Pinus sylvestris L. East European populations: growth and behaviour in one Lithuanian field trial

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In 1975 there was a series of Scots pine provenance trials established in the European part of the former Soviet Union following the unified methods drawn up by Prokazin. The provenance test plantation in this study is a part of it. Forty four geographically distant populations were used for establishment.

In this study only superior trees (modified Kraft classes 1, 2 and 1+2) were used for analyses. The results show no clear genetic differentiation of populations, except for diameter. There was a pronounced latitudinal transfer effect, but sometimes longitudinal transfer had some impact on growth trait as well. Populations of northern origin always have inferior growth compared to southern regions.

An attempt was made to evaluate individual geographic regions by the use of breeding indices. However, due to low significance's, no superior seed source could be recommended for further research. The unreplicated trial establishment design is the major reason for this. Therefore, it was not recommended to proceed with any further investigation activities in trials with such a design.

Key words: *Pinus sylvestris*, population, provenance trial, region, transfer effect.

Introduction

There are many reports indicating that the local population is rarely the best performing one. This is particularly pronounced under Scandinavian conditions (Eiche 1966, Persson and Persson 1992). Also for north American tree species, conifers as well as hardwoods, the same results were obtained (Wells and Lambeth 1983, Jonsson and Eriksson 1989).

In tree species from the temperate zone, growth cessation at the end of the growth period is mostly triggered by the night length. The first report on this phenomenon was given half a century ago by Sylvén (1940). This triggering means that transfers from south to north cause a later growth cessation than at the site of origin. This in turn means that plants get a longer growth period, and as consequence of this become taller. A good illustration of this was given by Velling (1979) for *Betula pendula* for which height growth was a reflected image of autumn coloring during the autumn, the smaller the trees, the more advanced autumn leaf coloring. The positive effect on growth of populations transferred northwards will disappear if the growth cessation takes place so late that plants are damaged by autumn frosts. Thus, there is a trade off between a long growth period and the risk for frost damage.

Another phenomenon that also must be considered for plantation forestry is that the adaptation that may have taken place in a population to its growth conditions may be inoptimal under artificial regeneration conditions. Thus, Eriksson and Lundkvist (1986) discussed the difference between Darwinian fitness and domestic fitness. The former is the ability of a genetic entry to transfer its genes to the next generation while domestic fitness is the ability of a genetic entry to produce utilities for man. Generally, the more different the artificial reforestation conditions are from those at self regeneration the higher the probability that Darwinian and domestic fitness differ (Eriksson and Lundkvist 1986).

Since Lithuania shares many climatic features with southern Scandinavia it is probable that local populations in plantation forestry are not necessarily the best for production. Thus, the provenance test plantations of the Prokazin series in Lithuania are useful to study whether or not some transferred populations are superior to the local population.

During the second world war Lithuanian forests suffered significantly, causing an urgent need for reforestation of a large area. The lack of good local seed sources called for establishment of new provenance trials to identify good populations for Lithuania. This was one of the reasons for establishment of *Pinus sylvestris* provenance trials in Lithuania in 1960. Unfortunately, this series of trials does not contain any Lithuanian populations. Moreover, a row-tree-plot design was used which will exaggerate differences among populations owing to competition among rows (populations). Therefore, another trial was established in 1961 containing both Lithuanian and foreign populations with a multitree plot design. As a remedy to this, the Prokazin series of provenance trials was planted in the mid 1970s.

The purpose of this study is to identify the best regions for cultivation at comparable site conditions to the ones at the Venta test plantation. An understanding of the evolutionary reasons for the results is also a goal.

Material and methods

The Venta test plantation (lat. $56^{0}11'$, long. $22^{o}35'$) contains 41 populations of eastern European origin (Fig. 1, Table 1). The seed was collected in natural stands of higher productivity than the mean in their respective area. The seed was sown outdoors in the Plunge nursery in 1974 (Barniškis 1980). The trial was established in 1975 by 1+0 year old seedlings with a spacing of 1.5x1.5 m, i.e. 4400 seedlings per hectare. In 1976 dead plants were substituted by 2+0 year seedlings. According to the classification system of sites applied in Lithuania, the Venta site is designated as Nc, which means that it is a good site for *Picea abies*.

