Acknowledgements

We wish to thank Prof. S. BRULLO for providing the samples of *Quercus virgiliana*. We also thank the reviewers for their useful comments.

References

ABBATE, G., BLASI, C., SPADA, F. and SCOPPOLA, A.: Analisi fitogeografica e sintassonomia dei querceti a *Quercus frainetto* TEN. dell'Italia centrale e meridionale. Not. Fitosoc. **24** (1987). — AFZAL-RAFII, Z.: Caractèristiques taxonomiques, morphologiques et isoenzymatiques du complex «Chene vert». Bull. Soc. Bot. France, 135. Lett. Bot. **14**/5: 342–352 (1988). — BATTAGLIA, E.: A new "5 minutes fixation" in chromosome analysis. Caryologia **9**: 368–370 (1957a). — BATTAGLIA, E.: A simplified Feulgen method using cold hydrolysis. Caryologia **9**: 372–373 (1957b). — BELLAROSA, R., DELRE, V., SCHIRONE, B. and MAGGINI, F.: Ribosomal RNA genes in *Quercus* spp. (*Fagaceae*). Pl. Syst. Evol. **172**: 127–139 (1990). — BIANCO, P. and SCHIRONE, B.: On *Quercus coccifera* L. s.I.: variation in reproductive phenology. Taxon **34**: 436–439 (1985). — BRANDHAM, P. E.: Inter-embryo competition in the progeny of autotriploid *Aloineae* (*Liliaceae*). Genetica **59**: 29–42 (1982). — BUTORINA, A. K.: Cytogenetic study of diploid and spontaneous triploid oaks, *Quercus robur* L. Ann. Sci. For. **50**: suppl. 1, 144s–150s (1993). — CLAUSEN, J.: Biosystematic consequences of ecotypic and chromosomal differentiation. Taxon **16**: 271–279 (1967). — D'EMERICO, S., BIANCO, P. and MEDAGLI, P.: Cytological and karyological studies on *Orchidaceae*. Caryologia **46**: 309–319 (1993). — DUFFIELD, W. J.: Chromosome counts in *Quercus*. Amer. J. Bot. **27**: 787–788 (1940). — DUPOUEY, J. L.: Analyse multivariable de quelques caractères morphologiques de populations de chenes (*Quercus robur* L. et *Quercus petraea* (MATT.) LIEBL.) DU HUREPOIX. Ann. Sci. For. **40**: 265–282 (1983). — JONSSON, A. and ERIKSSON, G.: Cytology, flowering frequency and hybridization in the genera *Acer, Fagus, Fraxinus, Prunus, Quercus, Tilia* and *Ulmus*. Dept. Forest Genetics, Swedish Univ., Agric. Sciences, Uppsala. Res. Note **43**, pp. 1–14 (1989). — JOVANOVIC, M. and TUCOVIC, A.: Genetics of common and sessile oaks (*Quercus robur* L. and *petraea* LIEBL.). Annales Forestales **7**: 23–53 (1975). — KISSLING, P.: Clé de détermination des chenes médioeuropéens (*Quercus* L.) Ber. Schweiz. Bot. Ges. **90**: 29–44 (1980). — KNOPS, J. F. and JENSEN, R.: Morphological and phenolic variation in a three species community of red oaks. Bull. Torrey Bot. Club **107**: 418–428 (1980). — LEVAN, A., FREDGA, K. and SANDBERG, A. A.: Nomenclature for centromeric position on chromosomes. Hereditas **52**: 201–220 (1964). — MEDAGLI, P., BIANCO, P., SCHIRONE, B., D'EMERICO, S. and RUGGIERO, L.: Il farnetto di Bosco Belvedere (Lecce). Note preliminari. Ann. Bot. (Roma) **XLVIII**, Supp. **7**: 77–83 (1990). — MEHRA, P. N., HANS, A. S. and SAREEN, T. S.: Cytomorphology of Himalayan Fagaceae. Silvae Genetica **21**: 102–109 (1972). — NATIVIDATE, J. V.: Investigacoes nalgumas especies e hybridos do genero *Quercus*. Bot. Soc. Brot. **12**: 21–85 (1937). — NIXON, KC.: Infrageneric classification of *Quercus* (*Fagaceae*) and typification of sectional names. Ann. Sci. For. **50**: 25–34 (1993). — OHRI, D. and AHUJA, M. R.: Giemsa C.banded karyotype in *Quercus* L. (Oak). Silvae Genetica **39**: 216–219 (1990). — PEDERICK, L. A.: Chromosome relationships between *Pinus* species. Silvae Genetica **19**: 171–180 (1970). — ROMERO ZARCO, C.: A new method for estimating karyotype asymmetry. Taxon **35**: 526–530 (1986). — SANTAMOUR, F. S. JR.: The chromosome number of *Quercus dentata*. Bull. Morris Arboret. **13**: 28–30 (1962). — SAX, H. J.: Chromosome numbers in *Quercus*. Arnold Arbor. **11**: 220–223 (1930). — SAYLOR, L. C.: Karyotype analysis of Genus *Pinus*-Subgenus *Strobus*. Silvae Genetica **32**: 119–124 (1983). — SCHIRONE, B., SCHIRONE, A., LOZUPONE, G., BELLAROSA, R. and GIORDANO, E.: Osservazioni sulle proteine di riserva del seme nel genere *Quercus*. Giorn. Bot. Ital. **125**: 231 (1991). — SCHWARZ, O.: *Quercus* L. In: Flora Europaea I. T. G. TUTIN et al. (eds.). Cambridge University Press, Cambridge. pp. 61–64 (1964). — STEBBINS, G. L.: Chromosomal evolution in higher plants. Edward Arnold Ltd., London (1971). — TUTASUK, V. H. and TURCHANINOVA, L. V.: About the chromosome number of *Quercus castaneifolia* C. A. M. Dokl. Akad. Nauk. Azerbajdzansk S. S. R. **24**: 47–50 (1968). — VIGNOLI, L.: Studio citologico sul genere *Quercus*. Lav. R. Ist. Bot. Palermo **4**: 25–39 (1933).

