The development of Scots pine (*Pinus sylvestris* L.) plantations at initial stage

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Growth at initial stage of pine (*Pinus sylvestris L.*) plantations that were established by use of different reforestation methods was studied. The minutest transplanting stress when establishing forest plantations appears planting 1-year old seedlings at the bottom of the furrow. The development of naturally regenerated plantations and these established from seed – derived trees lags behind the plantations that were established the same year by planting approximately in a period of 2 years and 3 years, respectively. Natural reforestation depends on seed bearing of the seed source and might be successful already during the first year or it might take several years.

Key words: Scots pine plantations, seedlings, soil genetic horizon.

Introduction

The greatest attention in modern forestry is given to the development of industrial forests that are established, cultivated and harvested to meet human requirements. In Lithuania, industrial forests make up the largest part of all forests. Due to various reasons and aims, need for industrial forests is constantly increasing. Currently, a great deal of reforestation systems exists which enables us to meet this need. Undoubtedly, here the most important is to choose the most proper method (strategy) of reforestation. The major requirements for currently existing reforestation systems of industrial forests are the following: an increase in survival, stimulation of the development of plantations as well as a decrease in financial expenses for reforestation and sylvicultural measures.

It is very important to choose a proper reforestation system due to three reasons:

- it determines how soon the territory will be returned to timber production;
- it determines the most favourable possibilities that will be available to management of the territory over the rotation period;
- it defines the possibility of undesirable expenses if too few or too many seedlings are planted on the area.

Scientific substantiation of reforestation methods is of great significance throughout the world, particularly in the countries of the most intensive forest management. The largest experience in choosing reforestation method in the pine stands is accumulated in Scandinavian countries as well as in North America (Parviainen, 1994, Kuusela, 1994, Leibundgut, 1981, Zobel, Talbert, 1984.).

Most of the authors who studied substantiation of the reforestation methods, the results obtained related to the output of commercial timber in an area unit and most efficient use of the financial resources.

In Scandinavian and North American countries, the output of commercial timber in the stands that were established by planting seedlings exceeds the output of commercial timber in natural stands and in these established from seed – derived trees by 9-44%. However, the most efficient use of the financial resources is in case stands are regenerated naturally (the ratio of income to expenses was 5.4:1) and the least efficient use is in case reforestation is performed by planting (3.13:1, respectively) (Mary L Duryea and Phillip M. Dougherty, 1991, Wiersum, 1984).

The aim of the study is to compare how soon the area is returned back to timber production (is reforested) by applying natural and artificial reforestation methods as well as to compare the seedling development by various methods in reforested plantations.

Methods

The test plantation was established under *oxalidosa* site conditions on the area where formerly a mixed spruce with pine stand of I class was harvested. The

thickness of forest litter, humus horizon and podzolic with illuvial horizon reached 3 cm., 10 cm. and 30 cm respectively. Here the studies were conducted on reforestation by using all reforestation methods currently applied in industrial forestry: planting, sowing and natural regeneration.

The soil on whole area concerned was prepared with the help of implements currently used in reforestation, i.e. forming furrows (by plough and forest cutter), slices or hillocks as well as smoothly removing forest litter along the surface and loosening the humus horizon of the soil at the 5 cm depth. Hillocks of 10 cm heigh and slices were formed of humus horizon only. Combined thickness of double humus horizon reached 20 cm. The regeneration of pine stands was studied on three different planting sites:

- in the furrow of illuvial horizon;
- in the humus horizon of the soil prepared smoothly with surface;
- in the hillock of double humus horizon.

The seedlings of various parameters were used to establish pine plantations when reforestation was done planting the seedlings in the soil prepared by all methods. The characteristics of planting material are presented in Table 1.

high germination capacity. The largest distance of naturally regenerated plot from the stand was 30 m., which was close to stand height. On average 24 seeds having germination capacity appear in each square metre within a zone of one tree's height close to the stand when seed yield is moderate. Evaluation was carried out in plots of 1 m^2 in size. A total of 20 study plots were selected in each variant of the experiments. The experiments consisted of five replications too. Only biometrical parameters were evaluated in the study plots, however, the number of germinated seeds was not recorded. Therefore, the study plots were selected at various distances from the seed stand in a zone of 30 m wide.

