ARBORETUM KÓRNICKIE
ROCZNIK XXXI – 1986

MACIEJ GIERTYCH

Provenance variation of Scots pine (*Pinus silvestris* L.) on a 46-years old international experiment in Poland

Abstract

Giertych M. 1986. Provenance variation of Scots pine (*Pinus sylvestris* L.) on a 46-years old international experiment in Poland. Arbor. Kórnickie 31: 183 - 193.

The 1938 IUFRO Scots pine provenance experimental area in Poland has been remeasured in 1984. The paper presents latest data from the experiment comparing them with those from other areas of the same study. The evidence consistently shows that lowland provenances south of the Baltic are most productive in volume and have straight stems. Scandinavian races have straight stems but are of low productivity. Some more inland continental provenances are highly productive but the trees are of poorer form. Straightness, self-prunning and branchiness are related traits but branch angle stands alone not contributing to tree quality nor productivity.

Additional key words: volume, straightness, self-prunning, branchiness.

Address: Maciej Giertych, Institute of Dendrology, 62-035 Kórnik

INTRODUCTION

As reviewed earlier (Giertych 1979) there are 16 experimental areas on record with material from the IUFRO (International Union of Forestry Research Organisations) 1938 experiment on Scots pine provenances. One of the areas (IUFRO no. 21) is located in Lubień Poland. Early data from it were published by Przybylski and Sztuka (1968). That paper gave information on the 1949 evaluations of survival, height, annual height increment, diameter, volume, date of flushing and shoot growth termination, percentage of flowering trees, percentage of trees affected by *Lophodermium pinastri*, *Melampsora pinitorqua*, the large pine weevil, the pine shoot moth and the pine looper moth, number of trees with irregular crooks, lengths of lower branches and needles, and ratio of tree height to branch length (slenderness) and also on the 1967 measurement of diameters (DBH) and basal areas. In 1977 a new assessment was made by M. Cierniewski in the area. Only height data was reported (Giertych 1979). The present paper reports the latest data obtained in February 1984.

MATERIALS AND METHODS

The basic data on the experiment were presented in the paper by Przybylski and Sztuka (1968), however some corrections are needed. The area is now located in Compt. 370 of Range Łęczno, Forest District Piotrków Trybunalski, into which the former Lubień Forest District was incorporated.

There is some confusion in labels. The experiment was outplanted in 1940, during the war, by the local forester, without scientific supervision. Nos. 1 - 24 are from the list of the "compulsory set". Nos. 6 and 7 are confused with each other, 6 being labelled as Svanøy and 7 as Hamar. In the IUFRO series Svanøy is 7 and Åsnes, Hamar is 6. They are both from Norway. It is difficult to tell whether the names were misplaced or the numbers. Here I assume the numbers are correct because prov. 6 has better growth and quality than prov. 7 and this agrees with Åsnes and Svanøy respectively as judged on the basis of performance in many areas (see Giertych 1979 and table 6 here).

Table 1

Data on the provenances used in the study

IURFO no.	Locality	Country	Lat. N	Long. E	Alt. m
1	Inari	Finland	68°40′	27°37′	140
2	Rovaniemi	Finland	66°25′	26°36′	250
3	Sääminki	Finland	61°40′	28°55′	85
4	Tonset	Norway	62°22′	10°48′	550
6	Åsnes, Hamar	Norway	60°32′	12°11′	230
7	Svanøy	Norway	61°30′	5°07′	50
11	Vecmokas	Latvian SSR	57°03′	23°10′	80
17	Glen Garry	Scotland	57°04′	4°55′ W	150
18	Herselt	Belgium	51°03′	4°56′	20
19	Diever	Netherlands	52°51′	6°21′	10
20	Brody (Pförten)	Poland	51°47′	14°46′	85
21	Göddenstedt	West Germany	52°59′	10°50′	75
22	Ruciane	Poland	53°41′	21°26′	120
23	Elmstein	West Germany	49°20′	7°57′	325
24	Zellhausen	West Germany	50°01′	9°00′	140
53	Mustejki	Lithuanian SSR	54°08′	24°25′	130
54	Rychtal	Poland	51°12′	17°55′	190
55	Luboml	Ukrainian SSR	51°15′	24°05′	195

