Germination Capacity of Seeds and Initial Development of Scots Pine (*Pinus sylvestris* L.) Seedlings in Various Soil Layers

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Abstract

Scots pine seed germination capacity in various genetic layers of the soil after sowing the stands and seedling growth at initial development stage of the plantations were discussed in this article. In different methods prepared soil at the same time also distinguished itself in a complex of different ecological conditions that had limiting to seed germination factor.

The most favourable germination was achieved by one-year old stratified seeds covered on furrow bottom. The highest Scots pine seed germination capacity was achieved at the humus horizon. The pine seed are not germinate when get into humus or illuvial horizons in hillocks. Differences in seedling development in various soil genetic horizons are not statistical significant. More intensive seedling development was observed in humus horizon as well as in litter mixed with humus and illuvial horizons.

Key words: soil genetic horizons, seeds, seed germination, sowing

Introduction

Forest regeneration in Lithuania starts from the last quarter of the 17th century. The sowing of pine cones in loosened soil was the only method of forest regeneration at that time. The first written papers concerning pine sowing in Lithuania reaches the year 1777. It was economic instruction for the estates of grand dukes (Lukinas 1968, Daujotas 1967).

In the period from 1861 to 1914 the area of artificially regenerated forest reaches 800 hectares. Almost half of the area was afforested by sowing of pine. After the clear-cut, the stamps were removed from the area, 2-3 years the area was used for agricultural purpose, and after that the pine seeds were sown (Lukinas 1984).

After World War I, when Lithuania regained independence, pine stands sowing started again in 1925, it was sown 672 hectares. The pine stands sowing starts increasing year in and year out, and in the year 1938 a total of 2,074 hectares of pine plantation was established by sowing. The pine plantation sowing was carried out manually on scarified soil spots (Daujotas 1967, Lukinas 1968).

After World War II pine stands sowing in Lithuania started from 1948. In 1951 pine plantations were sown on the area of 3,748 hectares. The survival of pine in the plantations ranged from 82 to 92 %. Pitch-sowing method was used, it means sowing of seeds on a small plot. This method enables to attain the same density and spacing of trees on a plot as planting seedlings or saplings. For sowing of 1 hectares 300-500 g of pine seeds were used (Lukinas 1968, Gradeckas 1968).

Later, the amount of pine plantation, established by sowing constantly decreased, and in 1968 a total of 84 hectares pine plantations were sown. From 1970 the establishment of pine plantations in Lithuania is carried out by planting of seedlings only (Lukinas 1968, Riepšas 2000). There are only few works of pine forest regeneration evaluation by sowing in Lithuania.

However, direct forest sowing is a universally acceptable forest regeneration method in places where there is no suitable seed source for natural regeneration, or where locality and soil assessment shows, that forest planting is hardly achievable, expensive or even impossible. This method may be applied regenerating forest both on small sites and in large areas. In Lithuania direct sowing may be an effective, fast and relatively cheap alternative for the regeneration of pine stands.

However, as well as other methods, sowing is an insufficiently secure method. If sowing is carried out in an unsuitable area or in a wrong period, in an inadequately prepared place, using low-quality, improperly prepared or too small amounts of seed, this method may fail to yield good results. Most of these drawbacks may be easily eliminated (Zobel and Talbert 1984, Leibundgut H. 1981).

To ensure sowing success, it is necessary to have high viability seeds, treat them before sowing. Storing of seeds may also influence sowing succes (Wiersum 1984).

The success of plantations established by sowing depends on properly chosen sowing place and time (Dengler 1990).

The most suitable time for pine sowing in Lithuania is spring, when the upper soil layer is moderately warm, however, still sufficiently moist. This time starts at the beginning of April (Skov 1996). The best sowing results are achieved following the first warm spring rain, in misty weather. Seeds sown at this time usually germinate in several weeks and until the beginning of summer, when the weather becomes dry and hot, they manage develop a sufficient root system (Smith 1986, Duryea 1991, Krussmann 1997).

Sowing in autumn is also possible, however it is not recommended, because due to an unstable weather repellents are washed from the surface of seeds, besides, lying on soil surface for a longer time they are exposed to various other dangers. Seedlings sprouting after autumn sowing are destroyed by birds and rodents in warm winters, when there is a lack of green vegetation. Besides, seedlings sprouting in a prepared soil suffer form winter frosts. (Leibundgut 1981, 1982).

