On the basis of the nature of the response observed here, the breeding of highly compatible rootstock families through the selection and crossing of highly compatible parents, as employed for Douglas fir (Copes, 1981), would not be a suitable approach to overcoming the early incompatibility problem in poop pine. The evidence for hoop pine suggests that crossing among the highly compatible scion clones generally would give rise to progeny which, as rootstocks, would be highly incompatible with the incompatible scion clones. Approaches which could be considered are:

- the segregation of compatible and early incompatible clones, and the use of appropriate rootstocks for each. For the compatible clones, a broad mixture of compatible x compatible progenies would be a situable and very convencient choice. For the early incompatible clones, rootstocks should comprise families or clones resulting from incompatible x incompatible matings.
- the identification and production of the broadly compatible rootstock families and clones which apparently exist. This approach, circumventing the need for the segregation of clones, would be preferable and is worthy of further investigation.

The extent to which a delayed incompatibility factor is common to I105 and HG (the delayed incompatible clone not represented in these experiments) would be of considerable interest. Only a modest improvement in the compatibility of I105 has been achieved by grafting onto progeny arising from crossing I105 whith a compatible clone. In the light of the pattern observed for early incompatible clones, the use of rootstock progeny resulting from the crossing of I105 and HG, or the selfing of these clones, warrants investigation.

Progeny arising from the crossing of I105 and compatible clones have produced only a minor proportion of genotypes carrying the postulated incompatibility factor as rootstocks. It might be speculated therefore that second generation selections made among HG progenies would include a similarly modest proportion of genotypes with the incompatibility factor as scions. On this basis, these selections should not be excluded from the breeding or propagation programs without prior testing of their compatibility status.

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Response of Norway spruce (Picea abies [L.] Karst.) Annual Increments to Drought for Various Provenances and Locations

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Summary

Annual diameter increments were measured for the years 1976 to 1985, which include the drought years 1982 to 1984, on 17 Norway spruce (*Picea abies* [L.] Karst.) provenances growing at four locations of a trial established in 1969.

Spruce responds to drought with reduced diameter growth. Variation in annual increment at individual locations is explicable by the weather conditions in the given year and place. The lowest increments were observed in the second year of drought and not in the year of lowest precipitation, which would indicate the importance of ground water. Differences between blocks and significant interactions between blocks and other parameters indicate that microsite variation is important in determining diameter growth response to drought.

Spruce populations, regardless of origin, react to drought similarly (weak genotype x environment interaction) thus one should not expect any benefits of selection for drought resistance in spruce. Variation in the interaction pattern of some provenances with different weather conditions was observed. Rare severe droughts of long duration may be responsible for the absence of natural stands of Norway spruce in northwestern Poland.

Key words: genotype x environment interaction, climadiagrams, *Picea abies*, provenances, annual increments.

Introduction

Relationship between weather conditions and annual diameter growth is complicated, however most authors believe that drought limits increment (Dmitreva, 1959; Tarasov, 1968; Borowski, 1974; Fritts, 1976; Tessier, 1982; Urbanski, 1987). There are few articles trying to explain genetic relations between increment and drought.

Norway spruce (*Picea abies* [L.] Karst.) is one of the most drought sensitive species (Koch, 1958; Bernhart, 1963; Feliksik, 1972; Krasnobaeva, 1972). It is of interest to establish, whether it is possible to find relatively drought resistant populations among Polish races of spruce. Obminski (1977) in a literature review on the influence of drought on growth of spruce stated, that the problem of provenance diversity in resistance to drought is still open. Schmidt-Vogt (1980) has shown in his investigations that there is a difference between upland and lowland provenances in drought resistance. In contrast Giertych (1987) observing dying trees and their coning before death, following drought, found lack of any genetic diversity with regard to the investigated traits. However he demonstrated clear influence of microsite on the appearance of these phenomena.

This paper is an attempt to find out, to what degree the relation between drought and annual diameter increment are genetically dependent.

Materials and Methods

Investigations were conducted on a provenance experiment established in 1969 (Giertych, 1970). During spring and summer of 1986 increment cores were collected from four locations of the trial: Kórnik, Gołdap, Międzylesie and Orawa. Seventeen provenances were analysed, which constitute an orthogonal part of the experiment. For each provenance samples were collected with a Pressler borer from three trees selected for more or less uniform diameter close to 15 cm, in each plot of three blocks. In all 612 cores were analysed. Measurements of diameter increments were executed by a "Widthmeter of Tree Rings GP-3" in the Department of Pedology, Institute of Biology, Nicolaus Copernicus University, Toruń.