The statistical data analyses were processed by MS Excel computer programme.

Results and discussion

Survival in the plantations established by planting

During the first vegetation period the highest survival was achieved in the pine plantations that were established from 1-year-old seedlings. Plough and forest cutter prepared the soil there. Survival of pine seedlings established in illuvial horizon, which was prepared

Seedling grade	D, mm	Last year Zd at the nursery, mm	H, cm	Last year Zh at the nursery, cm	D^2H, cm^3	Last year ZD^2H at the nursery, cm^3
1-year-old seedlings	2,3±0,08	2,3±0,08	4,5±0,17	4.5±0.17	0.2	0.2
2-year-old seedlings	4,2±0,11	1.8±0.06	21,4±0,63	14.0±0.33	3.7	3.3

Table 1. The biometrical parameters of seedlings used to establish pine plantations

Pine plantations were established using 1- and 2-year-old seedlings. They are the smallest and largest pine and spruce seedlings currently used in reforestation. The experiment consisted of five replications. A total of 100 trees per replication were evaluated.

Studies were conducted on reforestation performed sowing seeds in the soil prepared by all methods. The seed of high laboratory germination capacity was collected in a seed orchard of the first generation. They were sown in plots of 0.2x0.2 cm with 15-20 seeds per plot at the depth of up to 0.5 cm. In five replications 100 trees per replication were evaluated.

The studies on natural reforestation were carried out using of clear cutting method when a neighbouring mixed stand containing 60% of pine was used as a seed source for the area regenerated. The mean age was 60 years and density was 0.7. The stand of such age has good seed yield and ripens a large amount of seeds of

by forest cutter, and plough comprised reached 98% and 100% respectively, slightly lower survival was observed in the humus horizon, which was prepared smoothly with surface. There survival constituted 95%. The worst survival was in double humus horizon in the soil prepared by plough, where it made up 91%.

One of the reasons for low survival in double humus horizon is unstable humidity regime in the upper horizon. Weak root system of seedlings falls into the upper horizon during planting and reaches the lower horizon only at the end of vegetation period.

Survival in the plantations that had been established from 2-year-old seedlings was slightly influenced by soil genetic horizon where the plantation was established. The methods of soil preparation had a minor influence on survival too. Generally, the survival of these plantations in the soils prepared by all methods was found to be 93-94%.

The growth of pine plantations established in illuvial horizon at the bottom of furrow

Two vegetation periods after soil preparation, the states of forest plantations established by different methods were evaluated. The plantations regenerated naturally in the soil during two vegetation periods, which had been prepared by forest cutter and plough as well as in illuvial horizon. However, the largest seedlings appeared in the plot, which had been regenerated by planting. At the end of the second growth period, the pine plantations established from 2-year-old seedlings reached a height of 47.1 cm from the initial 21.4 cm. Slightly lower trees grew up in the plot which had been regenerated using 1-year old seedlings. Here, during two growth seasons the trees reached a height of up to 39.4 cm from the initial 4.5 cm. (cf. Table 2).

year. Forest plantations established from 2-year-old seedlings grew better than during the first growing season as well. Their height increment reached almost 20 cm or 142.2% of the height increment of seedlings at the nursery last year.

The pine plantation which had been established by sowing at the bottom of the furrow after two growth seasons reached a height of 17.1 cm. Of 15-20 seeds sown on average 8 seeds had germinated in the plots during the first vegetation period. The seedlings reached a height of 5.5 cm at the end of the first vegetation period. During the second year, a group of 3-4 leading seedlings was revealed out of 8-seedling group. The mean height increment during the second year was 13.4 cm.

