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Genetic investigations on Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) populations

CONTENTS

I. INTRODUCTION

Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco.) belongs to the huge pine family (*Pinaceae*) in the class of conifers (*Coniferae*). Among the genus *Pseudotsuga*, besides Douglas-fir, are also reckoned six species (Thomas and Ching 1968), if we are not to take into account four controversial units of classification from Mexico (Martinez 1963). Besides North America, where alongside Douglas-fir (Fig. 1) occurs *P. macrocarpa*, the genus *Pseudotsuga* also occurs in Japan, on Taiwan

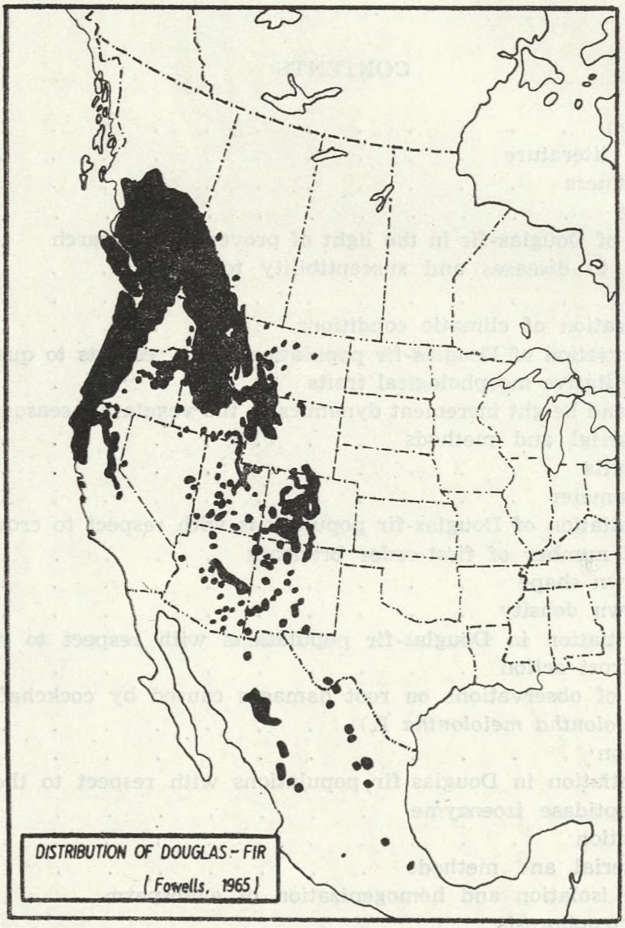


Fig. 1. Distribution of Douglas-fir (*Pseudotsuga menziesii*) in North America

and in China, represented in Asia by *P. japonica* Beisser, *P. forrestii* Craib., *P. sinensis* Dode. and *P. wilsoniana* Hayata (Henry and Flood 1920). In Europe Douglas-fir appeared in the Tertiary. When David Douglas sent in the autumn of 1826 Douglas-fir seeds from Fort Vancouver to Great Britain, he reintroduced thereby the *Pseudotsuga* genus onto the continent, on which this genus used to exist before (Herman and Ching 1973).

Nearly half a century ago Miklaszewski (1928) wrote that from among 29 North American species on which experimental plots were established in Poland at the close of the XIX th c. Douglas-fir yielded the best results, surpassing the comparable trees of pine, spruce or fir in its height, diameter and wood yield. Similar to the other European countries the earliest-established Douglas-fir stands did not have any seed origin certificates and hence it was impossible to replicate these trials. Subsequent experiments brought unfortunately a number of failures.

For it turned out that the phylogenetic evolution of Douglas-fir in North America was subject to the influence of a number of orographic factors having a very intensive effect on the species distribution. Apart from glaciers also lava eruptions tended to disintegrate the compact distribution of Douglas-fir; there are also the formation of extensive water and desert traits, as well as gigantic fires that all contributed to the arisal of disjunctive areas (Holiday and Brown 1943, Galoux 1965, Martin and Mehringer 1965, Hermann and Ching 1973). Many tree populations developed that differed one from another in morphological, physiological and biochemical characters, which differences, while complicating any endeavours aiming to introduce this species in Europe, yielded excellent material at the same time and became a reason for research on the intraspecies variation in populations whose distribution depended on natural forces only.

Biosystematics has assumed until recently the existence of three varieties within the *Pseudotsuga menziesii* (Mirb.) Franco. — var. *P. menziesii menziesii* — green variety, *P. menziesii* var. *caesia*-grey variety, and *P. menziesii* var. *glauca* — blue variety (Maciejowski 1951, Schenck1936, Kundzinsz A. V., Igaunis G. A., et al. 1972). It turned out, however, that this systematics is incoherent. It assumed geographical and morphological separation of the above-mentioned varieties (Hosie 1969), whereas in appreciable areas of Douglas-fir distribution we can encounter populations with intermediate morphological and chemical characters (Ching and Hermann 1973, Sziklai 1967, Rosenstock 1972). So we often use interchangebly ,,costal type'' meaning *P. menziesii* var. *menziesi,* because on the Pacific coast in Washington State cccurs a typical green Douglas-fir, while instead of var. *glauca* one says ,,Douglas-fir from the interior'', as this is the blue variety that is most frequently encountered in the Rocky Mountains. The grey variety, currently nearly ignored in the literature on the subject, was supposed to occur at the line of contact between the two afore-dicussed — var. *menziesii* (more commonly refered to as var. *viridis*) and var. *glauca*. In this study, when discussing our own results the designation ,,variety'' is abandoned; and we have made an effort to give the name of the provenance to which, alongside the place name, the population number after the IUFRO (B a r n e r 1966) is always attached.

II. SURVEY OF LITERATURE

The earliest attempts to introduce Douglas-fir into forest plantations in Europe date from the beginning of the XIX th c. B o o t h (1907), I l v e s s a l o (1926) and D o n g (1970) present the following succession of countries that introduced Douglas-fir: 1828 — England, 1834 — Scotland, 1860 — Denmark, 1874 — Switzerland, 1892 — Luxembourg. Yet these attempts suffered from a number of shortcomings, which was perfectly realized. T y n i e c k i (1891) writing on the introductory endeavours with North American forest trees states that „Such trials, carrried out in various quarters and in different localities, as can be easily conceived, worked to very diverse degrees of success and reports of good or bad results which were made public usually without an accurate statement under what conditions the populations exist, have not only done little to contribute to an elucidation of the issue, but on the contrary being often conflicting ones, they have blurred it while discouraging many". The author calls attention to a few moments in introductory work which lost none of their immediate interest, namely, we should have a more accurate knowledge of climatic, soil conditions and elevation, and also of the forest complex into the composition of which the acclimatized tree enters as well as we should needs conduct systematic constant observations and write down the results (T y n i e c k i 1903).

The oldest German experiments established by S c h w a p p a c h in 1910 in Chorin, and American experiments from 1912 already had the seed harvest location, hence we can term them as „provenance". The Chorin experiment consisted of 19 provenances, in that there were 2 provenances of *„viridis"* type Douglas-fir. The occounts of this experiment point to a predominance of the green Douglas-fir over *„glauca"* type Douglas fir with respect to tree height, diameter and wood yield per hectare (B o i s e l l e 1954, F l ö h r and D i t t m a r 1954).

The American provenance experiment from 1912 was really a progeny test from individual trees deriving from West Washington and Oregon. The experiment suffered from typical mistakes of all original population experiments on tree variation; namely from and inadequate number of replications and a wrong design within the experiment. It has drawn our attention to a little-known fact that some may grow better in some other area than in the place of their origin (M u n g e r and M o r r i s 1942). This phenomenon was later on borne out in Douglas-fir, similar to some other forest tree species, and they were termed „local incompatibility". It stems from the orientation of natural selection towards the production of rapidly reproducing types (N a m k o o n g 1969), or it is also an outcome of a high interaction between Douglas-fir populations and the environment (S t e r n 1974). An appraisal by S o k o ł o w s k i (1912) of the earliest attempts at Douglas-fir acclimatization in Poland pointed to an appreciable predominance of the green Douglas-fir yield over spruce, pine and fir stands, similar with respect to age and site. At the same time S o k o ł o w s k i called attention to the differences between „*viridis*" and „*glauca*" types with regard to frost susceptibility.

The green Douglas-fir is more susceptible and that is why S u c h o c k i (1926) recommends growing the green Douglas-fir in Wielkopolska region. M a c i e j o w s k i (1951) thinks that the Douglas-fir from Washington and British Columbia should be grown in the western part of Poland to the west of the Vistula. That author proposes growing the Douglas-fir i.e. „*caesia*" type in the regions of Poland lying east of the Vistula and he claims a complete uselessness of the grey Douglas-fir for growing in research on nurseries and plantations, come to the conclusion that the Polish forests. I l m u r z y ń s k i et al. (1968), on the strengh of their trees coming from Washington State exceed the Idaho New Mexico provenances with respect to height, diameter and viability.

It seems a valid supposition that some populations from Washington State and from Vancouver have great adaptibility and even in the USA and Canada they exceed in vigour the local Douglas-fir populations (C h i n g 1965). Subsequent experiments established in Poland indicate that also in Washington State there are populations with a very negligible tree height and diameter increment under the conditions prevalent in our country (B u r z y ń s k i and G u t o w s k i 1973, B i a ł o b o k and M e j n a r t o w i c z 1970, M e j n a r t o w i c z 1973). So any employment of the concepts of territories in which Douglas-fir with outstanding values for the needs of forestry of a country occurs should be restricted precisely to a concrete point on the map that determines the origin of populations used in the experiment. For some characteristics a very great variation within one population has also been found (E l L a k a n y and S z i k l a i 1971, C h i n g 1962, I r g e n s - M o l l e r 1967), and then differing intensity of the influence of environmental factors on tree heigth increment conditional on the age of trees. The environmental effect is the greatest in the juvenile stadium and late reproduction period, whereas it is the smallest in the early reproduction stage. Interpopulational differences, on the other hand, are the smallest in the juvenile stadium but have a constant tendency to grow (N a m k o o n g et al. 1972). S z i k l a i and R e c k (1973), who investigated correlations between wood density in young and old stands, come to the conclusion about the feasibility of the application of the early test for this wood character in Douglas-fir. D i x o n (1970) confirms the feasibility of the early test for a very important character of Douglas-fir trees which is the shape of tree crowns. In a series of experiments established in the years 1954 - 1964 attention was drawn to a considerable influence of experiment conditions on the results of research on a certain population of trees (Schober 1973, Dixon 1970).

When viewing the results of the up-to-date investigation in Europe, we can state that for the majority of countries the most convenient for a large scale growing have proved to be just coastal provenances from Washington State, sometimes from Oregon (Boiselle 1954, Suchocki 1926, Dong 1970, Holm 1957, Galoux 1956, Lacaze 1967, Poskin 1951, Gathy 1967, Syrotkin and Sieroglazova 1970, Pirgas 1970, Šika 1973, Veen 1951).

Most recent investigations indicate that some Douglas-fir populations growing at considerable elevations a.s.l. in New Mexico may yield a progeny well withstanding European climatic conditions (Stern 1974, Stephan 1973).

As criteria for the assessment of particular populations the most frequent to be adopted are: frost hardiness, height increment, phenological characters and disease resistance. We will discuss European data on the individual population characters according to the above-mentioned order.

FROST HARDINESS

This is one of the most frequently considered characters in researches in Central and Northern Europe on the differentiation in Douglas-fir populations, since it decides about the survival of a given population already in the early stadium of tree development. Many observations and experiments have been carried out seeking to single out those Douglas-fir characters that could be easily determined and correlated with frost hardiness of these plants. It is generally accepted that the green Douglas-fir is susceptible to frost, and grey and blue Douglas-firs are resistant to the action of this climatic factor (Sokołowski 1912, Kundzinsz 1972). The one established on the 99% confidence level is the correlation of poor growth in height with considerable resistance to frost (Białobok and Mejnartowicz 1970, Dymitri et al. 1974, Kleinschmidt and Racz 1973, Lacaze and Tomassone 1967).

Examing the relationship between catalase activity in sap and frost hardiness, Szönyi and Nagy (1968) find the following relationship: the higher the catalase activity, the more intensive the tree height increment and at the same time the smaller its frost hardiness. If these results could be confirmed in other experiments, that would be a quick test for ontogenetic frost hardiness which should however be referred to a definite moment in a tree's lifetime, as catalase activity changes together with the development and growth of a tree. By way of a chemical analysis of cell sap on calcium and potassium content and the mutual ratio of these two elements, one can find interpopulational differences among trees resistant and susceptible to temperature fluctuations and air humidity (Kral 1965, Scheumann 1962). Investigation on two-years-old cut-off shoots of Douglas-fir seedlings, on which electric conductivity of a diffusive solution has been measured, have been carried out by van den Driessche (1969). The results of these measurements point to a relationship between the level of relative electric resistance and cambium activity and trees frost hardiness. The lowest electric resistance was measured during lowest sap activity and highest frost hardiness at the same time i.e. in the winter period. Dimitri (1973) on material being part of the Douglas-fir seed harvest from the IUFRO 1966/67 collection, has carried out an experiment in which the seeds have been sown on an artificially prepared substratum, and then on the grown-up seedlings relative water-content in tissues has been measured and frost hardiness has been observed in the individual provenances. According to the results of measurements and observations, the provenances have been divided into three groups: 1) relative to average water-content in tissues amounting to 220 - 240% has been found in seedlings from Washington provenances and in some from Oregon. Low frost hardiness; 2) water-content from 190 - 220% has been found in seedlings from different provenances with intermediate frost susceptibility; 3) water-content between 150 to 190% has been found in seedlings with a high frost susceptibility mainly in British Columbia provenances. This division overlaps to a large extent with the former data obtained from a direct assessment of the quality and number of frost-damages from the same set of populations (Białobok and Mejnartowicz 1970).

Not only biochemical characters have been taken into account in our experiments on Douglas-fir's frost hardiness. Also a number of morphological characteristics of needles have been considered and their correlation with frost hardiness has been established. This establishment refers to the colour of needles, the mode of their placement on the shoot, the spin of a needle along its symmetry axis and also the level of leaf bud development in the winter period (Kleinschmit and Racz 1973, Lines and Mitchell 1970).

In countries where old Douglas-fir stands are to be found, one of the more reliable ways of obtaining positive selectional effects for the frost hardiness trait is obtaining seeds from the best local stands, which by the very fact of their presence there indicate that hey have successfully gone through the acclimatizing cycle, entering the reproduction phase (Kundzinsz, Igaunis et al. 1972).

TREE HIGHT

This character has been examined in nearly all experiments on intrapopulational differences in Douglas-fir in Europe. That follows on the one hand from the close correlation of this character with frost hardiness of trees and what follows, with tree mortality, and on the other hand this is undoubtedly one of the most important traits of a forest tree.

A very interesting one is Wright's (1971) experiment on genetic variation in the Rocky Mountains Douglas-fir. It has been ascertained in an established provenance experiment that tree mortality and their growth are more differentiated than in analogous experiments with pine and spruce. This is not an isolated observation. This would point to a singular susceptibility of Douglas-fir specimens to hostile environmental factors and also to the fact that adaptation of populations to very diverse environments must be genetically conditioned.

In a number of studies has been found a certain clinal variation in tree height. In investigations on provenance areas established in Ireland, Germany and in Poland, the provenances deriving from the northern part of Douglas-fir distribution as well as from higher elevations had lower progeny (Białobok and Mejnartowicz 1970, Dong 1970, O'Driscoll 1973, Hermann and Lavender 1968, Kleinschmit and Racz 1973, Kral 1965). On the other hand in a provenance experiment from the IUFRO 1966/67 series, the one established in Great Britain, no clinal tree height variation with respect to the elevation of a provenance, was found after the first year of seedlings lifetime and only a very tenous connection with the latitude of populations origin has been established (Lines et al. 1971). Also Ching (1962) points to a very great tree height variation within and between populations growing in similar conditions. In Scandinavia in Finland the highest height increments are to be observed in the populations of British Columbia provenances, while in Norway a number of populations from Washington give splendid results (Hagman 1973, Magnesen 1973).

PHENOLOGY OF DOUGLAS-FIR IN THE LIGHT OF PROVENANCE RESEARCH

The older experimental areas with Douglas-fir have been observed from the angle of quantitative characters. Phenological observations, on the other hand, have been caried out for a long time on various forest tree species, but Douglas-fir has remained outside their pale (Cieślar 1895, Engler 1908, Langlet 1936). Phenological character in the form of different development stages of leaf buds point to genetic differences between population from various region of the USA (Morris and al. 1957).

These differences remain irrespective of the place of establishment of the experimental area. Also investigations on the periods of autumn growth retardation in various populations point to significant differences depending on the place of seed origin. Pacific coastal plants were marked in Irgens Moller's (1959) experiment for a growth by 1 - 4 weeks longer than those from the provenances lying in the interior of Columbia and the High Cascades. Subsequent studies of this author pointed to the existence of very great interpopulational differences with relation to leaf bud flushing time with a small spatial separation of parental stands (Irgens-Moller 1967). The first to start their flushing are populations from the British Columbia interior, and the ones from the Pacific Ocean coast flush latest of all. In Polish conditions to the first group belong the populations: 1008 — Golden, 1014 — Eagle Bay, 1035 — Nelson and 1052 — Twisp. In the group of late-flushing populations are: 1073 — Hamptulips and 1086 — Naselle. The difference between these groups amounts to 32 days. The attachment of a population to any one of the groups we have mentioned does not determine the value of the annual height increment obtained (Mejnartowicz 1973). It has also been found in an experiment with analogous seed stock established in Great Britain that provenances from the centre and south of British Columbia started growing early and they sooner entered on the state of repose.

There is also a relationship between the location of the parental stand and the period of progeny populations growth inception. Lowland populations start growing later and mountains ones considerably earlier (Popa-Costea 1971), which also refers to height growth inception. It should be noted, however, that not all experiments give such unambiguous results. Lacaze (1968) notes that there are appreciable differences in growth rate of individual ecotypes, but the growth curves trend parallel to each other. Pintaric (1971), on the other hand, found small interpopulational differences in the vegetative period span, but considerable differences in the vegetation inception period and the shift of development phases with respect to one another in an interpopulational comparison.

