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## Results of a 70 years old Scots pine (*Pinus sylvestris* L.) provenance experiment in Pulawy, Poland

By J. OLEKSYN and M. GIERTYCH

Polish Academy of Sciences,  
Institute of Dendrology,  
62-035 Kórnik, Poland

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### Summary

The authors have found and described a provenance experiment on *Pinus sylvestris* L. established in 1912 by S. Z. KURDIANI in Pulawy, Poland. On the area provenances are represented from 15 provinces of pre-revolutionary Russia, from central Poland to eastern Siberia and from the White sea to the Caucasus. Most productive were provenances Ukraine (Volynia, Kiev), Latvia (Kurland) and from Poland (Lublin) — the local material. Least productive were pines from Siberia, Urals (Ufa, Jenisejsk, Tobolsk) and from Turkey (Kars). The factor affecting productivity most was the number of trees per ha, ie. survival. The earlier conclusions from a survey of the whole experimental series made by the authors are confirmed on this location, namely that the most adaptable provenances come from the region of mixed forests. It is suggested that the reason lies in the evolutionary adaptation to competition with broadleaf species.

A comparison of two progenies of trees differing in size of heartwood indicates that this trait is not heritable.

*Key words:* *Pinus sylvestris*, provenance, Genotype × environment interaction, heart-wood.

### Zusammenfassung

Die Autoren beschreiben einen von ihnen wiederentdeckten Kiefernprovenienzversuch (*Pinus sylvestris* L.), angelegt im Jahre 1912 durch S. Z. KURDIANI bei Pulawy in Polen. Auf dieser Versuchsfläche befinden sich Kiefernherkünfte aus 15 Provinzen des ehemaligen kaiserlichen Russlands von Mittelpolen bis Ostsibirien und vom Weissen Meer bis zum Kaukasus. Den höchsten Massenzuwachs erreichten Herkünfte aus der Ukraine (Wolhynien, Kiew), aus Lettland (Kurland) und aus Polen (Lublin — die einheimische Provenienz). Am wenigsten leistungsfähig sind in dieser Hinsicht die Herkünfte aus Sibirien, aus dem Uralgebirge (Jenisejsk, Tobolsk) und aus der heutigen Türkei (Kars). Der Massenzuwachs wurde am meisten durch

die Anzahl der Bäume/ha (Anzahl der überlebenden Bäume) beeinflusst.

Auf diese Weise wurden früher gezogene Schlußfolgerungen aus einer Übersicht des ganzen Versuches bestätigt, daß nämlich die anpassungsfähigsten Herkünfte aus der Mischwaldzone stammen. Es wird angenommen, daß die Ursache dieses Verhaltens in der evolutionsbedingten Anpassung an die Konkurrenz der Laubbölzer liegt.

Ein Vergleich zweier Nachkommenschaften, die sich durch die Größe des Kernholzanteiles unterscheiden, läßt den Schluß zu, daß diese Eigenschaft nicht vererbt wird.

### Introduction

In the years 1910—1916 in the European part of the Russian Empire several provenance experiments on Scots pine (*Pinus sylvestris* L.) have been established according to the methodology and partially under the supervision of V. D. OGIEVSKIJ. The two World Wars and various changes of frontiers have caused that out of the 21 places which received seeds for the experiment publications are known from only 7 locations (GIERTYCH and OLEKSYN 1981).

One of the experimental areas has been localized in the former experimental forest "Ruda" of the Novo-Aleksandria Institute of Rural Economy and Forestry in Pulawy, Poland. Information about this has been found in the annual report on forest research for 1910 (ANONYM. 1911) from prerevolutionary Russia. The scientific philosophy behind the experiment and its direct supervision were credited to S. Z. KURDIANI (ANONYM. 1914). He was a 1900 graduate from the Pulawy Institute and later, in 1914, became an assistant to the Chair of Forestry at the Institute lecturing dendrology (STRZEMSKI 1980).