Calculations were made on values of annual increments in the years 1976 to 1985. Three groups of data were used:
- for the whole period (1976 to 1985)
- for the years of drought (1982 to 1984)
- for the years of supposed optimum (1977 to 1980)

The selection of these time periods was made on the basis of meteorological data obtained from the Kórnik meteorological station.

Statistical analysis

For the fully orthogonal part of the experiment, including seventeen provenances, an analysis of variance was executed. The linear model used was as follows:

$$\chi_{ijkmn} = \mu + P_i + L_j + Y_k + LY_{jk} + PL_{ij} + PY_{ik} + PLY_{ijk} + B_{m(j)} + PB_{im(j)} + YB_{km(j)} + PYB_{ikm(j)} + E_{n(ijkm)}$$

where:

χ_{ijkmn} — observation on nth tree of ith provenance in mth block in kth year on jth locality
μ — experimental mean
P_i — effect of ith provenance
L_j — effect of jth locality
Y_k — effect of kth year

Table 1. — Model for the variance analysis.

Source of variation	Degrees of freedom	Expected Mean Square	F-test
Total	plybx-1		
1. Provenances(P)	(p-1)	$A = \sigma^2_E + yx\sigma^2_{PB} + lybx\sigma^2_P$	A / I
2. Localities(L)	(l-1)	$B = \sigma^2_E + yx\sigma^2_{PB} + pyx\sigma^2_B + ybx\sigma^2_{LP} + pybx\sigma^2_L$	B / (E+H-I)
3. Years(Y)	(y-1)	$C = \sigma^2_E + x\sigma^2_{PYB} + px\sigma^2_{YB} + lbx\sigma^2_{PY} + plbx\sigma^2_Y$	C / (F+J-K)
4. L * Y	(l-1)(y-1)	$D = \sigma^2_E + x\sigma^2_{PYB} + px\sigma^2_{YB} + bx\sigma^2_{PLY} + pbx\sigma^2_{LY}$	D / (G+J-K)
5. P * L	(p-1)(l-1)	$E = \sigma^2_E + yx\sigma^2_{PB} + ybx\sigma^2_{PL}$	E / I
6. P * Y	(p-1)(y-1)	$F = \sigma^2_E + x\sigma^2_{PYB} + lbx\sigma^2_{PY}$	F / K
7. P * L * Y	(p-1)(l-1)(y-1)	$G = \sigma^2_E + x\sigma^2_{PYB} + bx\sigma^2_{PLY}$	G / K
8. Blocks in localities(B)	l(b-1)	$H = \sigma^2_E + yx\sigma^2_{PB} + pyx\sigma^2_B$	H / I
9. P * B	l(p-1)(b-1)	$I = \sigma^2_E + yx\sigma^2_{PB}$	I / L
10. Y * B	l(y-1)(b-1)	$J = \sigma^2_E + x\sigma^2_{PYB} + px\sigma^2_{YB}$	J / K
11. P * Y * B	l(p-1)(y-1)(b-1)	$K = \sigma^2_E + x\sigma^2_{PYB}$	K / L
12. Trees in P*Y*B	plyb(x-1)	$L = \sigma^2_E$	

