Growth of Young Stands of Silver Birch (*Betula pendula* Roth.) Depending on Pre-Commercial Thinning Intensity

TOMS ZĀLĪTIS AND PĒTERIS ZĀLĪTIS
Latvian State Forestry Research Institute "Silava"

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Abstract

First pre-commercial thinnings at the average stand height of 3-6 m, leaving 1,500 – 2,000 trees ha^{-1} regardless of the stand density before thinning, are among the major tending practices in order to create highly productive stands. After the stand has reached the average height of 10 m, thinning from below has, for at least 12 years after thinning, no significant effect on the remaining stand. It is likely that self-pruning is a genetical particularity and has no bearing on the thinning intensity.

The field data of 26 sample plots of the experiment on young birch stands thinned with varying intensities show the taper ratio to be of no significance for reducing the risk of snow damage. The assumption that the HD^{-1} ratio in stable stands should be below 1.0 is not confirmed.

Key words: pre-commercial thinning, young birch stands, *Betula pendula* Roth.

Introduction

Self-preservation of forest over millennia invariably involves replacement of one generation of trees for another every two to three hundred years. Only genetically superior trees, best adapted to the local growing conditions, will be left to the next generation. Thick growth of seedlings sprouting up on the cutovers (often several tens of thousands per ha) is the source material for natural selection and a guarantee for forest survival. By the time the young growth reaches an average height of 1-2 m, a tough competition between the seedlings starts, and the weakest ones wither away. The yield tables, which show that the number of stems per unit of the stand area decreases along with an increase in the average height of stand, in a way reflect the outcome of this competition.

Not infrequently the foresters working in practical forestry are under a delusion that planting of young stands very densely is the best way to re-create forest. Watching how the forest develops naturally from a thick growth of saplings may be at the basis of such an assumption. Below we quote some quasi-logical assumptions of that kind and comment on them:

Assumption	Comment
• Self-pruning is more intensive in dense young stands, which ultimately improves the timber quality.	• According to research, self-pruning is to a great extent a genetical particularity, no special need to keep the stand dense.
• The only way to achieve a normal stand density (1.0) is to keep it as dense as possible at young age.	• Stand density at 1.0 is impossible over the whole rotation period; the number of trees and the basal area given in the yield tables do not agree with the stand growth.
• Young stand planted densely, somewhat mitigates the effects of slapdash planting on the structure of future stand.	• Planting dense has no bearing on the quality of planting or the spread of forest pathogens.

Assumption	Comment
• Maximum volume yield over the rotation period can be achieved only in full density stands.	• Tending for maximum volume yield should be applied to near-mature stands only; in younger age classes it provokes excessive competition, which will result in sparse stands with trees of relatively small diameter in the future.
• In dense young stands it is easier to select fast-growing trees, which would become future crop trees.	• In a stand with 3,000-4,000 well-planted seedlings per ha one can readily find some 1,000-2,000 best-performing future crop trees.

In Latvia, the pine stands currently account for 36%, spruce stands for 18%, and birch for 28% of the total forest area. The high proportion of birch cannot be explained only by inappropriate decision-making on the part of forest managers since many of birch stands emerged naturally on the former farmlands abandoned during and after WWII.

Pre-commercial thinning in broadleaved stands is a relatively new method in forestry, based mainly on abstract assumptions. Some of them are ruled out by actual practise. It is often claimed that heavy thinning, e.g. from 30,000 trees ha^{-1} to 2,000 trees ha^{-1} at the average stand height 3.0 m, is justified as it reduces the risk of snow damage. This conclusion appears to be based on a theoretical assumption that a young stand becomes unstable at the HD^{-1} ratio exceeding 1.0 after thinning.