Altitudinal Adaptation of Norway Spruce (*Picea abies* (L.) Karst.) Progenies Indicates Small Role of Introduced Populations in the Karkonosze Mountains

By J. Modrzyński

Department of Silviculture, Agricultural University in Poznań,
Wojska Polskiego 69, PL-60-625 Poznań, Poland

(Received 2nd July 1993)

Summary

It is believed that many of the Norway spruce stands in Karkonosze Mts. are of foreign origin. To determine what is the real share of such stands, eighteen were ecotypically identified based on the phenology and growth of progeny. The characters, observed or measured in 2 distant nurseries were: bud set index (in the first and second growing season), bud flushing index (second growing season), diameter and height (after the second and fifth growing season) as well as height increment, crown diameter and roots dry matter (after the fifth growing period). It appears that most of the investigated stands fit well into the altitudes at present occupied by them in the Karkonosze Mts. Even the poorest adapted populations show average altitudinal deviations of 125 m to 156 m which fit easily the tolerance zones accepted for the seed transfer. It is strongly recomended that spruce stands in Karkonosze Mts. be regenerated in a natural way and that local seed resources be used for artificial regeneration.

Key words: Picea abies, ecotype identification, progeny characters, ecological adaptation, regeneration, West Sudety Mts.

FDC: 165.5; 181.2; 232.1; 174.7 *Picea abies*; (234.5); (438).

Introduction

There exists a belief, corresponding with the opinion of RUBNER (1936), that in Karkonosze Mts. ("Riesengebirge" in German) Norway spruce stands located above 1000 m elevation (upper mountain zone) are native and those located below (lower mountain zone) are of foreign origin. MATUSZKIEWICZ, W. and MATUSZKIEWICZ, A. (1967) as well as SOKOŁOWSKI (1968) write, however, that some spruce stands in the lower zone of these mountains are of natural, local origin. On the other hand ZOLL (1958) as well as PEŘINA and SAMEK (1958) suggest that numerous spruce stands in the upper zone of the Karkonosze Mts. have been established artificially, whith the use of imported seeds.