From the "voluntary" set only nos 32, 33 and 34 are used but these are described as Mustejki, Rychtal and Luboml respectively. These three provenances have IUFRO nos 53,54 and 55 while 32,33 and 34 are IUFRO numbers for Griva (USSR), Breda (Netherlands) and Tinoava (Romania). Since 53 - 54 were seed lots supplied by Poland (Mustejki and Luboml were in Poland in 1938) probably local interest prevailed and it was these that were used here and therefore the names are correct and not the numbers. Thus the corrected list of provenances is assumed to be as in Table 1.

All plots are 20 m × 17 m except for two. Provenance 24 Zellhausen is on a plot 9.5 m × 6.6 m and provenance 23 Elmstein on a plot 9.5 m × 10.5 m. Nine provenances (nos. 1, 2, 3, 4, 6, 7, 11, 17 and 18) are replicated twice, three (nos. 53,54 and 55) are replicated thrice and the remainder (nos. 19, 20, 21, 22, 23 and 24) are unreplicated. There was no randomisation (Fig. 1).

During the visit to the area the height of 10 randomly selected trees per plot and DBH of all trees were measured and estimates were made of stem straightness, self-prunning, branchiness and branch angle on 10 randomly selected trees per plot. The quality scale for the three traits was 1 to 5 ascending and the branch angle was recorded as 30°, 45° or 90°.

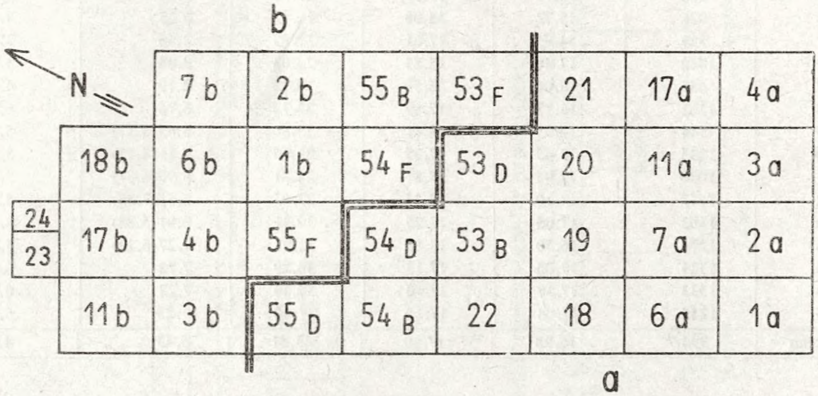

Fig. 1. Plan of the experimental area. Double line indicates proposed split-up into blocks *a* and *b*

Average stem diameters were obtained from the formula:

$$d=\sqrt{\frac{\sum d^2}{N}}$$

Basal area was calculated per hectar correcting for plot size. Volume estimate per ha per year assumed a common form factor of 0.6.

For provenances with 2 replicates a variance analysis was performed for all traits. In the analyses provenances 53, 54, and 55 were not included in spite of having 3 plots each, becuase in the layout of the area the plots of each of these provenances are run consecutively, forming in fact a single but larger plot (Fig. 1).

The variance analysis is not fully legitimate because there is no randomisation (Fig. 1). However since the numbers in each replicate block do not start from the same position there is in fact some permutation of neighbourhoods and therefore the deviation from legitimacy should not be considered too important.