Polish foresters have known about the experiment, however efforts made in the late forties to find it have failed because no plans nor archival documents on the experi-

ment were to be found. These were lost during the evacuation of the Institute from Pulawy with the approach of the German forces in 1914. (OLEKSYN and GIERTYCH 1982)

Having summarized data on the whole series of experiments (GIERTYCH and OLEKSYN 1981) we were keen to find the single location believed to be within the present frontiers of Poland. The search was begun in 1980 in the state archives in Leningrad, USSR, where the documents of the Department of Forestry of pre-revolutionary Russia are deposited. Forest Range Ruda in Pulawy was under the supervision of the Department. Simultaneously, thanks to the help of Prof. G. I. RED'ko from the Forest-Technical Academy in Leningrad we have looked through the archives and library of the Chair of Silviculture of that Academy for publications of former employees of the forestry School in Pulawy. It turned out, that after the 1st World War S. Z. KURDIANI settled in his native Georgia teaching dendrology in the Tbilisi Forest-Technical Institute. There in 1932 he published a book in a subscript of which he gave a plan of the Pulawy experiment and its description. He wrote:

"In view of the fact that in Pulawy (in Poland, in the former Lublin province) there could have survived the whole or part of the experimental area with races of pine of considerable scientific value I am presenting below its description.

The permanent experimental area "Pine races" has been established by me in Comp. 31 of Forest Range Ruda in

1912. The collection of seeds and the preparation of the planting material was begun in 1909. The area has about 2.82 ha. It is divided into 21 plots (Fig. 2). The area of plots numbered 1 to 16 and II, III, IV and V is 1365.6 m<sup>2</sup> \* and plot I has an area of 928.6 m<sup>2</sup>. Both plot 1 and plot 2 are divided into four parts and plot II into three. On plot "1a" a race with white seeds was outplanted, on plot "1b" with black seeds, on "1c" with brown seeds and on "1d" with spotted seeds. On plot "2a" a rapidly maturing pine race (cones on the mother tree opened in the autumn and not as usual in the spring) was planted, on plot "2b" progeny of an abundantly fruiting tree, on plot "2c" progeny of a 120-years old mother tree which was characterized by having an exceptionally developed red heart-wood and on plot "2d" progeny of a mother tree of the same age with no heart-wood".

Then KURDIANI (1932) continues to read out the content of each plot which information is tabularized in Table 1. Now to continue his text: "On plot I it was planned to sow in the autumn of 1914 and in the spring of 1915 hybrids of *Pinus sylvestris* with *P. rigida*, *P. austriaca* and *P. banksiana*. On plot IIa *Larix europaea* (mother tree), IIb *L. europaea* × *L. leptolepis*, IIc — *L. leptolepis* (paternal tree). The larches were outplanted in the spring of 1914 in plot III from Saratov province (Kapadojskoe Forest District) and in 1913 on plot IV from Germany (Spessart) and plot V from Belgium (Campinen).

The plots were separated from each other with a shallow ditch and the whole experimental area was surrounded with a deeper ditch. The seedlings were planted accurately in rows".

Table 1. — Provenances named by Kurdiani, here tabularized.

Plot	Province	Provenance Forest District
3	Kars <sup>1</sup>	Songalugskoe and Dorżonskoe
4	Arkhangelsk	Verkolskoe and Laskoe
5	Kharkov	Majaokoe and Kenig's estate
6	Olonec	Karganopolskoe and Podonskoe
7	Voronezh	Hrenovskoe
8	Vologda	Georgievskoe
9	E. Siberia <sup>2</sup>	Jenisejskoe /Kansko-Jenisejskoe/
10	Novgorod	Tihvinskoe
11	Tobolsk <sup>3</sup>	
12	Volyniya	Luskoe
13	Ufa <sup>1</sup>	Şajtanovskoe
14	Kiev	Dymarskoe
15	Tver	Viesiegonskoe
16	Kurland <sup>1</sup>	Iševskoe

1. In the Annual Report on Forest Research for the year 1912 (ANONYM 1913) there is no information on plot no. 3. In that report it is also mentioned that in plot 13 pine from Orenburg and Kazan provinces was outplanted and in plot 16 pines from provinces Kurland, Minsk and Grodno.
2. This is former Jenisejsk province (ANONYM. 1911).
3. KURDIANI (1932) does not give the Forest District from which the seeds came in this provenance. From earlier reports (ANONYM. 1911) it appears that these were Turinskoe and/or Jauturovskoe.

