ARBORETUM KÓRNICKIE
Rocznik XVI — 1971

Henryk Fober and Maciej Giertych

Variability of *Picea abies* (L.) Karst. seed size, weight and mineral content in Poland

INTRODUCTION

The weight of spruce seed in Poland has often been reported upon. The information has been recently reviewed by Dutkiewicz (1968). In his own studies on the subject he came to the conclusion that seeds from the northern range of spruce in Poland weight less than those from the southern range, the difference, depending on year, being of the order of 18 - 35%. Furthermore he has shown that within an area there is a decrease in seed weight with an increase in elevation. In Sweden Andersson (1965) has shown that seed weight declines with latitude and elevation, thus the same trends as in Poland appear to be present.

In another spruce species, *Picea sitchensis* (Bong). Carr. it has been shown that northern seeds are the more heavy ones (Burley 1965).

Our own studies of variation in spruce seeds of various origin were accessory to the general investigation of provenance differentiation of spruce seedlings. As a result they represent no more than a record of informations about the seeds used. This information helps in the interpretation of provenance differences observed (Fober and Giertych 1971) and will no doubt prove useful, when results of field provenance experiments based on the same seed collections (Giertych 1970) will become available. The seeds were extracted from cones described by Chylarecki and Giertych (1969).

The cones have been collected in the fall of 1964 from 25 widely scattered localities in Poland (table 1, fig. 1). In fig. 1 also the natural range of spruce in Poland is drawn in. As can be seen the range is disjointed. The northern one links up with the general range in Scandinavia and northern USSR, while the southern one with the Hercyno-Carpathian range. Much literature has been devoted to differences between spruce from these two ranges.

Table 1

Geographic coordinates of provenances used in the study

Provenance No.	Locality	Long.	Lat.	Alt. m
S–16–96	Brody	14°53′	51°42′	80
S–15–98	Kowary	15°52′	50°48′	625
S–03–99	Istebna	18°52′	49°33′	630
S–03–100	Wisła	18°56′	49°37′	650
S–04–101	Rycerka	19°00′	49°32′	530
S–04–103	Nowy Targ	20°07′	49°31′	1000
S–09–104	Wetlina	22°30′	49°08′	700
S–10–106	Garbatka	21°36′	51°31′	130
S–10–107	Bliżyn	20°42′	51°05′	320
S–14–109	Konstancjewo	19°08′	53°11′	90
S–07–110	Iława	19°34′	53°39′	116
S–07–111	Nowe Ramuki	20°34′	53°39′	143
S–07–112	Sadłowo	21°06′	53°55′	143
S–11–113	Myszyniec	21°09′	53°22′	120
S–11–114	Sławki	21°07′	53°03′	130
S–07–115	Borki	22°05′	54°06′	155
S–07–116	Przerwanki	22°04′	54°08′	150
S–01–117	Gołdap	22°24′	54°20′	150
S–01–118	Suwałki	23°07′	53°59′	170
S–01–119	Augustów	23°11′	53°54′	130
S–01–120	Białowieża	23°47′	52°40′	160
S–01–121	Zwierzyniec	23°47′	52°43′	160
S–05–122	Międzyrzec	22°57′	52°03′	154
S–15–125	Stronie Śląskie	16°55′	50°18′	870
S–04–133	Dolina Chochołowska	19°48′	49°13′	1400

MATERIAL AND METHODS

During cone extraction 50 winged seeds from each provenance have been measured by placing on millimetr paper. The measurements taken were a) wing length, b) wing width, c) seed length and d) seed width (fig. 2). Average values for each provenance are presented in table 2.

Samples of the dewinged seeds were sunk in 70% methanol to remove empty seeds by floating, surface dried and three 100 seed samples from each provenance were weighed (fresh weight), and then dried at 100°C for 5 days and weighed again (dry weight). The average values are presented in table 2.

Dried seeds were analysed for nitrogen content by the Kieldahl method (P i p e r 1957) for phosphorus content by the Kuttner and Lichtenstein method (F i n k 1963) and for the metallic macroelements by the flame photometric method (H u m p h r i e s 1956). Percentage concentrations of the mineral elements in the seeds are presented in table 3.