The age structure of birch stands has changed considerably over time. In the early 20th c. about a half of all the birch stands of Latvia were below the age of 20 years (Цирулис 1952); at the end of the 20th century the young stands of birch make up 10% of the total area under birch (Fig.1). According to the database *Latvijas Meža fonds* [*Latvian Forest Fund*], only 4% of the birch stands belong to the first age class

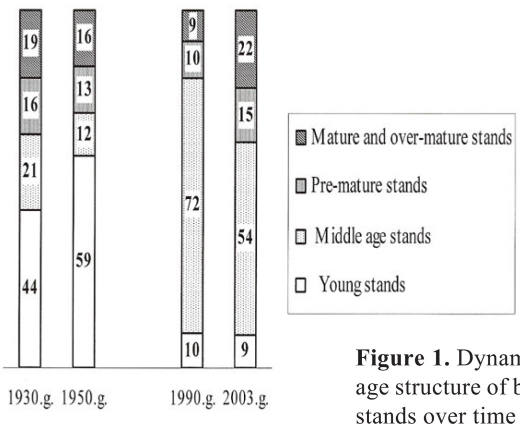

Figure 1. Dynamics of the age structure of birch stands over time (in % of covered area)

(<10 years). Goal-oriented restocking of fertile site-type cutovers by birch was planned only at 1.4% of the total area due to regeneration. That is why there has been no need to plan any pre-commercial thinnings in young stands of birch.

Consequently, at present it is possible to study the effect of thinnings only on the growth of medium-aged birch stands. In this respect the results obtained by two Latvian foresters, P.Maike (1952) and J.Taurins (1969), seem to be of great interest. Both of them studied the 30-40 year-old birch stands of 1,000 trees ha^{-1} before thinning. In our opinion, two most important conclusions of this study deserve mention:

1) Thinning from below does not significantly affect the growth of the remaining stand

2) To avoid the reduction of volume growth for the remaining stand only stunted and suppressed stems are thinned out.

By these conclusions the above researchers actually question the feasibility of thinning birch stands.

Increased growth and high productivity of birch stands can be achieved by using appropriate reproductive material for stand establishment and by well-timed and goal-oriented thinnings. Early and intense thinnings help birch and other light-demanding tree species develop strong crowns (Zerbe 2000). Thinnings also play an important role in creating a highly productive forest stand (Zalitis P. and Zalitis T. 2002, Niemistö 1996, Ewans 1984, Cameron 1996, Цирулис 1952). For birch, it is essential that the proportion of live crown should be at least 50% of the tree height, or else the stand growth slows down, i.e., the accumulation of standing volume decreases. It is properly timed thinnings and pruning that improve the quality of birch stems (Cameron 1996).

Materials and methods

In 1991, to analyse the effect and efficiency of pre-commercial thinnings in broadleaved stands on fertile soils from different geographical regions of Latvia, 26 sample plots of pure stands of birch were chosen. At that time the stand age on the sample plots was 7, 11, and 18 years with the average height 3.3, 9.2, and 10.4 m, and the number of trees before thinning 30,400 trees ha^{-1}, 10,400 trees ha^{-1}, and 13,000 trees ha^{-1}, respectively. During the thinning experiment the thinnest and stunted trees were removed, reducing the number of trees to 1,000-4,000 trees ha^{-1}. The trees on the sample plots were re-measured in 1993, 1997, 1999, 2002, and again in 2005. The breast height diameter, height and the length of the crown were measured. We also assessed the number of trees damaged by snow. The analysis of variance has been used to fulfil the objectives of the research.

The main purpose of this experiment was to study the possibility to decrease the competition among the trees within the stand with the help of the pre-commercial thinning and to retain more than the traditional number of 1000 trees per hectare in the 30-40-year old stands. We suggest that the thinning in the above-mentioned age of the birch stands might be profitable.

Results

The analyses of the 2005 regular measurement data on the sample plots demonstrate varied stand response to thinnings, depending on how intense the thinning was. These differences are explained mainly by the differences in stand age (also the average height) before thinning.

A decrease in the number of trees in the dominant stand is only partially related to the increase in the mean height. The variations of the number of crop trees in the stands created with a definite goal in view differ sharply from what is relevant for them in the 1924 yield tables. According to our data, in 15 years after thinning the average stand height increased from 3 to 17 m. The stand density after thinning was 1,500 trees ha^{-1}. Furthermore, all 1,500 trees have survived and no suppressed crop trees have been found. According to the yield tables, in full-density stands of the mentioned height the number of trees should reduce dramatically. In our sample plots, too, the number of trees has gone down considerably. For example, in the stand of 10,000 trees ha^{-1} and the mean height 3 m the density in the last 15 years went down to 2,500 trees ha^{-1}.