\* Plots 1—16 are actually 35 m × 40 m.

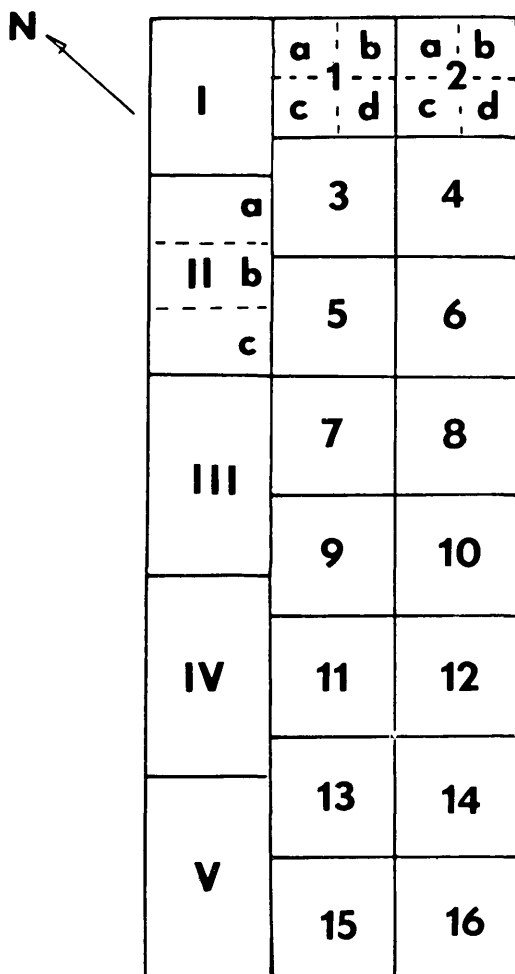


Fig. 2. — Plan of the experimental area in Pulawy (Forest range Ruda) in compt. no. 25 as published by KURDIANI (1932). Actually plots 1—16 are 35 m × 40 m.

So much for KURDIANI's (1932) own account. It might be mentioned that only remnant trees of the larch plantations exist in plot II and there is no evidence of any pine hybrids or larches ever being planted in plots I, III, IV and V.

*Other information on the provenances.*

The description of KURDIANI given above differs in some details from those given in earlier reports on forest research for the years 1909, 1910 and 1911 (ANONYM. 1910, 1911 and 1912). There are several reasons for this. The seeds sown in the spring of 1909 in the forest nursery in Pulawy got affected in the summer of the same year with *Lophodermium pinastri*. In spite of several sprays with the Bordeaux mixture till the winter needles of many plants got red. Pines from the southern and central parts of the Russian Empire suffered more compared to seedlings from the northern and eastern provenances. In order to save the surviving seedlings in the spring of 1910 the material from 7 provenances was outplanted onto a permanent experimental area in Comp. 7 of the Ruda Forest Range. Simultaneously in the same year new material was sown in an agricultural area, sterile as far as *Lophodermium pinastri* was concerned, using seed from the following provinces: Jenisejsk, Tobolsk (2 provenances), Tomsk (2 provenances), Ufa, Kurland, Tver, Kostroma, Kharkov and Borżom estate of WKMN (most probably Grand Prince (Wielkij Kniaz) Michail Nikolayewich).

In 1912 it was decided to transfer the experiment from compt. 7 of Forest Range Ruda (in the annual report for 1912 (ANONYM. 1913) it is said that the transfer was from compt. 9, presumably erroneously) to its new permanent location in compt. 31 presently compt. 25 and to combine it with new seedlings (ANONYM. 1913). The decision was made because it was considered that compt. 31 is more uniform in terms of soil and topography. The considerable distance of the compt. from villages and roads was to protect it from intruders. We assume that only those provenances were included in the final plantation which KURDIANI names in 1932.