RESULTS

The basic growth results are presented in Table 2 and qualitative results in Table 3. The results of the variance analyses are summarized in Table 4. For the sake of comparison in Table 2 also the average heights from New Hampshire USA (Wright

Table 2

Mean growth parameters at age 46 in Lubień. In brackets values corrected for block averages

IUFRO Prov. no.	No. of Trees per ha	Height in m	DBH in cm	BA/ha in m²	Volume per ha per year in m³	Height in USA at age 17 (Langlet 1959)
1	824	16.47	18.33	21.46	4.73	1.5
2	824	16.32	17.75	20.28	4.43	2.0
3	750	15.85	16.87	16.53	3.51	3.9
4	588	16.75	19.59	17.58	3.96	2.8
6	926	15.72	15.08	16.42	3.45	4.1
7	529	14.95	17.01	12.33	2.56	3.8
11	1412	17.40	15.85	28.03	3.84	5.4
17	485	16.00	16.56	10.30	2.19	4.4
18	1161	18.13	17.69	27.72	6.76	6.8
19	544	16.35	17.41	25.80	5.65(6.51)	5.5
20	1235	18.45	17.25	28.75	7.11(8.19)	5.9
21	1000	17.95	17.81	24.81	5.96(6.87)	5.7
22	1147	18.10	17.37	27.05	6.55(7.55)	5.8
23	1303	17.05	17.25	30.31	6.91(5.88)	5.8
24	1276	16.50	18.16	32.91	7.27(6.19)	5.8
53	1323	19.05	17.13	30.29	7.72	6.2
54	1333	17.58	17.10	30.64	7.22	6.0
55	1245	17.08	17.16	27.40	6.25	5.5
Mean	994.7	16.98	17.30	23.81	5.43	4.8

and Baldwin 1957) are given (as balanced averages recalculated by Langlet 1959), this being the only series of data with all the same provenances as in the Lubień experiment (Giertych 1979). These American height measurements at age 17 give a good correlation with our present height measurements at age 45 ($r=0.63$***) (Fig. 2).

Table 3

Mean estimates for quality traits. Scale 1 poor to 5 good. Branch angle recorded as 30°, 45° or 90°. In brackets values corrected for block averages

IUFRO Prov. no.	Straightness	Self-prunning	Branchiness	Branch angle
1	2.9	2.5	2.8	48.7
2	2.9	2.7	2.8	55.5
3	3.1	2.8	3.1	49.5
4	3.5	2.5	2.8	49.5
6	3.4	2.7	3.3	47.2
7	2.8	2.3	2.3	54.0
11	4.0	3.7	4.2	49.5
17	3.2	3.1	3.3	51.7
18	2.6	3.2	3.1	69.7
19	2.9(3.2)	3.0(3.2)	3.1(3.2)	45.0(43.1)
20	2.8(3.1)	3.4(3.6)	3.3(3.4)	45.0(43.1)
21	3.6(4.0)	3.5(3.7)	3.5(3.7)	49.5(47.4)
22	3.7(4.1)	3.3(3.5)	3.4(3.5)	45.0(43.1)
23	2.3(2.1)	2.4(2.3)	3.2(3.1)	49.5 (51.8)
24	2.4(2.2)	2.6(2.4)	2.9(2.8)	45.0(47.1)
53	3.9	3.7	3.8	51.0
54	3.1	3.3	3.5	47.5
55	3.1	2.9	3.1	54.0
Mean	3.18	3.01	3.21	50.19

Table 4

Results of variance analyses

Source of variation	Degrees of freedom	F_{emp}								
		N	Ht.	DBH	BA	V	Straightness	Self-Prunning	Branchiness	Branch angle
Provenance	8	2.50	2.56	1.00	2.14	3.00*	3.28*	3.67**	3.84**	3.39*
Block	1	1.04	1.84	0.02	0.62	5.40**	15.56***	6.11**	2.08	3.53*
Residual	8									

For provenances $F_{0.10}=2.59$*; $F_{0.05}=3.44$**; $F_{0.01}=6.03$***
For blocks $F_{0.10}=3.46$; $F_{0.05}=5.32$; $F_{0.01}=11.30$

Table 5

Matrix of correlation coefficients between traits that differ significantly for provenances

	Vol./ha/yr	Straightness	Self-prunning	Branchiness	Branch angle
Volume/ha/yr		0.10	0.52**	0.37	−0.17
Straightness			0.72**	0.68 **	−0.36
Self-prunning				0.86***	−0.18
Branchiness					−0.26
Branch angle					