This work aims to study germination capacity of pine seeds and initial development of seedlings in different genetic soil horizons, as well as the possibilities to change environmental conditions and their influence on plants by mechanical mineralization of soil surface and mixing of soil genetic horizons.

Material and methods

Germination capacity of pine seeds and the development of seedlings in different soil genetic horizons was studied on *vacciniosum* (Nb) and *vacciniosum-myrtillosum* (Lb) site types. The experimental plots were selected on clear-cut forest sites in Dubrava forest enterprise (lat. 54°52' N, long. 24°07'E, alt. 74m.). The pine seeds were sown in May 2003.

In these site types observation plots with 5 replications were prepared to study the germination capacity of pine seeds. Soil surface mineralization was done disclosing soil genetic horizons and manipulating them. In all these habitats seed germination was studied in the following soil genetic horizons:

a) forest litter;

b) humus horizon (litter was removed from soil surface);

c) illuvial horizon in the furrow slice (soil was prepared turning out illuvial horizon);

d) illuvial horizon on furrow bottom (soil was prepared in furrows);

e) in forest litter mixed with humus and illuvial horizon (soil was prepared with disc tillers);

In all variants on each plot at 100 pine seeds were sown with 5 replications. Seeds only of the last year crop were taken for testing, having separated empty seeds from full ones, so that their germination capacity could be close to 100%.

Studies focused on:

1) the influence of sowing on the germination of pine seeds and the development of seedlings.

2) the influence of the age of pine seeds on their germination and the development of seedlings.

3) the influence of stratification of pine seeds on their germination and the development of seedlings.

Studying the influence of insertion of seeds into the soil on their germination and development of seedlings, pine seeds in one trial variant in all soil genetic horizons were scattered on the soil surface, while in another – inserted into the soil. In all variants on each plot at 100 pine seeds were sown with 5 replications. Only seeds of the last year crop were used for the trials, having separated empty seeds from full ones.

Analogically was studied also the influence of the age of pine seeds on their germination and development of seedlings. The trial was established on Nb site using 1-year-old and 4-year-old pine seeds.

In seed-plots and nurseries prior to sowing coniferous seeds are specially treated seeking to increase their germination capacity and evenness (Skov 1996, Krussmann 1997). Presowing treatment of seeds may be carried out also regenerating stands by sowing. One of the more effective means to increase seed germination is additional stratification of pine seeds.

Seeking to study the influence of additional stratification on the generation capacity of pine seeds and development of seedlings, trials were established sowing seeds into a differently prepared soil, after having additionally stratified them for 2 and 4 weeks. The essence of additional stratification lies in the fact that seeds from long-term storage chamber (freezer) are withdrawn before sowing and kept for 1 week in room temperature premises. After a week the seeds are returned back to the freezer and stored in it for 2 or 4 weeks. This trial was conducted with 5 replications, sowing in each observation plot 100 seeds.

Ascertainment of the total number of sprouted seeds was done at the end of vegetation period. At the same time biometric parameters of pine seedlings were determined as well. Biometric parameters of seedlings were ascertained also at the end of the second vegetation period. The shoot height of seedlings was measured as the distance from the seedling top to the surface (accuracy 1 cm); the root collar diameter was measured (accuracy 0,1 mm) right above the root ball, using the digital sliding caliper.

The statistical analysis of data was conducted by the MS Excel program. The calculation of the significant of relationships between the results were made at the significance level $p < 0.05$.

Results and discussion

Influence of soil preparation and sowing method on the germination of pine seeds and biometric parameters of seedlings

Regenerating stands by sowing, seedlings, similarly to natural regeneration, develop from a seed. However, differently from natural regeneration, sowing allows to choose sowing place, to insert seed into the soil or apply special measures before sowing to induce germination capacity of seeds. Besides, regeneration stands by sowing do not require a natural source of seeds.