The observations of seedlings made by KURDIANI till the year 1914 (KURDIANI 1932) on the permanent location have shown that the vegetative period of northern provenances (province Arkhangelsk) was much shorter than in local pines. Seedlings from the north started flushing simultaneously or 3—10 days earlier than local ones, but already after 1—2 months terminated growth and formed a winter bud. Only single seedlings (1—2%) flushed again and resumed growth.

Southern pines, from Kars province have had a prostrate or bushy habit.

The northern pine grew much slower than local pine. Over the first 4 years of their life they attained half the size relative to the pines from Pulawy.

Pines of northern origin were characterized by considerable resistance to attack by *Lophodermium pinastri*, while seedlings from the central part of the area were very sensitive to it. Most severely attacked were pines from the south (Ukraine, Caucasus).

In the first period of growth seedlings from Siberia were similar to those from northern Europe and seedlings from the central part of the continent were similar to the local ones.

*Experiments on the inheritance of seed colour.*

Many works of S. Z. KURDIANI (1908a, 1908b, 1909, 1910, 1912, 1913a, b, 1916, 1932 and 1934) have been devoted

among other topics to the problem of seed colour races of Scots pine. The experiments established by him in Pulawy (Fig. 2, plots 1a, 1b, 1c and 1d) were to answer the question whether this character is in any way hereditary. KURDIANI (1932) mentions also that within the various provenances of Scots pine the seedlings were outplanted in row plots depending of seed colour. Starting from the north the rows were for the following varieties of *Pinus sylvestris* L., var. *leucospermata*, var. *melanospermata*, var. *phaeospermata* and *baliospermata*. They are respectively whitish, black, brown and spotted.

*Experiment on the inheritance of heartwood size.*

We were unable to find any information in the literature concerning the origin of the seeds used for the establishment of the experiment on the size of heart-wood and sap-wood (plots 2c and 2d, Fig. 2). On the basis of a paper published by S. Z. KURDIANI (1912) on the organisation of selection work in Russia, in which he describes results of his investigations on the variability in the size of heart-wood, one can suspect that the seeds came from the region of his investigation in forest range Piotrków. One has to assume that the seeds came from open pollination.

*Description of the experimental area.*

The mean annual precipitation for the years 1920—1981 for that region was 571 mm and the mean monthly temperatures over the same time were from  $-3.8^{\circ}\text{C}$  in January to  $18.5^{\circ}\text{C}$  in July. The experimental area lies at Lat.  $51^{\circ} 37'$  Long.  $22^{\circ} 06'$  Alt. 140 m and it is slightly sloping NW. The soils are sandy composed of shallow sands and gravels (TOMASZEWSKI 1928). Phytosociologically the area is a Pineto-Quercetum (MATUSZKIEWICZ and MATUSZKIEWICZ 1956).

In 1966, about 3 km from the experimental site, Zakłady Azotowe, a nitrogen fertilizer plant, started emitting into the atmosphere several chemical substances toxic to plants. In spite of the close proximity to the emission source the experimental area is relatively protected from pollution. This is primarily so because in the area western and south-

