Camiré 1985, Uri *et al.* 2001); besides, they have some essential advantages, which make them promising species for short rotation forestry. They grow rapidly, are symbiotically N_2-fixing by the actinomycete *Frankia*, and have only a few pests and diseases. The litter of alders decomposes quickly and improves soil properties (Edmonds 1980, Vares 2001). Silver birch is a very widespread and common broadleaved species in Europe (Evans 1984). In the Estonian climatic conditions, the species grows naturally on different mineral soils and is of a great economic importance. The parental species of hybrid aspen are European aspen (*Populus tremula* L.) and North American trembling aspen (*Populus tremuloides* Michx.). Hybrid aspen is found to be a very fast-growing deciduous tree in Scandinavia (Hagman 1997, Jakobsen 1976, Johnsson 1967, Langhammer 1976).

The aims of the present study were (i) to investigate the mean height and annual height growth of four fast-growing deciduous tree species on different soil types after the fourth growing season, (ii) to analyse the effect of polyethylene mulch on early growth of silver birch, (iii) to find out the suitability of the studied fast-growing deciduous tree species for afforestation of abandoned agricultural land in Estonia. Owing to comparable climatic conditions, our results may also present interest in the Baltic Sea region.

Material and methods

The present paper is based on the study of 21 plantations of deciduous tree species on private agricultural land, which are located in different parts of Estonia (58-59°N; 22-28°E) (Fig. 1). In Estonia, average temperatures range from +20.9°C in July to –5.8°C in February. Maximum temperature can rise to +32.0°C in summer and fall to –25.0°C in winter. Mean annual precipitation varies from 500 mm on the coast to nearly 700 mm in the uplands. Precipitation is highest at the end of summer and lowest in spring according to the data of the Estonian Meteorological and Hydrological Institute.

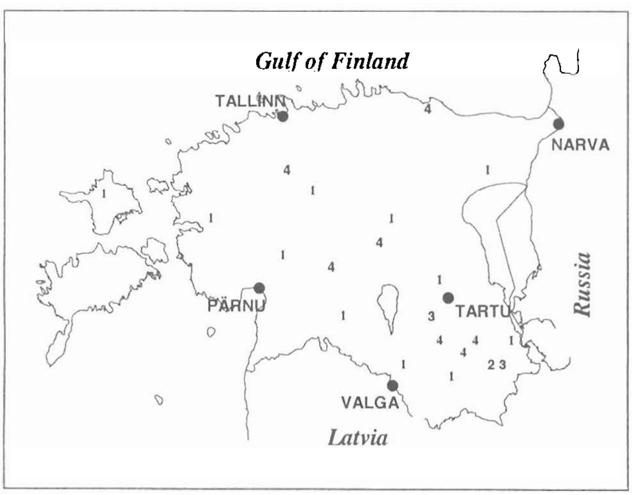

Figure 1. Location of the plantations (1- silver birch; 2 - grey alder; 3 - hybrid alder; 4 - hybrid aspen) in Estonia

The plantations of silver birch (n = 11) and hybrid aspen (n = 7) were established in the spring of 1999 and the plantations of grey alder (n = 1) and hybrid alder (n = 2), already in 1995 and 1996, respectively. In establishing plantations mainly one-two-year-old seedlings from the nursery were used. Fixed planting density was used for the tree species in each plantation. Soil preparation (ploughing) was done in most plantations to suppress weed competition and improve soil properties. Moreover, when planting silver birch, the black polyethylene mulch was used as the covering material. Stems of hybrid aspen were protected with biodegradable plastic tubes to prevent possible damage by voles and hares. The silver birch plantations are surrounded by wire fencing to prevent possible damage by big game (Tab. 1). Following the principle of contingency, one 0.1 ha sample plot was established in each plantation. The location of the sample plots in the plantations was marked to facilitate finding and re-measuring of model trees in the following years. In each sample plot, the height and the annual height growth of all trees (minimum 100 trees) were measured. Observation of the plantations was based on the method of single-tree, in which all measured trees were marked with numbered metal labels for further long-term observation. In the case of silver birch and alders, the trees were measured during four growing seasons after the establisment of the plantations, while the plantations of hybrid aspen were monitored only after the third and the fourth growing seasons.