Probably the interaction of a population with its environment is considerable and depends in a large measure on climatic factors. For we can observe differing patterns in flushing inception, i.e. spring height increment inception in successive years in the same area with relation to one and the same population. Observations of Douglas-fir half-sib progeny indicate that the character of early or late flushing is associated with a variation reduction within a population. If we assume that the paternal effect on the lateness of flushing is null and that this character is conditional on the additive action of genes, then we can achieve quite rapid selectional progress connected with lowering of variation in subsequent generations (Birot 1974).

Irgens-Moller (1968) reports for the experiment established in Oregon State that some populations derived from the Southern Rocky Mountains had in their vegetative season a spell of height increment cessation coming in after some 70 - 90 days of growth, thereupon the increment lasted another 30 - 40 days. Especially in populations from southern and coastal regions of Douglas-fir occurence there are to be frequently observed intensive Lammas increments which, on the one hand, are a negative tree characteristic because they increase the number of branches (O'Driscoll 1973) while on the other hand, they contribute to an appreciable increase in annual increment value, sometimes up to 30% (Mejnartowicz 1973).

RESISTANCE TO DISEASES AND SUSCEPTIBILITY TO PESTS

Douglas-firs very high resistance to pathogenic factors as well as its little susceptibility to pests have caused the fact that research on Douglas-fir's resistance to operation of these factors is a negligible fraction of the overall researches on this species. Several score of years after the introduction of Douglas-fir into Europe some parasible fungi also made their way onto the continent. To be true, they do not cause any major damages in the place of natural occurrence of Douglas-fir, yet considerable losses have already been ascertained in plantation of this species, ones most commonly caused by *Phaerocryptus Gäumanni* (Rhode) Petrak or by *Rhabdocline pseudotsugae* Syd. In western Europe both diseases were found about 1925. In Poland they did not appear until the Second World War (Mańka 1960, Ostrowski 1959). They cause needle falling impeding thereby tree bulk increment. These diseases are observed on trees in the IUFRO 1966/67 experiment in German Federal Republic. Ascertain there appreciable interpopulation differences in resistance to the fungal infection *Rhabdocline pseudotsugae*. In the juvenile stage the populations from the western slopes of the Cascade Mountains in the states of Oregon and Washington reveal high resistance; whereas the populations from the interior below the 45° latitude, especially those from Utah, Arizona and Colorado, are effected to a considerable degree. It is interesting that a group of populations from New Mexico is resistant to *Rhabdocline pseudotsugae* and distinquished by an appreciable increment dynamics (Stephan 1973) at that.

On the experimental area at Kórnik no occurrence of these diseases has so far been found, though the possibility of tree infection is substantial on account of the neighbourhood of old Douglas-fir stands. In Poland a considerable bar to Douglas-fir growing is put up not by fungal but by insectal pests. Dogulas-fir seeds collected from some old, very valuable stands are attacked in 100% by *Megastigmus spermatropus* Wachtl (S c h n a i d e r 1970), which renders a reproduction of these populations completely, impossible.

Another dangerous pest is the grub of cockchafer. The damages are wrougth by the grob during the first five years of trees lifetime (B u r z y ń s k i and G u t o w s k i 1973). They do not constitute, however, a major problem on account of the feasibility of agrotechnical measures restricting the development of cockchafer larvas.

III. METHODS

The IUFRO — proposed design for experimentation on interpopulational differences in Douglas-fir the 1966/67 seed collection (Fig. 2) suggested dividing the overall sample of seedlings into a possibly great number of subsamples which would have to be tested in various forest habitats in „one tree plots" experimental design. This undoubtedly a

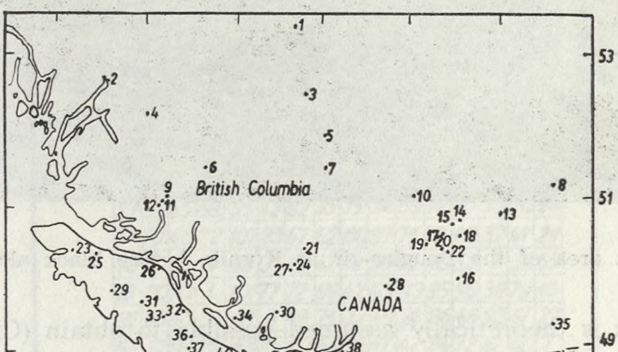


Fig. 2. Places of Douglas-fir seed collection in the IUFRO 1966/67 series

quick method of obtaining preliminary information as to the adaptive quality of the individual specimens from a given population. For execution of such a task one should have a great number of seedlings, at

Phot. K. Jakusz

Fig. 3. Test area of the Douglas-fir at Kórnik, before black alder planting

least such as is theoretically assumed possible to obtain (Circular letter IUFRO 20 April 1960).

Unfortunately, the quantities of seedlings obtained at Kórnik differed in minus from those predicted. It is possible that this would be an effect of applying spring sowing without stratification which yields worse results than autumn sowing does (Hofman and Heger 1962).

The seeds were sown in April, 1968; they had been steeped for 48 hours and protected with minium against vermins. Planting was done in four replications. The exact geographical data on the populations under investigations and results of their observations during the first year of their lifetime are in Białobok and Mejnartowicz's study (1970). In April, 1970, an experiment was established with 1+2 seedlings at the Zwierzyniec Experimental Forest Range near Kórnik (Fig. 3).

The area used for establishing the experiment was former arable land which used to be under constant cultivation. In empirical research the aim of an experiment determines its methods. Since the concern of the Kórnik experiment is research work on the adaptivity and genetic intra- and interpopulational variation in this species, one allowing us to look into the structure of green Douglas-fir populations and enabling us to make a correct choice of the provenance from which the seeds collected would give most valuable seed stock for introduction in our country's climatic conditions, that is why we have decided on a plot design of the experimental area. There are 25 specimens of one population on one plot, and they are distributed in a 1.5 × 2 m spacing. In between the rows being 2 m apart, black alder was planted contributing a lateral protection and a perfect biocoenotic component.

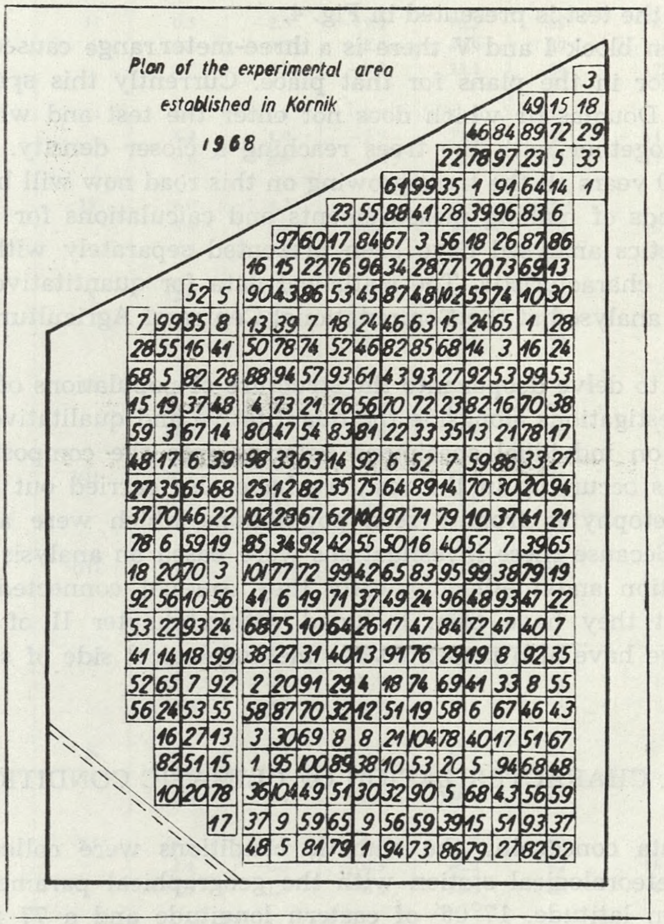


Fig. 4. Scheme of the experiment on Douglas-fir provenances established at Kórnik

Out of the initial full pool of one hundred and four populations, four populations had fewer than 25 seedlings each in the third year of their lifetim in results of low germinating power and subsequently frost damages, these populations were excluded from the experiment. They were: 1011-Klina-Klini, 1044-Jordan Rive, 1066-Scenic, 1103-Coquille. The remaining 100 populations were distributed in 6 unequalsized blocks with complete randomization of populations within a block. In the first block there are all populations, wheras in block VI — there are only 32 of them, each of which had at least 50 seedlings. Some populations had over 400 seedlings and they were used for the experiment protecion in the form of insulation. There are no specings between the plots. The losses in the test area and in the insulation are made up for with spruce and fir with the aim of using them as Christmas trees and brushwood. Plot boundaries in the field are permanently marked with oak stakes on which plastic labels with numbers for the populations were nailed. The scheme of the test is presented in Fig. 4.

Between block I and V there is a three-meter range caused by a road provided for in the plans for that place. Currently this space is overgrown by Douglas-fir which does not enter the test and which will be removed together with the trees reaching a closer density. At the age of about 20 years all the trees growing on this road now will be cut down. The methods of making measurements and calculations for each of the characteristics analysed have been presented separately with discussion of a given characteristic. The statistical data for quantitative characters have been analysed at the Computational Centre of Agricultural Academy in Poznań.

Trying to delve deeper into the structure of populations of the species under investigations alongside the quantitative and qualitative characters measured on indvidual specimens entering into the composition of the populations occurring in the test, we have also carried out research on macrogametophytes from 6 seed populations which were also used in this test. Because these investigations were based on analysis of isoenzymes variation and methodologically they are not connected with field experiment they have been included within chapter II of this study, wherein we have also presented the methodological side of such investigations.

IV. CHARACTERIZATION OF CLIMATIC CONDITIONS

The data concerning the climatic conditions were collected at the Kórnik meteorological station with the geographical parameters: 52°15′ of northern latitude, 17°06′ of eastern longitude and a 77 m elevation above sea level. The distance from the observation post to the test area amounts to 2 km in a straight line. The results of meteorological observations in the years 1972 - 74 collected in Table 1 indicate that these years were favourable to tree vegetation. In the period of intensive growth inception, when the shoots are very susceptible to damage by abrupt drops in temperature, i.e. at the turn of May in the past years 1972 - 74 ground frosts were not dangerous, for they occurred before the end of May, when phenological observations point to initial stadium of

Table 1

Meteorological data for Kórnik for the period 1972–1974

Years	Months	Temperature C°			Precipitation	Relative humidity	Number of frosty days	Number of snow days
		average temperature	average minimum	absolute minimum	mm	%		
1972	I	–4.5	–6.9	–18.8	17.1	83	19	6
1973		–0.4	–3.2	–13.0	16.9	90	25	3
1974		1.3	–0.7	–8.8	36.4	88	16	.
1972	II	0.5	–2.3	–19.9	10.5	88	4	9
1973		2.1	0.5	–8.2	49.9	87	11	3
1974		2.7	0.5	–6.2	33.1	86	12	.
1972	III	4.4	0,1	–9.4	39.7	71	.	1
1973		4.4	1,0	–7.9	27.9	88	11	.
1974		4.6	0.6	–6.8	5.7	72	17	.
1972	IV	8.0	4.2	–5.5	37.9	73	.	.
1973		5.9	2.0	–6.6	56.1	76	10	1
1974		7.5	2.0	–10.4	23.8	62	8	.
1972	V	12.9	8.1	–0.3	74.3	77	.	.
1973		12.8	7.7	–2.8	92.3	73	.	.
1974		11.8	7.0	–3.7	74.1	70	.	.
1972	VI	16.7	11.2	3.9	65.6	74	.	.
1973		16.4	10.7	–0.2	88.0	71	.	.
1974		14.8	10.7	2.0	76.1	74	.	.
1972	VII	20.3	14.7	4.8	78.2	75	.	.
1973		18.2	13.4	6.2	91.8	77	.	.
1974		15.9	12.5	7.3	101,0	78	.	.
1972	VIII	17.1	12.7	4.5	82.4	78	.	.
1973		17.9	11.0	4.3	5.8	66	.	.
1974		18.4	14.1	5.0	87.0	76	.	.
1972	IX	11.5	5.7	–0.4	48.2	85	.	.
1973		13.7	8.8	–3.7	23.9	75	1	.
1974		13.5	9.1	0.0	17.9	78	.	.
1972	X	6.5	2.7	–5.4	13.1	84	.	.
1973		6.8	3.5	–6.7	52.1	85	6	.
1974		6.4	4.1	–3.8	136.2	88	.	.
1972	XI	4.7	2.8	–6.2	33.7	82	.	1
1973		2.4	–0.3	–10.3	46.2	82	16	3
1974		4.3	1.9	–6.3	28.6	87	4	.
1972	XII	0.3	–2.7	15.8	11.1	85	9	.
1973		–0.6	–2.8	–24.4	50.9	90	21	15
1974		3.7	1.5	8.7	84.3	88	5	.

terminal bud development. The most important for Douglas-fir acclimatization in Great Valleys of central Poland is the period from May through June. At that time sometimes great decreases in temperature occur, causing time substantial frost damages. In our observations from 1975, not included in this study, we report considerable frostbites of shoot ends in result of a chill spell at the turn of May, with its peak on 2 June assuming the value —10.4°C while in previous years there were temperatures within the −0.2°C to +3.9°C range. On the basis of phenological data we can that of little importance are early ground frosts observed in the Kórnik test have their height increment already at the end. In the course of September absolute temperature minimus reach the values from —3.7°C to 0.0°C in the years 1972 - 1974. Mild transitions between positive and negative temperature values in spring to autumn promoted these population that start their vegetation period early as those that terminate their height increment in the latter half of the summer. Especially favourable was the year 1973, for in addition to warm spring, the precipitation in April was almost twice as high as in 1972 and 1974. Also the precipitation of May and June of 1973 was very high for the conditions in Central Poland characterized by a considerable landscape steppization. Annual precipitation amounted from 511.9 in 1972 to 704.2 in 1974, with the precipitation pattern not being very favourable, since the least precipitation goes for the spring period. Maximal temperatures have no special importance, for they reach values that are not dangerous to tree vegetation.

1. DIFFERENTIATION OF DOUGLAS-FIR POPULATIONS WITH RESPECT TO QUANTITATIVE AND QUALITATIVE MORPHOLOGICAL TRAITS

HEIGHT AND HEIGHT INCREMENT DYNAMICS IN THE VEGETATIVE SEASON

Material and methods

Starting form the first year after seed sowing, the grown-up plants underwent annual height measurements, with the exception of the years 1970 and 1971, for measurement in these years would be burdened with too great an error resulting from the influence that outplanting of plants exerts on their growth. As far as it was possible, the measurements were carried out on 100 specimens in four replications for each population. In autumn, when ceasation in height increment occurred in all trees and the terminal bud developed, tree height was measured with an accuracy to 10 mm. Annual height increment in the majority of Douglas-fir trees is made up of the spring increment and of secondary increment called also lammas or summer. That is why separate measurements were made for each of increments and for the total annual growth. The date of spring increment measurement was conditional on the results of phenological observations carried out during the whole vegetative period and was connected, with fixing the moment of development of the first terminal bud separately in each population. After a dozen or so days, the large scale leaves enveloping the bud and the second stage of on intensive height growth begins. On the shoot the large enveloping scale leaves hold on at the place of the spring terminal bud formation for a long time. The value of lammas increment can be obtained in two ways:

a) by calculating the difference between tree height in the current year and last year's height plus spring increment of the current year,

b) by measuring directly the length of a shoot from the autumn terminal bud to the scale leaves remaining on the shoot at the place of formation the moment spring increment ceases.

The latter way proved to be more accurate and was employed in this study.

Results

Tree height. In table 2 have been gathered the results of measurements concerning tree height in the individual years of measurements. Most important is the information on average tree height $\bar{x}$ from all 100 populations. Apart from this piece of information tree height values in the populations with the lowest trees (x_{min}) and in the populations with the tallest trees (x_{max}) have been given. These data allow one to take in quickly the dispersion of observations. We conclude about the variation of a given characteristic, in this case about tree height, on the basis of the S-standard deviation, for the triple value of this deviation practically comprises the total (exactly 99.73%) variation of observation. For tree height, and also in a number of other characteristics, the $S_{\bar{x}}$ value has also been calculated the one designating standard error, which depends on the observed frequencies in a sample. Calculating $S_{\bar{x}}$ is of great importance, for it allows us to determine the significance of differences between pairs of average values from various populations. On the basic of estimation theory we regard as significant those differences between two average values, when they exceed the double value of $S_{\bar{x}}$.

In order to make possible a comparison of a number of populations with respect to different characters or the same population in different years, the value of the variation coefficient $W = \frac{\sigma}{\bar{x}} 100$ has been calculated.

It has been found on the strength of variation coefficients that with

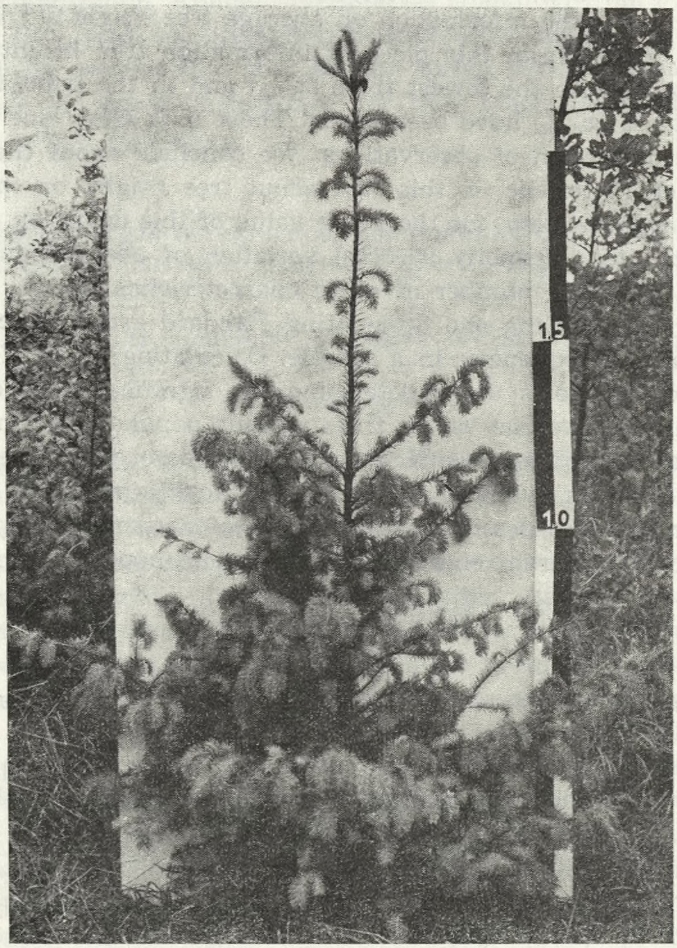
Table 2

Basic data on variation during 4 years in *Pseudotsuga menziesii* tree height in 100 populations

Year of observations	$\bar{x}$	x_{min}	x_{max}	S	$S_{\bar{x}}$	$W\%$	F_0	$F_{0.01}$
1969	14.0	10.6	17.3	1.4	0.14	10.3	6.02	1.45
1972	58.2	31.1	76.9	9.9	1.0	17.0	7.04	1.45
1973	89.1	47.0	115.0	14.4	1.4	16.2	4.60	1.45
1974	134.8	73.3	177.7	24.0	2.4	17.8	4.18	1.45

respect to tree height interpopulation variation was much lower in 1969 than in the other years. This is a reflection of a relatively low populational variation in the composition of general variation of observations made at the nursery (data from 1969 refer to the measurements carried out at the nursery) in comparison with environmental variation on a forty times larger area of a permanent test plot. Also small differences between coefficients in the years 1972 - 1974 speak in favour of such interpretation of these results.