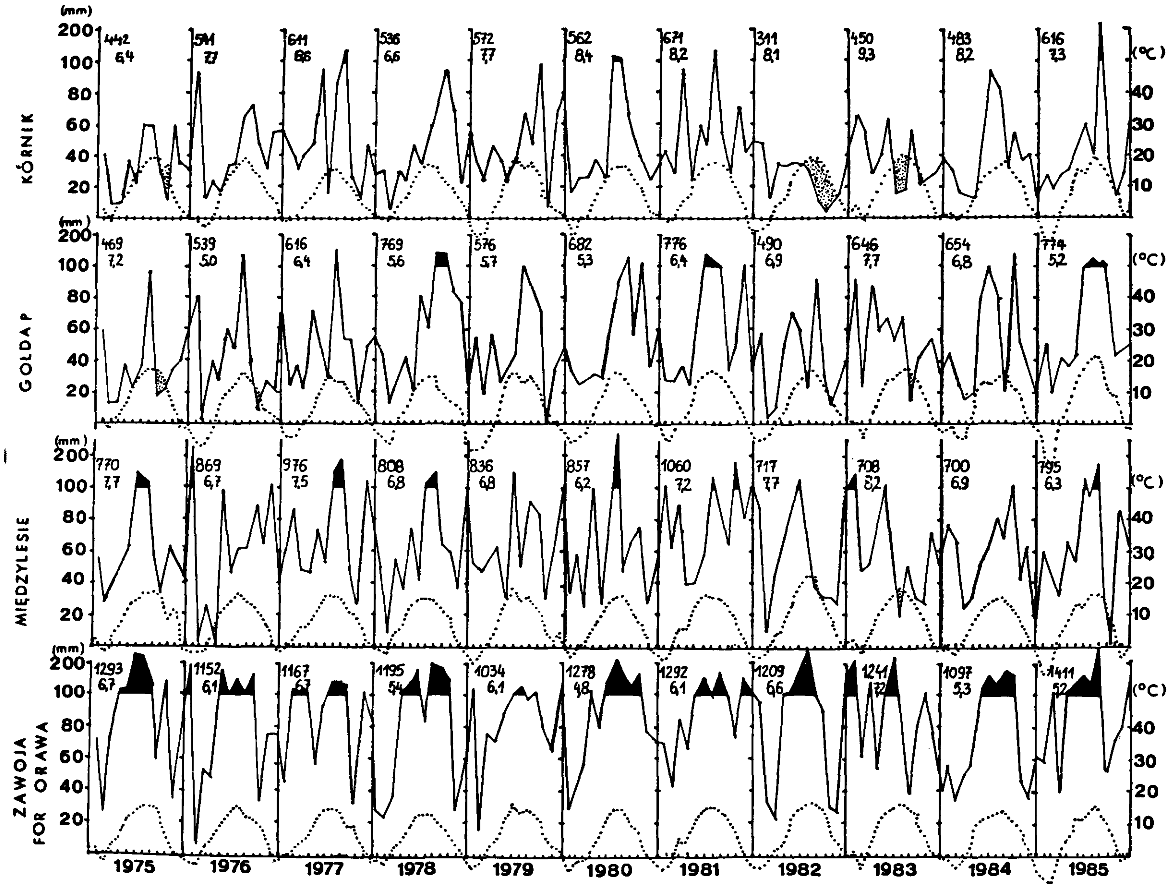

Figure 1. — Climadiagrams for consecutive years 1975 to 1985 for Kórnik, Gołdap, Międzylesie and Zawoja (for Orawa).

LY_{jk} — effect of interaction of j^th^ locality and k^th^ year

PL_{ij} — effect of interaction of i^th^ provenance and j^th^ locality

PY_{ik} — effect of interaction of i^th^ provenance and k^th^ year

PLY_{ijk} — effect of interaction of i^th^ provenance, j^th^ locality and k^th^ year

$B_{m(j)}$ — effect of m^th^ block within j^th^ locality

$PB_{im(j)}$ — effect of interaction of i^th^ provenance and m^th^ block within j^th^ locality (plot effect)

$YB_{km(j)}$ — effect of interaction of k^th^ year and m^th^ block within j^th^ locality

$PYB_{ikm(j)}$ — effect of interaction of i^th^ provenance, k^th^ year and m^th^ block within j^th^ locality (year x plot effect)

$E_{n(ijkm)}$ — random error

The expected mean squares (EMS) were defined by the method presented by HICKS (1973). *Table 1* presents the model of ANOVA. All sources of variation were assumed to be random.

Genotype x environment interaction was analysed according to the method of FINALY and WILKINSON (1963). For each provenance the regression coefficient *b* between performance in each environment and the average performance over all provenances was estimated, which is the measure of provenance stability in different environments. A value of *b* close to 1 indicates average stability, *b* less then 1 stability and *b* greater than 1 interactiveness (instability) of a particular provenance. Additionally *Vd* was calculated (after EBERHART and RUSSEL, 1966), as the variance of deviations from the regression line. In order to obtain a linear model logarithmic transformation of data was employed.

Table 2. — Results of variance analysis for selected time periods. Value of the F-test.