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 and USDA classifications (FAO-UNESCO 1994; Keys to soil taxonomy 1998). Bulk density (n = 4) from each genetic horizon was estimated with a 50 cm^3 open-ended steel cylinder. Particle size distribution was analysed combining a pipette and sieves. Soil samples were taken from each genetic horizon and were analysed for pH_{KCl}, total Kjeldahl nitrogen (Tecator ASN 3313), available (ammonium lactate extractable) phosphorus (Tecator ASTN 9/84) and potassium by flame photometric method (Tab. 2). Organic carbon was analysed by wetchemical combustion with CrO_3+H_2SO_4 according to Tinsley (1950). For chemical analyses, dry fine earth less than 1 mm was used.

One-way analysis of variance (ANOVA) and T-test were used in statistical analysis ($p<0.05$). Throughout the study, the means are presented together with standard error (± SE).

Table 1. Planted deciduous tree species, survival of the plants after the first growing season, initial height of the planting stock, planting density and soil preparation in the plantations

Plantation	Planted species	Initial height (cm)	Survival (%)	Planting density (trees ha^{-1})	Soil preparation (% of area)
Kõrveküla	Silver birch	25	60	1350	ploughing 25
Sillapää	Silver birch	30	50	2300	ploughing 100
Sõmerpalu	Silver birch	30	40	2000	ploughing 100
Kasevälja	Silver birch	25	75	2000	ploughing 100
Jõeküla	Silver birch	30	97	1330	ploughing 100
Rampe	Silver birch	25	98	1500	ploughing 25
Veneküla	Silver birch	15	93	2500	ploughing 100
Nadalama	Silver birch	25	92	2500	ploughing 100
Viluvere	Silver birch	20	95	1500	ploughing 100
Kullametsa	Silver birch	45	90	2250	ploughing 50
Reigi	Silver birch	45	85	1000	ploughing 100
Holvandi I	Grey alder	45	94	15750	no preparation 100
Holvandi II	Hybrid alder	25	94	6700	no preparation 100
Kambja	Hybrid alder	25	87	4400	no preparation 100
Ahjametsa	Hybrid aspen	45	92	1250	ploughing 100
Jõõgri	Hybrid aspen	45	95	1235	ploughing 100
Mikkeri	Hybrid aspen	45	90	1200	ploughing 100
Nässu	Hybrid aspen	45	97	1700	ploughing 100
Koogi	Hybrid aspen	45	90	1260	ploughing 100
Kauru	Hybrid aspen	45	95	1260	ploughing 100
Niidu	Hybrid aspen	45	91	1260	ploughing 100

