termediate latitude were growing at an intermediate rate *(Table 1)*. However, the performance of the southern Mississippi trees demonstrates major non-latitude related variation *(Fig. 2)*. The southern Mississippi trees were 2.2 feet taller than the southern Louisiana trees at both 5 and 10 years. No satisfactory explanation for this difference in growth rate is evident.

Variation in growth rate among trees within seed collection areas is also quite large. Statistically significant differences in height were noted within six of the nine seed sources at 5 years and five at 10 years *(Table 2)*. In addition, ANOVA of data from all seed sources combined indicated that the amount of individual tree variation in height at 5 and 10 years is significantly greater in some seed collection areas than in others. Altogether, this is evidence of considerably greater within-stand variation in growth rate than was the case in a similarly designed test of sycamore (Wells and Toliver, in press). In the sycamore test, only 1/3 of the seed sources showed significant variation within and the combined analysis with data from all seed sources showed a non-significant within-stand effect.

Other investigators have concluded that individual-tree variation is particularly large in green ash (Ying and Bagley 1976, Texas Forest Service 1978), and Steiner (1983) has reported a zone of particularly fast growth rate extending from west-central Illinois to eastern Nebraska. None have reported the large stand-to-stand nonlatitude related variation in growth rate exemplified here by the south Mississippi and Louisiana seed sources. This effect indicates that selection for fast growth rate would be most efficient if many stands were sampled at random within the chosen geographic area. Little emphasis should be placed on the phenotypes of the individual trees in these stands except perhaps some eugenic standards should be set. Once superior stands have been identified by progeny testing intensive selection for individual trees within these stands would be appropriate. This reasoning is based on only tenth year data, of course, but the nonlatitude related variation is quite strong and shows no signs of weakening between 5 and 10 years *(Fig. 2)*.

The progeny of one tree selected in southwest Mississippi (area 06) were of particular interest. The seed of this tree were much larger than average *(Fig.2)* and the 5-year-old progeny were straight, with light grey bark in contrast to all other progeny which were crooked with darker colored bark *(Fig. 3)*. At 5 years, this variation in straightness appeared to be an opportunity for sizeable genetic gain through selection but at 10 years it was observed that all the other families showed marked improvement in stem form to the point where the progeny of the large-seeded parent were indistinguishable. Natural stem straightening with age is characteristic of green ash (Schlesinger 1972) so it would seem superfluous to select for straightness in 5-year-old trees. The large-seeded parent may have been the variant referred to as pumpkin ash *(F. profunda* [Bush] Bush) as it is known to have large seed but all other characteristics of this particular parent tree seemed typical of green ash. The taxonomic status of pumpkin ash as a matter of controversy as some taxonomists consider the variation observed here to be within the limits of typical green ash (J. R. Watson, personal communication).

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Some Results of Inbreeding Depression in Serbian Spruce (Picea omorika (Panč.) Purk.)

By Th. Geburek

Federal Research Centre of Forestry and Forest Products, Hamburg, Institute of Forest Genetics and Forest Tree Breeding, Sieker Landstrasse 2, D-2070 Grosshansdorf 2 Federal Republic of Germany

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Summary

Results of a 24 year old inbreeding study of Serbian spruce *(Picea omorika)* are reported. Eleven selfs and 10 outcrosses were tested in five field trials located in northern West Germany. Height and d.b.h. were measured at age 4, 6, 9, 12, 15, and age 15, 24, respectively. At age of 15 years the average height of the selfs was 480 cm compared to a height of 660 cm for the outcrosses. The selfs had a diameter of 3.2 cm (age 15) and 6.9 cm (age 24) compared to 4.9 cm (age 15) and 9.9 cm (age 24) for the outcrosses. Variation of the metric traits was greater in selfed than in outbred progenies. In general, inbreeding depression was unexpected high.

Key words: *Picea omorika*, inbreeding depression, field experiment.