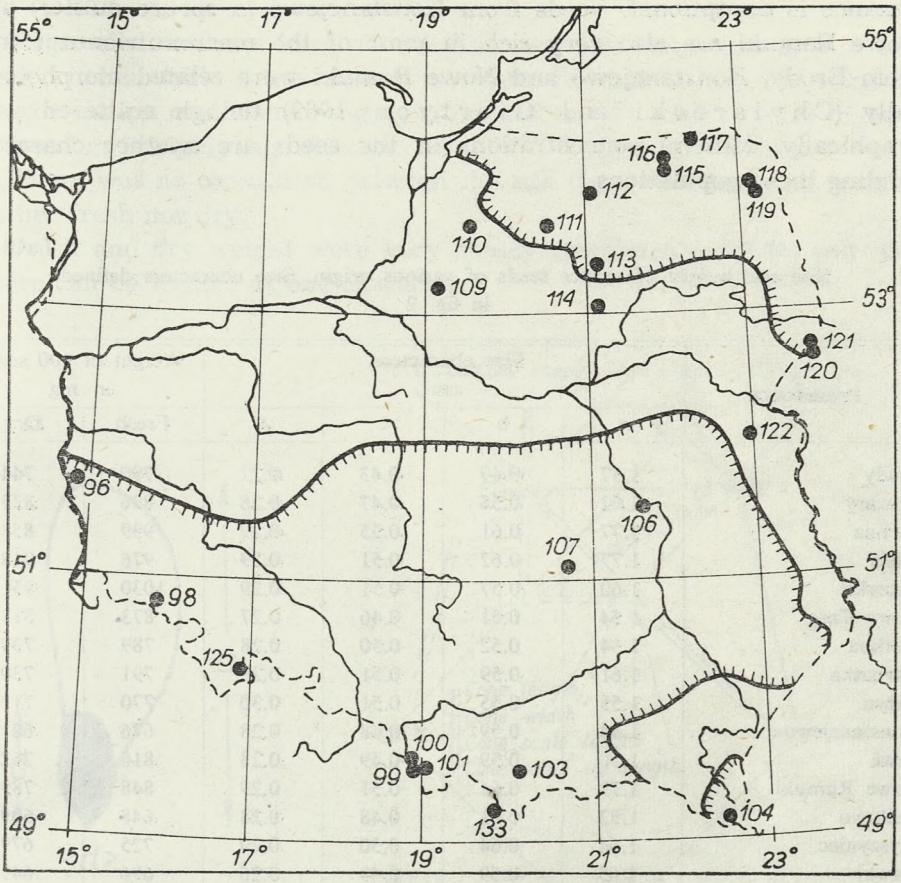

Fig. 1. The range of *Picea abies* in Poland and the location of the sites where seeds were collected

Correlation analyses have been performed between the various seed characters as well as with characters of cones from which the seeds were extracted (ex Chylarecki and Giertych 1969). The significant correlations are indicated in fig. 3.

RESULTS

A) POPULATION DIFFERENCES

Mineral content of seeds is no doubt in some measure a reflection of the nutrient availability in the site of seed collection. On this basis it can be said that soil in the Nysa river valley (Brody) is exceptionally rich in all the major macroelements (table 3). In this respect the Brody pro-

venance is exceptional. Seeds from Konstancjewo (a spruce outlier) and Nowe Ramuki are also very rich in most of the macronutrients. Cones from Brody, Konstancjewo and Nowe Ramuki were related morphologically (Chylarecki and Giertych 1969) though scattered geographically. Mineral concentrations in the seeds are another character binding these populations.