Table 2. Main soil characteristics of topsoils in the studied plantations

Plantation	Soil classification		Depth of A horizon	Bulk density	pH $_{KCl}$	Total N	Extractable		C/N ratio
							P	K	
	FAO-UNESCO	USDA	(cm)	(Mg m^{-3})		(g kg^{-1})	(mg kg^{-1})		
Kõrveküla	*Calcaric Luvisol*	*Alfic Argiudoll*	0-27	1.32	6.5	1.26	22	177	10.6
Sillapää	*Eutric Podzoluvisol*	*Mollic Glossaqualf*	0-31	1.38	6.5	0.81	54	94	13.4
Sõmerpalu	*Eroded Calcaric Luvisol*	*Entic Haprendoll*	0-24	1.52	7.0	0.94	79	191	9.7
Kasevälja	*Dystric Gleysol*	*Typic Endoaquent*	0-15	1.26	4.3	1.07	4	42	15.4
Jõeküla	*Calcaric Luvisol*	*Oxyaquic Eutrudept*	0-30	1.29	5.9	1.82	22	169	8.1
Rampe	*Dystric Planosol*	*Typic Glossaqualf*	0-30	1.25	5.0	1.23	15	59	11.5
Veneküla	*Glossic Podzoluvisol*	*Mollic Glossaqualf*	0-32	1.21	5.6	1.62	19	127	12.4
Nadalama	*Calcaric Cambisol*	*Rendollic Eutrudept*	0-31	1.41	6.2	1.46	56	214	10.7
Viluvere	*Mollic Gleysol*	*Typic Argiaquoll*	0-49	1.24	6.8	2.71	39	202	11.5
Kullametsa	*Dystric Gleysol*	*Spodic Psammaquent*	0-43	1.53	4.0	1.37	15	14	13.3
Reigi	*Rendzic Leptosol*	*Entic Haprendoll*	0-30	1.30	7.2	1.97	31	169	17.0
Holvandi I	*Glossic Podzoluvisol*	*Mollic Glossaqualf*	0-26	1.28	5.9	1.05	22	212	13.2
Holvandi II	*Glossic Podzoluvisol*	*Mollic Glossaqualf*	0-44	1.27	5.4	1.06	62	118	16.0
Kambja	*Buried Eutric Histosol*	*Buried Haplosaprist*	0-70	1.01	6.5	2.91	12	57	11.9
Ahjamets	*Glossic Podzoluvisol*	*Mollic Glossaqualf*	0-27	1.53	5.4	0.90	27	123	8.6
Jõõgri	*Eutric Histosol*	*Typic Haplosaprist*	0-60	0.35	4.7	24.10	55	373	13.4
Mikkeri	*Calcaric Cambisol*	*Rendollic Eutrudept*	0-36	1.36	7.1	2.70	148	326	9.8
Nässu	*Gleyic Podzoluvisol*	*Umbric Albaqualf*	0-30	1.36	4.2	1.20	38	96	11.7
Koogi	*Calcaric Luvisol*	*Oxyaquic Eutrudept*	0-28	1.39	5.8	1.70	36	223	10.0
Kauru	*Buried-gleyic soil*	*Cumulic Humaquept*	0-87	1.51	5.1	0.70	73	87	11.0
Niidu	*Eutri-umbric Gleysol*	*Fragiaquic Dystrudept*	0-21	1.08	4.6	4.40	31	399	10.9

Results and discussion

The survival of silver birches during the four growing seasons was high in all 11 plantations under investigation. By the end of the fourth growing season the tallest silver birches grown without mulching were measured in the plantation of Veneküla (2.7±0.2 m) and the shortest ones, in the plantation of Reigi (1.4±0.1 m). Mean annual height growth for the fourth growing season, too, was most intensive in the plantation of Veneküla (0.85±0.02 m) and the least in the plantation of Reigi (0.26±0.02 m) (Fig. 2). The growth trend of silver birch in different plantations in the fourth year was comparable with the results from the second year (Vares *et al.* 2001), which indicates the stability of the height growth of the tree species in different years. It can be supposed that the growth of silver birch in the first years after planting is significantly more affected by soil conditions and competition than by climatic conditions, which is generally characteristic of all pioneer tree species. According to edaphic conditions in the plantations, the height growth of silver birch was found to be more intensive on *Glossic Podzoluvisol/Mollic Glossagualf, Calcaric Luvisol/Oxyaquic Argiudoll* and *Dystric Gleysol/Typic Endoaquent*. Thus, soils with aquic conditions, i.e. periodic saturation with water, are preferable for young silver birches. Mean annual height growth of silver birch after the fourth growing season was highest at the topsoil N, P and K content of 1.62 g kg^{-1}, 19 mg kg^{-1} and 127 mg kg^{-1}, respectively (Tab. 2). Our previous results showed that N and P content in the topsoil had the greatest effect on the mean annual height growth of silver birch (Vares *et al.*, 2001). In general, silver birch showed sufficient growth and survival rate on different soil types ocurring in the plantations. On the base of our measurements, we conclude that silver birch is able to grow in different edaphic conditions and is a suitable tree species for afforestation of abandoned agricultural lands in Estonia. Our results are supported by Evans (1984) who has shown that during the first years after planting silver birch shows good growth under different growing conditions.