Zusammenfassung

Es wird über einige Ergebnisse geselbsteter und fremdbefruchteter 24jähriger Nachkommen bei der Serbischen Fichte *(Picea omorika)* berichtet. Elf Selbstungen und 10 Fremdungen wurden in fünf Feldversuchen in Niedersachsen und Schleswig-Holstein überprüft. Das Höhenwachstum wurde im Alter von 4, 6, 9, 12 und 15 Jahren, der BHD im Alter 15 und 24 aufgenommen. Im Alter 15 erreichten die Selbstungen eine Gesamthöhe von 480 cm, d.h. 72% der Leistung, welche die Fremdungen mit 660 cm erbrachten. Bezüglich des Durchmesserwachstums waren die Selbstungs- und Fremdungsfamilien mit 3,2 cm und 6,9 cm, d.h. mit 69% und 65% nach 15 bzw. 24 Jahren unterlegen. Die Variation der metrischen Merkmale war innerhalb der Selbstungsfamilien größer als innerhalb der Fremdungsfamilien. Die zu beobachtende Inzuchtdepression war unerwartet hoch.

Introduction

Detrimental effects resulting from crossing of related individuals is common in *Pinaceae*. Seed set, germination, survival, etc. of inbred populations is often low compared to outbred ones (Franklin 1970). Inbreeding depression is not limited to certain stages, but can continue to advanced ages as Eriksson *et al.* (1973) have pointed out for Norway spruce *(Picea abies)*. In general mating between close relatives should be avoided when wood production and adaptability are the objectives of an improvement program.

Picea omorika appears to have an exceptional position within the genus *Picea*. This species occupies an extraordinary small natural area in Serbia and is phenotypically vary uniform (Burschel 1965).

Therefore would be interesting to know if the genetic base of the species is diminished. Serbian spruce has proven to be highly self-fertile and self-compatible. Relatively large amounts of filled seed have been obtained and early survival has been high following selfing (Langner 1959, Koski 1973). Langner (1959) suggested self-fertility and the high degree of uniformity found in this species was caused, at least in part, from inbreeding over many generations. To test this hypothesis field trials with progenies from self- and cross-pollinations were established in northern parts of West Germany. If the inbreeding coefficient of this species has increased in the past due to its extremely small populations size, genetic variability within the populations should also be reduced. A high degree of homozygosity in *Picea omorika* should be expressed by reduced phenotypical variation, relatively high survival and growth of selfed compared to the outcrossed progenies. Results of the field experiments, focusing on growth-characters up to an age of 24 years, are presented.

Table 1. — Selfs and outcrosses on various sites.

BENZ*		TRITTAU		NORDHORN II	
Th 36 X Th 36	Th 36 X Th186	Th183 X Th183	Th 186 X Th 186	Th 36 X Th 36	Th 36 X Th186
Th 44 X Th 44	Th 44 X Th186			Th 44 X Th 44	Th 44 X Th 186
Th 75 X Th 75	Th 75 X Th186	MEPPEN		Th 75 X Th 75	Th 75 X Th 186
Th 76 X Th 76	Th 76 X Th 186			Th 76 X Th 76	Th 76 X Th 186
Th183 X Th 183	Th183 X Th186	Th 338 X Th 338	Th 338 X Th 186	Th 183 X Th 183	Th183 X Th 186
Th185l X Th185l	Th185l X Th186			Th185l X Th185l	Th185l X Th 186
Th185r X Th185r	Th185r X Th186	NORDHORN I		Th185r X Th185r	Th185r X Th 186
Th186 X Th 186				Th186 X Th 186	Th 186 X Th 75
Th188 X Th 188	Th188 X Th186	Th 338 X Th 338	Th 338 X Th 186	Th188 X Th 188	
Th338 X Th338	Th338 X Th186			Th338 X Th 338	Th338 X Th186
Th440 X Th440	Th440 X Th186	* SELFS AND OUTCROSSES PLANTED IN MIXTURES		Th440 X Th 440	Th440 X Th186

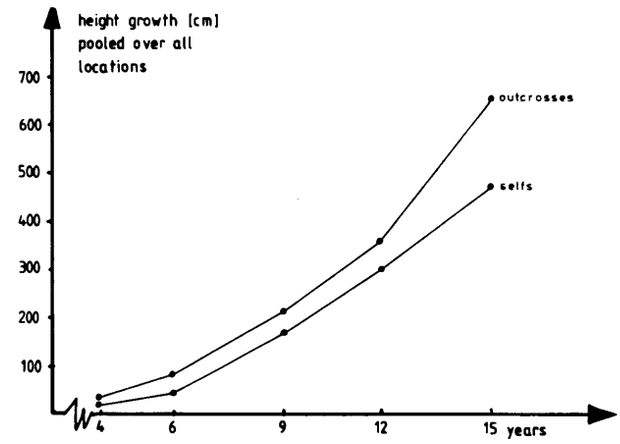

Fig. 1. — Height growth of self and outcrosses pooled over all locations.