Table 2

Size and weight of spruce seeds of various origin. Size characters defined in fig. 2

Provenance	Size characters, cm				Weight of 100 seeds in mg	
	a	b	c	d	Fresh	Dry
Brody	1.37	0.49	0.43	0.22	790	744
Kowary	1.62	0.58	0.47	0.28	896	833
Istebna	1.77	0.61	0.55	0.29	939	858
Wisła	1.77	0.62	0.51	0.29	976	918
Rycerka	1.60	0.57	0 51	0.29	1030	951
Nowy Targ	1.54	0.51	0.46	0.27	873	813
Wetlina	1.34	0.52	0.50	0.28	789	739
Garbatka	1.61	0.59	0.51	0.28	791	730
Bliżyn	1.55	0.55	0.51	0.30	770	712
Konstancjewo	1.44	0.59	0.48	0.28	676	621
Iława	1.50	0.59	0.49	0.28	816	762
Nowe Ramuki	1.79	0.64	0.51	0.29	848	789
Sadłowo	1.52	0.61	0.48	0.28	648	609
Myszyniec	1.64	0.64	0.50	0.29	725	679
Sławki	1.65	0.59	0.49	0.26	696	649
Borki	1.54	0.55	0.49	0.26	705	660
Przerwanki	1.41	0.55	0.47	0.26	699	652
Gołdap	1.58	0.59	0.50	0.28	764	713
Suwałki	1.50	0.56	0.49	0.28	726	673
Augustów	1.73	0.71	0.51	0.29	702	653
Białowieża	1.72	0.59	0.51	0.29	765	718
Zwierzyniec	1.66	0.61	0.53	0.29	795	737
Międzyrzec	1.50	0.57	0.48	0.29	898	843
Stronie Śląskie	1.64	0.64	0.51	0.29	815	769
Dolina Chochołowska	1.33	0.50	0.45	0.25	810	753

Seeds from Istebna and vicinity (Rycerka, Wisła) are relatively rich in phosphorus and potassium. The Dolina Chochołowska provenance from the high Tatras is exceptional in that its seeds are very rich in phosphorus and potassium and very poor in nitrogen, calcium and magnesium.

Seeds from Borki, a famous spruce reserve, are exceptionally poor in potassium and phosphorus. Seeds from adjacent Przerwanki are also very poor in these elements. Seeds from Białowieża and adjacent Zwierzyniec are very rich in magnesium and calcium.

B) CORRELATIONS AMONG CHARACTERS

Regression analyses have shown that seed size characters a, b, c and d reported in table 2 are closely correlated to each other, the value of the correlation coefficient ranging from 0.62 to 0.75 which for 24 degrees of freedom is highly significant.

There was no correlation between the size characters and seed weight, neither fresh nor dry.

Fresh and dry weight were very closely correlated ($r=0.99$) and therefore can be treated as one character.

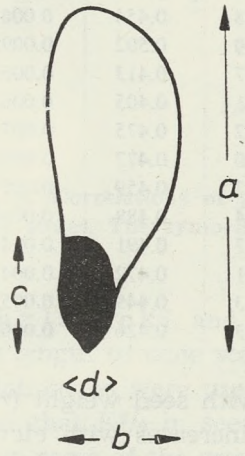

Fig. 2. The measurements taken on a winged seed

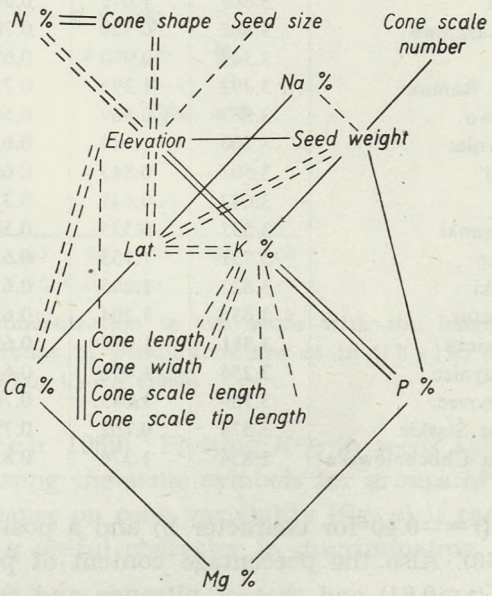

Fig. 3. Significant correlations between the seed characters, cone characters and geographic coordinates. Double lines indicate significance at 0.01 level and single lines at 0.05 level. Continuous lines indicate positive correlations and broken lines negative correlations

Seed weight is correlated positively with their percentage content of potassium ($r=0.44$) and phosphorus ($r=0.39$) and negatively with sodium ($r=-0.43$). As a result concentrations of potassium and phosphorus are correlated ($r=0.61$) with each other. Also magnesium concentration is correlated with calcium ($r=0.42$) and phosphorus ($r=0.43$) concentrations (fig. 3).