$r_{0.10}=0.40$*; $r_{0.05}=0.47$**; $r_{0.01}=0.54$***

Przybylski and Sztuka (1968) have expressed concern about the value of the Lubień experiment due to the presence of seeded-in natural regeneration of Scots pine, this being particularily obvious where the 1967 stocking exceeded the no. of tress counted in 1949. However the correlation with measurements made in USA tends to suggest that the area is still suitable for investigation, though the value of weaker provenances may be overestimated. It is obvious from Fig. 2 that only pro-

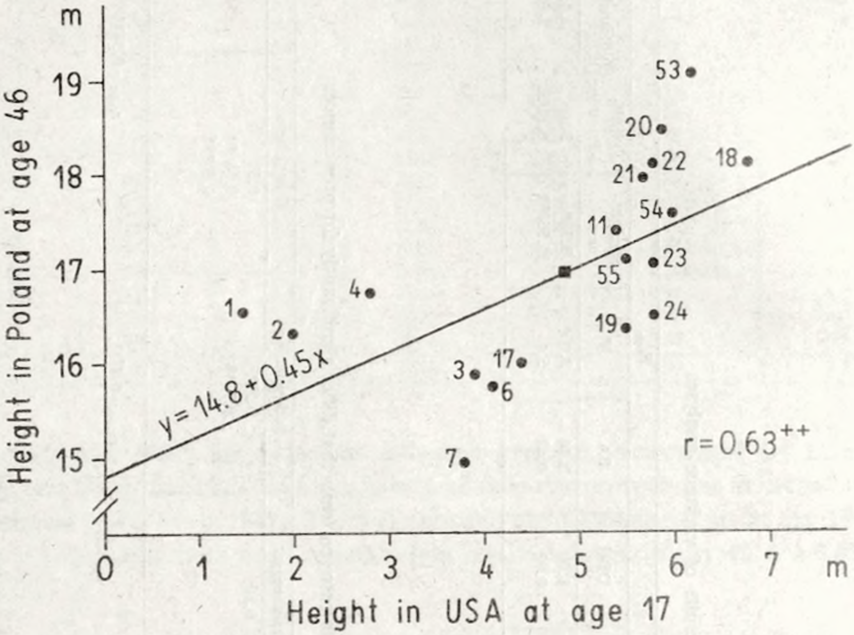

Fig. 2. Regression between average height at age 46 in Lubień and average height at age 17 in Herkimer, N. Y., USA. (after Wright and Baldwin 1957 as recalculated by Langlet 1959)

venances 1, 2 and 4 appear overestimated in the 46 years height measurement and possibly spoil the correlation itself. These three had the lowest number of trees per plot in 1949 and an increase in stocking between 1949 and 1967. In spite of sanitary thinnings made after 1967 which eliminated other species (birch etc.) and doubtful pines, in the plots of provenances 1 and 2 stocking is still greater than in 1949. Thus the data for provenances 1 – Inari (Finland), 2 – Rovaniemi (Finland) and 4 – Tönset (Norway), the three most northerly ones (above Lat. 62°N), have to be considered as doubtful. The rest however can still be useful. This concerns also provenances 23 Elmstein and 24 Zellhausen which Przybylski and Sztuka (1968) ignored altogether in 1967 because of smaller plots (see Fig. 1). The trees growing on these plots are obviously of a foreign provenance (all very similar in appearance), the stocking is high and quality traits are unmistakably distinctive. There is no reason to ignore this information in our evaluation though of course the lack of replication does not allow inclusion in the variance analysis.

The variance analyses (Tab. 4) have shown a significant provenance variation for wood volume and all quality characters (particularily for branchiness and stem cleaning). Generally the same characters were also significantly differentiated by blocks. The block differences concern only plots labelled *a* and *b*. There are no blocks as such, however since no original division of the area into blocks was made, this could be done now, latitudinally, as indicated by the double line in Fig. 1. Such a division would split the plots of provenances 53, 54 and 55 into two blocks. Consequently the unreplicated provenances nos. 23 and 24 would belong to block *b* and provenances 19 - 22 to block *a*.