The suspicion that Norway spruce stands in Karkonosze Mts. consist, at least partially, of introduced origins seems justified, for in this region artificial regeneration relying on imported seed and plant material of unknown origin was fairly common, especially in the period 1840 to 1925 (BOUVAREL, 1974; FANTA, 1974; SCHMIDT-VOGT, 1975; LÜDEMANN, 1978). Until the foreign, unadapted ecotypes are recognized, the indigenousness (or adaptedness) of all stands may be questioned, with serious consequences for silviculture in this area. The author was confronted with the problem of Norway spruce ecotypes when studying natural regeneration of this species in the Karkonosze National Park, where the utilization of spruce self-sowing was officially forbidden, despite its vitality (MODRZYŃSKI, 1978, 1979).

The purpose of this study was: 1. To identify the ecotype of 18 Norway spruce stands, to determine what proportion of stands in the Karkonosze Mts. are poorly adapted, and 2. To formulate some silvicultural recomendations for this region.

Material and Methods

For the study 20 Norway spruce stands were chosen on the map, if they met the conditions that they were over 80 years old and well distributed throughout the entire investigated area (15°28'E to 15°51'E and 50°45'N to 50°50'N). Two of these stands where later eliminated, because of insufficient cone bearing. From the remaining 18 mother stands (*Table 1*) cones were collected in the autumn of 1976.

The altitude of the center of the collection plot in the stand was measured by means of an aneroid altimeter.

Seeds from the mother populations were sown (in the spring of 1977) in 2 nurseries: Morawina and Rakownia. Morawina (nursery 1) is located at 51°15'N, 18°05'E and 180 m altitude; average annual temperature (during the 5 years of the experiment): 7,7 °C and precipitation: 628 mm. Rakownia (nursery 2) is located at 52°35'N, 17°05'E and 110 m altitude; average annual temperature: 7,9 °C and precipitation: 535 mm. Both climatic and nutritional conditions were for the young spruce trees more favorable in nursery 1 (Morawina).

The seed was sown in drills 20 cm apart. Two year old seedlings were transplanted at a spacing of 30 cm x 40 cm. Both sowing and transplanting was in the same plot design, a latin rectangle with three replicates.

During the first and second growing season observations were made on terminal bud setting, and at the beginning of the second growing season – on terminal bud flushing, following in general the method proposed by HOLZER (1975). Bud set observations were made at 10 day intervals, from mid-July to the beginning of October. The number of seedlings with brown bud scales was related to the total number of seedlings in the plot. Percentages from the observations in all 3 plots (replicates of the same population) were added and the sum was divided by the number of plots and the number of observations in the annual cycle. This became the bud set index, characterizing each specific population in the given nursery. The bud flushing index was calculated in a similar way. On the average 204 seedlings were observed per plot.

After the second growing period, root collar diameter and height of 50 randomly selected seedlings were measured in each plot. After the fifth growing season the root collar diameter, total height, current height-increment and crown diameter of 24 trees were measured in each plot. Additionally dry weight of root system of 10 trees per population and nursery was recorded.

Natural regeneration occuring wild in the stands was estimated by a method described earlier (MODRZYŃSKI, 1989).

Statistical parameters were estimated using the JMP program, version 2.0.5. (SAS Institute Inc., Cary, NC, USA). Also a graphical method of estimating altitudinal deviations for the investigated populations was applied. It is based on the assumption that mother stands 5 and 7 (lower zone) as well as 14 and 16 (upper zone) are indigenous because of their age (*Table 1*) which guarantees that they have been estabilished before the year 1830 (i. e. before artificial regeneration started).

Table 1. – Some data on the location and age of the mother populations.