Elevation of the site of cone collection appears to have a significant effect on the seeds. There is a negative correlation of elevation with seed

Table 3

Percentage concentration of mineral elements in spruce seeds of various origin

Provenance	N %	P %	K %	Ca %	Mg %	Na %
Brody	3.858	1.442	0.714	0.043	0.484	0.0044
Kowary	3.487	1.276	0.740	0.026	0.466	0.0062
Istebna	3.419	1.098	0.719	0.027	0.405	0.0035
Wisła	3.788	1.353	0.689	0.024	0.433	0.0063
Rycerka	3.376	1.031	0.676	0.032	0.434	0.0059
Nowy Targ	3.029					
Wetlina	3.798	1.279	0.803	0.028	0.451	0.0049
Garbatka	3.779	0.731	0.546	0.032	0.394	0.0047
Bliżyn	3.803	1.045	0.566	0.025	0.434	0.0068
Konstancjewo	3.802	0.924	0.708	0.038	0.475	0.0092
Iława	3.549	0.990	0.698	0.033	0.504	0.0066
Nowe Ramuki	3.492	1.295	0.713	0.030	0.472	0.0079
Sadłowo	3.557	0.869	0.566	0.034	0.439	0.0070
Myszyniec	3.500	1.149	0.631	0.028	0.454	0.0065
Sławki	3.502	0.843	0.607	0.040	0.502	0.0095
Borki	3.642	0.441	0.370	0.037	0.413	0.0069
Przerwanki	3.537	0.575	0.580	0.031	0.405	0.0069
Gołdap	3.731	1.135	0.620	0.032	0.475	0.0075
Suwałki	3.822	1.295	0.651	0.030	0.477	0.0056
Augustów	3.630	1.204	0.612	0.027	0.459	0.0051
Białowieża	3.381	1.055	0.691	0.034	0.488	0.0065
Zwierzyniec	3.254	1.066	0.636	0.037	0.491	0.0045
Międzyrzec	3.769	1.083	0.706	0.031	0.472	0.0043
Stronie Śląskie	3.574	0.762	0.798	0.023	0.449	0.0052
Dolina Chochołowska	2.854	1.376	0.837	0.023	0.426	0.0063

size ($r=-0.40$ for character b) and a positive one with seed weight ($r=0.48$). Also the percentage content of potassium increases with elevation ($r=0.61$) and that of nitrogen and calcium decreases ($r=-0.59$ and -0.67 respectively).

In Poland latitude and elevation are negatively correlated ($r=-0.82$) and as a result many of the above mentioned seed characters correlated with elevation have a similar but opposite correlation with latitude (fig. 3).

C) CORRELATIONS WITH CONE CHARACTERS

Since seed characters are phenotypic it was considered possible that their variability would be in some way related to variability of cone characters. As reported earlier (Chylarecki and Giertych 1969) 12 measurements were made on the cones or cone scales of the same material. The average values for each provenance have been compared with the seed characters reported in this paper. It was found that cone shape is correlated with nitrogen concentration in the seeds ($r=0.51$) and

the number of cone scales on a spiral with seed weight ($r=0.40$). Also potassium concentration was negatively correlated with 4 cone size characters all of which correlate with each other. Of these 4 three were among the most efficient ones in discriminating between populations