This test plantation belongs to a series of test plantations distributed all over the European part of the former Soviet Union. According to the requirements of the methods drawn up by Prokazin for the whole territory of the former Soviet Union, the test plantations consist of large and varying numbers of trees per plot without any replications. To allow a statistical evaluation of the data from this test plantation, populations had to be grouped into regions (Table 1), the latter was the unit in the ANOVAs.

The traits assessed are given in Table 2. Except for tree height, all trees growing in the center part of a plot, excluding two edge rows, were assessed to avoid possible errors due to different light intensity and any other interfering biological factors from neighboring populations. For labor reasons, measurement of tree height was limited to 8-12 trees/plot. The trees were classified into five classes, slightly modified from the classification by Kraft (1884). Class 1 is constituted by dominant trees usually making up the main part of a stand and class 2 means ordinary trees, having relatively well developed crowns. Classes 3-5 include trees of various degrees of suppression. Separate statistical calculations for classes 1, 2 and 1+2 were used for different growth traits.

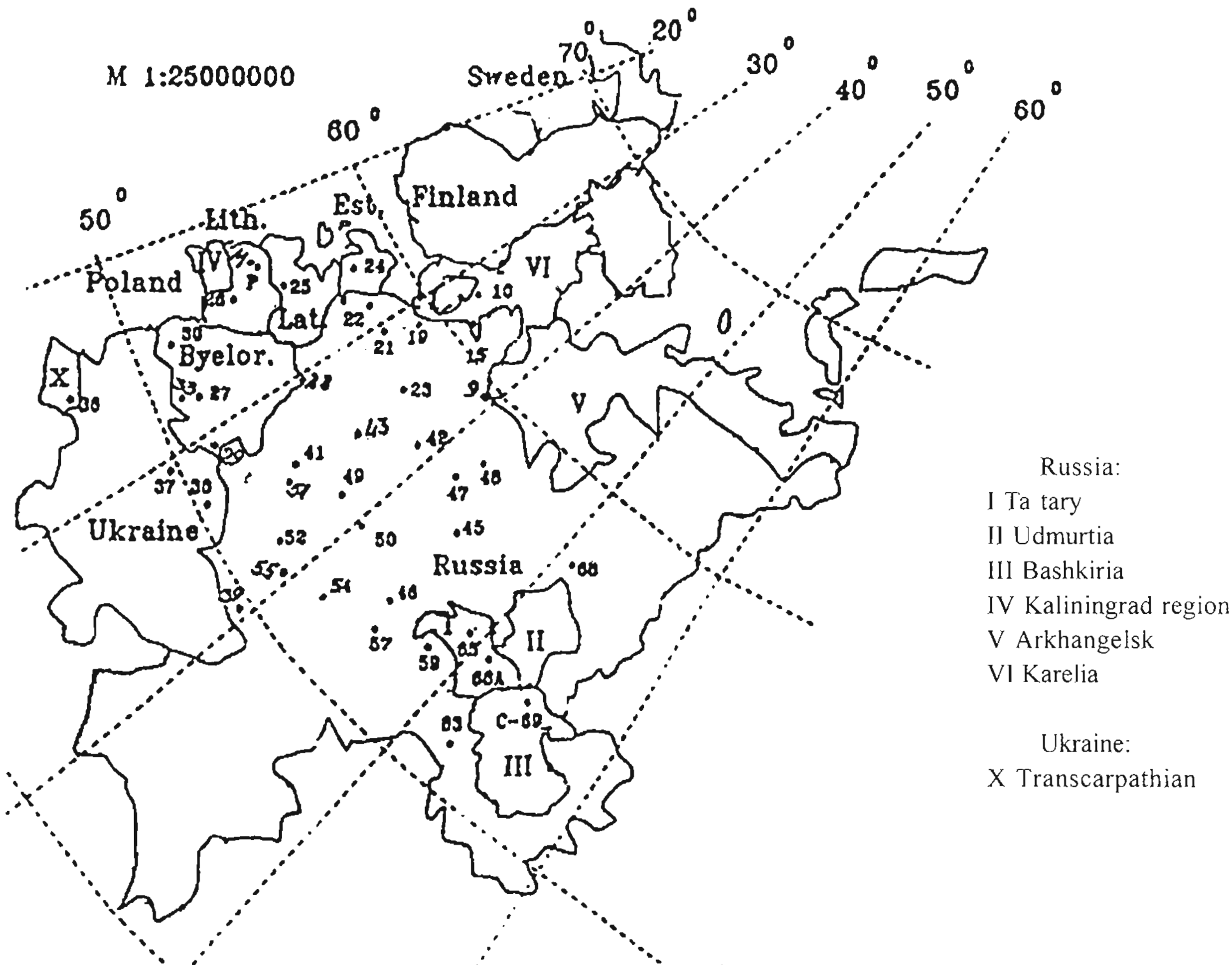

Fig. 1. Map of origin of populations tested.

Table 1. Populations studied

Region	Population	N lat.	E long.	Region	Population	N lat.	E long.
1	15 Karelia, Russsia	61°40'	33°40'	11	50 Ryazan, Russia	54°40'	39°45'
1	16 Karelia, Russia	61°50'	30°28'	11	51 Bryansk, Russia	53°20'	34°15'
2	19 S.-Petersburg, Russia	60°00'	30°25'	12	29 Gomel, Byelorussia	52°14'	31°43'
2	21 Pskov, Russia	57°43'	30°31'	12	37 Kiev, Ukraine	50°50'	31°20'
2	22 Pskov, Russia	57°50'	28°26'	12	38 Sumsk, Ukraine	52°01'	34°01'