The plantations did not regenerate naturally during the first vegetation season. It was attributed to very

Table 2. The height increment and height in the pine plantations that were established in illuvial horizon of the soil prepared in furrows

Method of reforestation	Height increment over 1 growth season		Height increment over 2 growth seasons		Height of 2-year old plantations, cm
	cm	% of last year height increment at the nursery	cm	% of last year height increment at the nursery	
1-year old seedlings	6.3±0.09	137.5	30.5±1.02	667.0	39.4±1.49
2-year old seedlings	8±0.06*	57	19.9±0.94*	142.2	47.1±1.3*
Sowing	5.5±0.07		13.4±0.77*		18.1±1.19*
Natural regeneration			5.2±0.08*		5.2±0.08*

*) Statistically significant differences (P-95%)

By comparing the height increment in the forest plantations that had been established both from 2 and 1-year-old seedlings one could see that the depression when transporting the seedlings from nursery to a regenerating plot mostly influenced 2-year-old seedlings. When comparing the height increment of the latters last year of the nursery and 1-year-old forest plantations it was observed that the growth rate of 1-year-old seedlings did not decrease in forest plantations.

The first-year the height increment made up 137.5% of the height increment at the nursery while the height increment of 2-year-old seedlings which had been transported to regenerating plot decreased almost twice (from 14.2 cm to 8 cm). It implies that large pine seedlings are sensitive to the replanting stress whilst the 1-year old seedlings adapt swiftly under new environmental conditions.

The forest plantations established from 1-year-old seedlings at the bottom of the furrow grew even faster during the second growth season than during the first season. Their height increment comprised 667% of the height increment of the seedlings at the nursery last

weak seed bearing of the neighbouring seed stand. The amount of the seed poured out was not enough for regeneration of the stand. But during that vegetation season pine flowering was moderate which led to average seed yield. On one tree approximately 800 cones were ripened. Such an amount of seed was sufficient to seed the neighbouring plot. The seeds poured out in early spring had germinated rather abundantly (on average of 6 seeds/m^2) and during the vegetation season the seedlings reached a height of 5.2 cm, i.e. almost the same as that reached by seedlings during the first growth period.

The radial increment of pines also depends on seedling age in the plantations that were established by planting. At the end of the second growth season, the mean diameter in the plantations established from 1 and 2-year-old seedlings was 9.7 and 8.8 mm, respectively which meant that the diameter in the plantations established from smaller seedlings was larger than that in the plantations established from larger seedlings (cf. Table 3). An influence of replanting on seedling diameter was analogous as that one on height. 1-year old

Method of reforestation	Radial increment during the 1-st vegetation period		Radial increment during the 2-nd vegetation period		Diameter of 2-year old plantations, mm
	mm	% of the last year radial increment at the nursery	mm	% of the last year radial increment at the nursery	
1-year old seedlings	3.1±0.07	138.2	4.2±0.08	184.6	9.7±0.86
2-year old seedlings	1.2±0.05*	63.2	3.4±0.07*	184.1	8.8±0.77
Sowing	2.0±0.04*		1.9±0.18*		3.9±0.09*
Natural regeneration			1.8±0.06*		1.8±0.06*

Table 3. The radial increment and diameter in the pine plantations that were established in illuvial horizon of the soil prepared in furrows

seedlings suffered less during replanting, therefore, already during the first growth season their radial increment exceeded that at the nursery (it made up 138% of the radial increment at the nursery). During the second growth season, the radial increment in the plantations which had been established from 1-year-old seedlings made up 4.2 mm (184% of the last year radial increment).

The radial increment as well as the height increment in the plantations established by 2-year-old seedlings were more influenced by seedling transporting from nursery to a reforesting area. During the first vegetation season, the radial increment in the plantations which had been established from 2-year-old seedlings reached 1.2 mm. It constituted 63.2% of the last year radial increment at the nursery. During the second vegetation season, the radial increment in these plantations increased almost 3 times as compared with the first year and reached 3.48 mm or made up 184,1% of the radial increment at the nursery last year.

had germinated during the second growth season only and at the end of it their diameter reached 1.8 mm.

A joint product of square diameter and height (D^2H) illustrates tree development best. This character is mostly used to evaluate seedling development at the nursery.