Interpopulational relations in the group comprising the lowest and highest tree height values are marked for a considerable stability. In 1969 and in subsequent years, in the group of populations with the lowest tree height values, we invariably find populations: 1001-Stoner, 1028--Merrit, 1029-Thasis, 1048-Republic and 1102-Upper Soda. In the group of populations where the tallest trees were observed there are: 1095-



Phot. K. Jakusz

Fig. 5. Crown shape and height of a 7-year-old tree from population 1047-Concrete

Table 3

Mean tree height values in cm during 1969 and 1972–1974 and annual increment during 1972–1974

	Provenances	Tree height				Annual increment		
		1969*	1972	1973	1974	1972	1973	1974
1001	Stoner	10.7	34.91	55.89	78.8	15.91	16.7	19.9
1002	Dean	16.5	68.85	111.40	174.1	28.70	34.8	58.8
1003	Alexandria	11.9	41.48	62.97	91.7	17.54	18.7	26.5
1004	Stuie	13.6	59.98	89.25	130.0	22.12	22.9	37.8
1005	Williams Lake	12.6	38.02	60.11	88.0	15.98	11.8	25.9
1006	Tatla	12.9	44.77	70.97	106.2	18.30	21.6	30.8
1007	Clearwater	12.8	55.11	80.45	126.2	23.44	22.6	41.3
1008	Golden	11.1	40.14	62.61	87.3	18.67	17.6	24.0
1009	Klina Klini	14.3	60.54	94.15	143.2	27.62	27.1	46.2
1010	Barriere	13.7	51.7	82.15	122.8	21.06	25.9	38.2
1012	Klina Klini	13.5	46.86	73.45	115.9	15.42	17.1	39.9
1013	Revelstoke	12.7	46.98	76.00	106.2	20.27	20.8	28.7
1014	Eagle Bay	16.5	56.64	72.65	102.8	23.75	16.5	24.2
1015	Blind Bay	13.8	51.20	74.85	115.7	20.00	20.4	37.2
1016	White Lake	14.5	53.57	78.76	114.3	20.20	19.0	32.7
1017	Squilax	14.0	54.80	79.84	114.2	20.49	23.0	32.5
1018	Salmon Arm	14.0	60.47	95.72	142.7	25.80	27.7	42.6
1019	Monte Creek	12.7	44.14	70.44	103.1	20.00	22.1	31.4
1020	Pillar Lake	12.6	41.41	72.09	108.6	18.06	25.2	33.2
1021	D'Arcy	16.0	60.49	94.08	140.8	25.13	27.8	44.6
1022	Fly Hill	13.7	50.86	80.67	120.6	22.30	23.3	36.9
1023	Jeune Landing	16.4	66.72	90.77	133.0	22.81	21.9	36.4
1024	Owl Creek	15.3	55.61	91.05	129.5	19.45	27.8	30.5
1025	Nimkish	13.4	56.72	86.10	124.3	23.77	32.0	33.6
1026	Stella Lake	13.5	43.90	86.13	145.5	23.35	24.9	51.0
1027	Alta	14.4	43.13	74.49	110.9	19.74	20.6	31.4
1028	Merrit	10.8	34.40	64.46	93.3	16.87	19.9	24.8
1029	Thasis	14.3	32.35	79.45	130.7	12.18	24.8	48.7
1030	Squamish	14.7	60.64	90.39	130.5	22.00	26.4	38.7
1031	Gold River	14.5	64.12	108.70	170.5	29.31	37.4	58.9
1032	Courtenay	16.2	65.62	93.25	136.4	23.16	23.7	38.1
1033	Forbidden Pl.	14.8	55.55	82.08	120.5	21.52	19.9	36.7
1034	Sechelt	13.2	59.04	81.25	140.1	24.36	21.3	51.3
1035	Nelson	12.9	46.68	66.26	88.8	18.19	16.3	21.7
1036	Alberni	13.3	73.00	114.00	162.6	33.56	32.1	44.5
1037	Franklin Riv.	16.2	61.22	90.90	130.8	22.38	25.3	38.7
1038	Chilliwack	15.3	67.47	103.23	148.6	26.18	26.7	46.5
1039	Chilliwack	15.8	61.96	103.49	162.0	27.02	34.0	59.3
1040	Cassidy	15.1	54.27	83.75	125.4	19.61	24.3	40.1
1041	Caycuse	17.4	59.94	90.21	135.9	24.00	25.4	42.4
1042	Duncan	13.2	53.26	83.45	130.8	20.08	22.1	45.2
1043	San Juan	14.3	53.30	82.64	128.2	19.17	21.2	44.5
1045	Sooke	14.8	54.20	90.00	150.3	23.25	30.4	55.1
1046	Diablo Dam	14.1	52.28	77.36	111.3	19.30	19.9	31.9
1047	Concrete	15.6	76.87	114.98	170.5	31.75	32.3	53.8
1048	Republic	11.2	31.10	47.10	73.3	12.18	13.7	25.5
1049	Bacon Point	12.8	52.18	88.28	129.7	18.71	27.6	40.1
1050	Marblemount	14.9	62,78	105.10	150.9	24.05	25.8	54.1
1051	Sedro Woolley	14.4	65.12	96.24	141.5	24.67	25.7	43.5
1052	Twisp	12.7	44.50	64.65	84.0	18.59	15.4	17.0
1053	Darrington	15.2	69.85	103.73	161.4	28.19	31.7	54.3
1054	Arlington	13.8	73.27	104.40	159.3	23.45	20.3	57.4
1055	Newport	11.6	42.80	65.39	97.2	17.80	19.8	28.7
1056	Sloan Creek	16.2	64.76	88.44	132.8	22.84	23.1	42.7
1058	Lake Crescent	12.4	65.40	104.85	156.4	23.75	32.9	51.1
1057	Granite Falls	15.4	61.05	95.20	155.9	22.00	20.2	56.9
1059	Perry Creek	16.3	58.92	91.98	137.5	21.97	25.9	44.5

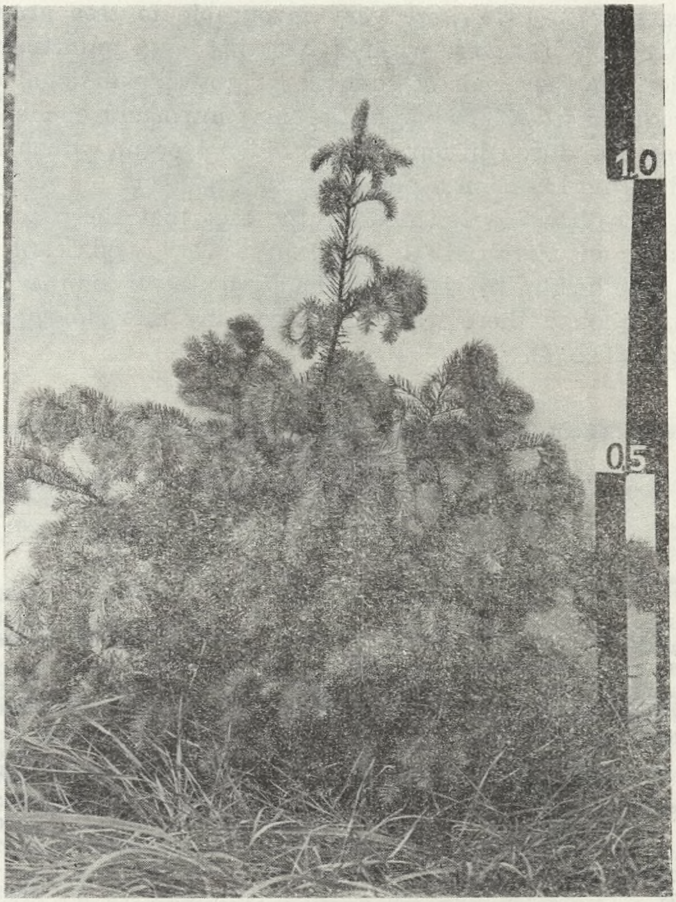
Table 3 — cont.

Provenances		Tree height				Annual increment		
		1969	1972	1973	1974	1972	1973	1974
1060	Sequim	15.2	59.04	87.10	121.1	20.87	24.2	34.6
1061	Louella Guard St.	13.0	64.85	103.55	165.8	30.28	31.8	60.4
1062	Forks	13.5	66.80	99.90	154.2	25.85	28.5	54.5
1063	Gold Bar	17.0	65.68	92.60	149.2	27.68	20.6	51.3
1064	Hoh River	14.3	59.33	91.97	119.6	22.86	23.2	46.2
1065	Spokane	13.6	45.26	72.69	125.2	17.79	23.3	33.8
1067	Skykomish	15.9	67.54	94.33	145.0	26.19	26.0	47.8
1068	Chiwaukum	16.4	53.33	81.93	115.1	18.47	21.2	32.8
1069	North Bend	14.8	69.73	104.96	155.9	26.55	29.1	48.7
1070	Denny Creek	15.4	66.07	98.29	149.7	27.33	31.2	50.0
1071	Keechelus Lake	12.7	54.19	90.90	152.3	22.24	30.8	55.3
1072	Chester M. Lake	15.8	64.49	99.35	153.9	27.43	28.6	51.8
1073	Humptulips	14.5	71.20	103.15	152.9	27.32	27.6	48.2
1074	Matlock	12.8	57.94	86.40	132.1	21.32	24.3	43.0
1075	Enumclaw	13.0	72.74	112.15	175.5	32.66	26.3	62.3
1076	Matlock	14.7	70.84	102.65	159.5	27.05	28.8	54.9
1077	Shelton	12.1	61.74	96.35	156.0	24.95	34.4	58.9
1078	Cle Elum	15.2	51.23	71.30	108.5	17.67	21.0	32.7
1079	Parkway	14.3	51.97	83.43	129.8	21.45	22.7	46.6
1080	Yelm	13.1	63.27	105.50	153.5	31.00	27.3	52.1
1081	Alder Lake	12.0	68.00	95.25	158.6	28.04	25.1	41.1
1082	Rimrock	14.6	50.22	68.56	93.4	19.54	16.0	23.3
1083	Packwood	15.0	58.88	87.58	129.6	21.05	23.7	38.6
1084	Packwood	14.2	65.58	101.72	148.3	24.01	29.0	50.4
1085	Randle	13.6	65.16	103.35	176.0	27.17	32.2	70.2
1086	Neselle	14.1	72.20	108.45	159.2	25.21	32.6	49.0
1087	Skamokawa	12.4	73.00	102.64	148.8	25.65	26.2	45.3
1088	Castle Rock	14.1	68.51	102.80	157.6	27.48	30.2	55.2
1089	Cathlament	13.6	58.60	87.46	134.9	21.29	24.3	41.3
1090	Couger	13.2	66.86	101.20	158.8	24.76	26.4	54.1
1091	Yale	15.1	66.12	100.56	147.7	22.08	26.3	44.2
1092	Glenwood	14.3	63.27	95.76	142.1	21.47	22.3	44.9
1093	Willard	16.1	67.20	100.23	159.9	27.99	28.8	55.3
1094	Vernonia	15.4	67.03	104.10	152.0	26.64	62.4	49.2
1095	Prindle	13.7	68.03	111.45	177.8	29.50	34.8	63.5
1096	Sandy	13.9	74.21	09.21	168.1	27.30	27.2	54.7
1097	Cherryville	12.6	64.65	96.20	152.9	26.60	25.9	48.7
1098	Hebo	13.3	62.29	99.20	134.4	24.08	26.7	39.3
1099	Pine Grove	14.9	57.26	85.67	127.2	21.86	23.8	38.6
1100	Grand Ronde Agency	14.0	56.56	85.15	127.9	15.83	23.0	40.4
1101	Waldport	13.8	54.73	98.90	151.2	24.00	34.4	52.6
1102	Upper Soda	10.6	52.79	86.45	130.6	21.02	27.7	42.7
1104	Brookings	13.4	64·82	97.50	142.3	20.70	25.4	45.1

* Measurement at spring 1969.

-Prindle, 1047-Concrete, as well as 1031-Gold River and 1075-Enumclaw, 1002-Dean (Fig. 5 and 6). Average height values for each population during 1969 and 1972 - 74 have been gathered in Table 3.

We can conclude about the relationships existing between tree height and other characters on the basis of inter character correlations contained in Table 4. We observe highest *r* values for the relationships existing between height measurements in previous years and later measurements of this character. If such a trend persists with further measurements as well, that will be a confirmation of the hypothesis that early testing gives a good basis for inference as to further growth of Douglas-fir trees.



Phot. K. Jakusz

Fig. 6. Crown shape and height of a 7-year-old tree from population 1001-Stoner

A very close relationship also exists between tree height and the number and dimensions of first-order branches. The value of *r* coefficients for these correlations oscillates in the individual years of measurements from +0.70 to +0.92. The tallest were those trees in which a wide crown with a large number of first-order branches was observed.

Probably, this characteristic is closely correlated with tree height in all Douglas-fir populations, for even in Douglas-fir stands currently some 100 years old most select trees are characterized by wide crowns. There is a direct close relationship between height and annual tree increment ($r = +0.93$ in 1974). However, viewing annual increment as sum total of spring and lammas increment, we find that spring increment has a far greater influence on tree height (r=from +0.73 to +0.88) than lammas does (r=from +0.38 to +0.86) a characteristic thing being great variation in summer increment depending on climatic factors in different years.

The years 1972 - 1974 were very favourable to tree growth with a complete abscence of severe winters. Yet this is an unfortunate climatic configuration for the needs of research on interpopulational differences, in the introduced trees. For one of the most important elements of selection of trees introduced in our climate did not occur, which is effect of winter and spring frosts on a plant's living organism. A very great significance of such effect is testified by the fact that the recorded winter frost damages in March, 1971, stood in a very significant correlation relation to tree height, by retarding their growth for another three years ($r=+0.59$), although there were no longer any morphological traces of tree damages (Tab. 4).

Table 4

List of characteristics with very significant coefficients of correlations with tree height during the years 1972–1974

Characteristics	*r* coefficient value		
	1972	1973	1974
Geographic parameters of parental population			
elevation	−0.49	−0.52	−0.53
northern latitude	−0.45	−0.48	−0.45
western longitude	−0.34	−0.38	−0.40
Tree characteristics in progeny populations			
number of seedlings in 1969	−0.49	−0.60	−0.64
number of seedlings in 1970	−0.49	−0.60	−0.64
number of first-order branches			
in 1970	+0.74	+0.70	+0.70
in 1972	+0.92	+0.81	+0.78
length of largest branch in 1972	+0.88	+0.85	+0.82
in 1973	–	+0.90	+0.91
Height increment	+0.88	+0.87	+0.84
spring 1972			
1973	–	+0.81	+0.82
1974	–	–	+0.73
Lammas 1972	+0.86	+0.54	+0.55
1973	–	+0.66	+0.38
1974	–	–	+0.93
annual 1972	+0.83	+0.85	+0.83
1973	–	+0.81	+0.82
1974	–	–	+0.93
Tree diameter in 1974	–	–	+0.90
Tree height in 1972	–	0.91	+0.86
in 1973	–	–	+0.95
Degree of tree freezing in March of 1971	+0.55	+0.58	+0.59
Period of vegetation initiation			
of lateral shoots in 1973	–	−0.30	−0.36
of terminal buds in 1973	–	−0.29	−0.27
Mean time of growth of terminal bud in 1973	–	+0.43	+0.48

The relationships existing between the geographical parameters of parental populations in America and tree height in the Kórnik experiment indicate that progeny deriving from low-elevation provenances has higher average tree height ($r=-0.53$) and that average tree height increases from north to south ($r=-0.45$) and from east to west ($r=+0.40$).

Tree height increment. The measurements and observations of tree height increment concerned two issues:

1. value of increments: a) annual, b) spring, c) summer,
2. tree increment dynamics in the vegetative season.

1.a) Annual increment value has been measured in all trees occurring in test during 1972 - 1973 and 1974 and the mean values calculated in Table 2. Measurement accuracy amounted to 5± mm. We have ascertained a gradual increase in the increment value in the course of the years under investigation, to which testify the increasing variation coefficients *W* (Table 5).

Table 5

Data concerning variation in Douglas-fir populations with respect to annual tree height increment

Year of observations	$\bar{x}$	x_{min}	x_{max}	S	$S_{\bar{x}}$	$W\%$	F_0	$F_{0.01}$
1972	22.9	12.2	33.6	4.3	0.43	18.6	2.6	1.52
1973	25.0	13.7	37.4	4.9	0.49	19.7	1.9	1.52
1974	42.8	16.9	70.1	10.7	1.07	25.0	2.3	1.52

Throughout all previous years in which annual height increment measurements were made, in each case the significance of interpopulational differences reached the confidence level of at least 99% for the *F* coefficient in analysis of variation of this characteristic (Table 5). Such a high degree of differentiation results mainly from a large range between minimum and maximum values of this characteristic (Table 6).