3	24 Elvassk, Estonia	58°10'	26°28'	13	39 Cerkasiy, Russia	49°27'	39°03'
4	25 Jaunjelgava, Latvia	56°42'	25°10'	13	52 Orlov, Russia	52°50'	36°00'
5	10 Plungė, Lithuania	56°18'	22°13'	13	55 Voronez, Russia	51°50'	39°20'
5	20 Mažeikiai, Lithuania	57°15'	22°40'	14	45 Nizniy Novgorod, Russia	56°40'	43°28'
5	26 Prienai, Lithuania	54°38'	23°58'	14	47 Kostroma, Russia	58°00'	40°50'
6	28 Vitebsk, Byelorussia	55°25'	30°20'	14	48 Kostroma, Russia	59°00'	41°00'
7	27 Mogiliov, Byelorussia	53°18'	28°40'	15	46 Nizniy Novgorod, Russia	54°56'	43°50'
7	30 Gardin, Byelorussia	53°25'	25°15'	15	54 Tambov, Russia	53°12'	41°20'
7	33 Rovno, Byelorussia	51°30'	27°40'	15	57 Penza, Russia	53°50'	46°00'
8	36 Transcarpathian, Ukraine	48°07'	24°30'	16	59 Ulyanovsk, Russia	54°14'	49°35'
9	9 Vologda, Russia	59°15'	39°30'	16	65 Tartary, Russia	55°50'	48°09'
10	23 Novgorod, Russia	58°15'	33°28'	16	66 Tartary, Russia	55°40'	51°26'
10	42 Kalinin, Russia	57°45'	36°40'	17	69 Baskiria, Russia	55°30'	54°40'
10	43 Moscow, Russia	55°40'	37°10'	18	83 Orienburg, Russia	52°47'	52°15'
11	41 Smolensk, Russia	54°00'	33°00'	19	68 Kirov, Russia	58°49'	50°06'
11	49 Kaluga, Russia	54°25'	36°16'				

Table 2. Traits evaluated

Trait	Evaluation unit	Description
D	cm	Breast height diameter over bark.
H	m	Height above ground estimated for a certain number of trees differentiated by diameter.
K	m	Height from ground to first living branch.
V	dm^3	Stem volume above ground over bark.
Straightness	points 2 – very crooked 3 – crooked 4- straight	Stem straightness, evaluated visually.
Tree status	points 1 – vital 2 – injured 3 – suppressed 4 – dead	Visually evaluated tree status.
Branch angle	points 1 – very acute 2 – acute 3 – right	Angle of branchiness, evaluated visually at the 5-th whorl from ground surface.