The reduction of birch trees ΔN in the dominant stand can be described by the following equation:

$$\Delta N\text{, trees/ha}^{-1} = 58.06H_0\text{, m} + 0.946N_0\text{, trees ha}^{-1} - 1984,$$

where $R^2 = 0.99$, and the variations in ΔN are explained by the initial number of trees N_0 (76%) and the height of dominant stand H_0 (23%).

By this equation it is possible to calculate the wanted number of trees in the remaining stand after thinning. Moreover, all the remaining trees are to produce timber at least for the coming 15 years, which is the follow-up period for the given study.

$\Delta N = 0$, if H_0, = 3.0 m and N_0 = 1913, *i.e.*, ~ 2,000 trees ha^{-1}, and

$\Delta N = 0$, if H_0, = 10.0 m and N_0 = 1483, *i.e.*, ~ 1,500 trees ha^{-1}.

The results of this experiment show that in very dense stands heavy thinning down to 2,000 trees ha^{-1} ensures a minimal risk of snow damage. None of the 26 stands, thinned with varying intensity during the last 3-15 years, showed significant damages by snow. In the entire sample plots only 6 trees were damaged out of a total of 5,000.

Over the study period the stands of different density show differences in the mean height of the dominant crop trees. By the year 2005, the stand with H_0 = 3.3 m and N_0 = 1,500 trees ha^{-1} had reached the average height H = 17.0 m, while this index for the stand with N_0 = 30,400 trees ha^{-1} was only 14.0 m. On the other hand, the stand with H_0 = 10.0 m and N_0 = 1,600 trees ha^{-1} had in 2005 the average height H = 20.5 m; for the stand with N_0 = 10,000 trees ha^{-1} (used as the control) this index was also 20.5 m.

In our opinion, the HD^{-1} ratio as an indicator for stand stability is overemphasized. In fertile site types, where the HD^{-1} ratio is invariably above 1.0, it would be impossible to manage the birch stands as prescribed by the existing regulations. In our sample plots the average height of vital birch stands is between 5 and 20 m at the modal value of HD^{-1} ratio 1.5 (Fig. 2).

In different Kraft classes the HD^{-1} ratio argues also against the significance of higher HD^{-1} values as an indicator of increased risk. Taller trees (Kraft class

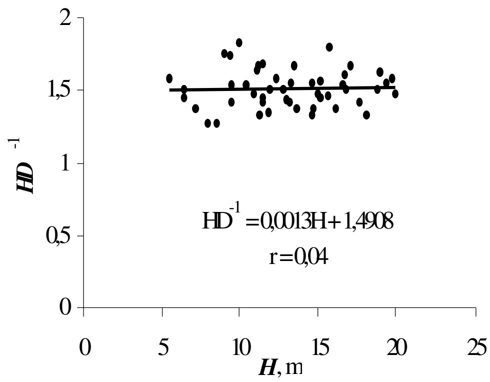

Figure 2. The taper ratio HD^{-1} of the dominant birch stand represented as function of H in the stands undamaged by snow and wind

I-II) with longer crowns have lower HD^{-1} values than the trees of Kraft class III (Fig. 3).

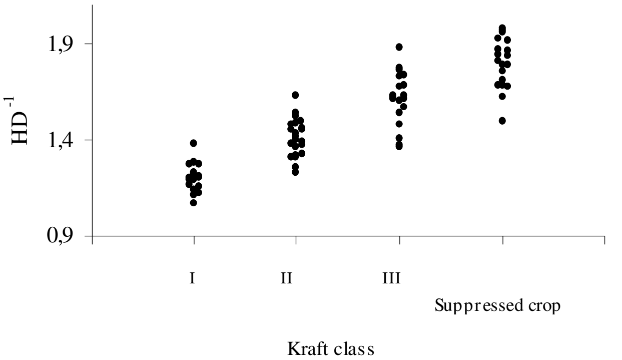

Figure 3. The taper ratio HD^{-1} in different Kraft classes in the stands undamaged by snow and wind

The biometrical analysis of our data shows the differences among the modal values of HD^{-1} ratio to be significant even for the trees in proximal Kraft classes. There is a pronounced negative correlation between hd^{-1} and the diameter or height of a single tree in heavily thinned stands (to 1,500 trees ha^{-1} at H_0=3.0 m) where the social status (Kraft class) of the trees cannot as yet be determined. Even if the hd^{-1} ratio showed imminent threat of snow damage, suppressed and less valuable trees or those of Kraft class III would be the ones most likely to suffer from snow damage. In such a case the snow would simply assist in thinning the stand.