Source of variation	All years 1976-1985	Drought 1982-1984	Optimal 1977-1980
1. Provenance (P)	1.292^{ns}	1.480^{ns}	1.551^{ns}
2. Locality (L)	2.175^{ns}	16.358*	3.031^{ns}
3. Years (Y)	28.900**	42.306**	13.609**
4. L * Y	8.490**	24.143**	10.929**
5. P * L	1.423^{ns}	1.327^{ns}	1.329^{ns}
6. P * Y	0.802^{ns}	0.313^{ns}	0.570^{ns}
7. P * L * Y	0.619^{ns}	0.225^{ns}	0.428^{ns}
8. Blocks in localities (B)	4.067**	3.922**	3.206**
9. P * B	8.288**	7.333**	7.220**
10. Y * B	1.305^{ns}	0.701^{ns}	0.384^{ns}
11. P * Y * B	2.795**	4.887**	4.020**

** — significant at 0.01 level
* — significant at 0.05 level
ns — not significant

Table 3. — Participation of the variance components as percentage of the overall phenotypic variance for the selected time intervals.

Component	All years 1976-1985	Drought 1982-1984	Optimal 1977-1980
1. σ^2_P	0.25	0.73	0.85
2. σ^2_L	0.84	7.98	2.32
3. σ^2_Y	13.23	6.17	3.77
4. σ^2_{LY}	14.10	12.62	10.96
5. σ^2_{PL}	1.43	2.00	2.03
6. σ^2_{PY}	0.00	0.00	0.00
7. σ^2_{PLY}	0.00	0.00	0.00
8. σ^2_B	1.83	3.15	2.40
9. σ^2_{PB}	8.92	15.80	15.94
10. σ^2_{YB}	0.61	0.00	0.00
11. σ^2_{PYB}	21.97	29.09	30.97
12. σ^2_E	36.72	22.46	30.76

Weather conditions

The most important meteorological factors, defining drought are precipitation and temperature. To present weather conditions for all years in each place climadiagrams (Walter and Lieth, 1964) have been drawn. They combine mean monthly temperature and monthly precipitation. Suitable scales of these variables reveal drought periods, which are always dependent on both factors. The drought is marked as the dotted field (*Figure 1*).

To compare annual diameter increments and weather conditions, climadiagrams for the years 1975—1985 and four localities have been made (*Figure 1*). In Kórnik the greatest drought occured in 1982 to 1983 and short drought periods appeared in 1975, 1977 and 1979. In Gołdap a deficit of precipitation was observed in 1975 to 1976 and 1982 to 1984, in Międzylesie a serious drought period was noted only in 1983, and finally there was no drought in Zawoja — the closest meteorological station to the Orawa locality. The lowest annual precipitations were observed in Kórnik (down to 311 mm in 1982), which lies outside the natural range of spruce. In contrast the highest ones were noted in Zawoja, which lies in the mountain region (from 1034 mm in 1979 to 1411 mm in 1985).

The climadiagrams do not show the distribution of precipitation within a month. The authors had no information about the level of ground water, but for trees it could be a more important factor than the amount of precipitation.

Results and Discussion

Genetic variability

Results of variance analysis obtained separately for all years, drought years and optimal years, are presented in *Table 2*. The study demonstrated lack of any significant provenance diversity in drought resistance of spruce. During the drought period trees reduced the annual increment regardless of origin. This is indicated by the insignificant interaction of provenances with years for the whole investigated period and for the drought years (*Table 2*), as well as by the low variance components (*Table 3*). This is the most important result in this study.

Insignificance of provenance differences comes from the mode of tree selection with more or less equal DBH. Provenances do differ in diameter growth (Giertych, 1988)

Table 4. — Interaction of provenances and localities for the whole period estimated by the method of Finlay and Wilkinson (1963) (F+W) and Eberhart and Russel (1966) (E+R).

Provenance	Prov. No.	b(F+W)	Vd*100(E+R)	r
1. Brody	96	1.87	0.12	0.84
2. Kowary	98	2.17	0.19	0.82
3. Istebna	99	1.72	0.08	0.87
4. Wetlina	104	1.38	0.11	0.77
5. Bliżyn	107	-0.11	0.21	-0.07
6. Konstancjewo	109	0.08	0.05	0.10
7. Iława	110	-0.50	0.15	-0.35
8. Nowe Ramuki	111	0.74	0.19	0.44
9. Sadłowo	112	1.44	0.26	0.63
10. Myszyniec	113	-0.15	0.15	-0.11
11. Suwałki	118	1.09	0.17	0.61
12. Augustów	119	1.63	0.12	0.80
13. Białowieża	120	0.96	0.17	0.56
14. Zwierzyniec	121	0.66	0.07	0.60
15. Międzyrzec	122	1.70	0.01	0.99
16. Stronie Śląskie	125	1.39	0.21	0.66
17. Dolina Chochołowska	133	0.54	0.12	0.41

r — correlation coefficient indicating the quality of linearity following logarithmic transformation.