One of the most efficient ways to increase germinative capacity of the sown seed is their insertion into the soil. From the data presented in Table 1 it can be observed, that insertion of seeds into the soil increases their germinative capacity from 2 to 10 times. On Nb site type the highest germinative capacity of uncovered pine seeds was attained on illuvial horizon on the bottom of furrows. Here germinated 10% of the sown seeds. Having inserted seeds into the soil in the same sowing place, their germinative capacity augmented up to 36%. After inserting seeds into the soil in the humus layer, their germinative capacity increased from 5 to 36%. In forest litter mixed with humus and illuvial horizons, having covered seeds, their germinative capacity increased from 7 to 26%. The least germinative capacity of seeds was attained in the illuvial horizon on a hillock. However, even here, insertion of seeds into the soil increased their germinative capacity from 5 to 17%.

The greatest positive effect having covered pine seeds with soil was attained on Lb site. Having sown and covered pine seeds in the illuvial horizon, their germinative capacity increased from 10% to 72%. Insertion of seeds in the humus horizon of the same site raised their germinative capacity from 6% to 64%. On the hummock of illuvial horizon seed germinative capacity increased from 16 to 56 %. The weakest positive effect of seed insertion into the soil is observed in cultivated and leveled off soil (mixing litter with the humus and illuvial horizons). Here germinative capacity even of uncovered seeds reached 22%, while having inserted them into the soil, germinative capacity of seeds augmented up to 32%. Seeds occurring in a cultivated soil are in contact with surrounding soil particles by a larger surface, as compared to seeds, which occur on the surface of illuvial horizon. Thus, germinative capacity even of uncovered seeds here was the highest, while their insertion into the soil had the lowest positive effect.

Comparing biometric parameters of seedlings developed from covered and uncovered seeds (Table 2), it can be observed, that on Nb site type the diameter of pine seedlings nearly fails to react to seed insertion into the soil. Although absolute values of seedlings sprouted in different genetic soil horizons differ, however, the differences are not statistically reliable. On this site there are also no essential differences in diameters of the two-year-old seedlings, which have developed from covered and uncovered seeds. The height of pine seedlings in the first year also has almost no differences. However, in the second year the height of seedlings developed from covered seeds is greater than that of seedlings developed from uncovered seeds.

The greatest difference in height of the two-year-old seedlings is in the soil prepared by mixing forest litter with humus and illuvial horizons. Here the height of seedlings developed from uncovered seeds reached 8.5 cm, while that of seedlings developed from covered seeds already reached 12.5 cm. In the humus layer seedlings attained 8.7 cm and 11.9 cm, respectively. Less height differences were observed in the illuvial horizons: the height of seedling at the bottom of furrows in the illuvial layer comprised

Table 1. Germination of seeds inserted into the soil and uncovered, according soil scarification method

Soil scarification method	Seed germination %, according site types			
	Vacciniosum (Nb)		*Vacciniosum-myrtillosum* (Lb)	
	Uncovered seeds	Inserted seeds into the soil	Uncovered seeds	Inserted seeds into the soil
Illuvial horizon in the furrow slice	5	17	16	56
Illuvial horizon on furrow bottom	10	36	10	72
Humus horizont	5	36	6	64
In forest litter mixed with humus and illuvial horizon	7	26	22	32

Table 2. The development of pine seedlings by applying different soil scarification methods