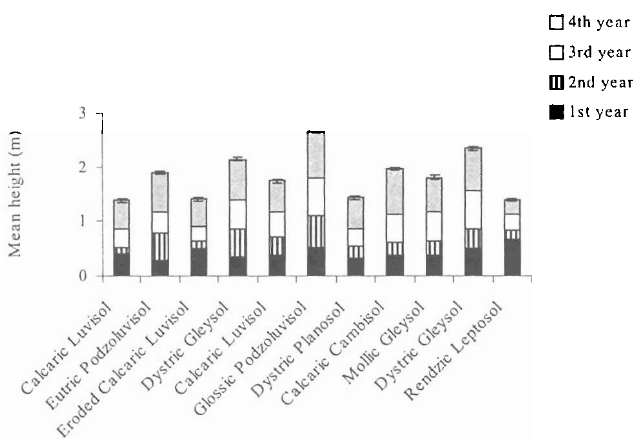

Figure 2. Mean height (±SE) of silver birches grown without mulching during the four growing seasons after the establishment of the plantations.

Silver birch has also proved a fast growing tree species on agricultural land in Finland (Hynönen and Saksa 1997, Hynönen 2000) where by 1994 it had been planted on an area of 100 000 ha (Ferm *et al.* 1994). In Finland, in comparison to conifers, silver birch has been found to be more profitable for afforestation of abandoned agricultural lands (Niskanen 1999).

Concerning an alternative to traditional treatment methods, it is possible to prevent the growth of weeds on abandoned agricultural land by using various covering materials (Davies 1985, Ferm *et al.* 1994). Moreover, weeding of plants by hand or over-ground haymowing have been found to be less effective than use of covering materials. The last method improves light conditions for the tree but does not preclude root competition (Atkinson 1990, Richardson 1953). In the studied plantations of silver birch, polyethylene mulch was used as the covering material. The effect of the polyethylene on height and height growth of silver birches in the fourth growing season was studied. Analysis of variance showed that polyethylene mulch had a significant effect on the investigated growth parameters of silver birches. The tallest silver birches cultivated with the use of polyethylene mulch were measured after the fourth growing season in the plantation of Kõrveküla (average height 4.2±0.2 m) (Fig. 3). The plantation in Veneküla with a moderate effect of polyethylene was exceptional. Apparently, polyethylene plays a significant role in competition with weeds (both in root competition and in competition for light), but it depends on the area of the ground covered with polyethylene. We state that the promoting effect of polyethylene mulch on the growth of silver birches was related to better moisture and temperature conditions in the soil. Some investigations support our supposition that polyethylene mulch increases soil temperature under it and maintains soil moisture, promoting tree growth (Bowersox and Ward 1970, Davies 1988). On the other hand, polyethylene mulch may increase the risk of damage by voles (Ferm *et al.* 1994; Siipilehto 2001; Vares *et al.* 2001). In the first growing years, silver birch can also be damaged by moose and roe deer (Daugaviete 2002, Viherä-Aarnio and Heikkilä