Table 6

Extreme values of height increment in Douglas-fir populations in cm

Year of observations	$\bar{x}_{min}$	populations	$\bar{x}_{max}$	populations
1972	12.2	Thasis (1029)	32.7	Enumclaw (1075)
	12.2	Republic (1048)	31.8	Louella Guard St. (1061)
	15.4	Klina Klini (1012)	31.8	Concrete (1047)
1973	13.7	Republic (1048)	37.4	Gold River (1031)
	15.4	Twisp (1052)	34.8	Dean (1002)
	16.0	Rimrock (1082)	34.8	Prindle (1095)
	16.7	Stoner (1001)	34.4	Waldport (1101)
			34.4	Shelton (1077)
			32.9	Perry Creek (1059)
1974	16.9	Twisp (1052)	30.2	Randle (1085)
	19.9	Stoner (1001)	63.5	Prindle (1095)
	21.2	Nelson (1035)	60.2	Louella Guard St. (1061)
			58.9	Gold River (1031)
			58.8	Matlock (1076)

With an average value of annual height increment ammounting to 22.9 cm for the value test; 25.0 cm and 42.8 cm in the years 1972, 1973 and 1974, maximal increment amounted to 32.7, 37.4 and 70.2 cm respectively. We can see here a singular increase in the increment in 1974, which is almost twice as high as in previous years.

This an expression, on the one hand, of the natural growing rhythm of Douglas-fir entering in that period on a rapid growth and on the other hand this is also an expression of the emergence of a certain adaptation of trees to the environmental conditions of the test. The mean values of the annual increment presented in Table 3. subjected to analysis of variance indicate that interpopulational variation in Douglas-fir with respect to this characteristic is very great and has a tendency to deepen with the passage of years. Such a conclusion can be drown on the basis of comparisons of variation coefficients *W* from the years 1972 - 74.

The average value of annual increment of a given population is relatively little influenced by the geographic parameters of location of the parental population (table of correlations 7). Statistically, however, it is significant and it will increase from year to year, that for the data from 1974 one can find that the populations from the eastern extremes of the geographic distribution and the high elevations have smaller annual increments (Table 7), than the remaining populations. A very close positive correlation exists between annual increase in height and diameter of trees and their height from previous years. A very significant and also

Table 7

List of characters with very significant coefficient of correlations with tree height increment in the years 1972–1974

Characters	Value of *r* coefficients 1972	1973	1974
Geographic parameters of parental populations			
elevation	-.35	-.38	-.53
northern latitude	n.s.	-.32	-.43
western longitude	n.s.	.33	.39
Characters of trees in progeny populations			
number of seedlings in 1969	-.43	-.54	-.64
number of seedlings in 1970	-.43	-.52	-.65
number of first-order branches in 1970	.51	.47	.54
number of first-order branches in 1972	.71	.49	.66
lenght of largest branch in 1972	.81	.64	.68
lenght of largest branch in 1973		.76	.83
Height increment			
spring 1972	.94	.69	.70
spring 1973		.99	.76
spring 1974			.92
lammas 1972	.76	.45	.50
lammas 1973		.50	.44
lammas 1974			.93
annual 1972		.69	.70
annual 1973			.76
Tree diameter at a height of 30 cm in 1974			.81
Tree height in 1972	.86	.62	.72
Tree height in 1973		.81	.85
Tree height in 1974			.93
Degree of tree freezing in (III) 1971	.38	.37	.59
Period of vegetation inception of lateral shoots			
in 1973		.58	n.s.
in 1974			.58
Average time of leader shoots flushing in 1973		n.s.	.50

positive correlation occurs between annual increment and the value of spring increments, and a weaker correlation occurs with lammas increment, which however exercised a considerable influence on annual increment in 1974.

The populations, from whose seeds the greatest number of specimes fit to be planted on the test area have been obtained can be considered to be best compatible in the juvenile stage with climatic conditions.

Yet this characteristic is negatively correlated with the value of annual increments and other characteristics of interest to forestry, such as tree height increment, diameter and others. This is a very common phenomenon in practical genetic research.

The ones to correlate negatively are also annual increment in heigh and frost hardiness.

We can assume that the fastest increasing populations will always be more damaged by frosts in their juvenile stage than the slower-increasing ones, hence the necessity of their raising under a glass or plastic roof during their first two years of life.

The phenological observations on the initiation by lateral and leader shoots have provided information that there is a poor and varing dependence of annual increment on these characteristics. This results from the nonsignificant interpopulational variation in Douglas-fir with respect to the vegetation season inception by leader shoots. From the individual characteristics of a tree, crown density exerts a very great influence on annual increment. The more first-order branches in the crown, the lager they are, this is undoubtedly connected with the expansion of the tree's assimilating surface.

1. b) Value of spring increments. The value of annual increment is constitued by 80% of the spring increment, and the remaining 20% from, in our climatic conditions unreiterated summer increment. Average values of summer increments in all these populations which were examined in the test have been gathered in Table 8. The spread of this characteristic expressed in the form of variance S points to very great differences between extreme values of populations (Table 9). Spring height increment and its dependence on other observed characters are given in Table 11.

In the lowest-increment group only few populations stay from year to year. To these belong the ones mentioned in Table 9: Twisp and Rimrock. From this group is considerably more stable the set of populations with maximum values of spring increment. This is beyond doubt a significant results for prognosis of subsequent tree development on the basis of early testing. Yet the range between mean increment values in the group of its lowest values is far greater than in the populations with maximum spring increment values.

The significance of interpopulational differences is on the level 99% confidence (Table 10).

Table 8

Mean values of spring and Summer (Lammas) increment in analysed populations during 1972–1974

Provenances		Spring increment in cm			Summer increment in cm		
		1972	1973	1974	1972	1973	1974
1001	Stoner	11.5	16.5	19.8	1.7	0.2	0.1
1002	Dean	21.9	33.0	50.5	6.8	1.8	8.3
1003	Alexandria	13.7	18.3	24.0	3.6	0.4	2.5
1004	Stuie	17.4	22.9	30.6	4.9	0.0	7.2
1005	Williams Lake	13.5	18.6	24.2	2.6	0.2	1.7
1006	Tatla	14.7	21.3	27.4	3.6	0.3	3.4
1007	Clearwater	17.9	22.6	33.4	5.5	0.0	7.9
1008	Golden	14.9	17.6	21.3	3.8	0.0	2.7
1009	Klina Klini	18.5	26.4	35.6	9.1	0.7	10.6
1010	Barriere	16.7	25.4	34.4	4.3	0.5	3.8
1012	Klina Klini	13.0	15.8	27.6	5.5	1.2	12.3
1013	Revelstoke	16.4	20.7	23.5	3.9	0.1	5.2
1014	Eagle Bay	17.5	15.8	18.6	6.3	0.7	5.6
1015	Blind Bay	14.8	20.1	27.6	5.2	0.3	9.6
1016	White Lake	15.4	18.4	26.8	6.3	0.6	5.9
1017	Squilax	16.8	22.8	29.1	3.7	0.2	3.4
1018	Salmon Arm	20.6	26.7	35.0	5.2	1.0	7.6
1019	Monte Creek	14.6	21.4	25.7	5.5	0.6	5.7
1020	Pillar Lake	15.3	25.2	31.0	2.8	0.0	2.2
1021	D'Arcy	18.2	27.3	35.5	6.9	0.5	9.1
1022	Fly Hill	17.0	22.8	29.6	5.3	0.5	7.3
1023	Jeune Landing	17.1	21.7	29.1	5.8	0.2	7.3
1024	Owl Creek	16.0	26.8	29.7	3.5	1.1	8.8
1025	Nimkish	19.6	22.0	25.2	4.2	0.0	8.5
1026	Stella Lake	17.8	24.4	42.3	5.4	0.5	8.7
1027	Alta	14.9	20.4	26.7	3.0	0.2	4.7
1028	Merritt	12.8	19.6	20.6	4.1	0.1	4.2
1029	Thasis	10.3	24.8	34.0	1.9	0.0	14.7
1030	Squamish	16.9	24.8	30.5	5.0	1.6	8.2
1031	Gold River	23.2	37.0	41.2	6.1	0.4	17.7
1032	Courtenay	19.2	23.7	29.8	4.0	0.0	8.3
1033	Forbidden Plat.	17.1	19.9	29.0	4.4	0.0	7.7
1034	Sechelt	17.2	20.1	33.6	7.1	1.2	17.7
1035	Nelson	13.3	15.8	18.5	4.9	0.4	3.2
1036	Alberni	25.8	31.8	40.1	7.8	0.3	4.4
1037	Franklin River	17.5	24.5	33.3	4.9	0.8	5.5
1038	Chilliwack	19.1	24.4	36.7	7.1	2.3	9.8
1039	Chilliwack	21.6	31.7	42.1	5.6	2.3	17.2
1040	Cassidy	16.2	23.3	30.8	3.4	1.0	9.3
1041	Caycuse	18.2	24.7	35.0	5.8	0.7	7.4
1042	Duncan	16.6	20.5	32.8	8.6	1.6	12.4
1043	San Juan	16.5	20.7	32.7	2.7	0.5	11.7
1045	Sooke	16.4	29.0	41.1	6.8	1.4	14.0
1046	Diablo Dam	14.1	18.3	21.9	5.2	1.5	10.0
1047	Concrete	24.4	32.2	44.8	7.4	0.1	9.0
1048	Republic	10.7	13.6	22.3	1.5	0.1	3.2
1049	Bacon Point	14.6	25.7	32.0	4.2	2.0	8.1
1050	Marblemount	19.0	24.2	39.9	5.1	1.6	14.2
1051	Sedro Woolley	20.1	22.7	36.2	4.6	3.0	7.3
1052	Twisp	13.7	15.4	14.3	4.9	0.0	2.7
1053	Darrington	22.2	29.8	46.0	6.0	1.9	8.3
1054	Arlington	20.7	20.3	42.7	2.8	0.0	14.8
1055	Newport	14.3	19.4	24.9	3.5	0.4	3.8
1056	Sloan Creek	19.0	22.9	34.2	3.8	0.2	8.5
1057	Granite Falls	17.8	20.2	42.0	4.2	0.0	14.9
1058	Lake Crescent	20.1	30.5	40.1	3.7	2.4	11.0
1059	Perry Creek	17.6	25.0	37.4	4.4	0.9	7.1

Table 8 - cont.

Provenances		1972	1973	1974	1972	1973	1974
1060	Sequim	15.0	22.5	26.6	5.8	0.7	8.0
1061	Louella Guard St.	21.2	30.6	43.9	9.1	1.2	16.5
1062	Forks	22.4	28.5	49.1	3.5	0.0	5.4
1063	Gold Bar	18.8	20.1	35.5	8.9	0.5	15.8
1064	Hoh River	18.3	22.5	35.5	4.6	0.6	10.0
1065	Spokane	15.5	23.0	31.0	2.3	0.2	2.9
1067	Skykomish	18.8	26.0	38.2	6.4	1.0	9.6
1068	Chiwaukum	15.1	20.7	25.5	3.3	0.4	7.3
1069	North Bend	20.1	27.4	34.3	6.5	1.7	14.4
1070	Denny Creek	20.8	30.2	40.5	6.5	1.1	9.5
1071	Keechelus Lake	17.8	29.9	46.5	4.5	0.8	8.8
1072	Chester Morse Lake	20.8	27.2	41.6	6.6	1.4	10.2
1073	Humptulips	24.0	26.6	40.9	3.3	0.0	7.3
1074	Matlock	18.0	21.9	38.0	3.3	2.4	5.0
1075	Enumclaw	25.3	25.4	45.7	7.3	0.9	16.6
1076	Matlock	21.1	27.9	44.9	5.9	0.8	10.0
1077	Shelton	17.3	30.7	45.0	7.6	3.7	13.9
1078	Cle Elum	14.9	20.2	28.2	2.7	0.9	4.5
1079	Parkway	16.8	22.6	37.4	4.7	0.1	9.2
1080	Yelm	22.1	26.8	34.2	8.9	0.5	17.9
1081	Alder Lake	22.8	25.1	32.6	6.3	0.0	8.5
1082	Rimrock	15.2	15.7	18.0	4.4	0.3	5.3
1083	Packwood	17.3	22.3	29.7	3.8	1.4	8.9
1084	Packwood	18.8	27.9	37.2	5.3	1.1	13.2
1085	Randle	21.0	28.9	51.2	6.2	3.3	19.0
1086	Naselle	21.2	30.4	41.3	4.1	2.2	7.7
1087	Skamokawa	20.9	25.3	36.1	4.7	0.9	9.2
1088	Castle Rock	21.8	28.9	38.7	5.7	1.3	16.6
1089	Cathlament	18.0	23.0	34.6	3.3	1.3	6.7
1090	Cougar	22.1	25.9	40.3	2.7	0.5	13.8
1091	Yale	17.9	25.3	35.6	4.2	1.0	8.6
1092	Glenwood	16.6	21.8	32.7	4.9	0.5	12.2
1093	Willard	20.3	28.1	41.2	7.7	0.7	14.1
1094	Vernonia	20.5	22.4	36.0	6.1	0.0	13.2
1095	Prindle	20.5	33.7	46.3	9.0	1.0	17.2
1096	Sandy	20.2	25.9	38.8	7.1	1.3	15.9
1097	Cherryville	20.1	25.7	38.0	6.5	0.2	10.7
1098	Hebo	19.3	26.1	27.7	4.8	0.6	11.6
1099	Pine Grove	16.2	23.3	30.2	5.7	0.5	8.4
1100	Grand Ronde Agency	13.0	21.5	31.2	2.9	1.5	9.2
1101	Waldport	18.4	33.5	33.1	5.6	0.9	19.3
1102	Upper Soda	17.0	25.8	33.4	4.0	1.9	9.3
1104	Brookings	16.7	25.0	33.7	4.0	0.7	11.4

1. c) Value of summer (Lammas) increments. This characteristic has been viewed from a quantitative angle by measuring the length of shoots grown in the course of summer increment and also in the qualitative aspect by measuring the number of lammas shoots grown in 1972. Interpopulational differences with respect this characteristic as well as interpopulational variances are very great, greater than for other characteristic (Table 12).

The character of summer increment variation is completely different from annual or spring increment variation. We observe here a very negligible dispersion in 1973, smaller than in the 1972 and 1974.

So there is a lack of deepening of differences from year to year, as was observed in number of other characteristics (Table 13).

Table 9

Extreme values of averages from populations with lowest and highest spring increment, in cm

Year of observations	Populations with min. increment		Populations with max. increment	
1972	10.3	Thasis (1029)	25.3	Enumclaw (1073)
	10.6	Republic (1048)	24.4	Concrete (1047)
	11.5	Stoner (1001)	24.0	Humptulips (1073)
1973	13.6	Republic (1048)	37.0	Gold River (1031)
	15.4	Twisp (1052)	33.7	Prindle (1095)
	15.7	Rimrock (1082)	33.5	Waldport (1101)
			33.0	Dean (1002)
			32.2	Concrete (1047)
			31.8	Alberni (1036)
			31.7	Chilliwack (1039)
1974	14.3	Twisp (1052)	51.2	Randle (1085)
	17.9	Rimrock (1082)	50.5	Dean (1002)
			49.1	Forks (1062)
			46.3	Prindle (1095)

The presented interpopulational range in 1973 is so great that the variation coefficient W reached the 94% value, yet even in that year no population was found that would not have trees with summer increment. This characteristic is not only distinguished by any specific character of variation and its great range, but also by an exceptionally low degree of dependence on other observed characters. Out of 39 characters which were observed and subjected to correlation analysis, certain relationships with 19 characters only were found in 1974, and still fewer in the years 1972 and 1973 (Table 14).

Table 10

Statistical data concerning interpopulational variation in Douglas-fir with respect to the spring tree increment

Year of observations	$\bar{x}$	x_{min}	x_{max}	S	$S_{\bar{x}}$	$W\%$	F_0	$F_{0.01}$
1972	17.9	10.3	25.8	3.1	0.31	17.5	3.0	1.52
1973	24.1	13.6	37.4	4.6	0.46	19.0	1.8	1.52
1974	33.8	14.2	51.1	7.7	0.77	22.9	2.2	1.52

A particularly important result is the finding of lack of correlation in 1972 and 1973 with geographic parameters of parental populations. It seems that Lammas increment is a characteristic outstandingly dependent on local climatic conditions for the formation of populations. On the basis of correlations from the 1974 data, we can state that summer increment occurs more frequently in population from the Pacific Coast and the Cascade Mountains. Also populations from the southern area of Douglas-fir distribution have a greater number of trees producing secondary shoot increments.

Table 11

Spring height increment in 1972 and 1973 and its correlations with other observed characters

Characteristics	Value of *r* coefficient		
	1972	1973	1974
Geographic parameters of parental populations			
elevation	−.39	−.36	−.33
latitude	−.31	−.36	−.42
longitude	.26*	.34	.34
Characteristics of tree in progeny populations			
number of seedlings in 1969	−.45	−.54	−.60
in 1970	−.45	−.51	−.60
Degree of tree freezing in III 1971			
number of first - order branches			
in 1970	.56	.47	.48
in 1972	.75	.48	.60
length of largest branch			
in 1972	.84	.64	.69
in 1973		.77	.81
Height increment			
spring increment 1972		.71	.74
1973			.79
Lammas increment 1972		.71	.40
1973			.40
annual increment 1972		.62	.70
1973			.80
Tree diameter in 1974			.82
Tree height in 1972		.62	.71
in 1973			.81
Average time of growth of terminal buds in 1973		n.s.	.54

* Confidence level of 95%.

Correlations with the number of trees after one year and two years of life, which quantity was determined chiefly by frost damages, suggest that the populations susceptible to frost have greater Lammas increments. Secondary increment developing on the top of the leader often undergoes forking, which leads in effect to the development of tree crowns with a number of branches. This was manifest in a positive correlation of Lammas increment with the number of first-order branches ($r = +0.47$) in 1971. In the years in which trees form intensive terminal increments we ascertain the occurrence of a very significant positive correlation of these increments with the height (Table 14).