We studied if there was any relationship among mean area available for a tree within a block and number of dominating trees (class 1) in that block. No clear trend was observed.

To identify the populations most suitable for Lithuanian site conditions, the method of breeding indices was suggested by Danusevičius (1987). Calculations were carried out according to the following formula:

$$t_i = \frac{x_i - x}{s} a \qquad (1)$$

where: t_i - breeding index, x_i - population mean value of a certain trait, x - overall mean of the same trait, s - standard deviation, a - economic value of the trait.

Since the provenance test experiment is of scientific value but not of commercial one, the economic factor was not included into calculations, i.e. a=1.

In all previous studies (Barniškis 1980, Stalerūnas 1992, Abraitis 1994), the populations were evaluated according to the sum of indices of all the traits studied. In our case, four separate indices were calculated for each population with 4 traits that were considered to be of greatest importance (Table 3). Moreover, they were assumed to be independent of each other. Stem volume was used as growth trait while tree status, branch angle, and stem straightness were used as quality traits. The weighing of the traits in the index is illustrated in Table 3.

Table 3. Percentage weights given to the traits for breeding indices

Trait	Index			
	1	2	3	4
Stem volume	100	50	25	0
Stem straightness	0	16.7	25	33.3
Branch angle	0	16.7	25	33.3
Tree status	0	16.7	25	33.3

Stem volume was calculated according to Brandel (1990) by use of the equation:

$$V=0.17144 \cdot D^{1.87368} \cdot (D+20.0)^{0.01317} \cdot H^{1.99652} \cdot (H-1.3)^{-1.02070} \cdot K^{0.02882} \qquad (2)$$

where: *D*, *H*, *K* – are explained in Table 2.

This function is valid only when height above ground is >1.3 m.

The statistical calculations evaluating the effect of transfer on separate traits were estimated by stepwise regressions as indicated below:

$$y_{ij} = \mu + b_1 Lat_i + b_2 Long_i + b_3 Lat_i^2 + b_4 Lat*Long_{ij} + b_5 Long_i^2 + e_{ij} \quad (3)$$

where: y_{ij} is the observed mean of population i, μ is the overall mean, Lat_i, $Long_i$, Lat_i^2, $(Lat*Long)_{ij}$, $Long_i^2$ are the latitude, longitude, latitude square, joint latitude-longitude product and longitude square, respectively and e_{ij} is the error term.

The following ANOVA model was used for the original data:

$$y_{ijk} = \mu + r_i + p_{i(j)} + e_{ijk} \quad (4)$$

Where: μ - overall mean, r_i - regional effect, $p_{i(j)}$ - replicational (population) effect, e_{ijk} - error within population.

In both models the data for individual populations and for geographical regions were analyzed. All the traits of the superior trees (class 1, 2 and 1+2) only were used as dependent variables, since suppressed trees are not representative of the population.

To obtain a more detailed information on the impact of longitudinal transfer, a separate stepwise regression (the same slightly modified model) was carried out for latitudes 53^0-56^0, for which a good coverage of populations at different longitudes was available.

SAS procedures REG, GLM and VARCOMP were used in calculations. Relative components of variance were obtained after using the SAS package and standard errors were found by series expansions following the delta technique (Bulmer 1980).

Results

From Table 4 it is evident that the genetic differentiation with respect to quality traits is absent in this experiment. Even if the growth traits showed much larger genetic determination the precision in the estimates is low with the exception for breast height diameter.