D^2H of pine plantations at the bottom of the furrow differs in relation to seedling grade or method of reforestation. After two growth periods, the highest D^2H was observed in the plantations that had been established by planting. It is worth mentioning that the plantations established both from 1 and 2-year-old seedlings after two vegetation periods reached equal D^2H (37.5 and 37.2 cm^3, respectively cf. Fig. 1).

The D^2H increment in these plantations varied in relation to the influence of replanting stress on the seedlings. During the first vegetation period, the D^2H increment in the plantations established from 1-year-old pine seedlings made up 3.0 cm^3. By comparing it with the D^2H increment of the same seedlings at the nurs-

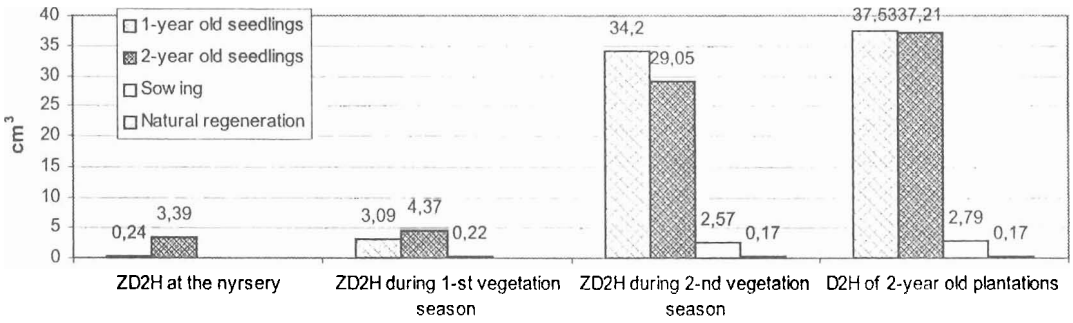

Figure 1. D^2H and D^2H increment of pine plantations that were established in illuvial horizon of the soil prepared in furrows

During the first vegetation season, the diameter reached 2 mm in the plantations that had been established by sowing and differed negligibly from the diameter of 1-year-old pine seedlings grown at the nursery (2.3 mm). During the second growth season the radial increment of the sown pine seedlings was slightly smaller than during the first growth season and reached 1.92 mm. At the end of the second growth season the diameter in the pine plantations established by sowing reached 3.9 mm.

The smallest diameter was in the pine plantations that had been regenerated naturally. Here the seedlings

ery, it increased 1288% during the first vegetation season. It implies that transporting of 1-year-old seedlings from the nursery to a regenerating area has almost no impact on the D^2H increment.

Transporting of 2-year-old seedlings from the nursery to a regenerating area influenced their D^2H increment more. During the first vegetation period the D^2H increment of 2-year old seedlings reached 4.3 cm or 115.3% of their D^2H increment at the nursery last year. During the second vegetation season the development of the plantations that had been established from 2-year-old seedlings became more intensive and the D^2H

increment there makes up 766.4% of the increment of these seedlings at the nursery last year.

D^2H in the pine plantations established by sowing reached 2.7 cm^3 at the end of the second growth season. It tended to increase annually from 0.2 cm^3 during the first vegetation season to 2.5 cm^3 during the second one.

The plantations regenerated naturally at the bottom of the furrow only during the second vegetation period; therefore, their D^2H was lowest when comparing it with the plantations established using of other methods.

The growth of pine plantations in the humus horizon in the soil prepared smoothly with the surface

The soil was prepared smoothly with the surface when mineralizing and hoeing the upper soil horizon at the depth of 5 cm. The seed was distributed over the humus horizon when reforesting naturally or by sowing and the seedling roots were introduced to the humus and partly illuvial horizons.

At the end of the second vegetation period after the plantations had been established, the highest plantations were these established by planting 2 –year-old seedlings. Their height reached 43.7 cm. However, they were slightly lower than the plantations established in the same way at the bottom of the furrow. The plantations which had been established from 1-year-old seedlings in the soil prepared smoothly with the surface reached a height of 39 cm and were of the same height as the plantations established at the bottom of the furrow. Naturally regenerated plantations and these established by sowing were slightly lower than these plantations established at the bottom of the furrow. The sown seedlings grew up to 10.7 cm while naturally regenerated pine seedlings had a height of 4.6 cm (cf. Table 4).