Many Douglas-fir trees have very scant summer increments mani-

Table 12

Statistical data concerning summer increment in cm in Douglas-fir populations

Year of observations	$\bar{x}$	x_{min}	x_{max}	S	$S_{\bar{x}}$	$W\%$	F_0	$F_{0.01}$
1972	5.0	1.5	9.1	1.7	0.2	34	1.8	1.52
1973	0.8	0.01	3.6	0.8	0.1	94	2.1	1.52
1974	9.3	0.05	19.3	4.4	0.4	48	2.7	1.52

Table 13

Populations with minimal and maximal Lammas increments in the years 1972–1974

Years of observations	Populations with min. increment cm		Populations with max. increment cm	
1972	1.5	Republic (1048)	8.9	Gold Bar (1063)
	1.7	Stoner (1001)	9.1	Klina Klini (1009)
	1.9	Thasis (1029)	9.1	Louella Guard (1061)
1973	0.01	Stuie (1004)	3.7	Shelton (1077)
		Clear water (1007)	3.3	Randle (1085)
		Golden (1008)	3.0	Sedro Wooley (1051)
		Pillar Lake (1020)		
		Thasis (1029)		
		Nimkish (1025)		
		Courtenay (1032)		
		Forbidden Plateau (1033)		
		Twisp (1052)		
		Humptulips (1073)		
		Alder Lake (1081)		
		Vernonia (1094)		
		Gold Bar (1063)		
		Arlington (1054)		
		Granite Falls (1057)		
1974	0.05	Stoner (1001)	19.3	Waldport (1101)
	1.7	Williams Lake (1005)	19.0	Randle (1085)
	2.2	Pillar Lake (1020)	17.7	Sechelet (1034)

festing themselves merely in the unfolding of scales on buds and emergence of needle tuffts. The number of buds on a tree which, when developing give secondary increment depends neither on height nor many other tree characters such as, e.g. magnitude of annual increment, dia-

Table 14

Values of *r* coefficients in analysis of correlation of Douglas-fir characters with Lammas increment in the years 1972–1974

Characters	Value of *r* 1972	1973	1974
Geographic parameters of parental populations			
elevation	n.s.	n.s.	−.51
latitude	n.s.	n.s.	−.46
longitude	n.s.	n.s.	+.32
Characters of trees in progeny populations			
number of trees in 1969	n.s.	n.s.	−.54
number of trees in 1970	n.s.	n.s.	−.55
degree of tree freezing in 1971	n.s.	.34	.63
number of first-order branches in 1970	.30	n.s.	.47
height increment-spring 1972	.52	n.s.	.52
height increment-spring 1973		.36	.50
height increment-spring 1974			.57
Lammas 1972		n.s.	.52
Lammas 1973			.34
annual 1972		n.s.	.53
annual 1973			.52
tree height in 1972		n.s.	.52
tree height in 1973			.66
number of Lammas shoots 1972	.37	n.s.	n.s.

meter or dimensions of first-order branches. We did not succeed in ascertaining if there is any connection between, the number of secondary shoots formed and geographic parameters of the origin of a population. In all probability, the decisive role is played here by local environmental factors at the test site which may stimulate or retard the formation of Lammas shoots.

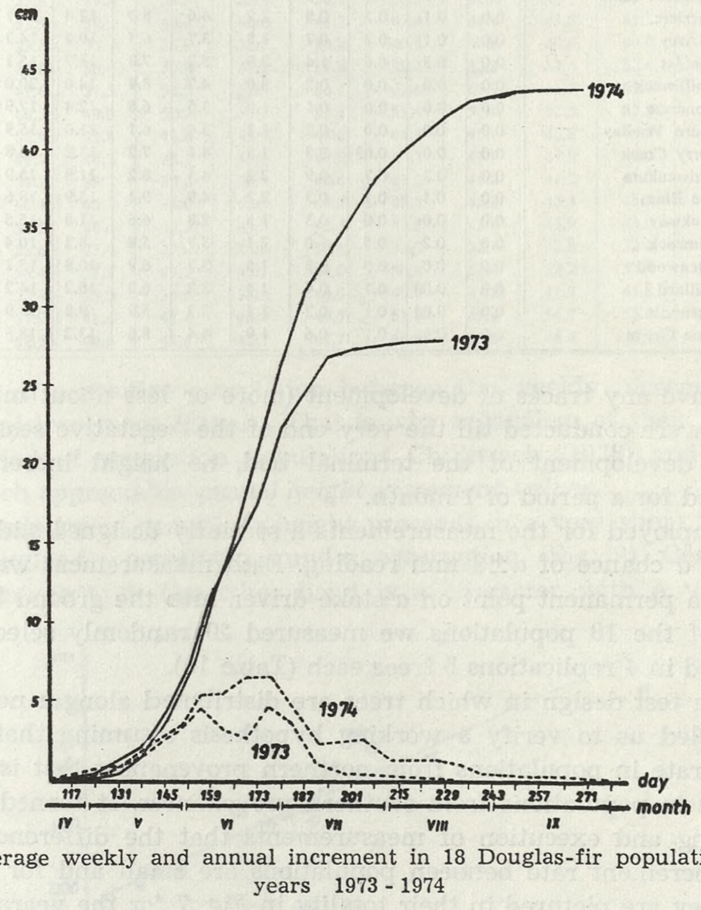


Fig. 7. Average weekly and annual increment in 18 Douglas-fir populations in the years 1973 - 1974

G r o w t h d y n a m i c s i n g r e e n D o u g l a s - f i r t r e e s d u r i n g t h e v e g e t a t i v e s e a s o n. In order to examine growth dynamics in green Douglas-fir trees, and the correlationship between height increment rate and geographical location of their parental population in North America, 18 populations situated along a north-south axis have been selected (Table 15).

The progeny from the above-mentioned populations growing on the test area at Kórnik was subjected to exact height measurements carried out in 7-day intervals. We started the measurements when tree buds did

International provenance tests with Douglas-fir (*Pseudotsuga menziesii* Franco) at Kórnik. Mean values obtained

Provenances		Dates of measurements										
		19.4	26.4	2.5	10.5	17.5	24.5	31.5	7.6	14.6	21.6	28.6
1001	Stoner	0.0	0.0	0.0	0.1	0.7	2.6	4.9	8.3	11.9	15.6	20.4
1003	Alexandria	0.0	0.0	0.0	0.3	1.2	3.4	6.6	10.5	15.0	20.5	26.5
1005	Williams Lake	0.0	0.0	0.0	0.2	1.1	3.3	5.6	8.3	13.1	17.6	22.3
1010	Barriere	0.0	0.1	0.3	0.8	2.2	4.6	8.0	12.4	17.1	22.5	28.7
1021	D'Arcy	0.0	0.1	0.2	0.7	1.8	3.7	6.5	10.4	14.3	19.3	24.6
1028	Merritt	0.0	0.3	0.6	1.4	2.9	5.2	7.8	11.7	15.1	19.9	23.4
1038	Chilliwack	0.0	0.0	0.0	0.2	2.0	4.7	8.4	14.6	20.0	27.5	34.4
1047	Concrete	0.0	0.0	0.0	0.1	1.0	3.5	6.8	12.4	17.9	25.4	32.7
1051	Sedro Voolley	0.0	0.0	0.0	0.2	1.1	3.4	6.1	11.0	15.9	21.8	27.4
1059	Perry Creek	0.0	0.0	0.03	0.3	1.5	4.1	7.2	13.2	18.8	25.1	31.7
1068	Chiwaukum	0.0	0.3	0.7	0.9	2.2	4.5	8.2	11.9	15.9	20.1	24.3
1078	Cle Elum	0.0	0.1	0.1	0.3	2.2	4.9	9.1	13.9	18.6	24.6	31.6
1079	Parkway	0.0	0.0	0.0	0.3	1.5	2.8	6.6	11.8	15.5	20.8	25.7
1082	Rimrock	0.0	0.2	0.5	1.0	2.1	3.7	5.8	8.2	10.4	16.1	18.4
1092	Glenwood	0.0	0.0	0.0	0.3	1.5	3.7	6.9	10.8	15.1	19.3	24.4
1093	Willard	0.0	0.03	0.1	0.4	1.4	3.2	6.0	10.2	14.2	19.5	24.7
1094	Vernonia	0.0	0.03	0.1	0.2	1.1	3.3	5.9	9.8	13.9	18.2	25.5
1099	Pine Grove	0.0	0.1	0.1	0.6	1.9	4.4	8.6	13.2	18.5	24.4	29.4

not yet have any traces of development (more or less about mid-March) and they were conducted till the very end of the vegetative season when, after the development of the terminal bud, no height increment was ascertained for a period of 1 month.

We employed for the measurements a specially designed slide calliper giving us *a* chance of $a \pm 2$ mm reading. Each measurement was carried out from a permanent point on *a* stake driven into the ground by *a* tree. In each of the 18 populations we measured 20 randomly selected trees distributed in 4 replications 5 trees each (Table 15).

Such a test design in which trees are distributed along a north-south axis enabled us to verify a working hypothesis assuming that there is a grouth rate in populations from northern provenances that is different from that in populations from southern provenances. It turned out after data listing and execution of measurements that the differences in the weekly increment rate between populations are small and for all populations they are pictured in their totality in Fig. 7 for the years 1973 and 1974. The rate of growth seen in this diagram has the shape of a curve with two peaks corresponding to periods of maximum increment. The periods of increment culmination come in between 1 - 8 and 22 - 29 June in all populations in both observed years 1973 and 1974. Only population Merrit (1028) has its first height growth culmination earlier, for it is the period from 25 till 31 May. We can draw the conclusion that irrespective of weekly increment values, all Douglas-fir populations share a common biological rhythm probably conditional on climatic conditions under which, in all the populations investigated, tree height increment intensifies or diminishes. There is on the other hand, very close relationship

Table 15

Growth dynamic on 360 Douglas-fir specimens derived from 18 populations in 1974 from four replications

Dates of measurements												
5.7	12.7	19.7	26.7	2.8	9.8	16.8	23.8	30.8	6.9	13.9	20.9	27.9
23.3	24.2	25.2	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1
31.1	33.7	36.2	39.1	39.9	40.7	41.6	42.2	42.4	42.5	42.6	42.6	42.6
25.0	26.4	27.8	29.2	29.5	29.8	30.2	30.5	30.6	30.7	30.7	30.8	30.8
34.8	36.3	37.9	39.8	40.2	40.6	41.1	41.4	41.5	41.5	41.5	41.5	41.5
28.7	31.0	33.3	35.7	36.9	38.2	39.4	40.5	40.6	40.6	40.6	40.6	40.6
26.1	27.6	29.0	30.4	30.8	31.2	31.8	32.1	32.2	32.4	32.4	32.4	32.4
40.1	44.0	47.8	51.5	54.3	57.3	60.1	61.6	61.7	61.7	61.7	61.7	61.7
39.0	42.6	46.2	49.9	50.3	50.7	51.1	51.4	51.4	51.5	51.5	51.5	51.5
33.0	35.9	38.8	41.8	42.8	43.7	44.8	45.4	45.6	45.8	45.9	45.9	45.9
36.7	38.9	41.7	44.2	45.1	46.1	47.0	47.7	47.9	47.9	48.0	48.0	48.0
27.3	30.2	33.1	36.1	37.6	39.2	40.6	41.2	41.2	41.2	41.2	41.2	41.2
36.0	38.1	40.1	42.2	43.0	43.9	44.7	45.1	45.3	45.3	45.3	45.3	45.3
32.6	34.6	36.5	38.6	40.3	41.3	42.3	43.3	43.6	43.9	44.0	44.0	44.0
20.1	21.9	23.6	25.4	27.0	28.8	30.4	32.7	32.8	32.8	32.8	32.8	32.8
28.5	31.5	34.4	37.5	42.3	45.1	48.0	50.2	51.1	52.2	52.4	52.5	52.5
28.6	30.2	32.4	35.0	36.6	38.3	40.0	40.7	41.2	41.7	41.8	41.8	41.8
31.1	34.5	37.9	41.4	41.4	46.9	49.7	51.8	53.4	54.7	55.0	55.2	55.2
33.6	33.3	38.5	40.6	41.6	42.7	43.7	44.8	45.6	46.6	46.8	46.9	46.9

expressed in a positive correlation between the weekly increment value and annual increment (Fig. 8). That is why regardless of their relatively short period of vegetation populations Chilliwack (1038) and Concrete (1047) reach appreciable annual height increment values.

The inception of growth in height proceeds in a very short time span in all Douglas-fir populations under observation (Fig. 9). Cessation of height increment on the other hand is a character with a very great

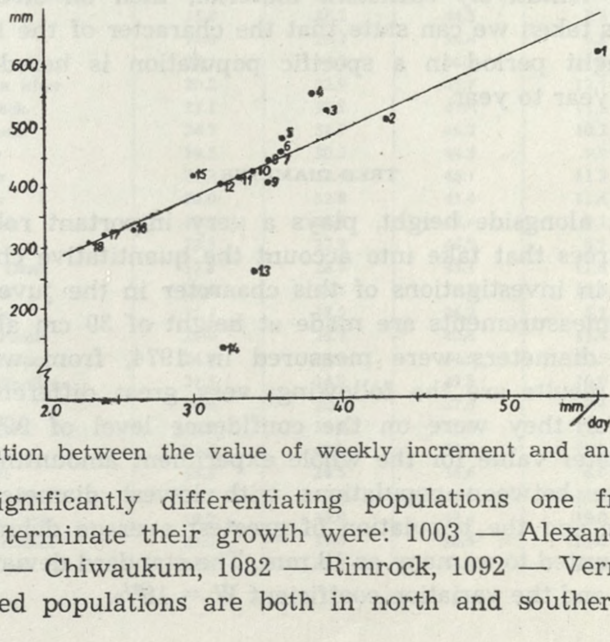


Fig. 8. Correlation between the value of weekly increment and annual increment

dispersion significantly differentiating populations one from another. The first to terminate their growth were: 1003 — Alexandria, 1028 — Merrit, 1068 — Chiwaukum, 1082 — Rimrock, 1092 — Vernonia. As the just-mentioned populations are both in north and southern geographic

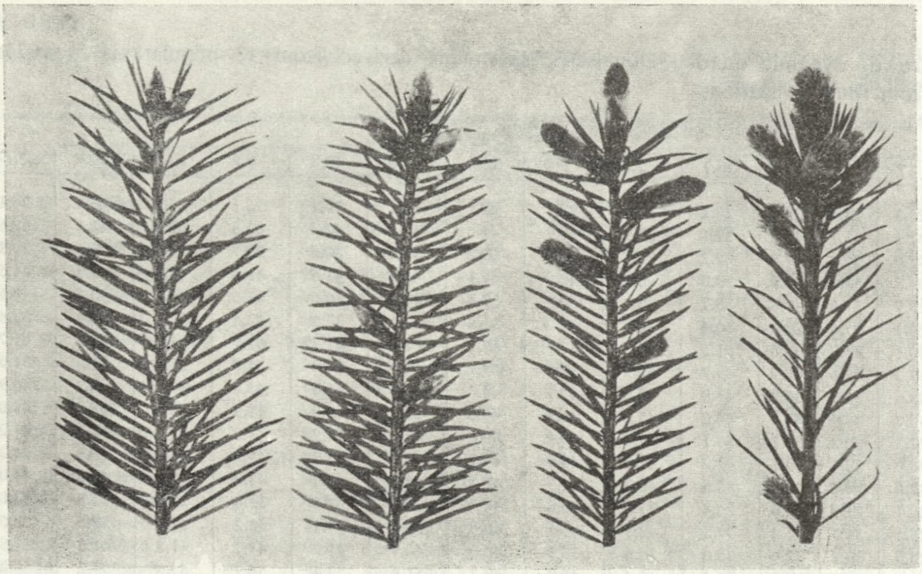

Phot. K. Jakusz

Fig. 9. Variation in the vegetative season inception in population 1075-Enumclaw

regions of Douglas-fir distribution, we can assume that growth termination is not a tree trait that would in a very significant way depend on latitude of provenance. The trees from the populations: 1021—D'Arcy, 1051—Sedro Wooley, 1093—Willard took the longest time to increase in height. Also in this group of populations we find the occurence of both a northern and southern provenances. If two-year observations can serve as tentatively sufficient material, then on strength of the measurements taken we can state that the character of the length of the growth-in-height period in a specific population is hereditary, for it reccurs from year to year.

TREE DIAMETER

This trait, alongside height, plays a very important role in genetic research on trees that take into account the quantitative characteristics. Traditionally in investigations of this chaarcter in the juvenile stadium of trees, the measurements are made at height of 30 cm above ground. In this way diameters were measured in 1974, from which measurements the results are the following: very great differences between populations for they were on the confidence level of 99%. With an average diameter value for the whole experiment amounting to 21 mm, the difference between populations with lowest diameter values — 1048 Republic and the population of greatest average diameter — 1047 Concrete amounted to as many as 18 mm. The standard deviation amounted to 3.8 mm and the variation coefficient $W = 18\%$.

Table 16

Average diameter values in 1974(I), dimensions of largest branches in 1972(II) and 1973(III) and the number of first-order branches in 1970(IV) and in 1972(V)

Provenances		I	II	III	IV	V
1001	Stoner	12.6	23.8	29.7	5.4	13.9
1002	Dean	23.6	46.4	69.5	10.1	22.1
1003	Aleksandria	16.2	23.3	31.9	7.4	16.0
1004	Stuie	19.7	35.2	47.2	11.3	22.7
1005	Williams Lake	15.3	21.7	32.3	6.5	15.9
1006	Tatla	16.0	26.5	39.1	7.5	17.8
1007	Clearwater	20.9	32.0	45.2	8.1	19.8
1008	Golden	13.8	24.5	35.3	5.3	14.7
1009	Klina Klini	22.3	33.8	48.5	10.7	20.3
1010	Bariere	20.1	29.7	42.5	9.0	20.0
1012	Klina Klini	15.7	30.8	40.4	11.5	18.9
1013	Revelstoke	16.7	26.1	37.5	8.7	17.3
1014	Eagle Bay	14.9	29.7	36.0	9.6	21.1
1015	Blind Bay	16.8	26.1	34.4	8.9	19.7
1016	White Lake	19.6	28.9	33.1	9.9	21.0
1017	Squilax	19.2	30.5	39.8	9.7	19.7
1018	Salmon Arm	22.3	32.5	45.8	8.4	21.7
1019	Monte Creek	15.9	25.6	35.7	7.5	18.1
1020	Pillar Lake	17.1	24.7	38.0	6.7	16.0
1021	D'Arcy	23.2	32.2	45.0	10.4	21.7
1022	Fly Hill	21.0	29.3	40.2	8.2	20.0
1023	Jeune Landing	19.9	30.8	41.3	12.4	25.4
1024	Owl Creek	20.6	29.7	45.9	12.1	21.6
1025	Nimkish	17.5	31.3	44.0	9.5	19.5
1026	Stella Lake	21.3	31.8	44.8	10.1	17.5
1027	Alta	17.6	26.6	38.1	10.6	17.3
1028	Merritt	14.3	21.1	31.7	5.7	14.0
1029	Thasis	16.3	19.8	46.6	9.4	10.6
1030	Squamish	18.7	36.6	44.3	11.6	22.6
1031	Gold River	25.9	37.7	55.7	12.7	20.3
1032	Courtenay	21.8	35.4	48.3	11.1	23.4
1033	Forbidden Plateau	19.8	30.1	41.0	10.7	20.3
1034	Sechelt	15.4	28.2	44.5	8.8	20.7
1035	Nelson	14.0	25.2	34.4	6.8	16.2
1036	Alberni	24.3	44.2	56.5	11.0	21.4
1037	Franklin River	20.2	32.9	45.7	12.4	22.3
1038	Chilliwack	23.1	36.9	47.4	11.5	24.5
1039	Chilliwack	24.7	31.7	44.7	10.2	21.4
1040	Cassidy	19.5	30.3	44.5	9.9	20.4
1041	Caycuse	20.9	32.4	45.1	11.3	22.4
1042	Duncan	20.0	32.8	43.4	11.4	22.3
1043	San Juan	19.5	28.4	42.4	9.1	19.8
1045	Sooke	22.3	27.9	46.9	8.9	20.8
1046	Diablo Dam	17.8	26.8	35.1	11.6	21.1
1047	Concrete	29.4	38.5	56.7	13.5	27.8
1048	Republic	11.5	18.5	26.2	5.1	12.3
1049	Bacon Point	21.4	26.7	40.8	11.4	19.0
1050	Marblemount	24.9	34.8	54.5	10.5	25.2
1051	Sedro Woolley	21.5	34.9	49.2	10.0	22.9
1052	Twisp	14.3	22.3	32.6	8.4	15.3
1053	Darrington	25.9	34.4	51.6	11.9	25.1
1054	Arlington	21.6	40.1	54.1	12.5	27.5
1055	Newport	15.8	24.5	36.6	6.0	17.0
1056	Sloan Creek	22.7	32.8	44.6	11.3	24.7
1057	Granite Falls	19.2	30.8	49.4	10.0	28.0
1058	Lake Crescent	23.7	37.6	50.5	13.6	23.7
1059	Perry Creek	22.6	30.8	43.0	11.1	21.1

Table 16 - cont.