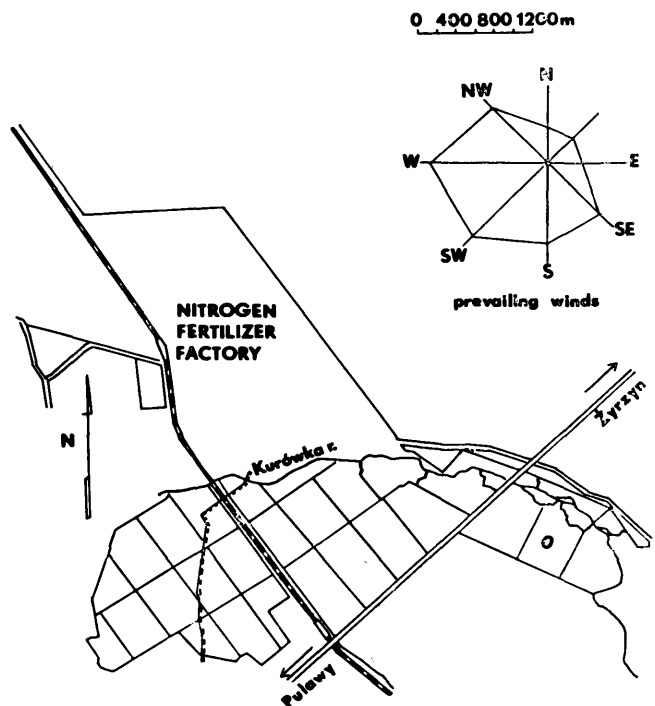


Fig. 1. — Map of Forest Range Ruda. The location of the experimental area is marked O. The relative position of the fertilizer factory and the wind distribution are also shown.



Fig. 4 — An original corner pole existing since 1912.

ern winds predominate (SOKOŁOWSKI, KAWECKA 1973, Fig. 1) leaving the area on the windward side from the plant. Nevertheless the plantation is obviously suffering. An analysis of the consequence of the presence of the fertilizer plant on wood increment to pines of various provenance has been presented in another paper (OLEKSYN, 1983).

## Materials and Methods

Thanks to the presence of the shallow ditches separating the various provenances and the deep ditch surrounding the whole area we have had no difficulty in reconstructing the whole experiment. Actually the plots are slightly different in size and shape (Fig. 2) than given by KURDIANI (1932). Until this day a few of the original wooden poles denoting corners of plots could be found rotting in the soil, and one even standing (Fig. 4). In the spring of 1981 for the first time ever measurements were made on this 70 years old stand. The original spacing was deciphered to be 1 m × 2,13 m (0,5 × 1 sažen') and trees which were outside the original rows were excluded from analysis on the assumption that they came from natural regeneration. The total number of such trees among the pines was below 5%. There are also many oak and other tree species in the area that do not belong to the experiment and most are obviously younger. On each plot for all experimental trees a measurement was taken of the diameter at 1.3 m from the ground and on 10 randomly selected trees the height was measured to the nearest 0.5 m. The measurements obtained were used to calculate the volumes.

On plots 2c and 2d (Fig. 2) on which the progenies of two mother trees differing substantially in the dimension of the heart wood were planted we have felled three sample trees per plot and on ten trees wood samples were taken with a Pressler borer.

For all trees in the experiment the following observations were made:

- 1/ Stem form — this was estimated on a 5 point scale where 1 indicates very crooked trees and 5 ideally straight ones.
- 2/ Cleaning — this was estimated on a 5 point scales where 1 indicates trees with many dead branches and 5 trees free of any dead branches.
- 3/ Branchiness — this was estimated on a 5 point scale where 1 indicates very heavy branches and 5 very thin ones.
- 4/ Branch angle — this was estimated on a three point scale where 1 indicates an angle below 30°, 2 — an angle close to 45° and 3 an angle close to 90°.

In view of the fact that KURDIANI when establishing the

Table 2. — Results of 1981 measurements of Scots pine trees in the provenance experiment established in 1912 in Puławy (Poland).

Provenance (former province)	Trees per ha	Diameter cm	Height m	Volume m <sup>3</sup> /ha	Stem	Clea- ning	Branchi- ness	Branch angle
Volynia	718	26.5	23.9	437.7	3.5	3.4	3.1	2.1
Kiev	498	25.3	24.5	287.4	4.3	3.8	3.5	2.7
Kurland	586	23.5	23.7	284.5	3.8	3.3	3.5	2.2
Lublin/Puławy/	586	24.8	21.8	283.1	2.6	2.6	3.1	2.2
Voronez	409	26.5	23.5	243.3	4.0	3.6	3.5	2.0
Olonets	264	30.2	22.3	205.2	2.8	2.7	1.8	2.0
Kharkov	308	27.3	23.6	195.2	3.2	2.7	2.6	2.1
Arkhangelsk	242	30.9	22.8	188.1	3.1	2.2	1.8	2.0
Novgorod	176	31.0	23.5	154.5	3.1	3.4	2.1	2.0
Vologda	183	32.2	21.9	150.0	3.2	2.7	2.1	2.1
Kars	198	27.3	23.7	130.6	2.4	1.8	1.8	2.0
Ufa	227	24.6	21.5	122.3	3.8	3.3	3.1	2.1
Jenisejsk	139	31.6	23.0	125.3	2.8	2.3	2.1	1.9
Tver	198	23.3	22.2	88.7	4.2	3.3	3.2	2.4
Tobolsk	110	30.5	22.0	87.1	3.1	2.2	2.1	2.0
Mean	323	27.7	22.9	198.9	3.3	2.9	2.6	2.1