Replanting stress influenced stronger the growth of the plantations established in the soil prepared smoothly with the surface. Certainly, the effect of the humidity regime, which was different than that at the bottom of the furrow, on the growth was of a major importance as it had influenced for a seedling survival longer period. During the first vegetation period, the height increment in the plantations established from 1-year-old seedlings reached 3.8 cm and made up 82.9% of the seedling height increment at the nursery last year. The first year the height increment in the plantations established from 2-year-old seedlings reached 6.1 cm which made up just 43.5% of the seedling height increment at the nursery. During the second period plantations growth did not become more intensive. However, as at the bottom of the furrow, the plantations established from 1-year-old seedlings exhibited faster growth. During the later vegetation season, the plantations which had been established from 1 and 2-year-old seedlings had a height increment of 29.4 and 19.0 cm, respectively. In comparison to the height increment in these plantations with the height increment of the seedlings at the nursery last year, it made up 642.8 and 136.1%, respectively.

Prolonged seedling survival period influenced the changes in diameter as well. Depression in the radial increment became evident during the first year after replanting. The radial increment in the pine plantations that had been established from 1 and 2-year-old seedlings during the first vegetation season made up 81.8% and 47.6%, respectively (cf. Table 5). Over the second year, the radial increment in the plantations established by planting 1-year old seedlings increased. During the first vegetation season in the plantations established from 1 and 2-year-old seedlings it reached 4.3 mm and 3.9 mm, respectively. It exceeded the radial increment of the seedlings at the nursery almost twice. At the end of the second vegetation season, the diameter in the plantations established from 1 and 2-year-old seedlings reached 8.5 mm and 9.0 mm, respectively.

During the first vegetation season the radial increment in the plantations established by sowing reached 1.8 mm and slightly decreased during the second one (reached up to 1.15 mm). After two vegetation seasons it reached 2.9 mm and was almost by 25% less than one in the plantations established by sowing at the bottom of the furrow.

Table 4. The height increment and height in the pine plantations that were established in humus horizon of the soil prepared smoothly with the surface

Method of reforestation	Height increment over 1 growth season		Height increment over 2 growth seasons		Height of 2-year old plantations, cm
	cm	% of last year height increment at the nursery	cm	% of last year height increment at the nursery	
1-year old seedlings	3.8±0.17	82.9	29.4±1.04	642.8	39.0±1.17
2-year old seedlings	6.1±0.31*	43.5	19.0±0.95*	136.1	43.7±1.51*
Sowing	5.5±0.28*		7.5±0.56*		10.7±0.58*
Natural regeneration			4.6±0.13*		4.6±0.13*

*) Statistically significant differences (P-95%)

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Naturally regenerated pine plantations were thinner as compared with these regenerated at the bottom of the furrow. After two growth seasons the diameter of naturally regenerated pines in the soil prepared smoothly with the surface reached 1.2 mm.

D^2H in the soil prepared smoothly with the surface also depends on the quality of seedlings and on the method of reforestation. However, this character in all variants of reforestation in the soil prepared smoothly with the surface was lower when comparing with the corresponding seedlings planted in the soil prepared in furrows. After two vegetation seasons the highest D^2H was achieved in the plantations which had been established from 2-year-old seedlings and reached 35.5 cm^3. It was slightly lower in the plantations established from 1-year-old seedlings (28.1 cm^3). The values were considerably higher than these in the plantations established by sowing or regenerated naturally (0.9 cm^3 and 0.1 cm^3, respectively cf. Fig. 2).

year and reached 2.9 cm^3. The D^2H increment during the first vegetation season in the plantations established by sowing was 0.2 cm^3.

The seedling replanting stress ends already during the first vegetation season, therefore, during the second growth season the D^2H increment increased considerably. In the plantations which had been established from 1-year-old seedlings during the second year it reached 26.7 cm^3 and made up even 11162% of the increment at the nursery last year. In the plantations established from 2-year-old seedlings the D^2H increment during the second year reached 28.7 cm^3 and constituted 758.8%.