Table 4. Percentage variance components of region effect ± standard error for three growth traits and three quality traits for provenance regions with separate estimates for the modified Kraft classes 1, 2 and 1+2 (cf. Methods)

Trait	Class		
	1	2	1+2
Height	9.5 ± 10.7	19.1 ± 24.1	19.4 ± 10.2
DBH	16.5 ± 5.8	12.9 ± 5.7	12.0 ± 4.6
Stem volume	9.5 ± 5.2	5.6 ± 9.9	2.7 ± 2.8
Stem straightness	2.1 ± 1.3	1.9 ± 1.4	2.0 ± 1.2
Branch angle	1.5 ± 1.7	0.8 ± 1.4	0.8 ± 1.2
Tree status	0	0	0

Only transfer effects with $R^2 > 0.50$ are graphically illustrated (Figs. 2-3). These figures reveal that there is a latitudinal transfer effect, sometimes accompanied by an effect of longitudinal transfer. Populations of northern origin always have inferior growth compared to southern regions.

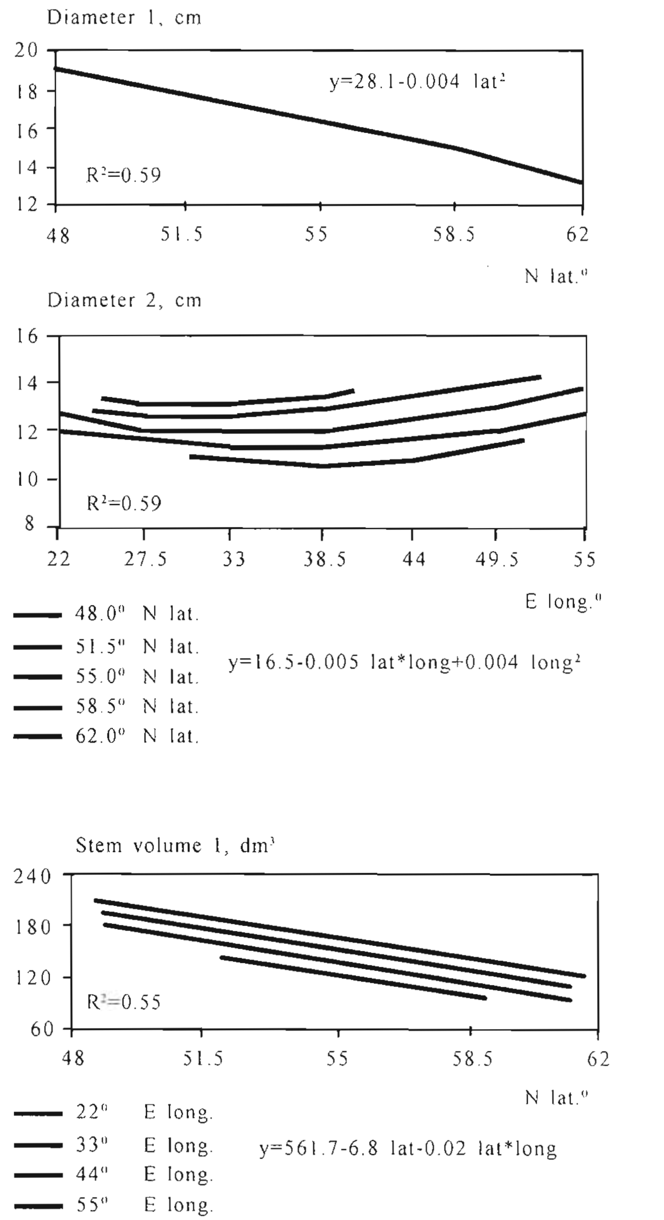

Fig. 2. Influence of geographical transfer on growth traits when geographical regions are compared.

After calculating breeding indices the following five populations could be selected with the objective that gain in quality could be obtained without any losses in growth (cf. Table 5): 83 Orienburg Rus., 24 Elvassk Est., 22 Pskov Rus., 54 Tambov Rus., 55 Voronez Rus. Four of them (except Pskov) enter exactly the same lists of the "best" 10 regions for all indices except index 2 and almost in the same order (Table 5).