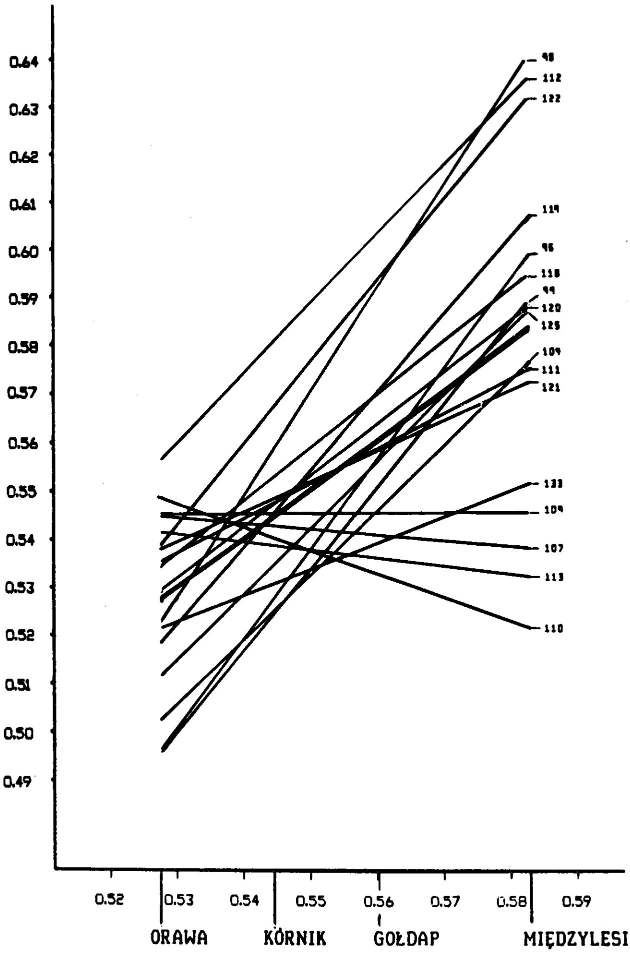

Figure 2. — Interaction of provenances and localities estimated by the method of Finlay and Wilkinson (1963).

GROUP NUMBER	TYPE OF REACTION IN PARTICULAR PERIOD		CHARACTERISTIC PROVENANCE	OTHER PROVENANCES
	DROUGHT (1982-1984)	OPTIMUM (1977-1980)		
1	stable	unstable	99	120, 125
2	unstable	stable	109	119
3	unstable	unstable	111	121
4	stable	stable	113	107
5	intermediate	intermediate	122	110
6	unstable	intermediate	104	98, 96
7	intermediate	stable	112	133, 118

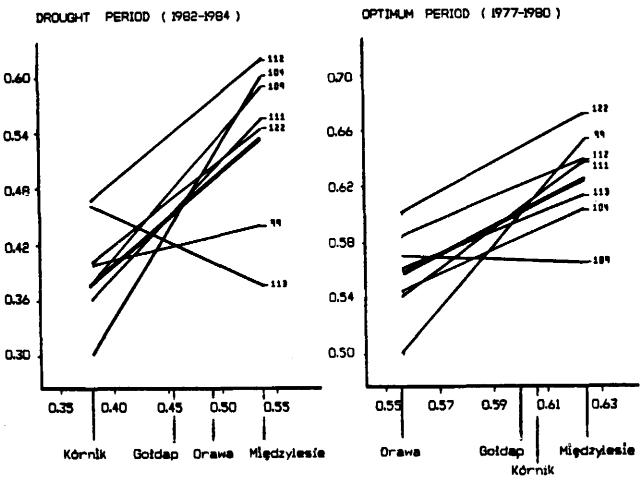

Figure 3. — Comparison of relative stability of particular provenances in drought and optimal periods.

but the sampling method suppressed these differences.

Low σ^2_{PY} for drought years (*Table 3*) substantiate the opinion that search for drought resistant populations is futile, all the more since the provenances used in the experiment originate from different parts of Poland and represent as wide a variance range of native spruce, as possible.