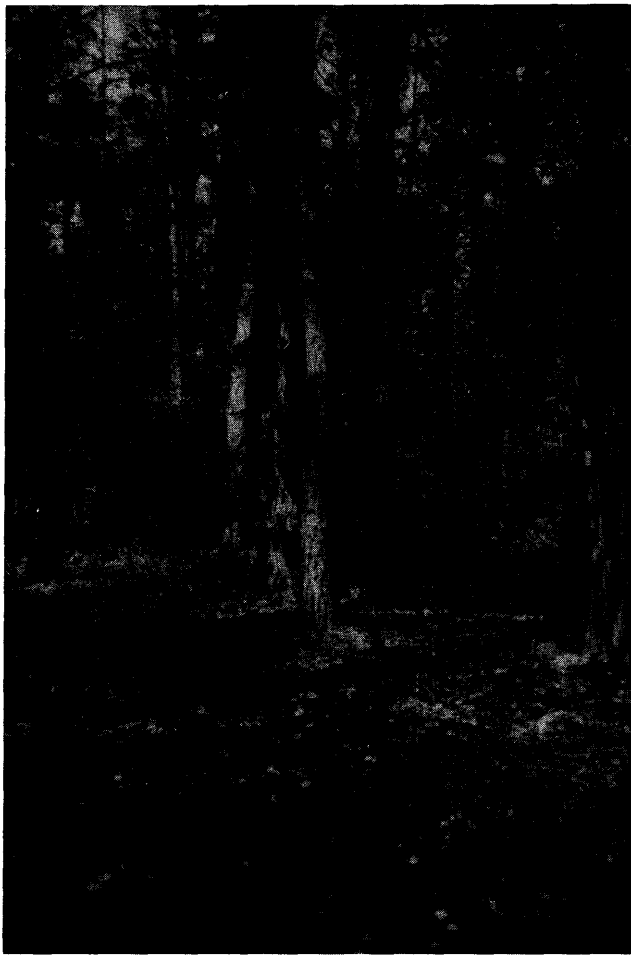


Fig. 5. — The general appearance of a pine row in the most productive plot of the experiment representing provenance Volynia. The spacing used is clearly visible.

area did not have a special plot for local material we have considered as local plots 1 and 2 with the eight sub-plots (Fig. 2) each representing the half-sib progeny of a single tree selected for some special reason. There is no doubt that the 8 trees were selected either in Pulawy or in close proximity, certainly in the Lublin province, though of course they are not exactly representative for pine of the region.

### Results and Discussion

From the data presented in Table 2 it appears that most productive were plots with pine from Volynia, Kiev, Kurland, Lublin (local), Voronezh and Olonets provinces. Volume on plots with all the other provenances was below average for the whole experiment.

The factor determining the size of the standing volume was the number of trees, i.e. survival. At the same time this was the most variable factor. Compared to the best provenance here, Volynia, the plots with pine from Siberia and the Urals (Tobolsk, Jenisejsk and Ufa) have had several times less trees. There is a negative correlation ( $r = -0.58$ ) between the mean diameter of trees per ha only stressing the fact that differentiation in volume production per ha depends more on stocking than on individual tree size. This can be quite small for the most productive provenances in spite of the fact that gaps between pines were usually filled-in with other tree species from natural regeneration, primarily oak. As regards tree height there was very little provenance differentiation, however the provenances with a greater total volume have usually also had a slightly higher average tree height.