	Provenances	I	II	III	IV	V
1060	Sequim	20.6	32.9	43.0	11.6	23.4
1061	Louella Guard St.	25.0	34.1	50.1	11.2	25.9
1062	Forks	21.5	36.6	51.6	10.9	25.7
1063	Goid Bar	22.8	34.5	47.8	9.2	25.0
1064	Hoh River	21.5	30.9	45.3	10.4	20.6
1065	Spokane	19.5	26.4	38.6	7.9	17.7
1067	Skykomish	23.1	33.7	49.1	11.6	24.7
1068	Chiwaukum	19.3	30.7	43.1	8.7	20.6
1069	North Bend	23.9	32.7	47.3	10.9	25.3
1070	Denny Creek	24.2	33.8	47.1	9.8	23.8
1071	Keechelus Lake	24.8	34.7	47.6	8.9	21.5
1072	Chester Morse Lake	23.8	35.0	47.9	10.5	24.7
1073	Humptulips	23.8	31.8	48.0	13.6	26.9
1074	Matlock	20.7	29.9	41.7	8.6	23.4
1075	Enumclaw	26.4	41.3	56.8	11.7	27.1
1076	Matlock	25.0	37.0	51.1	9.6	26.7
1077	Shelton	23.0	31.9	50.4	8.5	20.3
1078	Cle Elum	21.3	29.5	33.1	10.7	18.4
1079	Parkway	21.3	28.5	42.3	9.5	19.9
1080	Yelm	21.7	39.6	58.7	8.9	22.1
1081	Alder Lake	23.3	36.6	48.8	11.8	25.8
1082	Rimrock	16.3	29.0	37.1	8.0	18.9
1083	Packwood	19.7	31.4	43.0	11.5	21.4
1084	Packwood	22.8	31.5	48.7	9.2	23.4
1085	Randle	27.7	35.6	50.1	10.6	23.7
1086	Naselle	26.3	34.4	49.0	11.0	27.4
1087	Skamokawa	23.7	37.3	46.9	12.3	26.6
1088	Castle Rock	24.2	41.0	54.2	12.1	24.8
1089	Cathlemet	22.0	29.7	40.3	9.2	23.4
1090	Cougar	26.2	35.8	51.7	10.5	25.3
1091	Yale	24.0	36.3	47.9	11.0	25.8
1092	Glenwood	24.7	31.7	46.9	11.5	24.1
1093	Willard	28.3	34.4	49.5	12.1	26.3
1094	Vernonia	24.3	35.9	49.7	12.2	24.4
1095	Prindle	29.0	37.8	55.4	10.9	25.4
1096	Sandy	28.0	34.1	49.3	12.8	29.5
1097	Cherrywille	23.9	33.3	47.6	9.7	23.7
1098	Hebo	21.5	35.2	48.3	10.2	21.2
1099	Pine Growe	23.5	28.9	41.9	13.4	21.7
1100	Grand Ronde Agency	22.4	33.0	43.4	11.4	23.1
1101	Waldport	21.5	32.6	48.5	11.1	21.4
1102	Upper Soda	21.7	29.8	44.6	9.1	20.2
1104	Brookings	21.3	37.3	51.4	10.6	26.5

Apart from population Republic having an average diameter of 11 mm in the group with lowest values there were also: 1001 — Stoner, 1008 — Golden, 1036 — Alberni and 1028 — Merrit and 1052 — Twisp. Within this group were also included populations with average diameters from 11.2 mm to 14.3 mm. The highest diameter value were found in the populations: 1047 — Concrete, 1095 — Prindle, 1093 — Willard, 1096 — Sandy and 1085 — Randle. They reached values from 27.7 mm to 29.4 mm. Detailed data for all populations regarding the trait under discussion are included in Table 16.

We have not found tree diameter increments in the test area to stand in any significant correlational relation to parental populations in America. It has been calculated however that average tree diameters from northern and mountain populations are smaller than in trees of the same age deriving from populations lying in the northern parts of the range under investigation and also from low-elevation provenances (Table 17). This is however merely a general trend in interpopulational variations modified by the influence of other factors not liable to easily calculation, e.g., the influence of the Pacific Ocean, landscape relief and others. A good example of such deviations from the general trend is the pair of populations: 1048 — Republic and 1047 — Concrete. The first has trees with smallest diameters, the other with greatest ones and they share the same latitude of parental populations. The populations whose progeny has the highest index of survival after a year and two years of life are characterized not only by poorer height increments, but also diameter increments ($r = 0.52$).

A very substantial influence on Douglas-fir tree diameter is exerted by the number of first-order branches as well as their dimensions. The more ramified is the crown and the branches have greater dimensions, the greater diameter is attained by the tree. The ascertained correlation value on the level $r = +0.90$ between tree diameter and height in 1974 allows of a favourable prognosis for raising selection of Douglas-fir trees of negligible trunk tapering.

The relationship between tree diameter values and the period of vegetation inception by a given population can be observed in some years only, namely, when there comes about the phenomenon of vegetation inception extension in time, giving in effect significant interpopulational differences. In such years the populations that start their vegetation early had a greater tree bulk increment. This is significant in as much as the duration of the vegetative period does not in our conditions depend on the moment of vegetation inception, but rather on its termination (Table 17).

DIFFERENTIATION OF DOUGLAS-FIR POPULATIONS WITH RESPECT TO CROWN SHAPE AND NUMBER OF FIRST-ORDER BRANCHES

Crown shape

On the basis of observations of crowns in some 12 000 Douglas-fir trees, a uniformity in their shapes has been found. The forkings that developed on crown leader-shoots have either been caused by frostbites in the first years of life (Fig. 10), or in sporadic cases, by the substitution of the Lammas shoot for the leader-shoot.

As the measure of crown width has been adapted the size of the largest first-order branches. The measurements of this character carried out in the years 1972 and 1973 were gathered in the form of average values for populations in Table 16. Variation within populations and between populations with reference to tree crown width is very signi-

Table 17

List of characters with very significant coefficients of correlation with tree diameter measured 30 cm above ground in 1974

Characters	Value of r
Geographic parameters of populations	
elevation	−0.32
northern latitude	−0.53
western longitude	n.s.
Characters of trees in progeny populations	
number of seedlings in 1969	−0.52
number of seedlings in 1970	−0.52
Number of branches in 1970	+0.68
number of branches in 1972	+0.72
length of largest first-order branches in 1972	+0.76
in 1973	+0.78
Height increment	
spring 1972	+0.79
spring 1973	+0.78
spring 1974	+0.82
Lammas 1972	+0.50
Lammas 1973	+0.36
Lammas 1974	+0.58
annual 1972	+0.77
annual 1973	+0.77
annual 1974	+0.81
tree height in 1969	+0.36
tree height in 1972	+0.84
tree height in 1973	+0.89
tree height in 1974	+0.90
wegetation period inception	
by lateral shoots in 1973	n.s.
by lateral shoots in 1974	+0.57

ficant and it remains on the confidence level of 99%. On the other hand the level if interpopulational differences in comparison with data from different years is the same and it amounts to $W = 16\%$. A rise of the standard deviation from 5.0 to 7.1 cm in 1972 is connected with normal crown expansion in this period of a tree's lifetime (Table 18).

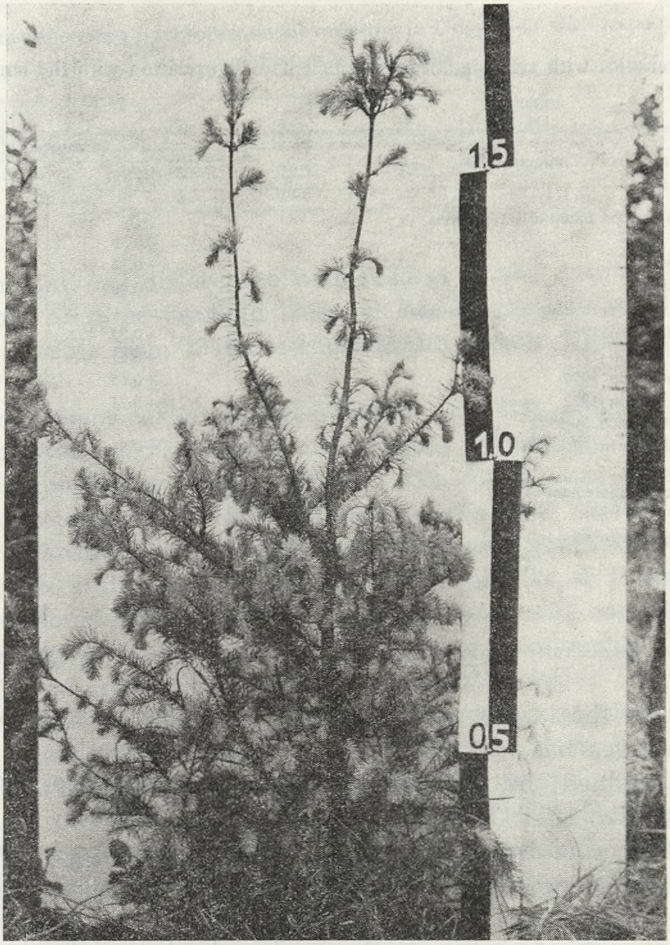
Whereas populational differences increased clearly way in the growth of test function F from a value 1.81 in 1972 to 2.64 in 1974. Similarly increase interpopulational differences with relation to a number of other quantitative characters (Tables 12 and 18).

There can clearly be found influences of climate and other geographic elements at the place of development of a given population on characteristics of the progeny raised in the Kórnik experiment. Tree crowns

Table 18

Statistical data concerning Douglas-fir interpopulational variation with respect to tree crown width

Year of observations	$\bar{x}$	x_{min}	x_{max}	S	Variation coeffic.	F_0	$F_{0.01}$
1972	31.8	18.5	46.3	5.0	16%	1.81	1.52
1973	44.8	26.2	69.5	7.1	16%	2.64	1.52



Phot. K. Jakusz

FIG. 10. Forking of leader shoot developed in result of frost damaged leader shoot. Tree from population 1075-Enumclaw

deriving from mountain populations are more slender than those from lowland populations. Also trees from northern provenances have narrower crowns than those from southern provenances.

This is a frequently encountered phenomenon of the convergence between mountain and northern plants. The correlation expressing the relation between the crown and longitude of a provenance ($r = +0.40$ in 1972, $+0.46$ in 1973) is undoubtedly the result of simultaneous fall in elevation and increase in the influence of the Pacific Ocean on the microclimate of parental populations when moving from east to west in the region of natural occurrence of Douglas-fir.

The narrow-crowned trees were lower ($r = +0.90$) in a very significant manner than the wide-crowned ones, but they were characterized by a high survival rate ($r = —0.62$ in 1973). In the populations in which

Table 19

List of characteristics with very significant coefficients of correlation with the length of largest branch

Characteristics	Value of r	
	1972	1973
Geographic parameters of parental populations		
elevation	−0.50	−0.56
northern latitude	−0.34	−0.35
western longitude	+0.40	+0.46
Characteristics of tress from progeny populations		
number of seedlings in 1969	−0.53	−0.62
in 1970	−0.51	−0.62
number of branches in 1970	+0.65	+0.69
in 1972	+0.77	+0.69
length of largest branch in 1972		+0.88
tree height increment in spring 1972	+0.84	+0.81
1973		+0.77
Lammas tree height increment 1972	+0.51	+0.50
1973		n.s.
annual tree height increment in 1972	+0.81	+0.79
1973		+0.76
tree height 1969		+0.32
1972	+0.34	+0.80
1973	+0.88	+0.90
degree of frost freezing in 1971	+0.46	+0.53

the average of the largest branch attained high values a greater degree of frost damages has been found, so that the correlation of these two characters attained the value $r = 0.53$ on the confidence level of 99% for the data from 1971 (Table 19).

The influence of frost damages on tree crown shape is expressed in its deformation, for alongside the damaged leader shoot there grow vigorous upward-pointed lateral shoots (Fig. 10). Cases were also observed when after the freezing of the leader shoot no lateral shoot took over its role and a broom-shaped crown formed.

Crown density

In 1972 in five-year-old trees the number of first-order branches was calculated, i.e. such branches as grow off directly from the tree trunk. On the average, a Douglas-fir tree has at this age first-order branches placed along the whole trunk length (Table 20). Interpopulational differences with respect to this character rule in such a way that the trees in populations deriving from the northern regions of Douglas-fir distribution have a smaller number of first-order branches. An extremely low number of branches ($x = 10$) has been found in population 1029 — Thasis, which was also characterized by a very great intrapopulational variation attaining a varince of $S^2 = 84$ and the variation coefficient $W = 87\%$. So great an intrapopulational variation has been found in no other populations.

Table 20

Statistical data concerning interpopulational variation in Douglas-fir with respect to the number of first-order branches

Year of observations	$\bar{x}$	x_{min}	x_{max}	S	Variation coeffic.	F_0	$F_{0.01}$
1972	22	10.6	29.5	3.7	17%	6.64	1.46
1970	10	5.0	13.6	1.9	19%	1.94	1.44

Interpopulational differences with respect to the number of branches in a number of three-year-old trees, as has been found on the basis of the measurements from 1970 are considerably smaller than in subsequent years.

A measurement taken two years later, in 1972, yielded in variance analysis the value of F_0 function many times higher than the F function test on the confidence level of 99% (Table 20). It was found that the trees from mountain and northern provenances have smaller number of first-order branches than those from lowland and southern provenances. A considerable influence of frosts on the formation of Douglas-fir tree crowns was noted. This is indicated by the results of correlation calculations yielding $r = -0.54$ in $P = 99\%$ for the relationship between the number of first-order branches in 1972 and the degree of tree damage in a given population in 1971 (Table 21). A smaller number of branches appear in those trees in which a higher degree of frost damages was recorded in 1971. Crown density affects tree height increment in an obvious way. In the populations in which a positive standard deviation from the average number of branches was ascertained, also a positive standard deviations from the average tree height was always found.

Table 21

List of correlation coefficients with very significant r values for first-order branches in three- and five-years-old Douglas-fir

Characteristics	Value of r 1970	Value of r 1972
Geographic parameters of parental populations		
elevation	−0.48	−0.44
northern latitude	−0.38	−0.52
western longitude	+0.47	n.s.
Characteristics of trees in progeny populations		
number of seedlings in 1969	−0.44	−0.44
in 1970	−0.45	−0.45
length of largest branch 1972		+0.77
height increment in spring 1972		+0.76
Lammas increment 1972		+0.43
annual increment 1972		+0.71
tree height 1969	+0.52	+0.43
1972		+0.92
degree of shoot freezing in 1971		−0.54

DIFFERENTIATION IN DOUGLAS-FIR POPULATIONS WITH RESPECT TO RESISTANCE TO FROST ACTION

The influence of low temperatures on the growth and development of trees is most strikingly expressed in such climatic configurations when a considerable fall in temperature occurs in the course of the vegetative season. Such phenomena come about in Kórnik's climatic conditions, more often than not, in late spring and autumn. Less dangerous to Douglas-fir are winter frosts especially if they are connected with the occurrance of snow cover. As a result of frost action there are to be observed damages in terminal shoots and the leader in tree populations of little resistance. In the populations of trees resistant to the operation of low temperatures there was to be observed a change in needle colour to brick-red, there were external changes in the colour of shoots and needles. The interpopulational differences with respect to this character are very distinct and occur with the confidence level of 99%. Greatest frost damages were observed in the first and second year of life in the nursery, especially in the populations: 1060 — Sequim, 1042 — Duncan, 1009 — Klina Klini (Białobok and Mejnartowicz 1970). At the end of the winter of 1971, after a long period of warming, an abrupt chilling set in which became the cause of bud shoot and needle damages. The statistical data from the calculations referring to frost hardiness in Douglas-fir trees look as follows: interpopulational differences occur on the confidence level of 99% and amount to the value $F_0=4.16$ with $F_{0.01}=1.22$. The most resistant populations turned to be. 1005 — Williams Lake, 1006 — Tatla, 1007 — Clearwater, 1010 — Barriere, 1028 — Merrit, 1050 — Twisp, 1062 — Forks and population from Oregon State, 1098 — Hebo. The bulk of the above-mentioned populations lie in the north of the Douglas-fir distribution under investigation. That is why the significant correlation between frost hardiness of trees and the latitude in which a population under investigation lies is understandable. This correlation amounts to $r=0.38$. A still closer relationship exists between frost hardiness of trees and the longitude of a provenance ($r=-0.54$) and its elevation ($r=+0.53$). So the most resistant ones to frost were the trees from the populations in the interior as well as in the north and in the mountains. The greatest frost damages were recorded in the populations: 1012 — Klina-Klini, 1034 — Sechelt, 1050 — Marblemount, 1073 — Humptulips.