Next to highways one can often see birches damaged by snow. Quite often snow-damaged birches are also found in some bio-groups inside the stand. In a similar case closeness to the forest edge is the major factor responsible for snow damage. As light-demanding species, the birch stems lean towards an open space, and the crowns lose symmetry and can easily suffer damage even in a light snowfall. The results of our research show that also in heavily thinned stands the trees can develop slender stems and symmetrical crowns over the season of early spring or the beginning of summer. It contributes also to the survival of trees during the winters to come. Thus, the assumption that heavily thinned birch stands are more susceptible to snow damage is believed to be groundless.

The major objective of pre-commercial thinning is to provide for the maximum volume growth of the dominant crop. However, the stem quality is of no less importance. In the young and medium aged stands the self-pruned portion of the stem is an indicator of its quality. On the other hand, the physiological processes determining the accumulation of stemwood are directly related to the crown length.

The interdependence between the crown length, the self-pruned stem portion, and the standing volume are analysed for two different alternatives: 1) 3 m < H_0 < 6 m; 2) 9 m < H_0 < 12 m.

In the first alternative (1,500 trees ha^{-1} < N_0 < 5,000 trees ha^{-1}), there is a negative correlation (r = -0.98) between the crown length and the number of the remaining trees after thinning (Fig. 4 A). Increasing the number of trees by 1,000 trees ha^{-1} in the 23-year-old stand reduces the crown length by 1.0 m. In thinned stands, the relative crown length accounts for 48%, in non-thinned, for 32% only.

The correlation between the number of trees N_0 and the length of the self-pruned stem portion is less regular: r = +0.82. Due to the increase in the number of trees by 1,000 the self-pruned portion of the stem increases by 0.1 m only. It is worth noting that at N_0 = 1,500 trees/ha^{-1} the mean length of the self-pruned stem portion is as high as 9.0 m, and 9.5 m at N_0 = 5,000 trees ha^{-1}.

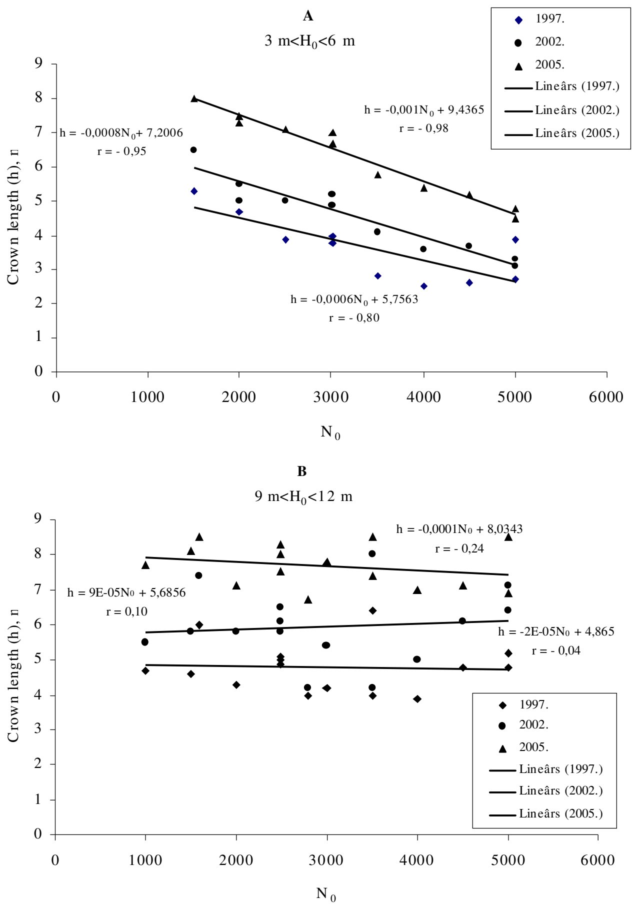

Figure 4. The crown length of the dominant crop trees

In the second alternative there is no significant correlation (r = -0.24) between the crown length and N_0 (Fig. 4 B). The crown length is up to 8.0 m high, i.e., 42% of the tree height. Here, in the stands of differing density the self-pruned portion of the stem (58%

of the tree height) stays constant. Thus, it confirms the assumption that self-pruning is a genetical particularity and to a lesser extent affected by the stand density.