In terms of volume the average value for provenances replicated in block *a* is 3.34 m^3/ha/yr and block *b* 4.53 m^3/ha/yr as against the overall average of 3.94 m^3/ha/yr. For the sake of comparison the unreplicated plots have to be corrected accordingly increasing the values in block *a* by 15.2% and decreasing those in block *b* by 14.9%. The corrected values are given in brackets in Tab. 2.

The same operation was performed for the qualitative traits, all of which gave significant differences between provenances (Table 3 and 4). A matrix of correlation coefficients was made for the traits that gave significant differences in the variance analysis (Tab. 5).

The data presented in Table 2 show that the highest productivity is obtainable from nearest provenances, particularily from nos. 20 (Brody, Poland), 22 (Ruciane, Poland), 53 (Mustejki, Lithuanian SSR) and 54 (Rychtal, Poland). The other fairly productive provenances (nos. 21, 18 and 19) come from the northern West Germany and the Low Counteries, followed by nos. 23 ane 24 from central West Germany and 55 from the Ukrainian SSR.

The lowest volume production comes from the northern fringe provenances nos. 17 (Glen Garry, Scotland), 7 (Svanöy, Norway), 6 (Åsnes, Norway,) and 3 (Sääminki, Finland). It is likely that provenances 1 and 2 (northern Finland) belong here too but the presence of natural regeneration of pine has exaggerated the potential of these provenances here. The measured volume places them just below the middle of the scale – clearly an overestimation. No. 4 (Tonset, northern Norway), the other suspect provenance has a substancially below average performance, which is possibly still an overestimation though not necessarily so. In any case, all of these probably contaminated populations are below average, outproduced by closer provenances and therefore not to be recommended.

In stem straightness the best trees are from provenances 22 (Ruciane, Poland), 21 (Göddenstedt, W. Germany), 11 (Vecmokas, Latvian SSR) and 53 (Mustejki, Lithuanian SSR) and the worst ones from provenances 23 and 24, both from central West Germany. The present estimate is unrelated to the percentage of trees with crooks observed in 1949 (Przybylski and Sztuka 1968) the correlation coefficient being very low ($r = -0.20$).

Similarily the best self-prunning of stems was observed in provenances 21 (W. Germany), 53 (Lithuanian SSR), 11 (Latvian SSR), 20 and 22 (Poland) and worst in provenances 7 (Norway), 23 and 24 (West Germany).

Lowest branchiness was found in trees of provenance 11 (Latvian SSR), 53

(Lithuanian SSR), 21 (West Germany) 22, 54 and 20 (Poland) and the greatest in trees of provenances 7 (Norway), 24 (W. Germany) and 1, 2 and 4 the three suspect north Scandinavian provenances.

Branch angle was highest in provenances 18 (Belgium), 2 (northern Finland), 55 (Ukrainian SSR), 7 (Norway) and lowest in provenances 19 (Netherlands) 20 and 22 (Poland) and 24 (West Germany).

The first three qualitative traits are obviously correlated, but the branch angle is an independent trait (Tab. 5). Volume production correlates only with self-prunning (Tab. 5).

DISCUSSION

The main result boils down to a recommendation of the following 3 provenances since they are highly productive and have good quality stems: 22 (Ruciane, Poland), 53 (Mustejki, Lithuanian SSR) and 21 (Göddenstedt, West Germany). Provenances 20 (Brody, Poland) and 54 (Rychtal, Poland) are also high producers, the former with well prunning stems and the latter with fine branches, but in other quality traits about average. Provenance 11 (Vecmokas, Latvian SSR) has exceptionally good quality stems, but is well below average in volume production.

It is usually assumed that a branch angle close to 90° is the most advantageous, allowing for easier prunning and less coarse branches. This was not confirmed here. Branch angle as we have estimated it, proved unrelated to straightness, self-prunning or branchiness and the correlation coefficients if anything were negative (Tab. 5) suggesting that a more acute branch angle is preferable. The main objection to acute branch angle is the danger of forking or double leaders, never much of a problem in Scots pine and in this experiment if there were any forked trees they were already eliminated in thinnings. Thus the present tendency as regards branch angle is irrelevant.