Provenance Volynia (Fig. 5) which was decidedly the best one in the study is characterized by great plasticity in seed transfer as was indicated in our earlier review (GIERTYCH and OLEKSYN 1981). Pines from that region were characterized also by good technical properties of the trees — good stem form, good cleaning and thin branches (Table 2). In stem form they were much better in the

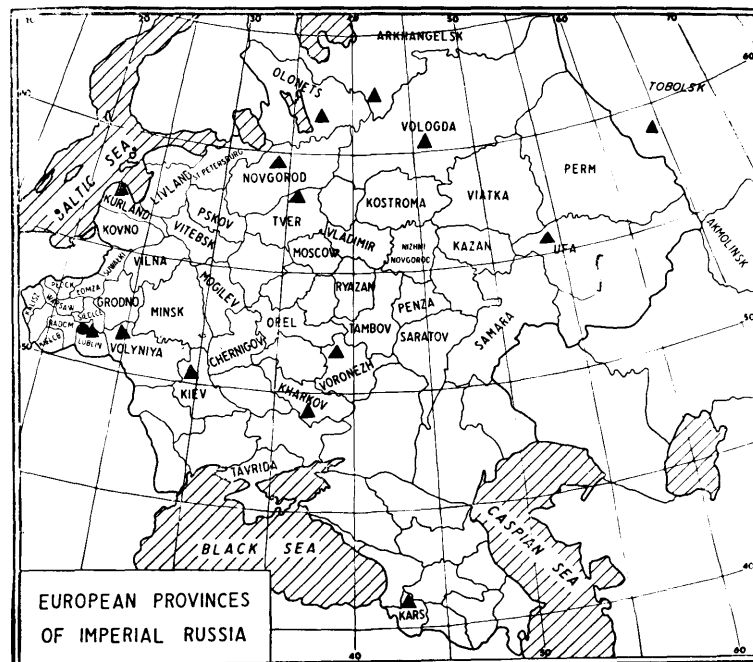


Fig. 3. — Frontiers of European provinces (gubernias) of prerevolutionary Russia. Those with triangles represented in the Pulawy experiment (block dot).

Pulawy experiment than after transfer eastwards or northwards (FOMIN 1940).

We were rather surprised to find a relatively good productivity of pines from provenance Olonets which has a volume per ha above average for the experiment. Pines representing this provenance have had a good productivity when planted not far from the collection site but on southward transfer (to Briansk), to a latitude comparable to that of Pulawy, were much inferior (GIERTYCH and OLEKSYN 1981). In Pulawy pines of this provenance have poorer than average technical properties, the branch angle being close to average. However the last mentioned trait was not very variable (Table 2). Only in pine of the Kiev provenance the branch angle was close to 90° and differed much from the others.

The results of this experiment confirm the poor productivity reported earlier for outlier populations (GIERTYCH and OLEKSYN 1981). The most southerly provenance Kars, from the Caucasus (Fig. 3), besides having poor volume production was also characterized on the Pulawy plot with the poorest stem form, cleaning and branchiness.

The data presented in Table 2, combined with an analysis of pine growth in the other Russian provenance experiments of the 1910—1916 period (GIERTYCH and OLEKSYN 1981) indicate that the most adaptable provenances originate from the zone of mixed forest, that is from the west-central part of the former Russian Empire. One can suspect that the reason why pines from this region are more plastic than those originating from the taiga or from the forest-steppe regions lies in the evolutionary necessity to compete with other, primarily broadleaf, species.

The measurements of sap-wood and heart-wood made in the trees from plots 2c and 2d indicate that there is no variation between the two plots in this respect. Progeny of the 120 years old tree that had a much developed heart-wood has had at age 70 a heart-wood covering 58,9% ( $\pm 8.3\%$ ) of the radius and progeny of tree that had only sap-wood had a heart-wood covering 59,2% ( $\pm 3.9\%$ ) of the radius. Thus it appears that the size of heart-wood is not under genetic control.

Results on the colour of seeds, amount of cones and time of cone opening are unavailable. Presumably due to the pollution of air from the fertilizer factory cones do not mature, and presently on the area there are practically no cones at all. We have grafted selected trees so perhaps we shall have some information on this at a later date.

## Literature

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