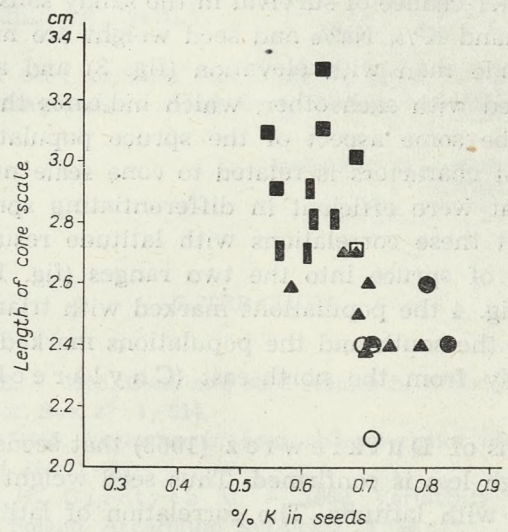

Fig. 4. Correlations of potassium concentration in the seeds with the length of cone scales. The symbols for the groups of populations are as in Chylarecki and Giertych (1969)

(Chylarecki and Giertych 1969). Plotting K% in seeds against the length of cone scales, and using the same symbols for groups of populations as were used in the paper on cone variability (fig. 4) it can be seen that K% in seeds is also a useful character in discriminating between some of the groups.

DISCUSSION

The correlations of seed characters reported in fig. 3 indicate considerable dependence on geographic distribution. Since elevation and latitude are inversly correlated it is difficult to say which of the two has more of an effect on spruce seeds. The characters Ca%, N% and seed size are more closely correlated with elevation and not at all with each other. Each of these characters is therefore related to elevation for different reasons. With shallower soils nitrogen is likely to be less available at higher elevations. The more severe weather conditions at higher elevations are possibly responsible for the smaller seeds as well as shorter cones. This agrees with Andersson's observations in Sweden (1965).

Calcium is likely to be very low in the lowlands where spruce grows primarily on sandy soils. Thus the richer calcium content in the seeds from these localities is hard to explain. Possibly it is an adaptation to calcium shortage, the seeds being provided with more calcium to give the seedlings a better chance of survival in the sandy soils.

On the other hand K%, Na% and seed weight are more closely correlated with latitude than with elevation (fig. 3) and are all, together with P%, correlated with each other, which indicates that these characters jointly describe some aspect of the spruce populations variability. Since this group of characters is related to cone scale number and cone size characters that were efficient in differentiating spruce populations it can be said that these correlations with latitude result broadly from the differentiation of spruce into the two ranges (fig. 1), north-eastern and southern. In fig. 4 the populations marked with triangles and circles come mainly from the south and the populations marked with rectangles and squares mainly from the north-east (Chylarecki and Giertych 1969).

The observations of Dutkiewicz (1968) that seeds from the north eastern range weigh less is confirmed. Thus seed weight is strongly correlated negatively with latitude. The correlation of latitude with elevation results also in a positive correlation of seed weight with elevation. However Dutkiewicz's (1968) and Andersson's (1965) observation that seeds from trees from higher elevations weigh less is probably true, since in our material seeds from Dolina Chocholowska though from the southernmost and highest locality weigh considerably less than would be required from the regression of seed weight with elevation.

The correlation of Mg% with Ca% and P% (fig. 3) regardless of the geographic correlations of the latter two is probably a reflection of the fact that generally soils richer in one mineral element are also richer in another. These correlations appear to include K% but not N%, which is not unexpected since the latter is dependent on organic content of the soil while the others more on the inorganic composition of the soil mineral skeleton.

SUMMARY

Seeds of *Picea abies* from 25 Polish provenances have been analysed for internal concentrations of nitrogen, phosphorus, potassium, magnesium, calcium and sodium. Since these concentrations are a reflection of soil conditions in the site of seed collection, they may prove useful in the interpretation of results of provenance studies established from these seeds. Correlations between the various seed characters are discussed (fig. 3). K%, P%, Na% and seed weight together with some cone cha-

racters are related to the differentiation of populations into the two Polish ranges of spruce. Seed size, N% and Ca% are related to elevation of the site of seed collection. Mg%, Ca%, P% and K% are correlated with each other (reflection of inorganic soil status) but not with N% (reflection of organic soil status).