The presented results confirm in situ observations (GIERTYCH, 1987), that no significant differences between provenances in response to drought are observable. In contrast SCHMIDT-VOGT (1980) demonstrated drought resistance differences between upland and lowland provenances of spruce, the latter being more resistant. But this author used a different method dependent on the measurement of transpiration regulation capacity. In view of the difference in methodology and lack of comparison of those results with resistance in the field, contrast with the present data may be only apparent.

Genetic diversity of populations was not found in this study, however interaction of provenances with localities was close to significance and it could be interesting to study their interactivities.

The FINALY-WILKINSON coefficient *b* estimated for all years varied widely from —0.50 for provenance No. 110 to 2.17 for provenance No. 98 (*Table 4, Figure 2*). A group of provenances was destinguished for which *b* is very small — stable provenances (107, 109, 110, 113, 133). A common characteristic of these populations is their origin, close to the limit of the range : north west (107, 109, 110) or close to the upper tree limit in Tatra mountains (133).

It is interesting to compare interactions of individual provenances during the drought and optimal periods (*Figure 3*). According to changes in the type of reaction (stable, unstable or intermediate) the provenances were divided into seven groups and one provenance was chosen in a group as characteristic. The reaction of groups 3, 4, 5 was constant in both periods. But groups 1 and 2 exhibit strong change of reaction type from stable to unstable in the first group and from unstable to stable in the second group. Changes in groups 6 and 7 exist also, but are weaker. This result shows that the genotype x environment interaction of idividual provenances can vary in different weather conditions.

Climatic variability

Spruce is a relatively sensitive plant to weather changes and microsite differences (KOCH, 1958), which may be connected with its flat root system. Differences in mean annual increments between localities were significant only for the drought period. The trees growing in Kórnik suffered most. That area lies outside the natural range of the species and in the years 1983 to 1985 there were numerous loses of spruce trees growing there (GIERTYCH, 1987). Hence the conclusion that extreme environmental

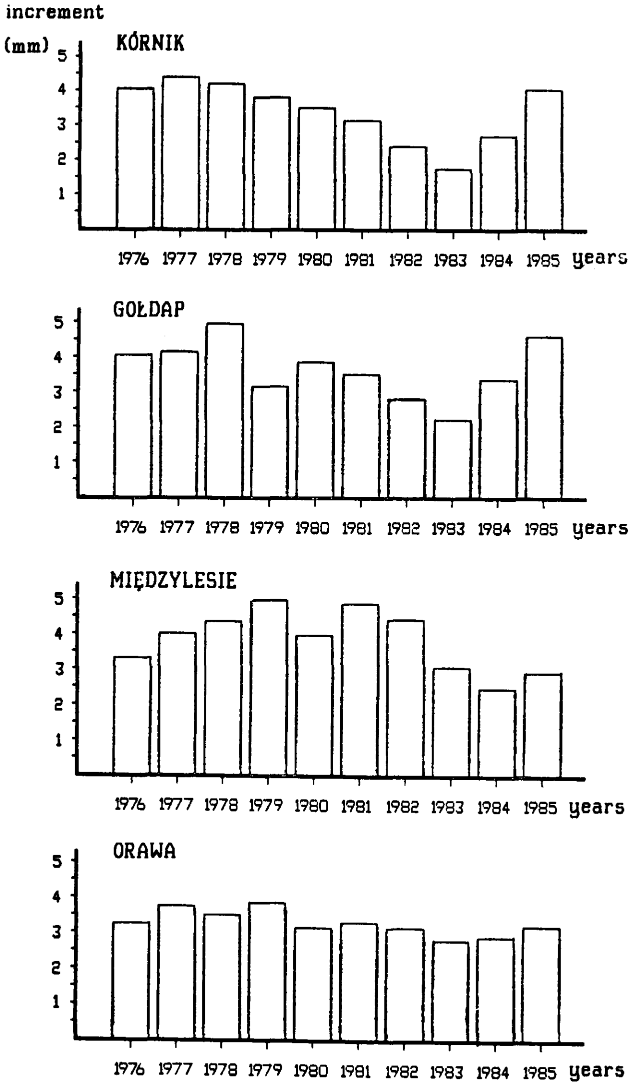

Figure 4. — Tree diameter increments in consecutive years on the four experimental areas.

conditions (like in the years 1982 to 1984) determine the range of spruce and not the average ones.

Significant differences are observable when comparing annual increments in individual years (*Table 2, Figure 4*). Overall the best increment occured in 1978 and the lowest in 1983.