By alleviating the competition among the trees and precluding an emergence of suppressed crop trees it is possible to achieve a marked increase in stand productivity. In both alternatives the highest difference in the volume growth was for the stands with 1,000-2,000 trees ha^{-1} remaining after thinning. A higher number of the remaining trees reduces the stand productivity to 7 m^{3}ha^{-1}yr. already at N_0 > 3500 trees ha^{-1} and 3 m < H_0 < 6 m. At 9 m < H_0 < 12 m, the stand productivity is 5 m^{3}ha^{-1}yr. Paradoxically as it is, a lesser number of the remaining trees after thinning produce higher standing volume.

Normally, the standing volume, m^{3}ha^{-1}, is used as an indicator for appropriately chosen method of stand tending. On the other hand, it cannot be used to decide on the feasibility of pre-commercial thinning in young stands since the standing volume becomes a significant indicator only after a longer period of time. In young stands at 3 m < H_0 < 6 m (Fig. 5), the highest standing volume is in the stands with a higher number of trees remaining after thinning (r = +0.93). This trend holds true for seven years after thinning (1997). In ten years after thinning the volume growth evens out and in another five years for the 22 year-old stands the highest standing volume is reached (150 m^3 ha^{-1} at 1,500-2,000 trees ha^{-1}). It is important to note that the number of trees in the mentioned stands remained the same.

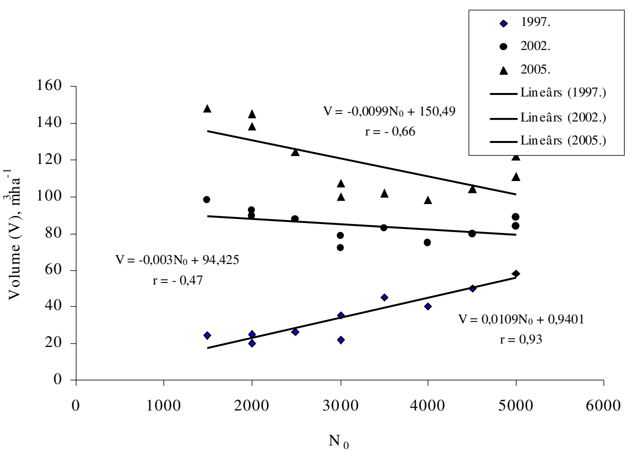

Figure 5. The standing volume of dominant crop at 3 m< H_{1991} < 6 m

In slightly older stands (9 m < H_0 < 12 m) the first pre-commercial thinning does not result in considerable volume differences for stands with varying number of trees 10 years after the thinnings. In another five years these stands show the same regularities as mentioned before for younger stands. The highest standing volume develops in intensely thinned stands, reaching 220 m^3 ha^{-1}. It must be pointed out that in the stand with N_0 = 1,600 trees ha^{-1} all the trees of the standing volume of suppressed crop trees below 15 m^3/ha^{-1} survived. At N_0 = 5,000 trees ha^{-1} the standing volume is only 143 m^3 ha^{-1}.

Re-measuring the stand parameters every three years revealed another regularity: at the same mean height of the stand the tree diameter is greater in thinned stands (Fig. 6). Over the first six years after thinning, the mean diameter at the same mean height approximately is the same in both thinned and non-thinned stands. The difference increases with the time