Soil scarification method	Uncovered seeds					Seeds inserted into the soil				
	One-year old seedlings		Two- year old seedlings			One-year old seedlings		Two-year old seedlings		
	D, (mm)	H, (cm)	D, (mm)	H, (cm)	Zh, (cm)	D, (mm)	H, (cm)	D, (mm)	H, (cm)	Zh, (cm)
					Vacciniosum Nb					
Illuvial horizon in the furrow slice	1.05±0.11	4.5±0.44	2.5±0.5	6.5±0.9	2.75±0.7	1.15±0.14	4.41±0.41	2.17±0.17	7.17±0.91	2.17±0.4
Illuvial horizon on furrow bottom	1.58±0.16*	6.3±0.52*	3.5±0.34*	9.5±1.6*	4.33±0.91*	1.49±0.22*	5.02±0.55	3.11±0.21*	11.14±0.92*	5.43±0.61*
In forest litter mixed with humus and illuvial horizon	1.21±0.09	3.9±0.28	3.16±0.5	8.5±1.8*	4.8±1.3*	1.37±0.16*	5.0±0.22	4.0±0.28*	12.46±1.19*	5.08±0.9
Humus horizont	0.9±0.08	4.0±0.31	2.33±0.3	8.7±3.1*	4.67±2.6*	1.26±0.21	5.3±0.34*	3.06±0.28	11.88±0.91*	5.0±0.65
					Vacciniosum-myrtillosum Lb					
Illuvial horizon in the furrow slice	1±0.1	3.07±0.18	3±0.92	10.3±1.1	7.7±0.8	1.02±0.09	3.22±0.22	3.19±0.16	13.0±0.78	9.11±0.73
Illuvial horizon on furrow bottom	1±0.08	3.38±0.14	3±0.88	15±2.6*	10.5±2.5*	1.1±0.08	2.85±0.23	3.53±0.34	12.59±1.1	9.12±0.95
In forest litter mixed with humus and illuvial horizon						1.0±0.09	3.38±0.26	3.59±0.24	14.06±0.81	10.29±0.71*
Humus horizont	1±0.09	3.32±0.14	3±0.25	14.5±2.5*	9±2.0	1.0±0.11	3.11±0.16	3.04±0.19	11.83±0.8*	8.3±0.75

*) Differences statistically significant, significance level p <0,05

9.5 cm and 11.1 cm respectively, while on a hummock 6.5 and 7.7 cm.

On Lb site type the influence of seed insertion into the soil on biometric parameters of sprouted pine seedlings is controversial. The insertion of seeds into the soil has no influence on biometric parameters of the one-year-old seedlings and on the diameter of the two-year-old seedlings. Meanwhile, maximum height of the two-year-old seedlings was attained on a hummock in the illuvial horizon having covered seeds with soil, while at the bottom of furrows in the illuvial horizon and in the humus layer – on the contrary, higher seedlings developed from uncovered seeds.

Little effective was the insertion of seeds into the soil on the height increment (Zh) of pine seedlings during 2nd growing period. The statistically significant differences in the height increment were observed among pine seedlings, growing in different soil horizons only. Comparing height increment of pine seedlings during 2nd growing period developed from covered and uncovered seeds on the same soil horizons, it can be observed, that absolute values has no essential differences (the differences are not statistically reliable).

The greatest height increment of the two-year-old seedlings is in the soil prepared by mixing forest litter with humus and illuvial horizons, and in the illuvial horizons on furrow bottom. Here the height increment of seedlings developed from uncovered seeds in illuvial horizons on furrow bottom reached 10.5 cm. Seedlings developed from covered seeds in the soil prepared by mixing forest litter with humus and illuvial horizons already reached 10.3 cm.

The influence of additional stratification of pine seedlings on their germinative capacity and the development of seedlings.

Additional stratification of seeds has positive influence on pine seed germinative ability (Table 3). Stratified seeds germinate better in all soil genetic horizons. The most observable influence of stratification is on seeds sown on the bottom of furrows. Here their germinative ability increased from 30% (unstratified seeds) to 49% (stratified for 2 weeks) and up to 56 % (stratified for 4 weeks). Positive influence of stratification was observed also on seeds sown into the soil, prepared by mixing forest litter with humus and illuvial horizons. Here seed germinative capacity augmented from 24% to 32% and 43%, respectively. Stratification improves also the germinative capacity of seeds sown into humus horizon. Here it increased from 26% to 30 and 32%, respectively. Seeds stratified for 2 weeks before sowing also germinated better sown on a hummock in the illuvial horizon. Here their germination augmented from 17% to 31%. However, germinative capacity of seeds stratified for 4 weeks on the hummock in the illuvial horizon remained the same as that of unstratified ones.

Although stratification of seeds before sowing has undoubtedly a positive effect on their germinative capacity, however, no essential influence on further development of seedlings was observed. The results of biometric parameters presented in table show, that there exist differences between separate trial variants. However, it is difficult to determine development tendency of seedlings based on the obtained results. Biometric parameters of the one-year-old seedlings practically fail to differ (the differences are not statistically reliable). Among the two-year-old seedlings greater differences were observed only in the height of seedlings, however, this most probably was more influenced by the soil genetic horizon rather than pre-sowing seed stratification.