The growth of pine plantations in the hillock (slice) of the double humus horizon

When establishing the plantations by planting seedlings in the soil prepared by hillocks or slices, the plant roots come to the double humus horizon. Depend-

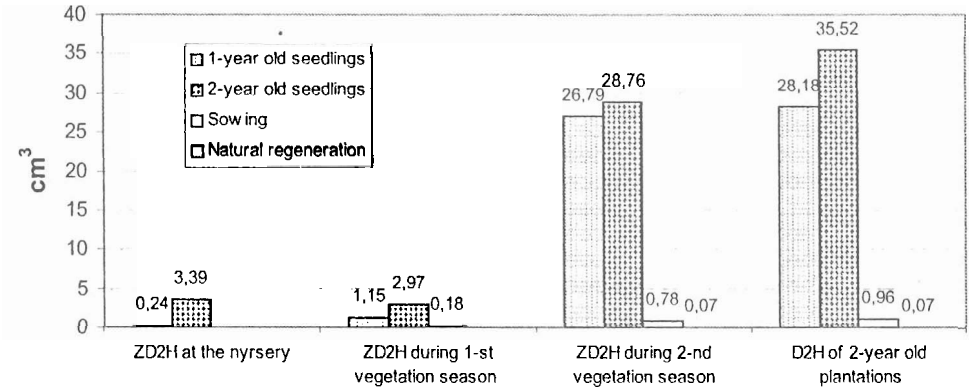

Figure 2. D2H and D2H increment of pine plantations that were established in humus horizon of the soil prepared smoothly with soil surface

During the first vegetation season, the D^2H increment decreased in the plantations established planting 2-year-old seedlings when comparing with the D^2H increment at the nursery last year. In the plantations established from 1-year-old seedlings it reached 1.1 cm^3 or 479.2% of the increment at the nursery last year. In the plantations established from 2-year-old seedlings the D^2H increment during the first vegetation season made up only 87.6% of the increment at the nursery last

ing on seedling parameters, the roots might be planted in the humus horizon in the hillock (1-year old seedlings) or in the humus horizon of untouched soil below the hillock or slice. Survival of plantations and their further growth depend on this, as humidity regime of the humus horizon below the slice is more stable for the plants than that in slice or hillock.

The data presented in the Tables illustrate it clearly. The height in the plantations established from 1 and

2-year-old seedlings after two vegetation seasons differs considerably (28.1 cm and 42.5 cm, respectively Table 6). In contrast to the plantations established at the bottom of the furrow and humus horizon in the soil prepared smoothly with the surface, the height increment in the pine plantations established from 1-year-old seedlings in hillocks during the first vegetation period was lower than that grew up of the pine seed sown in the hillock reached a height of 3.6 cm. During the second vegetation period the height increment of pine seedlings attained 5.1 cm and the mean height of 2-year old pine seedlings was 8.0 cm.

Pine regenerated naturally during two growth seasons after soil's mineralization took place in the soil

*) Differences statistically significant (P-95%)

year-old seedlings (1.4 mm and 1.3 mm or 64.5% and 68.8% of the radial increment at the nursery last year, respectively). The plantations that had been established from 1-year-old seedlings exhibited higher radial increment during the second growth season too. Their radial increment reached 4.5 mm and made up 196% of the radial increment at the nursery last year. These values in the plantations which had been established from 2-year-old seedlings were 3.0 mm and 160.3%, respectively.

During the first growth season the D^2H increment did not decrease in the plantations that had been established in the humus horizon on the hillock (Fig. 3).

Conclusions

Reforestation might be done both by planting and sowing and naturally from the neighbouring stands in the soil prepared in furrows. Seedling age is not a limiting factor of reforestation performent by planting. The plantations develop equally when established both by 1 and 2-year-old seedlings. The pine plantations established by sowing lag behind by development of the plantations established by planting approximately 1 year.

Natural reforestation depends on seed bearing of the seed source and might be successful already during the first year or might continue for several years.

