The effect of early thinning on the growth of pine and spruce stands

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Kuliešis A., Saladis J. 1998. The effect of early thinning on the growth of pine and spruce stands. *Baltic Forestry*, 1: 8-16.

Densities of the stands, the time and intensity of the first thinning are among the most important factors concerning stand yield and timber quality. In the article the growth of 6 young thinned stands of pine (*Pinus sylvestris* L.) and spruce (*Picea abies* Karst.) has been studied. The trials with plots of different thinning intensity in 1990-1993 were established and in 1995 remeasured. The early thinning in young stands leads to less random selfthinning. Diameter increment rises by 1.4-2.4 times, while change in the height growth in most cases is insignificant. Due to decreased selfthinning and diameter increment rise on the best trees, intensively thinned stands accumulated additionally 5-13 % of the increment volume during observation period. The greatest current annual increment is attained having thinned stands up to 1.2 - 2.4 thous. trees/ha. It has been found out that early thinning at age 4-15 years leads to greater stability of stands and is a precondition of a higher yield level.

Key words: thinning, yield level, productivity, stability, *Pinus sylvestris* L., *Picea abies* Karst.

Introduction

In Lithuania there are favourable conditions for intensive growing of forests. During a rotation on productive sites on average it is possible to obtain up to 600-800 m^3/ha. However, the mean growing stock of mature stands does not exceed 250 m^3/ha. Such a low growing efficiency leads to the search for more effective ways to produce greater yield and accumulation of the volume increment under different natural conditions (Kuliešis, 1989, 1997 b; Kuliešis et al., 1995). Forest regionalisation has been conducted in Lithuania to get better use of natural conditions (Kuliešis, 1997 a).

One of the most important achievements in the forest yield science of the 20th century are yield levels worked out by E.Assmann, F.Franz (1963) and suggestions by F.Franz (1967) for practical yield level determination: the greater the average stand diameter when the average stand height and basal area are the same, the higher stand yield level. The effect of density in a stand on the growth, selfthinning, timber quality and stand stability have been studied for more than 100 years in trials of Timiryazev Agricultural Academy (Итоги ..., 1964), in Ukraine (Гаврилов, 1963, Шинкаренко и др., 1981), in Lithuania (Kairiūkštis et al., 1985). The studies have shown, that stands thinned out early may have 2 and more times greater average diameter than unthinned ones. Many works were devoted to study tree growth in diameter, height, stand stability depending on density in a stand (Kairiūkštis and Juodvalkis, 1985; Usolcev, 1985; Nielsen, 1990; Huss, 1995). The latter two authors stress the necessity to grow forest with spacely and evenly distributed trees and carry out intensive thinning at early age in order to grow stable and productive stands. The results of the trial established on different density in spruce stands by L.Kairiūkštis et al. (1985) 40 years ago have shown that such experiments are very actual. They should be continued not only in spruce, but also in pine stands covering different ecological conditions, geographical regions. It is especially important to extend investigations in stands where the initial density is 1000-8000 trees/ha.

Methods and materials

The aim of investigations was to study the effect of early thinning of different intensity done in 4-11-year old pine and spruce stands on their growth, increment accumulation and stability which were established on former clear cut areas or arable lands. Early thinning are aimed at regular distribution of trees, formation of optimal spatial structure of stands eliminating gaps in them.

Sites for the experiment were chosen in six places of Lithuania favourable for growing pine and spruce stands in natural-climatic and soil conditions. Experimental plots were established in 1990-1992 and remeasured in 1995 (Table 1).

Table 1. Characteristics of trials.

Trial No	Forest enterprise, district, number of block and compartment	Tree species	Plot's establishment and thinning year, month	Remeasurement year, month	Stand age		Land use category	Number of plots
					establishing	remeasuring		
201	Valkininkai, **Pirčiupiai**, 19-1	Pine	1990 04	1995 05	8	13	arable land	2x5
202	Vilnius, **Sudervė**, 126-8	Spruce	1990 09	1995 05	9	13	arable land	2x5
203	Pakruojis, **Rozalimas**, 36-4	Spruce	1991 10	1995 05	11	14	clear-cutting	2x4
204	Kretinga, **Mikoliškiai**, 53-11	Spruce	1992 05	1995 08	11	15	arable land	2x5
205	Plungė, **Mostaičiai**, 16-18;17-4;5;21	Spruce	1992 05	1995 08	9	13	arable land	1x4
206	Jurbarkas, **Mociškiai**, 29-2	Pine	1992 09	1995 08	4	7	clear-cutting	2x5

For growing pine the most suitable site *Vaccinio-myrtillosa*, for spruce – sites *Oxalidosa* and *Carico-mixtoherbosa* were selected. For each trial (tree species, location) on a possibly more even and regular (square, rectangular) areas of 3-5 ha in size, 4-8-year old pine and 9-11-year old spruce plantations with well growing evenly distributed trees and minimal admixture of deciduous trees were chosen. It was checked if trees had not been damaged by diseases, insects, animals.