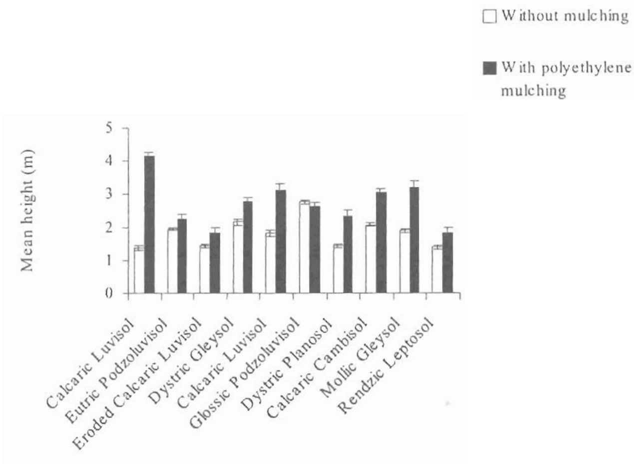

Figure 3. The effect of polyethylene mulch on the mean height (±SE) of silver birch after the fourth growing season
* hybrid aspen plantations were not monitored

2002). However, this was not observed in the studied plantations, because they were fenced.

Alder plantations were established with higher initial density compared with the other plantations of broadleaved species, with the purpose to produce bioenergy, which is the most widespread area of using alder wood in Estonia. The survival rate of alders was high after the first growing season (87-94%) despite the intensive growth of herbaceous plants. The mean height of the studied grey alder plantation after the fourth growing season was 4.7±0.2 m. When comparing the growth of alders in the Holvandi areas, the grey alder plantation was significantly higher than the hybrid alder plantation (3.5±0.1 m). The mean height of the studied plantations of hybrid alder (Holvandi II and Kambja) also revealed significant differences. The mean annual height growth in the fourth growing season varied in alder plantations from 0.35±0.01 m to 0.98±0.02 m, being the highest in the grey alder plantation. In the hybrid alder plantation in Holvandi the mean height of trees in the autumn of the fourth growing season was 3.5±0.1 m, while in Kambja the respective parameter was 1.7±0.1 m. Since the plants originated from the same batch and were planted at the same time, and since the plantation with a lower growth rate (Kambja) was even tended, the significant difference in the growth rate of the trees was evidently related to the site, primarily to edaphic conditions. In 1999 P content in topsoil in Holvandi was estimated at 62 mg kg^{-1} and K content was estimated at 118 mg kg^{-1}, whereas in Kambja P content was 5.5 times and K content two times lower than in Holvandi (Tab. 2). Agreeing with Ingestad (1987) we concluded that limited P and K supply of the soil limits the growth of nitrophilous alders, especially hybrid alder, because their demand for all macronutrients is high in comparision with the other tree species. In fertilization experiments with alders, tree growth has been affected mostly by addition of phosphorus fertilizers (Hytonen *et al.* 1995). Moreover, phosphorus deficit may slow down the development of alder roots and nodules as well as inhibit nitrogen fixing capacity of alders (De-Bell and Radwan 1984).

Based on our results, hybrid aspen has proved to be a fast-growing tree species in Estonia. The mean height of the studied plantations of the hybrid aspen varied from 1.0±0.1 to 3.0±0.2 m (mean annual height growth varied from 0.32±0.01 to 0.84±0.03 m) after the fourth growing season. Larger mean height in these plantations was noted after the fourth growing season on *Gleyic Podzoluvisol/Umbric Albaqualf, Buried-gleyic soil/Cumulic Humaquept* and *Eutric Histisol/Typic Haplosaprist*. The fertility of all these soils varied considerably, but their common characteristic was good water supply. The mean annual height growth of hybrid aspen after the fourth growing season was highest at the topsoil N, P and K contents of 0.70 g kg^{-1}, 73 mg kg^{-1} and 87 mg kg^{-1}, respectively (Tab. 2). However, it is not possible to draw any profound conclusions about the relationship between the growth of hybrid aspen and soil, as in several plantations tree growth was significantly influenced by the activity of game (moose, roe deer) and by the mass occurrence of *Galega orientalis* Lam. (Reisner 2001). More hybrid aspen plantations have been established in Finland and Sweden where this species has proved to be among the most fast-growing ones on abandoned agricultural land (Hynönen and Saksa 1997, Johnsson 1967). Aspen pulp has great economic importance in Northern Europe and it may become one of the main raw materials for paper industry in the XXI century (Croon 1992). Utilization of aspen for pulp in North America too has increased significantly over the last 20 years (Li 2002).