It is interesting that volume production proved correlated only with self-prunning (Tab. 5). This suggests a relation with fine branches (trunk more of a sink for reserves than branches) though sturdier stems appear to have sturdy branches and thus the correlation with our estimate of branchiness was not significant. Stem straigthness is completely unrelated to volume production, though as mentioned above it is related to self-prunning and branchiness (Tab. 5).

Finally a word is needed about the relation of this result to others from the same experimental series. My review of the IUFRO Scots pine experiments (Giertych 1979) is the last on the subject, however it deals only with tree height. As already mentioned above the present height data correspond to those obtained elsewhere (Fig. 2). The general conclusion of that review was that "*most adaptable races are to be found in lowland Central Europe ... particularity ... the Baltic countries and north and western Poland*". This agrees well with the result presented here.

Dietrichson (1964) reports data on relative branch thickness for sample trees from the experimental area in Matrand, Norway, however there are only 7 provenances in common with the Lubień area. Provenance 7 (Norway) is noticably with sturdy branches in Norway and the same is true in Lubień, but in general the estimates for the two areas do not correlate significantly ($r = 0.56$).

Straightness was estimated on several areas, in some simply by alloting trees to different quality classes. For provenances in common with the Lubień experiment this data is pooled in Table 6. Where the trees were assigned to quality classes the estimate was obtained from the $\sum$ (class $\times$ % trees in class) if necessary reversing the sequence of classes to obtain high values for populations with better stems. Table 6 gives each value as a percentage of the mean.

Table 6

Stem straightness estimated in various experimental areas and expressed as percentage of the mean

IUFRO Prov. no. Literature	Lubień Poland	Les Barres France 3	Royal France 3	Como Italy 8	Matrand Norway 1	Herkimer N.Y. USA 7	Bugac Hungary 5	Hůrky ČSSR 9
1	91							
2	91				118			
3	98			114	122	116	111	
4	110				128			
6	107			142	123		109	112
7	88	109	100		59			100
11	126			112	85	111	100	110
17	101				64			100
18	82			96			95	98
19	101			97		92	92	
20	98	84	102	100		95	99	99
21	126			97		99	104	100
22	129	106		107		105	103	104
23	66			78		92	100	79
24	69			51		92	94	81
53	123			109		100	96	109
54	98			103		98		
55	98		98	95		101	97	108
Correlation coef. r with Lubień		0.18	0.00	0.62**	0.25	0.54*	0.30	0.77***

The Lubień data significantly correlated with only 3 of the areas but generally the agreement is rather good. First of all it is clear that provenances 23 and 24 (Elmstein and Zellhausen, West Germany) have trees with very bad form. This result is very consistent at all sites. Also poor are provenances 18 and 19 (Hersselt, Belgium and Diever, Netherlands). The straightest stems are observable in almost all provenances from Scandinavia (nos. 2, 3, 4, 6). There are a few exceptions (eg. no. 7, the coastal Norwegian provenance especially in Lubień and Matrand) but the overall picture is consistent. Low values for provenances 1 and 2 in Lubień, may be associated with the contamination with local natural regeneration. The other provenances with consistently straight trees dominating are nos. 11 (Vecmokas, Latvian SSR), 53 (Mustejki, Lithuanian SSR), 22 (Ruciane, Poland) and 21 (Göddenstedt, West Germany). These are all Baltic provenances, somehow probably related to the Scandinavian ones. More continental East European provenances, (20, 54, 55) are slightly below average in straigthness. The Scottish provenance (17) is also average at two locations but distinctly crooked in Norway. In this it appears similar to the coastal Norwegian provenance Svanöy (7) from the other side of the North Sea.

This short review of data on stem straightness (Table 6) confirms the continued utility of the Lubień experiment in spite of some contamination in weaker provenances. There is good consistently appearing evidence that the most productive and qualitatively valuable provenances are from the lowland regions south of the Baltic (provenances 53, 22 and 21).