Population	Compt.* number	Altitude (m)	Exposition and slope		Mean age (years)
1	122 g	670	N	8°	124
2	112 c	705	NE	10°	107
3	43 b	720	NNW	20°	104
4	130 d	847	NNW	15°	133
5	46 d	855	N	10°	159
6	141 f	890	NNE	15°	110
7	45 k	895	NE	5°	150
8	180 i	955	NE	18°	108
9	188 b	970	N	15°	102
10	49 a	980	NNE	10°	132
11	26 d	1038	N	28°	131
12	195 d	1082	NNE	10°	83
13	148 j	1085	N	22°	92
14	67 f	1136	N	10°	178
15	157 c	1169	N	15°	135
16	10 a	1190	N	32°	149
17	201 g	1195	NNE	8°	143
18	19 f	1235	NNE	30°	132

*) Compartment number in the Karkonosze National Park

Results

The bud setting index at both nurseries and in both observation years followed a very similar pattern (*Fig. 1*). Statistical parameters for all combinations of location and growing period indicate a highly significant relationship between this character of the progeny and the altitude of mother stands.

The relationship between bud flushing index of the progeny and the altitude of mother populations (*Fig. 1*) was significant in both nurseries.

Height and diameter of progeny populations, both after second (*Fig. 2*) and fifth (Fig. 3) growing period show a significant regression on altitude of mother populations. The differentiation of progeny populations however was greater in the 5-year old material and there were some changes in ranking compared with the 2-year old trees.

There was a higly significant relationship between height increment and crown diameter of the 5-year old spruce-trees and the altitude of their mother populations (*Fig. 3*).

When estimating altitudinal deviations, data from both nurseries and different observation years were combined, since no interactions between populations, nurseries and years were observed for bud set index or between populations and nurseries for growth traits and bud flushing index.

The graphically estimated deviations usually show quite random values for the same population in different characters (*Table 2*). The deviations averaged over all studied characters

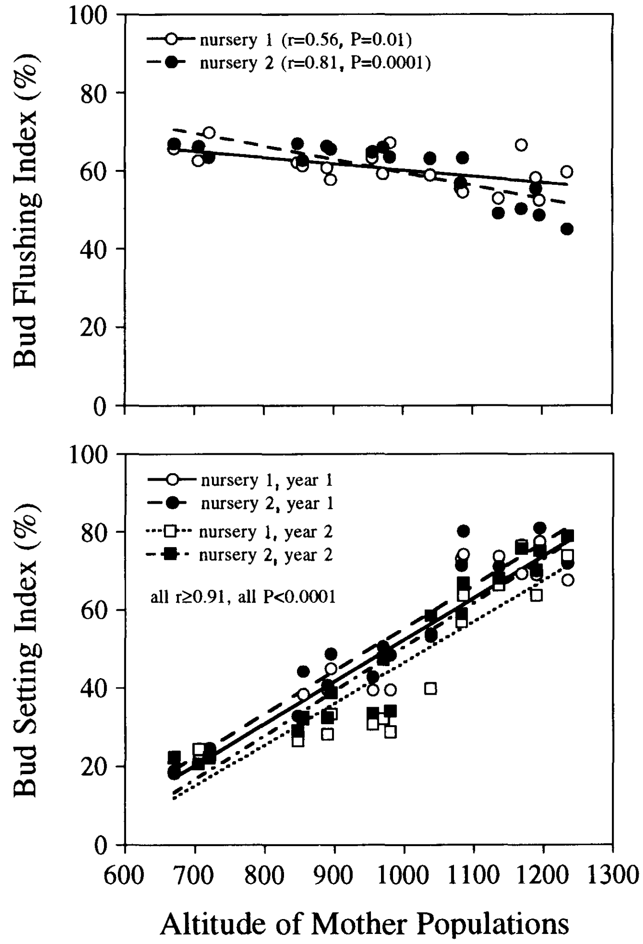

Figure 1. – Relationship between bud setting index (first and second growing season) as well as bud flushing index (second growing season) of progeny grown in 2 different nurseries and the altitude of mother populations.