This work has been partially supported by grant No. FG-Po-174 from the U. S. Department of Agriculture, under U. S. Public Law — 480.

Institute of Dendrology and Kórnik Arboretum
Kórnik nr. Poznań

LITERATURE

1. Andersson E. — 1955. Cone and seed studies in Norway spruce (*Picea abies* Karst.). Stud. For. Sue. 23 : 1 - 214.
2. Burley J. — 1965. Variation in seed characteristics of Sitka spruce. Adv. Front. Plant Sci. 10 : 11 - 24.
3. Chylarecki H., Giertych M. — 1969. Variability of *Picea abies* (L.) Karst. cones in Poland. Arboretum Kórnickie 14 : 39 - 71.
4. Dutkiewicz W. — 1968. Variation in seed weight in relation to boundaries of two ranges of spruce in Poland. ex. Population studies of Norway spruce in Poland, Warszawa, IBL, 45 - 51.
5. Fink J. — 1963. Wstęp do biochemii fosforu roślin. PWRiL, Warszawa.
6. Fober H., Giertych M. — 1971. Variation among Norway spruce of Polish provenances in seedling growth and mineral requirements. Arboretum Kórnickie 16 : 107 - 120.
7. Giertych M. — 1970. Doświadczenia proweniencyjne nad świerkiem pospolitym (*Picea abies* Karst.) założone w roku 1969. Arboretum Kórnickie 15 : : 263 - 276.
8. Humphries E. C. — 1956. Mineral components and ash analysis. ex. Modern Methods of Plant Analysis. Ed. Paech and Tracey vol. 1 : 468 - 502.
9. Piper C. S. — 1957. Analiza gleby i roślin. Warszawa PWN.

HENRYK FOBER I MACIEJ GIERTYCH

Zróżnicowanie nasion świerka (Picea abies Karst.) w Polsce pod względem wielkości, wagi i zawartości soli mineralnych

Streszczenie

Nasiona *Picea abies* z 25 polskich pochodzeń zanalizowano na zawartość azotu, fosforu, potasu, magnezu, wapnia i sodu. Ponieważ stężenia tych pierwiastków w nasionach są zależne od zasobności gleby, ich znajomość może okazać się pożyteczna przy interpretacji wyników badań proweniencyjnych założonych w oparciu o te nasiona. Omówiono szczegółowo korelacje pomiędzy różnymi cechami na-

sion (rys. 3). Stężenie potasu, fosforu i sodu oraz waga nasion razem z niektórymi morfologicznymi cechami szyszek są uzależnione od pochodzenia z jednego z dwóch polskich zasięgów świerka. Wielkość nasion oraz stężenie azotu i wapnia są zależne od wysokości nad poziomem morza terenu zbioru nasion. Stężenia magnezu, wapnia, fosforu i potasu są ze sobą skorelowane (wpływ składu nieorganicznego gleby) ale nie ze stężeniem azotu (zależnym od organicznej zasobności gleby).

ХЕНРЫК ФОБЕР И МАЦЕЙ ГЕРТЫХ

Изменчивость семян Picea abies (L.) Karst. в Польше по величине, весу и содержанию минеральных солей

Резюме

Проведен анализ семян ели из 25 польских местонахождений на содержание азота, фосфора, калия, магния, кальция и натрия. Поскольку концентрация указанных элементов в семенах зависит от их содержания в почве, эти данные могут оказаться полезными при интерпретации опытов по испытанию семян разного происхождения. Детально обсуждены явления корреляции между разными признаками семян (рис. 3). Концентрация калия, фосфора и натрия, а также вес семян и некоторые морфологические особенности шишек зависят от того, из какой из двух частей польского ареала ели происходят эти семена. Их величина, а также концентрация азота и кальция зависят от высоты над уровнем моря места их сбора. Концентрация магния, кальция, фосфора и натрия коррелируются между собой (влияние неорганической части почвы), но не коррелируются с содержанием азота, зависящим от органических компонентов почвы.