Accepted for publication 1986

LITERATURE

1. Dietrichson J., 1964. Proveniensproblemet belyst ved studier av vekstryme og klima. Medd. f. Det norske Skogforsksvesen 19 (71): 499 - 656.
2. Giertych M., 1979. Summary of results on Scots pine (*Pinus sylvestris* L.) height growth in IUFRO provenance experiments. Silvae Genetica 28 (4): 136 - 152.
3. Lacaze J. F., 1964. Comparison de divers provenances de pin sylvestre (*Pinus sylvestris* L.) représentées dans les arboretums forestiers. Rev. For. Franc. 8/9; 658 - 677.
4. Langlet O., 1959. A cline or not a cline – a question of Scots pine. Silvae Genetica 8: 1 - 36.
5. Magyar P., 1964. Erdeifenyö-származási kisérletek Bugacon Erdészeti kutatások 60 (1/3): 5 - 31.
6. Przybylski T. and Sztuka J., 1968. Doświadczenie proweniencyjne z sosną zwyczajną (*Pinus silvestris* L.) w Nadleśnictwie Lubień. Arboretum Kórnickie 12: 261 - 274.
7. Schreiner E. J., Littlefield E. W. and Eliason E. J., 1962. Results of 1938 IUFRO Scots pine provenance test in New York. Sta. Pap. Ntheast For. Exp. Sta. No. 166: 1 - 23.
8. Tocci A. V., 1976. Esperienze sulle provenienze del pino silvestre (*Pinus sylvestris* L.). Ann. Inst. Sperimentale per la Selvicoltura 7: 203 - 232.
9. Vincent G., 1965. Die Ergebnisse der Kiefernprovenienzversuche in der ČSSR. In Tagungsberichte Nr. 75 d. Dt. Akad. d. Landwirtsch. wiss zu Berlin: 125 - 135.
10. Wright J. W. and Baldwin H. J., 1957. The 1938 International Union Scots pine provenance test in New Hampshire. Silvae Genetica 6: 2 - 14.

Zmienność proweniencyjna sosny zwyczajnej (Pinus sylvestris L.) w 46-letnim międzynarodowym doświadczeniu w Polsce

Streszczenie

W roku 1984 dokonano ponownych pomiarów na polskiej powierzchni doświadczalnej z proweniencjami sosny zwyczajnej założonej z inicjatywy Międzynarodowej Unii Leśnych Placówek Badawczych (IUFRO) w 1938 roku. Przedstawione są tu ostatnie dane z tego doświadczenia wraz z porównaniem z wynikami na innych powierzchniach z tego samego doświadczenia. Wszystkie dane zgodnie wskazują, że nizinne proweniencje z obszarów na południe od Bałtyku dają najwyższą produkcję masy oraz posiadają proste pnie. Rasy skandynawskie mają proste pnie, ale jednocześnie niską produktywność masy. Bardziej kontynentalne proweniencje z Europy Środkowej i Wschodniej są bardzo produktywne, lecz jakość drzew jest gorsza. Prostość pni, oczyszczenie i gałęzistość są ze sobą skorelowane, natomiast kąt osadzenia gałęzi jest cechą izolowaną, nie związaną z jakością i produktywnością drewna.

МАЦЕЙ ГЕРТЫХ

Провененционная изменчивость сосны обыкновенной (Pinus sylvestris L.) в 46-летнем международном опыте в Польше

Резюме

В 1984 году были вновь произведены измерения на польской поверхности с географическими культурами сосны обыкновенной заложенными по инициативе Международного Союза Лесных Научно-Исследовательских Институтов (ИЮФРО) в 1938 году. В работе приведены последние данные по этому опыту вместе со сравнением с результатами полученными на других поверхностях этого опыта. Все данные указывают на то, что низинные провененции с территории к югу от Балтики характеризуются самой большой продуктивностью и прямоствольностью. Скандинавские расы прямоствольны, но одновременно у них низкая продуктивность массы. Более континентальные провененции из Центральной и Восточной Европы очень продуктивны но качество стволов у них значительно хуже. Прямоствольность, очищенность и количество сучьев являются чертами взаимно скоррелированными, в то время как угол между ветвями и стволом является чертой изолированной, не связанной с качеством и продуктивностью древесины.