Table 3. The influence of additional stratification of pine seeds on their germinative capacity and the development of seedlings on *vacciniosum* (Nb) site type according to soil scarification method

Soil scarification method	Seed germination %	1year old seedlings		2 year old seedlings		
		D, (mm)	H, (cm)	D, (mm)	H, (cm)	Zh, (cm)
Unstratified seeds						
Illuvial horizon in the furrow slice	17	1.15±0.14	4.41±0.41	2.17±0.17	7.17±0.91	2.17±0.4
Illuvial horizon on furrow bottom	30	1.49±0.22	5.02±0.55	3.11±0.21	11.14±0.92	5.43±0.61
In forest litter mixed with humus and illuvial horizon	24	1.37±0.16	5.0±0.22	4.0±0.28	12.46±1.19	5.08±0.9
Humus horizont	26	1.26±0.21	5.3±0.34	3.06±0.28	11.88±0.91	5.0±0.65
Seeds stratified for 2 weeks						
Illuvial horizon in the furrow slice	31	1.28±0.31	5.2±0.42	2.5±0.2	11.25±1.0	7.56±0.8
Illuvial horizon on furrow bottom	49	1.56±0.45	4.8±0.2	2.96±0.13	11.57±0.62	7.67±0.62
In forest litter mixed with humus and illuvial horizon	32	1.21±0.16	4.3±0.08	2.0±0.24	8.44±0.99	4.37±0.51
Humus horizont	32	1.75±0.45	5.7±0.92	3.35±0.25	12.43±1.22	7.65±0.88
Seeds stratified for 4 weeks						
Illuvial horizon in the furrow slice	17	0.94±0.38	4.1±0.94	2.0±0.1	9.0±0.89	6.2±0.77
Illuvial horizon on furrow bottom	56	1.33±0.12	4.9±0.33	2.45±0.1	9.45±0.39	6.34±0.52
In forest litter mixed with humus and illuvial horizon	43	1.61±0.18	5.5±0.22	3.02±0.18	11.43±0.75	7.57±0.31
Humus horizont	30	1.67±0.42	6.5±0.21	3.4±0.26	12.68±0.96	8.32±0.4

Influence of the age of pine seeds on their germinative capacity and seedling development.

Extracted coniferous seeds until sowing are usually stored in chambers of controlled climate and remain viable for a long time. However, seeds stored even in such conditions inevitably undergo biochemical processes, which influence seed viability and later development of sprouted seedlings.

Seeking to ascertain the influence of the age of seeds on their germinative capacity and development of seedlings, in different soil genetic horizons the one- and four-year-old pine seeds were on Nb site. The obtained results (Table 4) show, that the age of seeds is an essential factor limiting their germinative ability and development of seedlings. In all soil preparation variants (soil genetic horizons) far better was germinative capacity of the one-year-old seeds. The greatest difference in seed germination was obtained having sown seeds on a hummock in the illuvial horizon. Here germinative capacity of the one-year-old seeds comprised 17%, meanwhile germinative capacity of the four-year-old seeds comprised only 2%. At the bottom of furrows on illuvial horizon germinated 36% of fresh seeds, while only 14% of the four-year-old ones. In the humus horizon germinated 36% and 10% of the seeds, respectively. The one-year-old seeds germinated better also sown into soil, mixing forest litter with the illuvial and humus horizons. Here germinated 26% of the seeds, while the germinative capacity of the four-year-old seeds in the same conditions comprised only 7%.

From the data presented in the table it can be observed, that the age of seeds influences not only their germinative capacity, but also further development of seedlings. The differences of biometric parameters become clear already among the one-year-old

Table 4. Influence of the age of pine seeds on their germinative capacity and seedling development on *vacciniosum* (Nb) site type according to soil scarification method