The standard experimental scheme covers five density variants: unthinned-control, the first time thinned out up to 3.0-4.4, 2.0-2.4, 1.0-1.2 and 0.5-0.6 thous.trees/ha (Fig. 1). In trial areas, except (203, Rozalimas) and (205, Mostaičiai), 5 density variants with different thinning regime were singled out. Each stand density variant is represented by two 0.15-0.20 ha area sections. Around the sections protective belts with the same thinning regime were left. Strips separating sections with the same thinning regime were 5 m wide, while those separating different regimes and in the whole experiment 10 m wide. The biggest initial density of control sections in 4-8-year old pine stands was 5-8 thous.nu./ha, while in 9-11-year old spruce stands – 3-5 thous.nu./ha. During the trial only dead trees were removed in control sections. In trials (203, Rozalimas) and (205, Mostaičiai) due to a small area only 4 variants comprising 1 section each were singled out.

In all trials trees have been mapped. A plan of tree rows has been worked out and distances between trees as well as their location deviations from the row axis measured. The diameters of all trees at 1.3 m in height have been measured by finding the place of measurement with the help a ruler. The height was measured with a ruler of 5 m long at the accuracy of 0.1 m. Higher trees have been measured by using heightmeter. All trees before felling were measured.

While thinning the plots, branches of trees were left to protect soil against turf forming. In many cases the branches left acted instead of the taken off top and pine trees thinned 2 years later had 2-4, while spruce trees – 2-6 tops. Over 4 years these tops had reached 2.0 m and greater height, therefore, they had to be removed by additional felling.

The data were processed by using a unified system for dendrometric information (Kuliešis, 1993). The results

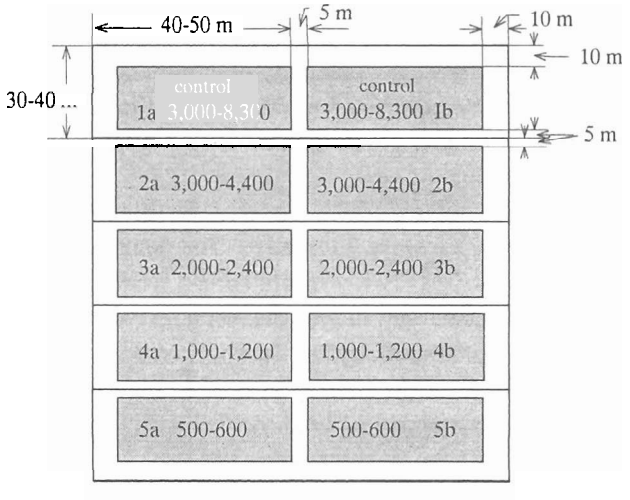

Fig. 1 .Trial scheme. 1,2,3,4,5 - variants with different densities; a, b - sections for replication

of each density variant were evaluated according to the average results of two replications. To describe stand growing conditions height (H_{AB}) and diameter growth indices (D_{AB}) were applied. They have been determined with the help of the yield model (Kuliešis A., 1993).

Spatial distribution of trees was assessed by Hopkins aggregation index I_H (Hopkins, 1954).

$$I_H = \frac{\bar{r}^2}{\bar{l}^2},$$

where r – distance from random point to the nearest tree; l – distance from i-th tree to the closest tree.

When I_H equals 1, trees are distributed randomly in a stand, i.e. according to Poison's random distribution. When I_H <1, distribution is regular, when I_H >1 – clustered distribution. The type of tree distribution when establishing a plot and during remeasurement in 1995 was defined for trial 201.

Characteristics of experimental objects. Most studied stands (201, 202, 204, 205) have been established on former agricultural land (Table 1). It reflects the current situation of forest plantations – it is not easy to find coniferous plantations of bigger density on clear cut areas in accordance with the requirements for this experiment. Most of them contain admixtures of natural regeneration and irregular distribution of trees. It is even more complicated to find young pine stands, thus, only 2 stands represent them. Experimental stands of spruce grow on sites of different productivity, but most of them have been planted on former arable land. Pine trials represent only *Vaccinio-myrtillosa* vegetation type.

Before planting the area for trial 201, Pirčiupiai was ploughed in rows every 2.0 metres. Plantation was established in 1982, by manually planting one-year old seedlings in rows every 0.5 m (10,000 seedlings/ha). In the eighth year after planting there were 5-6 thous. pine trees per ha.

The area for trial 202, Sudervė for planting was ploughed in rows every 2.0 metres. The plantation was established in 1982. Two-year old spruce seedlings were planted in a manual way. In rows the seedlings were planted every 1.0 m (5,000 seedlings/ha). Survival comprised – 96% in the first and in the second year after planting. The plantations were tended in 1985. At the onset of the trial there were 4-4.5 thous. spruce trees per ha.