Materials and Methods

In 1956, self- and cross-pollination were performed in Grosshansdorf (Langner 1959). Eleven trees were self- pollinated and 10 trees were outcrossed using, with one exception, pollen of tree Th 186. The parent trees were probably derived from indigeneous forest stands in Serbia (Langner 1959). The trials were established in Lower Saxony and Schleswig-Holstein in 1961. The progenies planted in the various field trials are listed in *Table 1*. Further information concerning the locations is published in Geburek and Krusche (1985).

At location NORDHORN II a 5 × 5 simple lattice was employed, whereas a randomized block design was used for the remaining sites (Cochran and Cox 1950). Each trial was established with 6 replications. The square plots contained 16 trees planted at a 1.0 × 1.0 m spacing. Height at ages 4, 6, 9, 12, and 15 years and diameter (d.b.h.) at age 15 and 24 were measured. Mortality was recorded at each of these ages. Height, diameter, and survival of selfs was compared with the corresponding outbreds. Data analysis was performed by ANOVA using weighted means (model with fixed effects). As calculation units the plot-means weighted with their reciprocal variances were used. Linear contrasts were also computed for the trial NORDHORN II following Scheffé (1953). The percentage "p" of survival was transformed by arcsin ($\sqrt{p}$) to stabilize variances and normalize the distribution.

Results

Survival as a criterion for the ability of a genotype to withstand biotic and abiotic stress was on the average not significantly affected by inbreeding. Up to an age of 24 years 86% of the selfs and 92% of the outcrosses survived. In TRITTAU, however only 53% of the selfs (Th183 × Th183) and 79% of the outcrosses (Th183 × Th186) survived (age 24). It is interesting that these selfs also had the lowest survival rate at the seedbed stage (Langner 1959). Nevertheless the correlation coefficient for survival at age 1 and age 24 was only 0.3.

At all locations the outcrossed families were taller than selfs. Average height of selfs (age 15) was 480 cm compared to 660 cm for the outcrosses. The development of the height growth from 4 up to 15 years is shown in *Figure 1*. Progenies from self-pollination were 16% and 28% shorter than outcrossed progenies at age 4 and 15 years, respectively. The extent of inbreeding depression was highly variable *(Figure 2* and *3)*. Thus progenies of selfed Th186

Table 2. — Significance levels concerning height growth and d.b.h. at different ages for the selfs compared to the respective outcrosses. The respective designations of selfed and outcrossed mother trees are shown in column tree No. . (n.s. ≙ no significance, * ≙ $p \leq .05$, ** ≙ $p \leq .01$, *** ≙ $p \leq .001$).

			height					d.b.h	
location:	tree No.		4	6	9	12	15 years	15	24 years
NORDHORN II	Th	36	n.s.	**	**	*	**	*	***
	Th	44	***	***	*	**	***	**	***
	Th	75	***	**	*	**	***	**	***
	Th	76	***	**	**	**	***	***	***
	Th	183	**	***	**	**	**	**	***
TRITTAU	Th	183	n.s.	**	**	***	***	***	***
NORDHORN II	Th	1851	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*
	Th	185r	***	**	*	n.s.	*	*	***
	Th	186	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Th	338	**	**	**	*	**	**	***
MEPPEN	Th	338	*	n.s.	n.s.	*	**	*	**
NORDHORN I	Th	338	***	**	*	*	**	***	***
NORDHORN II	Th	440	**	***	***	***	***	***	***
BENZ	mixtures		n.s.	n.s.	n.s.	**	**	**	*