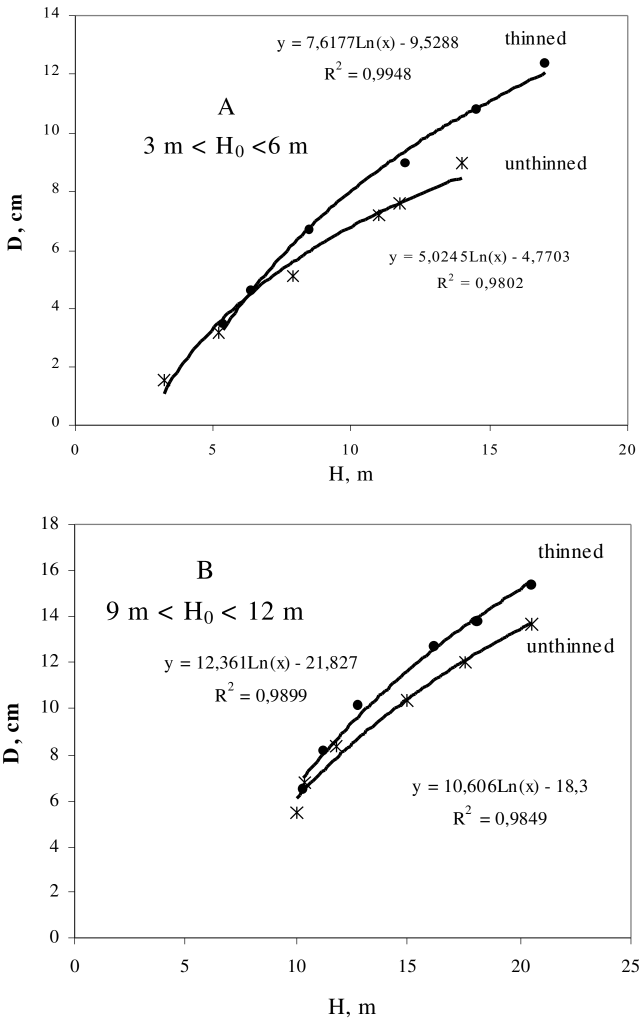

Figure 6. Mean diameters (D, cm) at the same height (H, m) of the intensely thinned (Fig. 6A) and non-thinned (Fig. 6B) birch stands

and in 15 years (the follow-up period for the given trial) the mean diameter in the thinned stands by is 2 cm greater than in the non-thinned ones even at the same mean height of the stands. This regularity can help identify the stands which have been intensely thinned many years ago.

In denser stands the differentiation of trees (emergence and partial dieback of suppressed trees) is very fast, and re-measuring the trees every three years occasionally shows no volume growth at all for the dominant trees, although the volume growth of suppressed trees in the two instances of measurement does not exceed 20 m^3 ha^{-1}. It is statistically proven that highly productive birch stands are often found on unstable ground; that is why we believe a regular removal of suppressed trees of so small a volume is both ecologically and economically infeasible. The maximum volume should be taken out in the first thinning (3 m < H_0 < 12 m), reducing the number of the trees to 1,500-2,000 trees ha^{-1} regardless of the initial stand density.

Discussion

Quest for acceptable thinning regimes for birch (thinning intensity and frequency) has for decades been based on an unquestionable assumption that the number of trees in young stands is very high: only one parameter, the lower limit of the number of the trees to be retained, was determined, normally, from 3,000 to 8,000 trees ha^{-1}; no analysis was for the upper limit. According to the literature sources, the Finnish researchers were among the first who in 1971 established a trial, laying out young birch stands of 400-5,000 trees ha^{-1}. They claimed that the number of birches in a young stand should not exceed 1,600 trees ha^{-1} (Niemisto 1996). The results of our trial, by now running for 15 years, confirm that the quoted figures for the number of birch stems in a young stand are optimal, and emphasize also the crucial significance of pre-commercial thinnings for the formation of highly productive stands.

As for the stem quality, the results of our research confirm the P. Maike's (1952) conclusion of no close correlation between the number of trees in the stand and the self-pruned portion of the stem. The assumption that self-pruning is more intense in denser stands is not confirmed. In a non-thinned stand (1,492 trees per hectare) the average length of self-pruned stem portion was 11.4 m, whereas in thinned stands with the number of trees reduced to 796 and 630 trees ha^{-1}, the same indicator was 13.2 m and 12.2 m, respectively. In sparser stands, however, 15 years after thinnings the self-pruned stem portion was contrary to the expectations significantly longer than in the stand that was not thinned. Intense self-pruning in all the analysed stands indicate that self-pruning in birch is genetical particularity.