The stand for trial 203, Rozalimas was planted after clear-cutting aspen stand of high yield. Four-year old spruce plants were planted manually in 1980 in rows every 3.0 m at 1.0 m (3,300 plants/ha) spacing. In the second year it was suplemented. Survival was high. At the moment of trial initiation 3 thous. spruce trees were found.

The area for trial 204, Mikoliškiai for intensive growing of plantations was prepared by ploughing it entirely. Planting was performed manually in 1981 in strips in 5 rows. The spacing between rows was 1.7 m, between strips – 3.0 m. In rows the seedlings were planted at 1.0 m (5,100 plants/ha) spacing. Four-year old spruce plants were used. In 1982 the plantation was supplemented. Survival was high. At the onset of trial there were 4.2 thous. spruce trees per ha. Tending was conducted in 1983, 1985. In 1984, 1985 and 1986 the plantations were fertilised with nitrophoska (250 kg/ha) by using tractor-driven attachable distributor.

The area for trial 205, Mostaičiai was prepared by making 0.4-0.7 m high furrows every 2.0 m in a mechanized way. On these furrows in 1983 manually were planted 2-year old spruce seedlings every 0.5 m (10,000 seedlings/ha). Survival was moderate. At the beginning of the trial there were 5-5.5 thous. spruce trees. The area was chosen to assess the resistance of the stand against windthrow in the future.

Stand for trial 206, Mociškiai was regenerated instead of a clear cut pine stand. The area was ploughed in rows every 2.0 m. In 1988 one-year-old pine seedlings were planted manually. Within rows the seedlings were planted at 0.7 m (7,140 seedlings/ha) spacing. Survival constituted 95% in the first and in the second year after planting. In the second year it was suplemented by one-year old pine seedlings (2,000 seedlings/ha). At the onset of the trial there were 8-8.3 thous. pine trees per ha.

The area of most experimental plots was of rectangular (close to a square) form and the same size. The greatest difference in form and area of trial sections is in plots 205, 206. The diversity of plots in trial 205 was predetermined by the small size of plantation area. In trial 206 the plots were singled out in a stand where after cutting strips of residues were very wide in some places. While establishing plots between the "rows" of residues, they have acquired the form of elongated rectangular. The places of experimental objects and main data are given in Table 1.

Results

Site productivity estimation by height growth index H_{AB}. Most analysed stands are 13-14 years old. Site indices according to height growth of both pine stands differ insignificantly. Pine stand for trial 201 was established on arable land and is characterised by H_{AB}

index 25.9-26.7 m while that on clear cut area (trial 206, Mociškiai) – 27.0-27.6 m (Table 2). Variation in the index in different variants and replications is small. It varies within the range of 0.6-0.8 m.

Mostaičiai (205) spruce stands. They have the greatest height growth index as well. On the whole, D_{AB} indices are similar in all plots with insignificant differences between pine and spruce stands. Diameter indices in all plots have

Table 2. Site productivity indices at remeasurement.

Tree species	Trial No	Vegetation type	Site indices according to height (H_{AB}) and diameter (D_{AB}) growth				
			Variant No				
			1	2	3	4	5
Pine	201	*Vaccinio-myrtillosa*	26.0	26.7	25.9	26.4	26.1
			40.1	45.7	48.4	55.7	57.9
	206	*Vaccinio-myrtillosa*	27.6	27.3	27.0	27.1	27.4
			41.4	42.0	41.2	45.5	46.3
Spruce	202	*Oxalidosa*	31.4	32.1	31.0	35.2	36.6
			42.2	45.3	45.5	58.1	64.2
	203	*Carico-mixtoherbosa*	34.1		30.3	33.3	32.8
			42.9		40.2	47.7	50.3
	204	*Myrtillo-oxalidosa*	33.2	34.9	34.9	32.6	36.0
			46.2	40.7	53.3	53.8	63.0
	205	*Oxalidosa*	39.9		39.7	37.7	36.1
			51.0		60.5	63.2	61.1

Site indices H_{AB} of spruce sites vary in a wider range – 30-40 m. The least site index – 31.0-31.4 m was observed in Sudervė (202) spruce. Rozalimas (203) and Mikoliškiai (204) plantations were raised on very different sites (*Carico-mixtoherbosa* and *Oxalidosa*). The first one was established on a clearcutted area, the latter – on arable land, but they have similar height indices ranging from 30 to 36 m. The growth of stands established on arable land slows down at older age when they have "overgrown" the fertile soil layer. Thus, in the future a decrease in height index of Sudervė, Mikoliškiai and Mostaičiai (203, 204, 205) spruce stand is expected. Mostaičiai (205) spruce plantations established on very high furrows have the highest index (36-40 m). Trees growing on double arable soil layer grow more intensively in young age. High site index (33-36 m) was observed in Mikoliškiai (204) spruce plantation, established for intensive growing and fertilized additionally in 1984-1986.