The result of calculations of interpopulational variation seems to be significant. The variance of frost hardiness in resistant populations is very small and attains a value of a variation coefficient equal to about 10%. Intrapopulational variation in the populations in which the trees were badly damaged by frost is quite different. The variation coefficient is very great and attains values equal to about 60%. That means that in such populations one can reckon on selecting frost-resistant trees by applying pedigree selection. In the populations with the highest average tree height there was to be observed resistance to frost action on the level of the average for the whole experiment or slightly below this average.

Apart from the above-mentioned characters a correlation with frost hardiness was found also for: seedling mortality $r = -0.46$, number of branches $r = -0.67$, tree diameter $r = -0.48$, annual increment: lenght of branches $r = -0.46$, number of branches $r = -0.53$, mean time of leader shoots increment $r = -0.53$. All the correlation coefficients mentioned are on a confidence level equal to 99%.

RESULTS OF OBSERVATIONS ON ROOT DAMAGES CAUSED BY COCKCHAFER GRUBS (*MELOLONTHA MELOLONTHA* L.)

We are familiar with the deer's selective browsing on tree shoots. In Douglas-fir a clear correlation was found between the degree of tree damage by deer and the concentration of chlorogenic acid in the shoots of damaged trees (Radwan 1975). So there was a probability of occurrence of such difference between populations of trees whose roots are also eaten by grubs. For establishing interpopulational differences with respect to this characteristic we isolated from all dead trees those on the roots of which were found traces of intensive grubs feeding. The degree of tree damage was sometimes so great that the main root was completely devoid of lateral roots, the bast and the terminal part. The greatest intesity in grubs feeding occurred in the first year after the planting of trees onto the field test area and it attained the value of 60% of total damage on the plantation at the time. The data obtained from the observation of dead trees in the individual populations, were subjected to variance analysis in the result of which it was found that interpopulational variation is smaller than between-block variation and that there are no significant interpopulational differences. It is conceivable that there are significant between-specimen differences, but their ascertainment would require establishing a seperate experiment.

DISCUSSION

None of the previous international experiments on variation of forest trees has embraced with its compass so great a spece wherefrom seed material was acquired and in none have so many countries taken part as in the investigations on Douglas-fir initated by IUFRO in 1966/67. Up to 1973; 45 research centres from 30 countries established their areas. Poland participates in this experiment through the Institute of Dendrology, Polish Academy of Sciences at Kórnik near Poznań as well as the Forest Research Institute from Warsaw.

The Institute of Dendrology has at its disposal research material from the whole pool of provenances from the 1966/67 harvest, whereas the Forest Research Institute possesses material from 38 provenances of the same 1966/67 series (Barner 1973, Burzyński and Gutowski 1973).

Such a large number of participants gives so far unknown possibilities for a comparison of results for some population and the relations occurring between populations. Although the modifying influence of environmental factors is considerable and is clearly evidenced in the differences between variation coefficients calculated for the measurements in the nursery and on the field test area, yet mutual interpopulational relations for a definite characteristic of trees within the experiment are very often maintained in similar designs on different test areas.

We observe such relations, for instance, for tree height from nine provenances from British Columbia which are for the experiment established in Finland (Hagman 1973) and at Kórnik, in Poland. For this group of populations were found in both countries the highest values of tree heights in the populations: 1002 — Dean and 1004 — Stuie. Although absolute values in both these populations differ very much one from another, population 1004 — Stuie has in the Kórnik experiment tree heights lying below the average from the experiment, while population 1002 — Dean attains values approximating the maximum data this characteristic.

On the basis of the results referring to growth development and frost hardiness in trees from provenances lying in British Columbia, we can divide the area into three regions:

1. Provenances from the interior are marked in the Kórnik experiment, and also in other experiments outside Poland, for a considerable compensation for interpopulational variation, low values of tree height and diameter increment, great crown density and early termination of the vegetative season. Most of these provenances have negative values of standard deviation from the general average of height and diameter with the exception of population 1039 — Chilliwack. which apart from its considerable resistance to frost is characterized by a very good tree growth and a relatively late inception of the vegetational period. Besides this population the British Columbia interior might be excluded from our plans for seed import to Poland. Once an assumption was put forward that the best old Douglas-fir stands introduced into Europe at the beginning of the XXth c. derived just from British Columbia and from the vicinity of the Salmon River. In the light of this experiment such a thesis seems highly improbable.

2. Populations from the Pacific coast. A great interpopulational variance was found here for growth and resistance characters. Beside poor-growing and very susceptible populations from the vicinity of the

mouth of the Klina-Klini there are also observed trees with a very good height and diameter increment in population Dean — 1002. Similar results were obtained with this population also in Finland, Norway, Belgium and Ireland (Hagman 1973, O'Driscoll 1973, Nanson 1973, Magnesen 1973). The negative character of trees from this provenance is an early anset of spring increment and a great susceptibility to the action of low temperatures. Where the source of such a great difference between population Dean and the coastal populations from the vicinity of the Klina-Klini lies can be answered solely through the familiarity with orographic and climatic factors of these regions.

3. Populations from Vancouver Island. Similar to the populations from the Pacific coast in British Columbia, they also have a great interpopulational variation in growth characteristics. Some of them have a very great adaptability revealing magnificent growth on different sites and in different climatic conditions. The trees from the populations Gold River — 1031 and Alberni — 1036 belong to best-growing ones, both in Poland, in Ireland and Norway. Yet they require a milder climate than in Poland because considerable damages caused by ground frosts are to be observed. Some other populations from Vancouver have very poor growth parameters, so that also Vancouver Island is rather not the best of seed sources for the purposes of introduction in Poland.

The greatest interpopulational variation is observed with reference to the set of populations from Washington State.

From extremely unadaptive populations such as e.g., 1048 — Republic to ones indicating highest height and diameter values in many experiments. Although the results referring to the worst populations with respect to raising are, of little economic significance they are interesting for cognitive reasons. Population Republic is marked for a negligible tree height increment on test areas in Poland, Italy, Ireland, Norway (De Vechi 1973, O'Driscoll 1973, Magnesen 1973). At the same time we found a low value of other quantitative characters, such as tree diameter and the ratio between height and tree diameter and separation of this population from the whole test sample with their biochemical properties. Such results allow us to infer about a considerable isolation and small gene flow between populations in certain regions of occurrence of the Douglas-fir. On the basis of further investigation into population Republic it will be possible to attempt a correlational of growth characters with the frequency of occurrence of isoenzymes within a population. The most valuable provenances for the area of Poland are populations 1047 — Concrete and Darrington — 1053. They lie within a close distance of several dozen kilometers from each other. The results achieved with the trees introduced from these provenances in a number of West Europan countries point to there as outstandingly adaptive and very fast growing.

2. DIFFERENTIATION IN DOUGLAS-FIR POPULATIONS WITH RESPECT TO THE LEUCINE AMINOPEPTYDASE ISOENZYME

INTRODUCTION

The knowledge of inter- and intrapopulation variability of Douglas-fir as well as of a number of other tree species is based mainly on researches into quantitative and qualitative characters being an expression of the action of a number of genes. Up to the early 1970's only a few traits (semi-lethal in character) have been known in the forest trees that possessed Mendelian characteristics of inheritance. Undertaking biochemical investigations into isoenzymes in trees has allowed us to ascertain a considerable polymorphism on their part, while examining the content of esterase in the needles and macrogametophytes of spruce, B a r t e l s (1971a) established that these isoenzymes are inherited in a fixed way and that they are of 1-locus 2 alleles character. Investigating esterase, acid phosphatase and leucine aminopeptidases in macrogametophytes of seeds derived from geographically distant populations has allowed us to ascertain considerable differences in the frequency distribution of genotypes and genes in populations of spruce, black pine, Douglas-fir and larch (B e r g m a n n 1973a, 1973b, 1973c, N i k o l i c and B e r g m a n n 1974, M e j n a r t o w i c z and B e r g m a n n 1975). A great number of alleles for various isoenzymes systems could be established when carrying out research into the progeny of trees obtained from controlled pollinations (B a r t e l s 1971, C o n k l e 1971, 1971a, F e r e t and S t a i r s 1971, R u d i n and R a s m u s o n 1973, L u n d k v i s t 1974). The investigations of peroxidase in Douglas-fir needles from identical populations as in the experiment established at Kórnik have shown that by employing the chi-square test populations can be distinquished on the 99% level of significance. In these investigations a singular position has been occupied by the 1048 — Republic population (M u h s 1974), which also in our experiment is distinguished by low values of growth characters. The bulk of the efforts published to date point to a possibility of identification of a definite population by means of its isoenzyme system. The least useful for those purposes seem however peroxidases which undergo significant changes under the influence of exogenic factors, such as fungal infections or climatic changes.

Material and methods

The macrogametophyte of gymnosperms is a multi-cellular formation performing the role of storage tissue and it at simultaneously protects the embryos from the influence of deleterious external factors. The outer layer of the gametophyte is constituted by the nucellus residue and the seed coat (Allen and Owens 1972). A gametophyte so isolated (also called endosperm) forms a perfect material for biochemical research (Sarvas 1962). Particularly by the application of the technique of isoenzyme research, the endosperm of gymnosperms is a material convenient for genetic analysis of the frequency of particular alleles. It results not only from a good repeatability of the material but also from a haploidal character of the tissue. Seeds from individual trees growing in the GFR have been acquired from the Hessian Forest Research Institute (Hessische Forstliche Versuchsanstalt, Abt. f. Forstpflanzenzüchtung, Hann. Münden), while partial samples from some of the seed populations that have been used for the establishment of an international provenance experiment on Douglas-fir have been kindly rendered accessible from the Tree Improvement Station in Humleback in Denmark (Statsskovenes Planteavlsstation Humleback). These were the populations: 1019 — Monte Creek, 1028 — Merrit, 1037 — Franklin River, 1048 — Republic, 1068 — Chiwaukum, 1074 — Matlock.

The whole of the biochemical research has been carried out at the University of Göttingen (Lehrstuhl für Forstgenetik und Forstpflanzenzüchtung der Universität Göttingen). They were based on the electrophoretic separation of enzymes in starch gel. The proceeding of the researches can be divided into three stages:

1. Isolation of the endosperm from the seed and its homogenization.
2. Electrophoresis on the starch gel.
3. Obtaining products of the enzyme action on a substratum and their visualization.

The isolation and homogenization of endosperm

We detach a dry endosperm from the diploidal tissues of the seed. We do this by dissecting each seed with a scalpel; we remove from the seed the embryo, the seed coat and the megaspore wall remnants. We place the gametophyte of each seed separately within the hollow of the homogenization plate. We pour 0.1 ml phosphate buffer pH 7.5 with the addition of 5 mM of sorbic acid, 5 mM of cystein a 10 mM of saccharose. After the homogenization of the endosperm we steep in the homogenate scraps of Whatman chromatographic paper, No. 3 MM, through the MN 10 B-Linsenpapier Machery — Nagel Co. paper filter. So prepared a homogenate is put into the gel.

Electrophoresis

The homogenate absorbed by the scrap of chromatographic paper is subjected to a horizontal electrophoresis in a discontinous buffer system after Poulik's (1957) modified method. The carrier in which the electrophoretic processs is going on is hydrolyzed starch from which the gel has been obtained by boiling 19 g of starch for 11 minutes, with an addition of 4 g of saccharose in 180 ml of the buffer Tris-Citric acid. The acidity of the gel buffer amounts to pH=8,7.

On bringing to boil and de-aerobing, the gel is distributed onto a set of microscope glasses and left for 2 hrs for setting. The glasses together with the gel are placed within frames and these in turn are placed in Boskamp (a FRG firm), electrophoresis chambers. Directly in the gel are placed the paper scraps containing the homogenate, which is the source of proteins seperated during the flow of electric current through the gel. If the starch gel is the carrier, than the segregation of protein molecules comes about not only owing to the differences in their electrophoretic mobility, but also thanks to the size of molecules by the molecular filtration principle (Szumiel 1972). Especially in investigations of leucine aminopeptidase does the starch gel yield far better results showing a greater sensitivity than the acrylamid gel (Thomas and Delacarpio 1971). At a voltage of 15 V/cm and with an average bridge distance of 7 cm, the electrophoresis process comes about during 2 hours.

Visualization of the products of leucine aminopeptidase action

Leucine aminopeptidase catalyses the hydrolysis of the N-terminal amino acid in peptides. To visualize the location of this isoenzyme contained after the electrophoresis in different parts of the gel, the isoenzyme is placed in a buffer of tris-maleate buffer pH 5.4 and 0.05 mol concentration. The incubation is done at 34°C. The typical substrat for this enzyme are L-leucine amide and L-leucine glycine. In our case has been used a solution of 40 mg L-leucine-β-naphtylamide-HCl and 50 mg of black K salt in 100 ml H_2O. The process of staining proceeds in the darkness at 35°C giving in effect dark-blue bands delimitating the zones occupied by individual isoenzymes, that is the so-called zymogram. Such a zymogram is then presented on a diagram. The process of staining consists in that we use chromogenic substrata which are, more often than not, 2-naphtol esters or 2-naphtylamide amino acids or peptides. From these substances the enzymes free the naphtol or naphtyloamine, which form azo dyes with two-azo salts (Pears 1960).

RESULTS AND DISCUSSION

Genetic analysis of leucine aminopeptidase variation (LAP)

Markert and Moller (1959), who were the first to have carried out all-out investigations on isoenzymes have suggested two different approaches to the results obtained. The first interpretation assumed that an isoenzyme corresponds to an individual gene; the other, on the other hand, assumed that each species may have a different potentiality to synthesise a number of isoenzymes. Later investigations have confirmed the first theory while making it more precise and reducing it to the concept „one gene-one isoenzyme" (Beckman et al. 1964, Shaw 1964, Beckman and Nilson 1965, Ashton 1965, Kaminishi and Gajos 1964, Hess 1968, Scandalious 1968). During the electro-

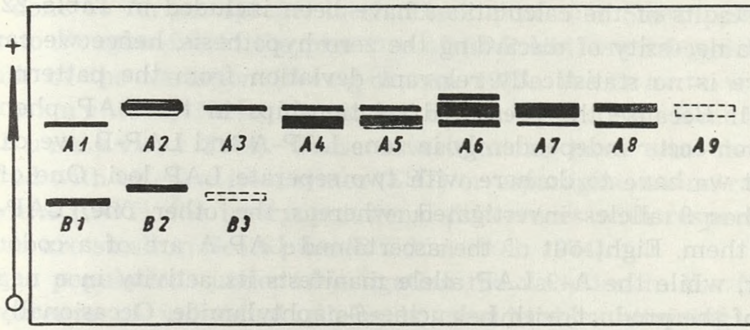


Fig. 11. LAP zymogram from a *Pseudotsuga menziesii* endosperm

phoresis, the LAP isoenzyme from the endosperm of Douglas-fir seeds are arranged in two zones which came to be designated A and B. The LAP-A zone concentrates molecules of a higher degree of electrophoretic mobility, which are located closer to the front, while in the LAP-B zone there are lower-mobility molecules, ones lying further away from the front. The LAP zymogram presented in the drawing is characterized by a large number of isoenzyme phenotypes. In the LAP-A zone we have as many as 9 phenotypes and in the LAP-B zone — three phenotypes. If we are to accept as valid a theory assuming that one gene corresponds to one polypeptide, then the isoenzyme phenotypes obtained should segregate after meiosis, in the haploidal tissue of the endosperm, alternately in the ratio of 1 : 1. When analysing a number of individual trees we state that some of them are homomorphic in a defined LAP zone, while others are heteromorphic. If we compare the phenotypes from one heteromorphic tree, then the the acquired patterns of frequency distribution for the phenotypes obtained approximate the 1 : 1 ratio. We verify the results derived from the biochemical analysis by statistical methods by applying the chi square (χ^2) significance test. We assume a case in which the results belong to two mutually exclusive groups. Thus we are dealing with a binary random variable.

Let p stand for the probability that this variable assumes the value 1, and p^o — hypothetical probability given a priori. Then the statistical hypothesis will assume the form:

$$H_0 : p = p^o.$$

Then the test function assumes the following particular shape:

$$\chi_0^2 = \frac{(f - np^o)^2}{np^o(1 - p^o)}$$

where f stands for the number of successes among n independent experiments (Oktaba 1966). The extremes for $\chi^2_{0.05} = 3.841$ and for $\chi^2_{0.01} = 6.635$ with a $v = 1$ degree of freedom.

The results of the calculations have been included in Table 22. They point to a necessity of discarding the zero hypothesis, hence we can state that there is no statistically relevant deviation from the pattern in the ratio 1 : 1. Because the presented relationships in the LAP phenotypes segregation occur independently in zone LAP-A and LAP-B, we can suppose that we have to do here with two seperate LAP loci. One of them LAP-A has 9 alleles investigated, whereas the other one, LAP-B has three of them. Eight out of the ascertained LAP-A are of a codominant character, while the A-9 LAP allele manifests its activity in a negligible amount of the product with L-leucine-β-naphtylamide. Occasionally there

Table 22

Frequency of distribution of different isoenzyme phenotypes in two LAP zones (A, B) in seed samples of individual *Pseudotsuga menziesii* trees

Segregation pattern of isoenzyme phenotypes	Total seed amount	χ^2	P
LAP A–1 : LAP A–5			
22 : 26	48	0.33	0.50%
LAP A–1 : LAP A–2			
68 : 65	133	0.07	0.75%
LAP A–1 : LAP A–9			
43 : 41	84	0.05	0.80%
LAP A–2 : LAP A–5			
44 : 40	84	0.19	0.60%
LAP A–3 : LAP A–4			
22 : 26	48	0.33	0.50%
LAP A–4 : LAP A–5			
39 : 32	71	0.69	0.40%
LAP A–5 : LAP A–6			
26 : 21	47	0.60	0.40%
LAP A–6 : LAP A–8			
24 : 30	54	0.67	0.40%
LAP A–6 : LAP A–7			
32 : 27	59	0.42	0.50%
LAP B–1 : LAP B–2			
16 : 20	36	0.44	0.50%
LAP B–1 : LAP B–3			
29 : 26	55	0.16	0.70%

is a total absence of reaction products. We have to do here with either a typical recessive allele (Bergmann 1973) or the action of the LAP A-9 is under the influence of some repressor, as it occurs with the hampering activity of the 4C peroxidase band in *Oriza sativa* L. (Pai et al.