Table 5. Lists of 10 superior populations for four indices comprising one growth and three quality traits (cf. Table 3)

Index			
1	2	3	4
10 Plungė, Lithuania	10 Plungė, Lithuania	10 Plungė, Lithuania	48 Kostroma, Russia
39 Cierkasiy, Russia	39 Cierkasiy, Russia	27 Mogilyov, Byelorussia	57 Penza, Russia
27 Mogilyov, Byelorussia	38 Sumsk, Ukraine	83 Orienburg, Russia	9 Vologda, Russia
36 Transcarpathian, Ukraine	27 Mogilyov, Byelorussia	24 Elvassk, Estonia	83 Orienburg, Russia
38 Sumsk, Ukraine	37 Kiev, Ukraine	54 Tambov, Russia	24 Elvassk, Estonia
83 Orienburg, Russia	36 Transcarpathian, Ukraine	55 Voronez, Russia	22 Pskov, Russia
24 Elvassk, Estonia	29 Gomel, Byelorussia	25 Jaunjelgava, Latvia	55 Voronez, Russia
54 Tambov, Russia	30 Gardin, Byelorussia	22 Pskov, Russia	54 Tambov, Russia
29 Gomel, Byelorussia	43 Moscow, Russia	51 Bryansk, Russia	25 Jaunjelgava, Latvia
55 Voronez, Russia	49 Kaluga, Russia	43 Moscow, Russia	27 Mogilyov, Byelorussia

To allow comparisons with data from other trials, the relative performance of each population to the local population Mažeikiai is given in Table 6. Higher percentages indicate better performance of the population concerned compared to the local one. However, it must be remembered that these figures are based on unreplicated material.

Discussion and conclusions

The only way to carry out a statistical analysis of the material from this test plantation was to group the populations into different regions. To avoid regions that were too large this grouping resulted in low number of replications.

Table 6. Relative performance (%) in quality and growth of the populations studied in comparison to the local population of Mažeikiai, for which observed data are given

Population	DBH	Height	Stem volume	Height to first living branch	Stem straightness	Branch angle
15 Karelia, Russia	74.6	89.1	75.4	83.9	107.4	90.3
16 Karelia, Russia	77.1	90.5	83.1	93.2	108.7	84.5
19 S.-Petersburg, Russia	82.5	98.1	77.9	122.6	101.3	112.7
21 Pskov, Russia	88.9	100.4	104.8	122.6	101.5	99.9
22 Pskov, Russia	84.2	93.6	97.9	114.6	103.6	109.5
24 Elvassk, Estonia	91.8	99.9	107.2	113.7	104.0	106.6
25 Jaunjelgava, Latvia	86.0	103.0	94.8	111.3	101.9	110.6
10 Plungė, Lithuania	88.9	101.0	97.9	102.1	102.0	105.5
26 Prienai, Lithuania	87.1	94.6	97.3	92.0	104.2	100.0
28 Vitebsk, Byelorussia	92.2	96.7	114.1	119.9	102.4	99.2
27 Mogilyov, Byelorussia	90.9	118.6	128.7	134.2	104.7	113.1
30 Gardin, Byelorussia	101.6	114.5	128.5	120.8	98.9	97.9
33 Rovno, Byelorussia	102.2	102.0	96.2	88.1	99.7	100.2
36 Transcarpathian, Ukraine	99.1	117.0	114.0	111.3	97.7	107.5
9 Vologda, Russia	78.0	83.0	70.4	81.6	102.5	105.0
23 Novgorod, Russia	83.6	100.9	80.5	116.7	104.5	101.7
42 Kalinin, Russia	81.4	89.1	79.4	107.7	100.0	109.4
43 Moscow, Russia	87.9	97.7	111.0	106.3	102.1	101.1
41 Smolensk, Russia	102.5	95.7	89.7	90.5	99.6	106.6
49 Kaluga, Russia	101.6	101.8	111.2	113.7	97.0	107.4
50 Ryazan, Russia	93.3	88.2	97.3	103.3	99.9	103.8
51 Bryansk, Russia	93.3	96.5	92.4	109.8	102.3	103.5
29 Gomel, Byelorussia	94.9	101.7	111.7	122.9	99.5	112.7
37 Kiev, Ukraine	117.8	89.6	118.3	62.2	97.5	104.3
38 Sumsk, Ukraine	138.3	104.1	183.1	91.1	93.9	99.0
39 Cerkasiy, Russia	130.1	84.5	150.1	45.5	93.8	116.1
52 Orlov, Russia	110.0	96.3	113.7	90.5	100.2	94.1
55 Voronez, Russia	131.2	90.9	132.1	48.2	98.7	115.7
45 Nizniy Novgorod, Russia	82.9	94.0	81.7	108.0	101.8	98.0
47 Kostroma, Russia	79.6	98.8	85.0	111.3	102.3	111.4
48 Kostroma, Russia	83.2	95.0	74.6	106.9	107.2	113.4
46 Nizniy Novgorod, Russia	95.7	99.1	103.9	106.9	99.8	93.3
54 Tambov, Russia	105.0	92.0	97.6	92.0	99.6	111.6
57 Penza, Russia	95.8	79.2	80.8	71.1	102.7	108.5
59 Ulyanovsk, Russia	93.6	98.3	99.8	100.3	101.4	102.0