Stand stability estimation by diameter growth index D_{AB}. The ratio of stand diameter to height well defines the stability of a stand. The greater the diameter of a stand, the more stable the stand, the greater potential growth and stand yield level possibilities. It is best revealed by diameter growth index D_{AB} , determined as predicted average diameter of mature stand. The greatest diameter growth index is observed in Mikoliškiai (204) and one general feature – they increase with decreasing stand density. In control plots diameter growth indices in most cases equal 40-43 cm, while in thinned up to 500-1,200, and often up to 2,000-2,400 nu./ha they reach 46-63 cm. It shows that thinning considerably promotes stand stability and its potential growth possibilities.

Spatial stand structure. Pattern of trees distribution was estimated in pine stand (201) during plot establishment and remeasurement (Table 3). In all stands including control and the most intensively thinned out variant trees are distributed regularly. With decreasing stand density the tendency towards regular distribution becomes stronger. As selfthinning of stand (201, Pirčiupiai) was not intensive, changes in aggregation index with age are also intangible. The index of control stand increased 0.03, that of thinned out stands – 0.01 towards random distribution type.

Selfthinning of stands. The most significant selfthinning of trees was observed in the densest (206, Mociškiai) pine stand established on a cutting site (Table 3). Selfthinning was observed even in the thinnest variant (1%). In the control variant annual selfthinning over 3 years reached 12%. In Pirčiupiai pine stand (201) selfthinning was ten times less, although in the first year after plot establishment the stand was severely damaged by needle cast *(Lophodermium seditiosum)* (Saladis,

1994). Besides, underbark bug *(Aradus cinnamoneus* Panz.*)* infestation was recorded (Mokslinio ..., 1995).

Table 3. Selfthinning in stands of different initial density and trees distribution at remeasurement.

Tree species	Trial No	Initial density, thous. trees/ha Selfthinning, trees/ha per year Hopkins aggregation index Variant No				
		1	2	3	4	5
Pine	201	5.1-5.7 133 0.38	3.0 5 0.31	2.0 4 0.34	1.0 0 0.33	0.6 0 0.29
	206	8.0-8.3 1040	4.4 42	2.4 53	1.2 14	0.6 5
Spruce	202	3.8-4.3 6	3.1-3.2 8	2.1 4	1.1 2	0.5 0
	203	3.0 8	–	2.2 3	1.2 3	0.6 0
	204	4.1-4.2 0	3.0 0	2.0 0	1.2 0	0.6 0
	205	5.3 3	–	2.3 0	1.2 0	0.6 0

In spruce stands selfthinning was found considerably less. In the oldest (15 yr.) Mikoliškiai (204) spruce stand not a single tree died over 4 years. In (205, Mostaičiai) spruce stand – only 3 trees per ha died in the control. Individual trees (0.2-0.3%) due to different accidental causes died in (202, Sudervė) and (203, Rozalimas) spruce stands. A conclusion may be drawn that spruce stands at age of 9-11 years thinned out to 2.0 thous. spec./ha can grow 3-5 years without selfthinning accumulating increment within the stand.

Stand growth in height and diameter. In analysed stands selfthinning was absent or so intangible that the change in the main stand parameters is close to their increment.

The average heights in pine stands were slightly dependent on stand density (Table 4). The height increment of the pine stand (201, Pirčiupiai) over 5 years after thinning tended to decrease, while that of (206, Mociškiai) pine stand even enlarged with decreasing stand density (Fig. 2).

The mean heights of spruce in plots of different density are not the same. The thinnest (202, Sudervė) spruce stand variants had average heights of 1.3 m and greater, while (205, Mostaičiai) by 0.5-0.9 m less than the control. This has predetermined in the first case a significant increase in the increment (39%), in the second case its decrease (13-20%) as compared to control

Table 4. The average stand diameters and heights, their ratio at remeasurement in stands of different initial density.

Tree species	Trial No	Height, m (H) Diameter, cm (D) D (cm) / H (m) ratio Variant No				
		1	2	3	4	5
Pine	201	4.7 5.8 1.23	4.8 6.9 1.44	4.7 7.5 **1.60**	4.8 9.0 1.88	4.7 9.5 **2.02**
	206	1.8 1.8 1.00	1.9 2.0 1.05	1.8 2.0 **1.11**	1.8 2.4 1.33	1.9 2.6 **1.37**
Spruce	202	4.7 5.0 1.06	4.8 5.7 1.19	4.5 5.7 **1.27**	5.7 8.2 1.44	6.0 9.5 **1.58**
	203	6.0 5.9 0.98	–	4.9 5.3 **1.08**	5.8 6.9 1.19	5.7 7.5 **1.32**
	204	6.4 7.3 1.14	6.9 8.4 1.22	6.9 9.0 **1.30**	6.2 9.0 **1.45**	7.2 11.1 **1.54**
	205	6.1 6.0 0.98	–	6.1 7.9 **1.38**	5.6 8.3 1.48	5.2 7.9 **1.52**

stands (Fig. 2). In all intensively thinned spruce stands an insignificant height increment decrease was observed in the first year after thinning.