Interesting interactions were obtained between localities and years, (*Table 2*). To explain differences among annual increments in the succesive years on different localities (*Figure 4*), it is necessary to refer to the meteorological data describing weather conditions in given years and places (*Figure 1*).

Many authors report a relation between annual diameter increment of spruce and precipitation (Koch, 1958; Bernhart, 1963; Tarasov, 1968; Feliksik, 1972; Krasnobaeva, 1972; Vazhov and Yaroslavcev, 1973). However these dependencies are very complicated (Dmitreva, 1959; Borowski, 1974; Fritts, 1976). There is an obvious connection between the reduction of increment in the years 1982 to 1984 and drought in this period in Kórnik. Despite close to normal precipitation in 1984 the water deficit in the environment and the stress to plants continued, resulting in a low increment in 1984. Similar relations though not so distinct exist for Gołdap. In the mountains, in Międzylesie drought appeared only in 1983 but it was less severe. A relatively large increment occured in 1983 and the inhibitive effect came one year later, when precipitation was lowest but due to low temperature there was no drought. Another situation is observed in Orawa. There was no drought at all and annual increment was less variable from year to year compared to other localities. The greatest increments were observed in the years of less than average precipitation — 1977, 1979. In contrast to Kórnik, in Orawa the limiting factor influencing the increment may perhaps be excess of precipitation, which could be observed on wetland sites (Fritts, 1976).

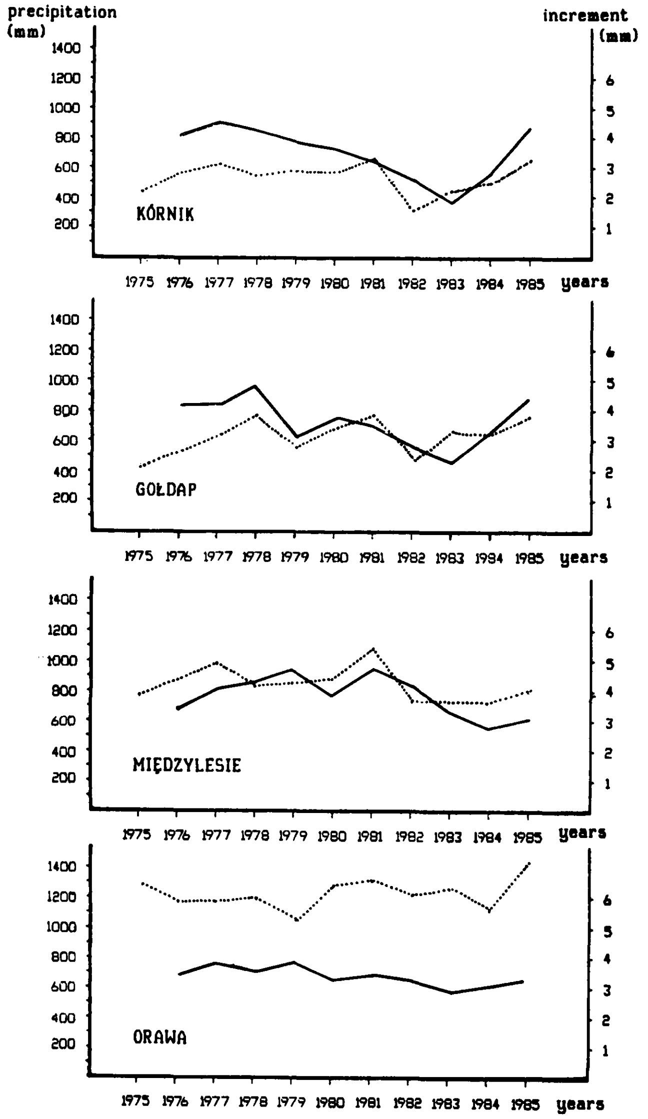

Figure 5. — Comparison of annual precipitation (. . . . . .) with the mean diameter increment (————) in various years for the four experimental areas.

Microsite variability

High values of variance components for blocks and interactions with blocks (*Table 3*), as well as the significance of these parameters, (*Table 2*) demonstrate the dependence of the discussed traits on microsite.

Dmitreva (1959), on the basis of an analysis of the influence of weather conditions on annual increment in Scots pine, found different responses on different sites. Similar results for spruce were obtained by Tarasov (1968). Information about microsite diversity, where soil factors could play a role, are lacking (Tessier, 1982).