Comparison of the studied deciduous tree species was performed on a similar soil (Fig. 4), *Glossic Podzoluvisol/Mollic Glossagualf*, which is the dominating automorphic field soil in Estonia (Kokk *et al.* 1991). This soil is the most productive forest soil next only to *Luvisols* in Estonia (Kõlli 2002). *Glossic Podzoluvisols* are productive for cultivation of field crops under optimized fertilization, and when limed they are characterised by a mollic epipedon. T-test revealed a statistically significant difference in the mean height between the studied tree species. According to analysis alders grew faster on this soil type, followed by birch and hybrid aspen whose growth rate was roughly equal. Nitrogen fixing ability of alders might have

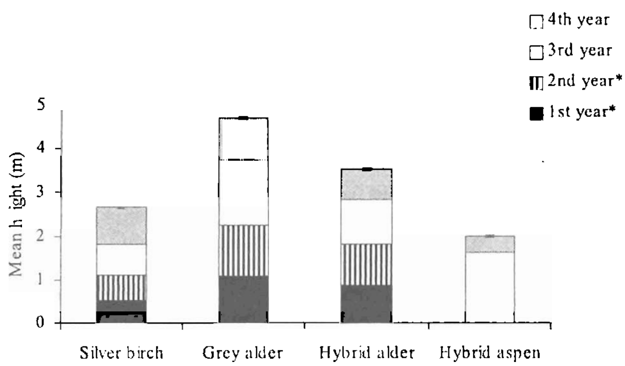

Figure 4. Mean height (±SE) of the studied deciduous tree species on *Glossic Podzoluvisol/Mollic Glossagualf* in Estonia.

been advantageous in this case, because the nitrogen mineralization capacity of Podzoluvisols was relatively low.

Conclusions

Silver birch and hybrid aspen grew well on most studied soil types, however, their cultivation in Estonia can be influenced in the future by game (moose, roe deer, hare). When planting silver birch, polyethylene mulch has to be considered a very effective covering material. Alders appeared to grow faster on *Glossic Podzoluvisol/Mollic Glossagualf* compared with silver birch and hybrid aspen. The growth rates of silver birch and hybrid aspen on this soil are roughly equal. From the ecological point of view, all fast-growing deciduous tree species under investigation are suitable for afforestation of abandoned agricultural lands in Estonia.

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РОСТ В ВЫСОТУ ЧЕТЫРЕХ ВИДОВ БЫСТРОРАСТУЩИХ ЛИСТВЕННЫХ ДЕРЕВЬЕВ НА БЫВШИХ СЕЛЬСКОХОЗЯЙСТВЕННЫХ УГОДЬЯХ ЭСТОНИИ

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Резюме

Настоящая работа выполнена на основе изучения 21 посадки лиственных деревьев на заброшенных сельскохозяйственных угодьях Эстонии. Для создания посадок были выбраны четыре вида быстрорастущих лиственных деревьев (*Betula pendula* Roth., *Alnus incana* L. Moench., *Alnus hybrida* A. Br., *Populus x wettsteinii* Hämet-Ahti). Береза повислая и осина гибридная хорошо росли на большинстве из изучаемых типов почвы, однако на перспективы их распространения в Эстонии может повлиять повреждение дикими животными (лосями, косулями, зайцами). При посадке березы повислой в качестве эффективного покрытия следует использовать мульчированный полиэтилен. Ольхи росли быстрее на *Glossic Podzoluvisol/Mollic Glossagualf*, по сравнению с березой повислой и осиной гибридной. Темпы роста березы повислой и осины гибридной на данной почве примерно одинаковые.

Ключевые слова: лиственные деревья, заброшенные сельскохозяйственные угодья, высадка, рост в высоту, тип почвы, Эстония