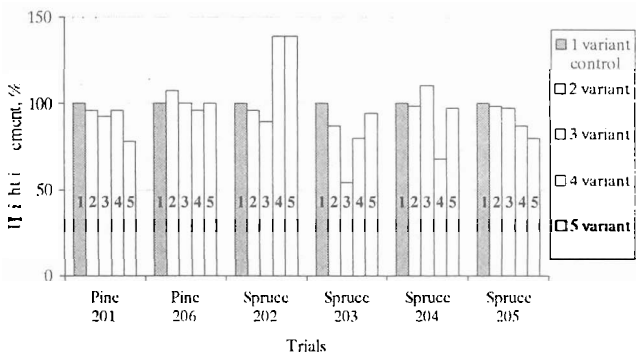

Fig. 2. Comparison of the height increment over 3-5 years in stands thinned at different intensities with the control.

On the whole, the height increment dependence on stand density is not very clear (Fig. 2). In most variants the maximum increment is observed in control and stands thinned up to 2-3 thous. trees per ha. An exception is (202, Sudervė) spruce plantation, where height increment of the most intensively thinned stands was even by 39% larger than that of the control stand. This might be due to different site conditions.

The height increments in pine and spruce trials are adequate to stand increments calculated by "Lithuanian stand increment and its utilization standards" (Kuliešis 1993). The mean diameter increment in stands with different initial density differs from height growth (Table 4, Fig. 3). The diameter increment in Pirčiupiai (201) stand, thinned up to 500-2,000 trees/ha, is 2-2.4 times larger than that in the control stand. In Mociškiai (206) stand the tendency remains, although differences are by far less. It can be explained by younger age of the stands and shorter observation period.

Stand basal area and the volume increment. Stand basal area and its increment in absolute variables diminish with decreasing density both in pine and spruce stands. However, it is important to pay attention to the fact that basal area increment percentage clearly tends to increase with decreasing initial density, as well as stocking level in all stands observed (Fig. 4). In the thinnest stands the percentage of the basal area increment rises 2-5% as compared to the control.

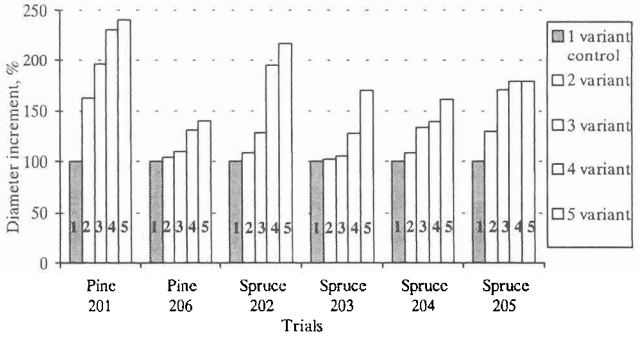

Fig. 3. Comparison of the diameter increment over 3-5 years in stands thinned at different intensity with the control.

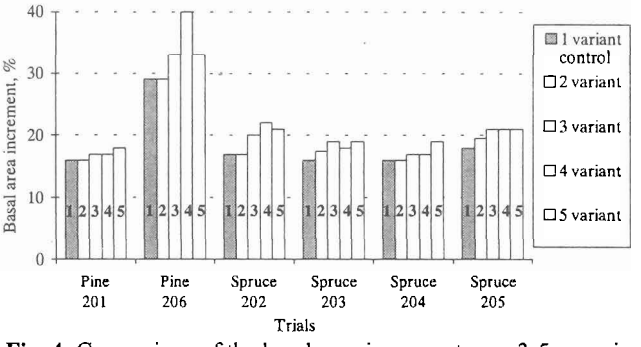

Fig. 4. Comparison of the basal area increment over 3-5 years in stands thinned at different intensity .

In all spruce stands the diameter increment is clearly growing with decreasing stand density. The most significant increase (29-117%) is observed in (202, Sudervė) and (205, Mostaičiai) spruce stands thinned to 0.6-2.3 thous. trees/ha (Fig. 3). Mikoliškiai (204) and Rozalimas (203) spruce stands with 0.6-2.2 thous. trees/ha have a slightly less, but an obvious increase in the diameter increment (34-70%). However, the diameter increment in spruce stands thinned to 3000 trees/ha changes insignificantly. It means that thinning in a 9-11 year-old spruce stand up to 3000 trees/ha has no effect on diameter increment conditions.