Soil scarification method	Seed germination %	1year old seedlings		2 year old seedlings		
		D, (mm)	H, (cm)	D, (mm)	H, (cm)	Zh, (cm)
One-year-old seeds						
Illuvial horizon in the furrow slice	17	1.15±0.14	4.41±0.41	2.17±0.17	7.17±0.91	2.17±0.4
Illuvial horizon on furrow bottom	36	1.49±0.22	5.02±0.55	3.11±0.21	11.14±0.92*	5.43±0.61*
In forest litter mixed with humus and illuvial horizon	26	1.37±0.16	5.0±0.22	4.0±0.28*	12.46±1.19*	5.08±0.9*
Humus horizont	36	1.26±0.21	5.3±0.34	3.06±0.28	11.88±0.91*	5.0±0.65*
Four-year-old seeds						
Illuvial horizon in the furrow slice	2	1.05±0.14	3.8±0.52	2.17±0.28	6.0±1.01	3.3±0.52
Illuvial horizon on furrow bottom	14	1.33±0.22*	4.3±0.44	2.65±0.42	9.12±0.95*	5.2±0.47*
In forest litter mixed with humus and illuvial horizon	7	1.07±0.19	3.7±0.37	2.33±0.37	7.78±0.78	4.1±0.66
Humus horizont	10	0.75±0.08	2.8±0.17	2.23±0.55	8.24±0.65*	4.0±0.71

*) Differences statistically significant, significance level p <0,05

seedlings. In all soil genetic horizons (soil preparation variants) the one-year-old seedlings, sprouted from the one-year-old seeds, were larger than seedlings sprouted from the four-year-old seeds. The greatest difference was observed among seedlings growing on humus soil. Differences in the development of seedlings remain in the second year as well. In all soil preparation variants the diameter and height of the two-year-old seedlings, developed from the one-year-old seeds, considerably exceed those of seedlings developed from four-year-old seeds.

Regenerating stands by sowing, in the area to be regenerated it is impossible to regulate the principal limiting seed germination factors, *i.e.* moisture and temperature. The soil moisture content and temperature may be regulated in nurseries. Therefore, seeds stored for a longer time in freezers should be, first of all, sown in seed-plots, while for forest sowing possibly younger seeds should be used.

Conclusions

1. The highest Scots pine seed germination capacity was achieved at the humus horizon on furrow bottom. The pine seed are not germinate when get into the humus or illuvial horizons on the hillocks.

2. Insertion of pine seeds into the soil increased their germinative capacity from 2 to 10 times. The greatest positive effect having covered pine seeds with soil was attained on *Vacciniosum-myrtillosum* site.

3. Differences in seedling development in various soil genetic horizons are not statistically significant. More intensive seedling development was observed in the humus horizon as well as in the litter mixed with humus and illuvial horizons.

4. Additional stratification of the seeds has positive influence on pine seed germinative ability however, no essential influence on further development of the seedlings was observed.

Age of seeds is an essential factor limiting their germinative ability and development of seedlings.

5. In all soil preparation variants (soil genetic horizons) far better was germinative capacity of the one-year-old seeds.

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ВСХОЖЕСТЬ СЕМЯН И РАЗВИТИЕ СЕЯНЦЕВ СОСНЫ (*PINUS SYLVESTRIS L.*) НА НАЧАЛЬНОМ ЭТАПЕ НА РАЗЛИЧНЫХ ПОЧВЕННЫХ СЛОЯХ

В. Сухоцкас

Резюме

Целью данного исследования явилось изучение всхожести семян сосны обыкновенной и роста сеянцев в посевах на различных генетичестких горизонтах почвы в первые 2 года их развития.

При подготовке почвы, в зависимости от применяемого способа, одновременно создаются различные экологичесткие условия, имеющие непосредственное влияние на всхожесть семян сосны.

Самая высокая всхожесть семян сосны оказалась при высеве свежесобранных стратифицырованных семян в борозде, покрытых слоем почвы. Самая большая всхожесть семян сосны наблюдалась в гумусовом горизонте почвы. Семена сосны, высеянные на гумусовый или иллювиальный горизонты на пластах, первый год вовсе недали всходов. Разницы в развитии сеянцев сосны на начальном этапе на различных генетичестких горизонтах почвы являются не существенными. Более интенсивно сосна развивается на гумусовом горизонте, а также на лесной подстилке, перемешанной с гумусовым и иллювиальным горизонтами.

Ключевые слова: генетичесткий горизонт почвы, семена, всхожесть семян, посев