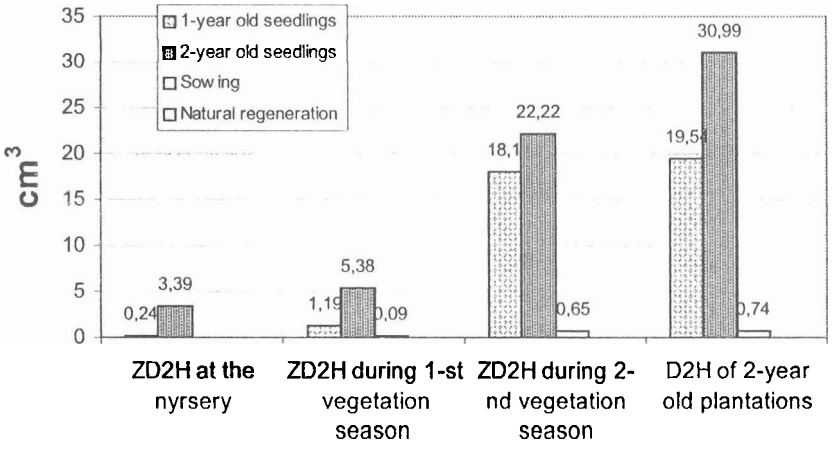

Figure 3. D^2H and D^2H increment of pine plantations that were established in humus horizon of the soil prepared in hillock

In the plantations established from 1-year-old seedlings it comprised 495.8% of the D^2H increment at the nursery last year. In the plantations established from 2-year-old seedlings it was lower and reached 158.7% of the increment at the nursery last year. During the second vegetation period the D^2H increment considerably exceeded the increment at the nursery last year. In the plantations which had been established from 1-year-old seedlings it was 18.1 cm^3 and made up even 7541.6% of the increment at the nursery. In the plantations established from 2-year old seedlings an increase in the D^2H increment was not so distinct. During the vegetation season it reached 22.2 cm^3 or constituted respectively 655.4% of the increment at the nursery. After two vegetation seasons the highest D^2H was achieved in the plantations that had been established from 2-year old seedlings and reached 30.9 cm^3. In the plantations established from 1-year-old seedlings D^2H reached 19.5 cm^3. The lowest D^2H value after two growth periods was in the plantations that had been established by sowing and reached 0.7 cm^3.

The minutest transplanting stress when establishing forest plantations appears when planting 1-year-old seedlings at the bottom of the furrow. The plantations established from 2-year-old seedlings develop slower during the first 2 vegetation seasons. After 2 vegetation seasons, the biometrical characters of the plantations that had been established from 1 and 2-year-old seedlings differred slightly.

The plantations established by sowing and naturally regenerated plantations by their development lag behind the plantations that were established the same year by planting in a period of approximately 2 years and 3 years, respectively. However, the success of natural regeneration depends on seed bearing of seed source. Therefore, the plantations might regenerate naturally the same year or this process might take place several years.

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РАЗВИТИЕ ЛЕСНЫХ КУЛЬТУР СОСНЫ ОБЫКНОВЕННОЙ (*PINUS SYLVESTRIS* L.) В НАЧАЛЬНОЙ СТАДИИ РОСТА

В. Сухоцкас

Резюме

Было исследовано развитие лесных культур сосны (*Pinus sylvestris L.*), созданных посадкой, посевом и методом естественного лесовозобновления в первые 2 года их роста. В результате исследований установленно, что лесные культуры сосны, созданные посадкой применяя 1-летние и 2-х летние сеянцы, развиваются почти одинакого. Лучше всех приживаемость и рост культур сосны в первые 2 года были получены при создании их в иллювиальном горизонте почвы.

Развитие культур сосны, созданных посевом, отстают от культур сосны, созданных посадкой, периодом времени, равным в 2 года. Развитие насаждений естественного возобновления отстают от лесных культур периодом времени равным в 3 года. Однако, в зависимости от плодоношения семенного источника, естественное лесовозобновление сосны может быть успешно уже в первом году.

Ключевые слова: генетический горизонт почвы, насаждения сосны, посадочный материал.