The ratio of stand diameter and height is considered to be a quite reliable index of stand stability. It is said that stand is stable if the ratio of diameter to height (D·100/H) is greater or equals 1.25-1.4 .A similar ratio was determined in all stands thinned up to 2,000-2,400 trees/ha and less (Table 4). The index in unthinned spruce stands was 0.98-1.14. D·100/H ratio increases with decreasing stand density and reaches 1.25 limit after thinning 2,000-2,400 trees/ha. An exception is the (203, Rozalimas) spruce stand, having exceeded the limiting ratio D·100/H – 1.25 only in the thinnest variant. Looking to the future of the stands, most density variants thinned up to 2-2.4 thous. trees/ha at mature age will be stable. Ratio $D_{AB}\cdot 100/H_{AB}$ of these and thinner stands exceeds 1.25-1.40 (Table 2).

Although the diameter increment enlarges with increasing thinning intensity, an increase in the basal area increment is not so regular (Fig. 4). The maximum basal area increment in trials (206, Mociškiai) and (202, Sudervė) was attained at density of 1.0-1.2 thous., while these in (203, Rozalimas) and (205, Mostaičiai) – 2.0-2.4 thous. trees/ha density. In trials (201, Pirčiupiai) and (204, Mikoliškiai) the greatest basal area increment was in the thinnest variants.

The maximum current annual volume increment in all trials was attained in the control and in 3.0-3.4 thous. trees/ha density variants (Table 5). The maximum volume increment percentage is observed in thinned stands up to 1.0-2.4 thous. trees/ha, only in trial (203, Rozalimas) the maximum volume increment percentage is found in the thinnest variant. Thus, it can be concluded, that relative maximum intensity of the volume increment and basal area in most cases is attained at density of 1.2-2.4 thous. trees/ha (Table 5). Culmination of the basal area and current annual volume increments at mentioned densities occurs when the average stand height is 5-7 m. It can be said that the greatest increment at age 7-15 years is reached in stands when height multiplied by tree number is less than 10,000.

Growing stock as well as basal area decreases with diminish stand density (Table 5). When the number of

trees decreases 7-10 times, the growing stock frequently diminishes not more than 3 times. The volume increment changes even less. Percentage of the current annual volume increment increases with decreasing stand density. In control and the thinnest stands the difference in volume increment percentage comprises 2-5%. It is the result of the intensified diameter increment and practically absent selfthinning in stands.

Table 5. Growing stock and the current annual increment in stands of different initial density.

Tree species	Trial No	Index	Growing stock, m³/ha while making remeasurement (M)				
			C.A.I., m³/ha per year (Z_M) over 3-5 years				
			C.A.I., % per year (PZ_M) over 3-5 years				
			Variant No				
			1	2	3	4	5
Pine	201	M	40	40	26	20	12
		Z_M	6.0	5.8	4.7	3.5	2.0
		PZ_M	15	17	18	18	17
	206	M	4	4	2	2	1
		Z_M	1.0	1.2	0.8	0.7	0.3
		PZ_M	25	30	40	35	30
Spruce	202	M	24	24	16	20	13
		Z_M	4.5	4.5	3.0	4.4	2.9
		PZ_M	19	19	19	22	22
	203	M	31		15	15	9
		Z_M	6.3		3.0	3.0	2.0
		PZ_M	20		20	20	22
	204	M	66	66	49	28	23
		Z_M	12.0	12.5	9.6	5.2	4.6
		PZ_M	18	19	20	19	20
	205	M	58		39	22	9
		Z_M	12.3		7.8	5.0	2.0
		PZ_M	21		20	23	22

Discussion

Stand density has a strong effect on stand growth, productivity and stability. Studying the growth of spruce stands of different initial density (100,000-820 trees/ha), L.Kairiūkštis and A.Juodvalkis (1985) have found out, that the denser the stand, the more intensive selfthinning and differentiation of trees. With decreasing stand density, the average diameter, height and volume of trees increase. The least number of selfthinned and the greatest number of potential crop trees is in spruce stands established with a density of 800 trees/ha. The greatest mean height at age 39 years (19.1 m) is recorded in the stand with the initial density of 2,000 trees/ha. The average height of a stand with 12,500 trees/ha initial density at that time reached 14.6 m. The volume and its maximum increment with age is observed in thinner stands. The greatest current annual increment at age 27 years was in a stand with initial density 6,500 trees/ha (19.2 m³/ha per year), at age 32 years – 3,010 trees/ha (22.1 m³/ha annually), while at age 39 years – in a stand with 1,970 trees/ha initial density (18.5 m³/ha annually). Maximal volume in each density variant is attained only once. The denser the stand, the earlier this culmination occurs.