and Th1851 were almost as tall as the controls at age 15 years. On the other hand selfs of Th440 and Th76 attained only 50% to 60% the height (age 15) of their respective outcrossed progenies. Selfs of Th338, planted at NORDHORN I, NORDHORN II and MEPPEN, were only 70% to 80% of the height of the respective outcrosses at age 4 to age 15. The relative growth-rates of these selfs were not strongly affected by different site conditions. Selfs of Th183 tested at two locations, NORDHORN II and TRITTAU were 80% the height of the outcrosses at age 4 and only about 65% and 50% at age 15 years. *Table 2* presents the significance of differences in height growth at different ages for the selfs compared to the respective outcrosses.

Pooled over all locations, the selfs had a diameter of 3.2 cm at age 15 and a high coefficient of variation (c.v.) of .59. In comparison, the outcrosses had an average d.b.h. of 4.9 cm (c.v. = .39). At age 24 the selfs averaged nearly 7.0 cm (c.v. = .40) and the outcrosses nearly 10.0 cm (c.v. = .26). Significance of differences in d.b.h. growth at the ages of 15 and 24 years are given in *Table 2*.

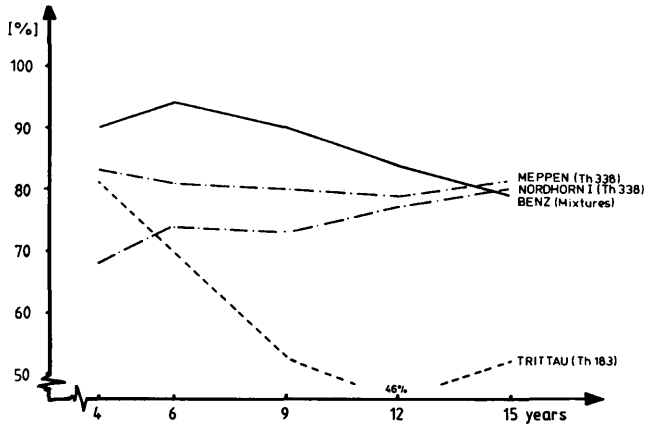

Figure 2. — Height growth of selfs in % of the respective outcrosses on location Meppen, Benz, Trittau, and Nordhorn I. Designations Th . . . and mixtures, respectively refer to the ratio of selfs/outcrosses of tree Th . . . and mixtures of selfs and outcrosses, respectively.

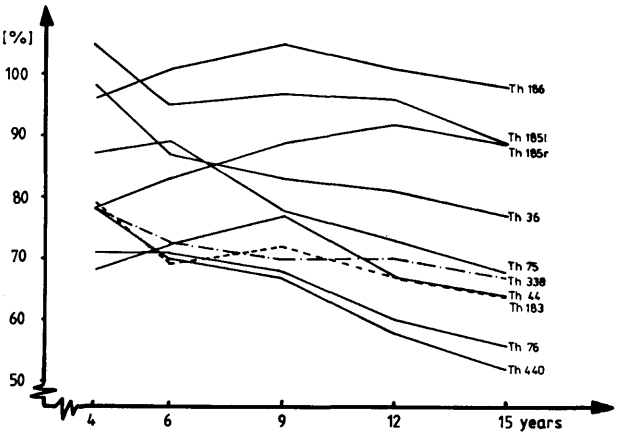

Figure 3 — Height growth of selfs in % of the respective outcross on location Nordhorn II. Designation Th . . . refers to the ratio of selfs/outcross of tree Th . . . .

Discussion

Deleterious effects of inbreeding (usually selfing) have been observed in many species of the family *Pinaceae* (Franklin 1970). The overall similarity of response to self-fertilization among the genera is striking. *Picea omorika* studied in this paper is no exception. The mortality rates were similar to those found by Fowler (1980) and were in the range reported for 27 year old *Picea abies* progenies after self- and cross-pollination (Langlet 1940).