In overstocked stands increased mutual competition lasts approximately till the stand reaches the age of 40 years. By this moment the stand has reached the peak of the current increment following the basal area and volume. With the peak of volume growth over, the role of individual trees in the stand survival increases. The trees of the dominant stand are assessed in greater detail, including marking out the trees that would form the ensuing generation of the stand. By the said age there are many suppressed trees that would perish approximately in 20 years, *i.e.*, at the age of 60 years. It should be remembered that in Latvia according to the *Improved Thinning Regulations* of 1985 this is the age at which the commercial thinnings of the dominant crop in the birch stands should be terminated. In older stands, an emergence of suppressed crop trees is less pronounced and hard to predict. That is why the thinning regulations do not envisage the removal of suppressed, diseased and withering trees; these trees may be removed if profitable.

The above facts illustrate significant differences in the growth of the two types of birch stands: one representing naturally regenerated or overstocked, artificially regenerated young stands; the other type are the young stands thinned for a definite end use with minimal mutual competition between the trees. In our forests, where dynamic and successful thinning of the existing and the establishment of new stands is under way, the amount of young stands of birch established with a definite end use in mind increases. It implies that for quite a long time the birch stands would comprise only strong, not weakened by mutual competition, and healthy trees. Consequently, the removal of suppressed trees, which according to the present regulations should be started at the age of 30-40 years, would be inefficient or even obsolete as at this age there would almost be no suppressed trees. All the trees would produce timber with a high probability to obtain a yield of 500-600 m^3 ha^{-1} of wood by the end of the rotation period.

Similar management regime with no removal of the dominant crop trees of the smallest diameter and thinning down to the lowest acceptable values of the basal area for the remaining trees is a novelty for the Latvian forestry. We can foresee that in stands of birch established for a definite end use the basal area of a healthy dominant stand would be considerably higher and its reduction to the level prescribed by the present regulations would be impossible because the regulations are adapted to the management regime for overstocked stands only.

Today, the forest regeneration (selection of the plants, careful planting, and protection of the plants) and shaping the young stands by way of pre-commercial thinnings assume essential importance in forest management. Thinnings in older stands will involve only removal of a few fairly large suppressed trees, perhaps, at the age of 50-60 years. Thinning each 20 years will be of no consequence. Decision to thin a stand would be made after evaluating the actual situation and considering the economical returns (costs, timber prices on the market) with all the dominant trees retained at that.

Conclusions

1. The field data of the given study regarding the effect of intense pre-commercial thinnings on the further development of the stand argue against the significance of the taper ratio HD^{-1} as an indicator of increased tree susceptibility to snow damage. The assumption that in a stable stand the taper ratio HD^{-1} should be below 1.0 is not confirmed.

2. The reduction of the number of trees at one go of pre-commercial thinning to 1,500-2,000 trees ha^{-1} regardless of the stand initial density (at the mean stand height 3 m $<H_0 <$ 12 m) is of essential significance for the formation of highly productive stand.

3. The self-pruning of trees should be considered as genetical particularity; intense pre-commercial thinning of the young stands does not affect the stem quality. In heavily thinned young stands (3 m $< H_0 <$ 6 m) 15 years after thinning the tree height and crown length are by 3 m longer than that in respective overstocked stands. In slightly older stands (9 m $< H_0 <$ 12 m) the differences in the tree height and crown length between thinned and non-thinned stands are less distinct.

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ВЛИЯНИЕ ИНТЕНСИВНЫХ РУБОК УХОДА НА ХОД РОСТА БЕРЕЗОВЫХ МОЛОДНЯКОВ

Т. Залитис и П. Залитис

Резюме

Изучены результаты повторных измерений параметров березовых молодняков на 26 пробных площадях, в которых 15 лет тому назад проведены интенсивные рубки ухода, сокращая число деревьев с 15-30 тыс. до 1.0-4.0 тыс. на га. Выявлена различная реакция оставленной части древостоя на проведение рубки, в зависимости от возраста или средней высоты древостоя.

Для выращивания высокопродуктивного насаждения, решающую роль имеет сокращение числа деревьев до 1500-2000 шт. на га при высоте древостоя 3-12 м, независимо от начальной густоты молодняка. Полученные результаты убедительно иллюстрируют необоснованность использования коэффициента стройности ствола hd^{-1} (отношение высоты, м, и диаметра, см) в роли качестве устойчивости древостоя.

Ключевые слова: березовый молодняк, рубка ухода, ход роста