Nielsen C.C.N. in his works (1990) has presented the conception of tending pure spruce stands which foresees initial density within the range of 2,500-4,000 trees/ha. The author has compared the growth of stands with 820-1,600 trees/ha and greater than 6,000 trees/ha initial density. The thinnest stands were thinned early and intensively, while the dense ones were unthinned for a long time. Stands of both groups were of similar density (400-978 and 350-889 trees/ha). The heights in spruce stands of low initial density differed from dense variants by -4 — +18%, diameters by +7 — +29%. The volumes in stands of low initial density were by 23-70% greater and in 2 stands out of 3 comprised 840-870 m³/ha. Besides, these stands were more stable than the dense ones.

Over recent 25 years Huss J. conducted studies on pine stands where the initial density ranged from 18,500 to 580 trees/ha. It has been found, that the average height of 100 biggest trees and their diameter in stands of different initial density did not differ at the beginning of the trial. Their diameter increment in thin stands (580-670 trees/ha) was 1.4-1.9 times larger than in dense unthinned stands. Total productivity in a thinned 30-year old stand made up 79%, while that of a 42-year old stand was already equal to the productivity in unthinned stands. More significant changes in the height increment were not observed by the author. The thinnest stands are most stable (by D/H ratio).

Our investigation objects were observed for a short period – from 3 to 5 years. Such a short observation period does not allow us to find out all advantages and disadvantages of intensive thinning in stands. However, according to the available data it is possible to state, that stand thinning leads to a significant increase in the diameter and stand stability, which enable the stand to attain a higher yield level. It is well reflected by diameter and diameter growth indices, basal area and the data on the volume increment. Thinning allows to decrease selfthinning at younger age and to form quite stable spatial structure with evenly distributed trees. The most

intensively thinned stands accumulate all increment and selfthinning in such stands is random. Only in the youngest pine stand control variant selfthinning of the smallest trees was detected, but it was predetermined more by individual resistance of trees than by external factors. This confirms the idea, that while thinning young stands a reserve should be left to compensate such things. In all thinned stands up to 10% more trees (in thinnest variants – 10-20%) were left.

The diameter increment of trees is very sensitive to thinning, especially when it is carried out in well growing 8-11-year old stands (201, Pirčiupiai; 204, Mikoliškiai). In stands established on cutting sites (203, Rozalimas; 206, Mociškiai) additional diameter increment over 3 years after thinning is small and observed only in the thinnest variants. The data on relative increment of basal area and volume, as compared to diameters, are similar. In most stands studied differences in basal area increment comprised 2-4% and in volume increment 2-5% as compared to the control with 1.2-2.4 thous. trees/ha and thinner stands.

This shows that intensive thinning at younger age may provide favourable conditions for the growth of potential crop trees and increment accumulation in the stand. In modal Lithuanian stands intensive selfthinning takes place at older age, therefore, rise in the increment is insignificant, while volume loss is quite substantial. In this case a decrease in volume increment percent has been recorded with decreasing stocking level (Kuliešis 1989, 1993). Increasing percentage of the volume increment under intensive thinning of young stands at age 4-11 years is observed in both pine and spruce stands on all sites, but significantly greater on sites favourable for growth, which shows that these measures are very important in essentially rising stand yield.

Conclusions

1. Intensive thinning in young pine and spruce stands leads to less random selfthinning and greater stability of stands.

2. The diameter increment in thinned pine and spruce stands increases 1.4-2.4 times, while the height increment in most cases is insignificant.

3. The greatest current annual increment of stand at an early age is attained having thinned stands up to 1.2-2.4 thous. trees/ha.

4. Due to decreased selfthinning and an increase in the diameter increment of the best trees, intensively thinned stands accumulated additional 5-13% volume increment per year.

5. Intensive thinning at younger age, leading to relative volume increment, is the precondition of a higher yield level.

References

Hopkins B. 1954. A new method of determining the type of distribution of plant individuals. Ann. Bot., N. S., v. 18, No. 70.

Huss J. 1995. Neue Ansätze für Begründung und Pflege von Kiefernjungbeständen. Walbaulichen Fragen der Kiefernwirtschaft [New methods for establishment and tending of young pine stands. The questions of management in pine stands]. – Kolloquium aus Amlaß des 100 jährigen Geburtstages von Adolf Olberg. Zusammengestellt von B. v. Lüpke. Schriften aus der Forstlichen Fakultät der Universität Göttingen und der Niedersächsischen Forstlichen Versuchsanstalt. Band 119.J.D.Sauerländer's Verlag Frankfurt am Main. S.88-131.

Kairiūkštis L., Juodvalkis A. 1985. Etaloniniai medynai ir jų formavimas [Standard stands and their formation]. Vilnius: Mokslas, 244 p.