Inbreeding depression in terms of reduced growth were similar to those found in other studies. Fowler (1980) elaborated that selfs of *Picea omorika* grew 74% to 90% the height of the outcrosses up to an age of 11 years. Wilcox (1983) investigated *Pinus radiata* and noted that compared with crosspollinated progenies selfs were about 10% smaller in diameter at an age of 7 years. Field experiments with Coast redwood *(Sequoia sempervirens)* showed a height reduction due to selfing of 42% at an age of 15 years (Libby *et al.* 1981). These authors reported that survival of selfs and outcrosses of *Sequoia sempervirens* was more or less high under good nursery conditions. Under stress conditions, however relatively more of the outcrossed progenies

survived. Differences in relative performance under favourable and stress conditions have been also noted in an other inbreeding study by ALLARD and HANSCHE (1984).

Selfing does not always have deleterious effects in forest tree species. FOWLER (1964) reported that Red pine *(Pinus resinosa)* exhibits little inbreeding depression after self-pollination. Up to age 9 survival of selfs and outcrosses was nearly equal (HOLST and FOWLER 1973). A high degree of inbreeding was probably due to a drastic reduction of the effective population size during the past. FOWLER (1964) suggested that reduction of the population size might have resulted in inbred populations in which there was a diminished genetic load. In this context it should be added that genic variation detectable via isoenzyme-assays are extremely low in this species (FOWLER and MORRIS 1977, ALLENDORF *et al.* 1981).

Increasing levels of growth depression by increasing age could be explained with higher demands to the genetic constitution of the trees by biotic and abiotic environmental stress. High levels of homozygosity should be on the average disadvantageously for the individuals. This is easy to understand considering the genetic diversity in terms of homo- and heterozygosity of forest tree species. HAMRICK (1979) has pointed out that the mean relative heterozygosity for *Pinus* and *Picea* species is in a range of about 20% and 40%. In comparison to other organisms heterozygosity of forest tree species is considered high (MITTON 1983). This could be an adaptative strategy in response to a heterogeneous environment over a long time period. It is understandable that selfs do not perform as well in variable environmental conditions because of reduced heterozygosity. The data further inicate, that advantages of higher heterozygosity become more obviously in advanced ontogenic stages.

It should be pointed out that inbred progenies are usually more variable than outbreds, when an outbreeding system is changed artificially to inbreeding (MATHER and EDWARDES 1943, ORR-EWING 1957). Selfs of *P. omorika* are characterized by high variability in their phenotypes when compared to related outcrosses. These results indicate that in spite of its limited distribution the genetic variability of *P. omorika* is greater than expected, based on results from seedling studies. At any rate the relatively small number of different selfs and outcrosses used in this study must be taken into consideration. With one exception only one father-tree was used for the outcrosses. Isoenzyme assays should provide evidence as to the genetic variability of this species. The available information of electrophoretic data of *P. omorika* indicates, that there is less genetic variation than in *Picea abies*, however variation could be observed in nearly all isoenzyme-systems (BERGMANN, pers. communication).

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Announcement

IUFRO Joint Meeting (S2.04-01 Population and ecological genetics, S2.09-15 Genetic aspects of air pollution).

Genetic Effects of air pollution in forest tree populations

The meeting shall be held in Großhansdorf-Schmalenbeck, Fed. Rep. Germany, at the beginning of August 1987, just after the International Botanical Congress in Berlin. From the first results of investigations on genetic effects of air pollutants there is evidence that air pollutants endanger genetic multiplicity in forest tree species. Concepts and methods of respective research projects as well as results and consequences for forests shall be discussed at this meeting. For more detailed information please contact:

Institute for Forest Genetics and Forest Tree Breeding Sieker Landstraße 2, D-2070 Großhansdorf 2. F. SCHOLZ

Herausgeberin: Bundesforschungsanstalt für Forst- und Holzwirtschaft: Schriftleitung: Institut für Forstgenetik und Forstpflanzenzüchtung, Siekerlandstraße 2, 2070 Großhansdorf 2-Schmalenbeck (Holstein). — Verlag: J. D. Sauerländer's Verlag, 6000 Frankfurt a. M., Finkenhofstraße 21. — Anzeigenverwaltung: J. D. Sauerländer's Verlag, Frankfurt am Main. — Satz und Druck: H. Robert, 6310 Grünberg, Hess. 1. — Printed in Germany.

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