1973). One would have to assume then the existence of an interaction between the repressor and LAP A-9. Similarly presents itself the activity of LAP B-3, one of the three alleles recognized in zone LAP B.

Inter- and intrapopulation variation of *Pseudotsuga menziesii* with regard to the frequency of occurence of LAP isoenzymes

It is interesting that the genetic analysis of LAP phenotypes segregation done so far on spruce, larch, black pine and Scots pine, points, similar to Douglas-fir, to the presence of LAP loci, one of which groups the bulk of the variation (Bergmann 1973, Mejnartowicz and Bergmann 1975, Nikolić and Bergmann 1974, Rudin at al. 1974, Lundkvist 1974). These investigations have also shown that compared with esterase isoenzymes (EST) or asparagine aminotransferasis isoenzymes (GOT), the interpopulational differences with respect to LAP variation are small in Scots pine (Rudin et al. 1974).

In the populations under investigation the variation in the frequency of occurrence of individual alleles is considerable, attaining at times a very high level of significance of interpopulational differences. The percentage values for the frequency of occurrence of all alleles in both LAP loci in the six investigated seed populations from the natural range of Douglas-fir in North America have been presented in Table 23. The

Table 23

The alleles frequencies in two izoenzyme loci of LAP from six populations of *Pseudotsuga menziesii*

Name of locality	LAP–A									LAP–B		
	A1	A2	A3	A4	A5	A6	A7	A8	A9	B1	B2	B3
A. Monte Creek (1019)	5.2	4.2	3.6	25.5	14.1	16.7	0	29.2	1.6	20.3	79.7	0
B. Merrit (1028)	7.3	4.2	3.6	9.1	3.6	27.9	0.6	40.0	3.6	24.2	75.8	0
C. Franklin River (1037)	14.7	5.8	8.3	16.0	5.1	7.0	1.3	41.0	0.6	24.4	73.7	1.9
D. Republic (1048)	11.4	0.6	1.8	25.2	18.0	7.8	0	29.3	6.0	7.8	92.2	0
E. Chiwaukum (1068)	11.8	3.9	7.2	3.3	2.6	33.6	0	34.9	0.7	13.8	86.2	0
F. Matlock (1074)	9.6	3.2	8.6	12.3	6.4	21.7	2.7	35.3	0	22.2	77.8	0

most frequent in occurrence is the allele LAP-A8 and LAP-B2. To the most infrequent in occurrence belong the recessive alleles LAP-A9 and LAP-B3, as well as LAP-A7. The significance of interpopulational differences in respect of the frequency of occurrence of individual alleles has been calculated by Berry's D^2 test (Berry 1961, Grewal 1962).

$$D^2_{st} = \{(Q_{si} - Q_{ti})^2 - (1/Ns + 1/Nt)\},$$

where $Q_{si} = \sin^{-1}$ (1-2psi),
where p = frequency of occurrence of the i-th band in s-th population; $Q_{ti} = \sin^{-1}$ (1-2pti),
where p = frequency of occurrence of the i-th band in t-th population.

Table 24

Results of D^2 analysis of endosperm leucine aminopeptydase (LAP) frequencies

Population comparison	Isoenzyme LAP											
	A–1	A–2	A–3	A–4	A–5	A–6	A–7	A–8	A–9	B–1	B–2	B–3
A–B	−0.004NS	−0.011NS	−0.011NS	0.187**	0.139**	0.062*	0.013NS	0.041*	0.005NS	−0.003NS	−0.002NS	−0.011NS
A–C	0.095**	−0.006NS	0.080NS	0.044*	0.087**	0.082**	0.041*	0.050*	−0.002NS	0.002NS	0.009NS	0.065*
A–D	0.041*	0.056*	0.002NS	−0.011NS	0.001NS	0.065*	−0.011NS	−0.011NS	0.047*	0.125**	0.123**	−0.011NS
A–E	0.047*	−0.012NS	0.014NS	0.468**	0.188**	0.144**	−0.012NS	0.003NS	−0.004NS	0.019NS	0.017NS	−0.012NS
A–F	0.018NS	−0.008NS	0.035*	0.106**	0.056*	0.006NS	0.098**	0.006NS	0.054*	−0.009NS	−0.008NS	−0.011NS
B–C	0.045*	−0.007NS	0.029NS	0.032NS	−0.007NS	0.320**	−0.007NS	−0.012NS	0.064*	−0.013NS	−0.010NS	0,064*
B–D	0.008NS	0.054*	0.007NS	0.181**	0.233**	0.287**	0.012NS	0.039*	0.001NS	0.202**	0.202**	−0.012NS
B–E	0.011NS	−0.012NS	0.013NS	0.058*	−0.009NS	0.003NS	0.011NS	−0.002NS	0.029NS	0.059*	0.059*	−0.013NS
B–F	−0.005NS	−0.009NS	0.034*	−0.001NS	0.005NS	0.009NS	0.019NS	−0.002NS	0.134**	−0.009NS	−0.009NS	−0.012NS
C–D	−0.003NS	0.098**	0.085**	0.040*	0.165**	−0.012NS	0.040*	0.048*	0.103**	0.205**	0.249**	0.064*
C–E	0.006NS	−0.005NS	−0.011NS	0.195**	0.004NS	0.478**	0.039*	0.002NS	−0.013NS	0.061*	0.087**	0.064*
C–F	0.013NS	0.004NS	−0.012NS	−0.001NS	0.009NS	0.176**	−0.002NS	0.002NS	0.012NS	−0.009NS	−0.003NS	0.065*
D–E	0.012NS	0.046*	0.063*	0.458**	0.293**	0.437**	−0.013NS	0.002NS	0.093**	0.025NS	0.025NS	−0.013NS
D–F	0.008NS	0.031NS	0.095**	0.101**	0.122**	0.151**	0.097**	0.005NS	0.234**	0.161**	0.161**	−0.011NS
E–F	0.007NS	−0.011NS	−0.009NS	0.104**	0.023NS	0.060*	0.097**	−0.012NS	0.016NS	0.036*	0.036*	−0.012NS

* Indicates means differ at 95% probability level
** Indicates means differ at 99% probability level

D^2 is significant on the level $\alpha=0.01$ if it is greater than $6\left(\frac{1}{Ns}+\frac{1}{Nt}\right)$ and on the level $\alpha=0.05$ if it is greater than $\left(\frac{1}{Ns}+\frac{1}{Nt}\right)$.

The results of calculations of the D^2 test have been presented in Table 24. They allow us to determine the significance of the differences with regard to the frequency of occurrence of each of LAP alleles in a comparison between any of two populations. Most clearly does population *D* stand out that is to say Republic (1048). Particularly great are the differences between this population and population C (Franklin River — 1037) and population F (Matlock — 1074). Out of 12 LAP-A and LAP-B alleles in comparison with populations C-D as many as ten occur in statistically significantly different frequencies, and in a comparison of F-D populations statistically significant differences occur in relation to the frequency of occurrence of eight isoenzymes. That points to a considerable distinctness of the Republic — 1048 population which stands out with its unique pattern of frequencies of occurrence of all leucine aminopeptidase isoenzymes, and in particular with its frequency of the recessive allele LAP-A9 and with a sparse occurrence of the alleles: A2. A3 and LAP-B1.

M u h s (1974), investigating the Douglas-fir population variation from the international experiment IUFRO populations 1966/67 states that 1048 — Republic stands out among the 12 investigated with the contents of isoenzyme peroxidase in the needles. The differences occur on a high level of significance. In the genetic investigations on Douglas-fir populations from the same 1966/67 IUFRO experiment in Poland, attention has been called to the separation of trees from the 1048 — Republic with respect to morphological and physiological qualitative and quantitative characters (B i a ł o b o k and M e j n a r t o w i c z 1970, M e j n a r t o w i c z 1973).

Taking into consideration the overall system of leucine aminopeptidase isoenzymes, we cannot ascertain among the six populations under investigation any such pair in an interpopulational comparison of frequency of occurrence of LAP isoenzymes that would not differ in at least two isoenzymes (Table 24). The least differences have been found in a comparison of populations F-B, i.e. Matlock — 1074, Merrit — 1028, where the outstanding ones are only LAP-A3 with $P=95\%$ and LAP-A9 with $P=99\%$. Similarly, in a comparison of C-F, i.e. Franklin River — 1037 with Merrit population (1028) there appears a difference in the frequency of occurrence of two isoenzymes: LAP-A6 in $P=99\%$ confidence and LAP-B3 in $P=95\%$ with LAP-B3 being anyway the least frequently occuring allele among the Douglas-fir populations under investigation.

The significantly greatest variation in the frequency of occurrence of LAP isoenzymes has been ascertained for LAP-A4 and LAP-A6. As regards these isoenzymes, significant differences appear in a comparison of 11 pairs of populations out of 15 possible comparisons, with 9 of them being on the level $\alpha=0.01$. It is also essential that these are the isoenzymes that, more or less frequently, yet in all the investigated gametophyte populations, we could ascertain their occurrence. The lowest differentiating value has been ascertained for the isoenzymes LAP-A1, LAP-2A and LAP-A8. Each of the alleles mentioned yielded significant differences only for four pairs of populations comparisons (Table 24).

DISCUSSION OF LAP ISOENZYMES ANALYSIS

Passing from field work based on quantitative characters over to laboratory work on biochemical characters in Douglas-fir became necessary when closer research on this species has revealed its great variation. The criteria based on the morphology of crowns, cones and needles have turned out to be unreliable. The populations of a character intermediate between the „green" type Dougles-fir from the Pacific coast and the „blue" type from the Rocky Mountains (Tusko 1963), turned out to be great in number.

Although many botanists and foresters tried to establish a clear-cut system of taxonomic and spatial division among the varieties of the species, they have been unsucessful so far. Even if one is to rule out from consideration the „grey" (*caesia*) variety, one cannot attain an uncontroversial separation between the Douglas-fir from the interior („blue variety") and that from the Pacific coast („green" variety), (Ching and Hermann 1973). This variability of Douglas-fir is not however of a continuous character. One can often observe differences on a very high level of significance between populations even not so much apart (Białobok and Mejnartowicz 1970, Mejnartowicz 1973, Muhs 1974). Such populations differ in fact from one another not only in morphological characters, but also in the amount of DNA contained in seed cells, the nuclear volume, the frequency and character of the protein of peroxidasis band (El-Lakany and Sziklai 1971, Muhs 1973). The work done within this scope points to the existence of a north-south cline and to the existence of differences between the relative amount of DNA per cell contained in the seeds of coastal provenances and the amount of DNA for interior provenances (El-Lakany and Sziklai 1973). That overlaps in some measure with the results obtained in this effort. Greatest differences in frequency of occurrence of leucine aminopeptidase alleles has been established between the seed gametophytes from the Pacific--coast samples, populations Matlock — 1074 and Franklin River — 1037 and the populations from the Rocky Mountains (Republic — 1048). We have not established on the other hand, that any trend towards a north-south cline would manifest itself. It is possible that the comparison of

6 populations could not have yielded such an effect on account of too scarce material. The differences between the eastern populations from the Cascade Mountains and those from the Rocky Mountains have been examined also by means of an analysis of oleoresins contained in needles. Rudloff (1972) has also uncovered differences in terpene patterns finding appreciable amounts of geranyl acetate in the needles of trees from the Pacific provenances in comparison with the interior provenances.

In an unpublished study by Yang, Ching and Ching (after Ching and Hermann 1973) on esterases in Douglas-fir seedlings have ascertained the occurrence of 15 phenotypes formed by five esterase enzymes which manifested great variation among the progeny of one parental tree, and also among trees of one provenence and between provenances.

The authors accept as possible the existence of ecotypic variations in esterases in the southernmost and northernmost provenances. The application biochemical characters for the needs of an analysis of Douglas-fir genetic variation has then created new possibilities for research based on characters directly associated with gene action products, and consequently, ones allowing us in many cases to rule out environmental variation. Very great populational differences in the frequency of occurrence of various forms of leucine aminopeptidase overlap with high interpopulational variation in this species with relation to morphological traits. Probably on the strengh of isoenzyme analysis it will be possible also to determine the value of populations with respect to some breeding characters. That points to decisive separation of population 1048 — Republic both in biometric investigations and in LAP isoenzyme analysis. Yet it is necessary to undertake further research on other isoenzymes systems and their possible interactions. To date, only interactions between individual esterases have been found in trees (Bergmann 1974). No one has been successful in finding correlations between various isoenzyme systems and between isoenzymes and morphological traits as well.

3. CONCLUSION FROM THE BIOMETRIC AND BIOCHEMICAL ANALYSIS OF VARIATION IN DOUGLAS-FIR POPULATIONS

1. The populations from the British Columbia and Washington interior are marked for low height increment and tree diameter values, as well as for an appreciable frost hardiness.

2. There is a great variation between Douglas-fir populations with respect to the examined characters: tree height, tree, number of first-orderd branches and frost hardiness.

3. The flushing initiation date is not correlated with the tree growth rate.

4. On the testing plot at Kórnik, relatively small differences have been found in the height increment initiation period and great differences termination.

5. A very great variation within populations is to be observed with respect to summer (Lammas) increment.

6. The well-established of some populations are a rapid height and diameter increment.

7. There is usually a negative correlation between the height of trees and their frost hardiness.

8. In some populations, e.g., 1048 — Republic, there is to be observed a very poor tree growth on all European experimental plots.

9. It has been found by means of isoenzymes that there is a considerable genetic polymorphism in leucine aminopeptidase (3.4.2.1.) in Douglas-fir populations, far greater than in the populations of Scots pine, spruce, larch and black pine.

10. Leûcine aminopeptidase is encoded in 2 loci: LAP-A and LAP-B.

11. So far the occurrence of 9 alleles in the LAP-A locus and 3 alleles in the LAP-B locus has been ascertained. In both loci do appear recessive alleles.

12. The genetic variation of Douglas-fir populations calculated by Barr's D^2 test points to a particular uniqueness of the 1048 — Republic population, which allows a real search for a correlation between the biometric characters and isoenzymes because this population is marked also for negative growth characters.

13. The highest frequency of occurrence of recessive alleles has been found in the 1048 — Republic population with worst growth parameters.

14. Clinal variation was demonstrated along latitudinal gradients for the following characters: mortality of trees, resistance to low temperatures, proportion of trees without Lamma's growth. These characters correlated positively with the latitude.

15. A negative correlation with the latitude was demontrated for the following characters: extent of spring growth, length of the longest 1st order branch, annual and spring growth increment, Lamma's growth, height of the trees, onset of lateral bud activity, number of 1st order branches.

16. Clinal variation was also observed along longitudinal gradients for the following characters: number of 1st order branches, spring, Lamma's and annual growth increments, dimentions of the largest 1st order branch, height of the trees, onset of activity by apical and lateral shoots, mean duration of apical growth. These characters correlate positively with longitude.

17. Clinal variation with a negative correlation with longitude was observed for frost resistance of the trees.

18. A positive correlation with the elevation of the site of origin of the provenance was observed for the characters viability and frost resistance.

SUMMARY

On a provenance area at Kórnik near Poznań the following characters were investigated in 100 Douglas-fir populations from the IUFRO 1966/ /67 series: height and increment rate, tree diameter, number of lst order branches, dimensions of largest branch, phenology and frost hardiness of trees as well as differentiation of some populations with respect to the frequency of occurrence of the LAP isoenzyme. Very significant interpopulational differences have been found for the majority of characters and economic usefulness of only a small number of populations. The following populations are regarded as best in respect of economy under conditions prevalent in Wielkopolska: 1047-Concrete and 1053-Darrington from the north-western part of Washington State.

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Badania gentyczne populacji daglezji zielonej (Pseudotsuga menziesii (Mirb.) Franco)

Streszczenie

Badania wykonano na diploidalnym materiale, jakim były drzewa daglezji od 1 do 7 roku życia pochodzące ze stu populacji z Północnej Ameryki oraz na materiale haploidalnym w postaci endospermu z nasion z 6 populacji tych samych drzewostanów matecznych, które uwzględniono w badaniach polowych. Z uzyskanego materiału w postaci 10 000 siewek daglezji zielonej w pierwszym roku życia założono powierzchnię doświadczalną w Kórniku, na której mierzono wysokość, średnicę, liczbę odgałęzień, rozmiary korony, a także szereg innych cech drzew, jak stopień zmrożenia pędów, podatność korzeni na uszkodzenia przez pędraki, początek i koniec

rozpoczynania sezonu wegetacyjnego. W 18 populacjach badano dynamikę przyrostu wysokości wykonując pomiary w odstępach 7-dniowych.

Analizując częstość występowania izoenzymów LAP w endospermie nasion stwierdzono występowanie 12 alleli tego enzymu w 2 locusach, LAP-A i LAP-B. Istotność różnic międzypopulacyjnych pod względem częstości występowania poszczególnych alleli LAP wynosi 99% ufności.

Za najbardziej przydatne dla leśnictwa w rejonie Wielkopolski uznano populacje 1047 Concrete i 1053 Darrington leżące w północno-zachodniej części stanu Waszyngton.

ЛЕОН МЕЙНАРТОВИЧ

Генетические исследования популяций лжетсуги тиссолистной (Pseudotsuga menziesii (Mirb.) Franco)

Резюме

Исследования проводились на диплоидальном материале, представленном деревями в возрасте от 1 до 7 лет и происходящими из ста популяций Северной Америки, а также на гаплоидном материале в виде эндоспермы семян из 6 популяций тех самых материнских древостоев, которые принимались во внимание в полевых исследованиях.

Из полученного материала в виде 10.000 тысяч саженцев лжетсуги тиссолистной в первом году жизни была заложена экспериментальная площадь в Курнике, на которой измерялись высота, диаметры, число ответвлений, величина кроны, а также ряд других признаков деревьев, таких как степень сомкнутости побегов, податливость к поражениям корней личинками, начало и конец начала вегетационного сезона. В 18 популяциях исследовалась динамика прироста высоты путем обмеров, проводимых с интервалами в 7 дней.

Анализируя частоту появления изоэнзимов ЛАП в эндосперме семян, автор обнаружил выступление 12 аллелей этого энзима в 2 локусах ЛАП-А и ЛАП-Б.

Наиболее пригодными для лесного хозяйства Великопольского района признаны популяции 1047 Concrete и 1053-Darrington, находящиеся в северо-западной части штата Вашингтон.