Table 6. Continued

Population	DBH	Height	Stem volume	Height to first living branch	Stem straightness	Branch angle
65 Tartary, Russia	97.4	110.7	120.1	104.8	100.3	89.0
66 Tartary, Russia	93.5	90.8	107.5	80.1	103.3	93.8
69 Baskiria, Russia	92.2	84.4	83.1	88.7	101.8	98.0
83 Orienburg, Russia	105.3	99.4	131.8	78.9	101.9	104.4
68 Kirov, Russia	82.9	83.2	85.7	63.4	104.2	97.6
20 Mažeikiai, Lithuania	**14.2 cm**	**10.6 m**	**99.6 dm³**	**3.4 m**	**3.27 points**	**2.13 points**

The low number of replications is probably responsible for the low precision in the estimates of variance components (Table 4). An alternative explanation would be that populations within region differ significantly. This was especially pronounced for the quality traits.

One of the most comparable provenance trials of *Pinus sylvestris* is the series analyzed by Johnsson (1971). He reported percentage variance components for height, stem volume, and volume per hectare in the range of 60-70%. These strong population effects were obtained in spite of a limited latitudinal range of the populations (56°-59°). A superior growth performance of populations of southern origin is also evident from a map presented by Giertych (1991, Fig. 6.1). The data in these publications support our suggestion that the low number of replications is responsible for the low differentiation of populations.

It is worth stressing that the variance component with the highest precision, breast height diameter, did not vary much between the three modified Kraft classes, 1, 2 or 1+2. If such a classification should be used in other trials in future a pooling of the trees from classes 1 and 2 might be satisfactory for an analysis.

Considering the large cost for assessments and the low precision in the estimates it cannot be recommended to continue to invest research efforts in this kind of trial.

Since there was no differentiation among populations for the three quality traits no geographic transfer effects were expected which was the case too. In agreement with several previous results for *Pinus sylvestris* (Johnsson 1971, Eriksson et al 1980, Giertych 1991) growth was mostly influenced by latitudinal transfer and that southern regions showed superior growth. Johnsson (1971) stressed that a clear clinal variation was obtained for height growth giving rise to a 0.83% height growth increase per degree of northward transfer.

The most reliable study of the effect of longitudinal transfer comprised the populations from latitudes 53°-56° only. It is evident from Fig. 3 that there is no great longitudinal impact on breast height diameter rather a latitudinal impact was observed.

In the absence of strong significances the indices selection of different regions must be regarded only as an exercise to demonstrate how different weighing of traits will influence