Having a flat root system spruce needs a high level of ground water or a sufficient amount of precipitation, appropriately distributed in the vegetative season. In this investigation the lowest increments appeared not in the years of most severe drought but in the following one, if the water deficit continued (*Figure 5*, compare *Figure 1* and *Figure 4*). Probably trees rely on old water reserves in the soil during the first year of drought and when that is depleted they suffer. However studies on the influence of ground water table on annual diameter increment of trees are lacking.

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Preliminary Genetic Parameter Estimates for Some Wood Quality Traits of Pinus caribaea var. hondurensis in Queensland, Australia

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Summary

Diametral increment cores were sampled from 27 open pollinated families to study juvenile wood characteristics in an 11 year old progeny trial of *Pinus caribaea* var. *hondurensis* planted at two locations. Heritabilities and phenotypic and genetic correlations were estimated for radial and height growth, stem straightness, and wood quality traits. Estimates of individual tree narrow-sense heritability for latewood percentage, compression wood percentage and basic density were consistent with those reported previously for *Pinus caribaea* and the southern pines, with values of 0.55, 0.02 and 0.62 respectively.

Spiral grain angles at growth rings 3, 5, 7 and 9 were measured using positive and negative signs to indicate direction of spiral for right hand and left hand spirals respectively. Heritabilities and phenotypic and genetic correlations were estimated both using and ignoring sign. Heritability estimates increased from 0.12 for ring 3 to 0.46 for ring 9 while those for radial standard deviation and mean absolute spiral grain were 0.24 and 0.28 respectively.

Heritability estimates for growth and straightness were consistent with those reported previously. Genetic correlations were relatively imprecise, but suggest an adverse correlation of radial growth with percent latewood and basic density. The results of subsequent studies are needed to clarify the relationship between growth and juvenile wood quality of *Pinus caribaea* var. *hondurensis* in Queensland and to extend this work to mature wood as material from older trials becomes available.

Key words: *Pinus caribaea* var. *hondurensis*, genetic parameters, wood quality.

Introduction

Pinus caribaea MORELET var. *hondurensis* BARRETT and GOLFARI is the exotic plantation species of major importance in Queensland, Australia. The Queensland Forest Service (QFS) has established some 48 000 ha to date (Queensland Department of Forestry, 1989), to supply saw timber and pulpwood. Genetic improvement of the species, undertaken since the early 1960s, has emphasized growth, stem and crown quality, and windfirmness (NIKLES, 1973; WOOLASTON *et al.*, 1990). Candidate plus trees are screened for wood density, spiral grain, latewood percentage, fibre length, compression wood percentage, micellar angle and mean ring width. About 10% have been rejected on the basis of aggregate wood quality score or specifically on the basis of high grain spirality.

Major studies estimating genetic parameters for growth, stem and branch quality, and windfirmness have been reported by DEAN *et al.* (1986) and WOOLASTON *et al.* (1990). Parameters for wood quality traits, other than basic density (KANOWSKI, 1986), have not been reported previously for *P. caribaea* var. *hondurensis* in Queensland although knowledge of these parameters is necessary for efficient breeding. This paper reports preliminary estimates for a sample of the Queensland breeding population of *P. caribaea* var. *hondurensis*. The material used is of the Belize, Mountain Pine Ridge provenance.

Materials and Methods

Experimental design and management

Wood samples were taken from two trials in the Experiment 467 series of the QFS, which was replicated on eight sites in coastal Queensland. The families represented in the trials originated from open pollinated seed collected from first generation plus trees selected in Queensland plantations. Details of the two trial locations sampled for this study are presented in *Table 1*. The parameter estimates reported are based on 471 samples taken from twenty seven families (20 trees per family), all of which were represented at Cardwell and twenty of which were represented at Elliott River.

The trials were established in a randomised complete block design. Eight blocks were established at each site. Blocks were comprised of six units; each unit containing one tree of each family as a single tree plot. The tubed seedlings were planted at a spacing of 3.0 m x 3.4 m, and

Table 1. — Details of the experimental sites sampled.

Location	Latitude/ longitude	Elevation a.s.l. (m)	Annual rainfall (mm)	Establishment date (mo/yr)	Sampling date (mo/yr)
Cardwell	18°15'S 145°55'E	20	2122	3/72	11/82
Elliott River	25°01'S 152°19'E	50	1019	3/72	3/83

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