Kuliešis A. 1989. Medynų našumas ir jo panaudojimas [Yield of forest stands and its use]. Vilnius. 141 p.

Kuliešis A. 1993. Lietuvos medynų priaugio ir jo panaudojimo normatyvai [Forest yield models and tables in Lithuania]. „Girios Aidas", 383 p.

Kuliešis A. 1997a. Lietuvos miškų rajonavimas pagal medynų našumą. [The regionalisation of Lithuanian forests according to stand yield] Lietuvos mokslas V tomas. 13-14 knyga. 45-53 p.

Kuliešis A. 1997b. Medyno skalsumas ir našumas [Growing stock level and yield of stand]. Lietuvos mokslas V tomas. 13-14 knyga. 67-73 p.

Nielsen C.C.N. 1990. Einflüsse von Pflanzenabstand und Stammzahlhaltung auf Wurzelform, Wurzelbiomasse, Verankerung sowie auf die Biomassenverteilung im Hinblick auf die Sturmfestigkeit der Fichte. (Effects of plant spacing and stem numbers on root form, root biomass, anchoring and biomass distribution in relation to the wind stability of Norway spruce). Schriften aus der Forstlichen Fakultät der Universität Göttingen und der Niedersächsischen Forstlichen Versuchsanstalt. Band 100. J.D.Sauerländer's Verlag Frankfurt am Main. S.279.

Saladis J. 1994. Pušinio spygliakričio pažeidimo povoikis įvairaus tankumo pušies jaunuolynams [Effect of pine needlecast damage on young pine stands of different density]. Doktorantų mokslinės konferencijos pranešimai. 1994 m. rugsėjo 14-17 d. 119-123 p.

Mokslinio tiriamojo darbo „Ištirti pagrindinių medžių rūšių medynų Lietuvos augimvietėse našumą ir jo panaudojimą, priklausomai nuo tikslinės medynų paskirties ir ūkinio režimo" baigiamoji ataskaita. [Final report „Investigations of Lithuanian forest stand yield of the main tree species and their use according to purpose and management regime]. Temos vadovas hab. dr. A. Kuliešis. Vykdytojai: Kuliešis A., Rutkauskas A., Saladis J. 1995 m. 180 p.

Wenk G., Antanaitis V., Šmelko Š. 1990. Waldertragslehre [Forest yield science]. Berlin: Dt.Landwirtschaftverl., 448 S.

Гаврилов Б.И. 1963. Лесные плантации быстрого прироста. [Fast growing forest plantations]. Лесной журнал, 1969, № 4. с. 14-16.

Итоги экспериментальных работ в лесной опытной даче ТСХА за 1862-1962 годы. [Results of investigations in

experimental forest district of Timiryazev Agricultural Academy during 1862-1962]./ под ред. Канторовича А.В., М., изд. ТСХА. 1964. 519 с.

Тябера А. 1980. Моделирование производительности и товарности сосновых древостоев разной густоты в условиях Литовской ССР [Modelling of yield and commodity of Lithuanian pine stands of different density]. Автореферат на соискание ученой степени канд. с.-х. наук. 20 с.

Усольцев В. А. 1985. Оценка показателей продуктивности в биогруппах разной густоты [Estimation of yield parameters in biogroups of different density]. Лесоведение, 2. С. 68-78.

Шинкаренко И. Б., Говорова Т. Т., Головчанский И. Н. и др. 1981. Разработка рациональных режимов выращивания искусственных сосновых плантаций [Investigations of efficient regimes of growing artificial pine plantations]. Лесоводство и агролесомелиорация, вып. 59. Киев. С. 3-8.

Received 14 January 1998

РОСТ МОЛОДЫХ ДРЕВОСТОЕВ СОСНЫ И ЕЛИ ПОСЛЕ РУБОК УХОДА

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Резюме

Густота древостоев, время и интенсивность первых рубок ухода являются основными факторами при выращивании продуктивных и устойчивых древостоев. В статье проанализированы результаты наблюдения роста 6 молодых древостоев сосны обыкновенной и ели европейской после ранних рубок ухода разной интенсивности. В 1990-1993 г. в древостоях заложено по 1-2 повторные серии пробных площадей (по 4-5 площадок в каждой), которые повторно были измерены в 1995 г. В изреженых пробных площадях снизился случайный отпад, на 1.4 - 2.4 раза увеличился прирост среднего диаметра по сравнению с контролем, в то время как увеличение прироста в высоту незначительное. Наибольший текущий прирост наблюдается при густоте 1,2-2.4 тыс.шт./га. Накопление прироста в изреженных древостоях по сравнению с контролем увеличился на 5-13 %. Это показывает, что ранние рубки ухода способствуют увеличению стабильности и переводу древостоев в более высокий уровень производительности.

Ключевые слова: рубки ухода, уровень производительности, продуктивность, стабильность, сосна обыкновенная, ель европейская.