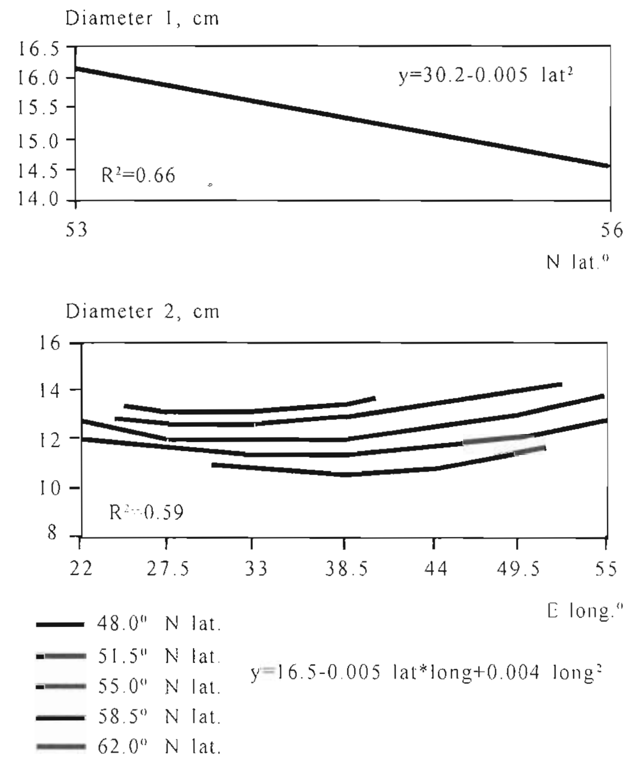

Fig. 3. Impact of latitudinal and longitudinal transfer on diameter growth when individual populations originated from latitudinal range of 53°-56° N were compared.

the selection of material for commercial plantations. The results of this exercise must not be taken as a definite recommendation of regions most suited for cultivation with focus on individual traits or combinations of them.

Table 5 shows that the excellent stem volume of population 10 Plungė, Lithuania, influences the two indices in which both growth and quality traits are included. The Russian population 48, Kostroma, illustrates the same phenomenon in an opposite way. Once stem volume is entered into the index, this population does not belong to the 10 best populations.

In an earlier study of the same material (Stalerunas 1992) the highest indices were found in declining order: Sumsk (Ukr.), Mogilyov (Byel.), Transcarpathian (Ukr.). All those populations originate from the southern part of the area concerned (Fig. 1). In a recent report from another test site of the same series of experiment Abraitis (1994) also reported high indices for populations of southern origin. Thus the Mogilyov population from Byelorussia had the highest index meaning that growth traits had a major impact on the indices (Abraitis 1994). Therefore, the Mogilyov population was found as entirely superior.

A comparison of our results with previous ones in which the mean value of all traits constituted the index shows that different recommendations might be given. Therefore, traits to be included in the index must be selected with great care to avoid ones that are positively correlated and cause a bias of the index calculated.

In conclusion neither major nor minor region differentiations were obtained for the traits studied, with the possible exception for breast height diameter. The unreplicated design at the population level is the main reason for this. Further research efforts on this type of trial cannot be recommended. Indices may be useful for identification of commercially useful material if the indices are constructed in a judicious way.

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PINUS SYLVESTRIS L. ВОСТОЧНО-ЕВРОПЕЙСКИЕ ПОПУЛЯЦИИ: РОСТ И ПОВЕДЕНИЕ В ОДНИХ ЛИТОВСКИХ КУЛЬТУРАХ

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Резюме

Целый ряд культур, происходящих из разных популяций сосны обыкновенной, было заложено на всей европейской части бывшего СССР, применяя единую методику Проказина. Географические культуры, являющиеся объектом исследований, принадлежат этому ряду. Культуры заложены используя 44 географически отдаленные популяции.

В данном исследовании в анализ были включены лишь доминирующие деревья (для трех отдельных вариантов отобраны деревья 1-ого, 2-ого и 1-ого + 2-ого класса по Крафту. Полученные результаты не показали существенных различий между популяциями, кроме как по диаметру.

Был выявлен эффект перемещения популяций по широте, однако в некоторых случаях перемещение по долготе также влекло за собой изменения показателей роста.

Используя селекционные индексы, также была сделана попытка оценить отдельные географические регионы. Несмотря на это, из-за низкого уровня достоверностей ни одно семенное происхождение не может быть рекомендовано для дальнейших исследований из-за отсутствия повторностей в схеме опыта. Поэтому дальнейшие исследования на подобных опытных участках не должны проводиться.

Ключевые слова: *Pinus sylvestis,* популяция, географические культуры, регион. эффект перемещения.