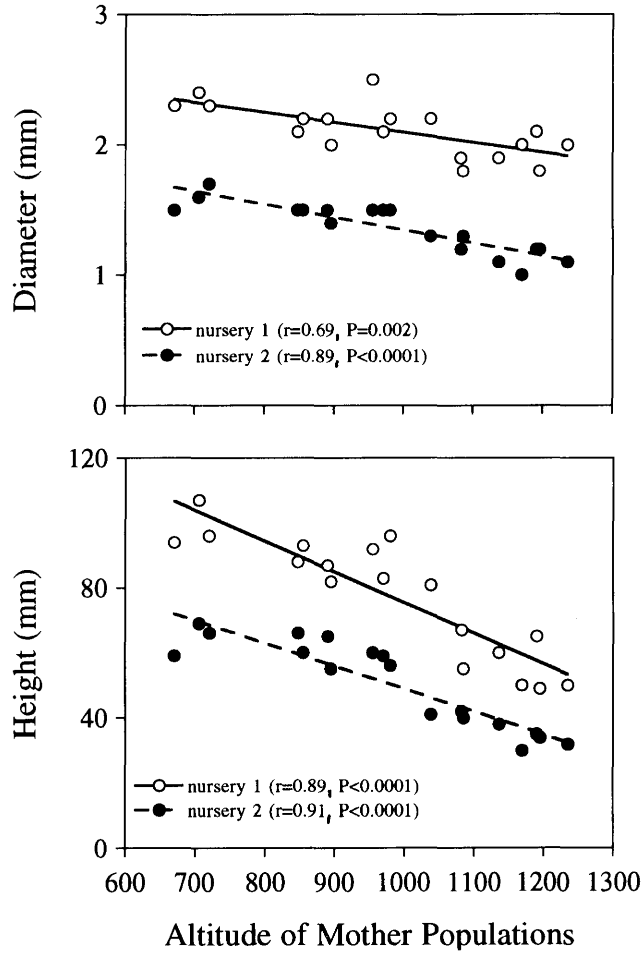

Figure 2. – Relationship between height and diameter of 2-year old spruce seedlings grown in 2 different nurseries and the altitude of mother populations.

range from –156 m to +125 m. Extreme deviations for any trait were from –546 to +416.

The ability of mother populations to regenerate naturally ranged from 10.0 to 14.5 on a 0 to 17 scale which indicates a rather high regeneration potential.

Discussion

Many authors have shown that Norway spruce ecotypes adapted to higher altitudes cease growth and set bud earlier then those adapted to lower altitudes (GIERTYCH, 1976; SCHMIDT-VOGT, 1978; DORMLING, 1979; HOLZER, 1988). In this study, spruce populations showed a close relationship between the progeny bud set index and the altitude of mother stands, which would indicate good ecological adaptation.

The bud flushing index exhibited a relatively little differentiation in the same material. It is not clear whether high-altitude ecotypes flush later (MOULALIS, 1971; GÄRTNER, 1980; HOLZER, 1984) or earlier (SCHMIDT, 1961; ROHMEDER, 1964; SCHMIDT-VOGT, 1977) than low-altitude ones. Therefore this character cannot be recomended for the identification of spruce ecotypes in the mountains.

SCHMIDT-VOGT (1977), HOLZER (1981) and NATHER (1988) claim that spruce seedling heights decrease with increasing altitude of the origin. This was also observed in the material studied, which would indicate that the investigated populations are mostly well adapted to the sites occupied presently by the mother stands.

The similar decrease in other investigated progeny traits (diameter, height increment and crown diameter) with the increase in origin altitude confirms the generally good adaptation of the studied populations to the altitudes at which they now occur (HOLZER, 1966, 1975, 1981, 1988; BOUVAREL, 1974; NATHER, 1988).

It appears that decrease in growth parameters of the populations originating from higher altitudes (apart from shorter growing period) may result from higher respiration and lower assimilation rates (SCHMIDT, 1979; TRANQUILLINI et al., 1980; KLEINSCHMIT et al., 1981). It seems that in the process of adaptation to the more severe environmental conditions of higher altitudes, spruce populations gain on hardiness at the expense of growth.

The poorer adapted populations (showing the highest average deviations in *table 2*) were: 1, 15, 13, 17 and 11. But even highest average deviations of +125 m to –156 m, scarcely exceeded half of the range of tolerance zones proposed for seed transfer in the mountains by ROHMEDER (1964): 250 m to 300 m, PRAVDIN and ROSTOVTSEV (1979): 150 m to 250 m, or HOLZER (1985): 200 m to 300 m. It cannot be excluded however, that the 2 stands eliminated from the study because of very poor cone bearing behaved differently because of foreign origin and lack of adaptation.

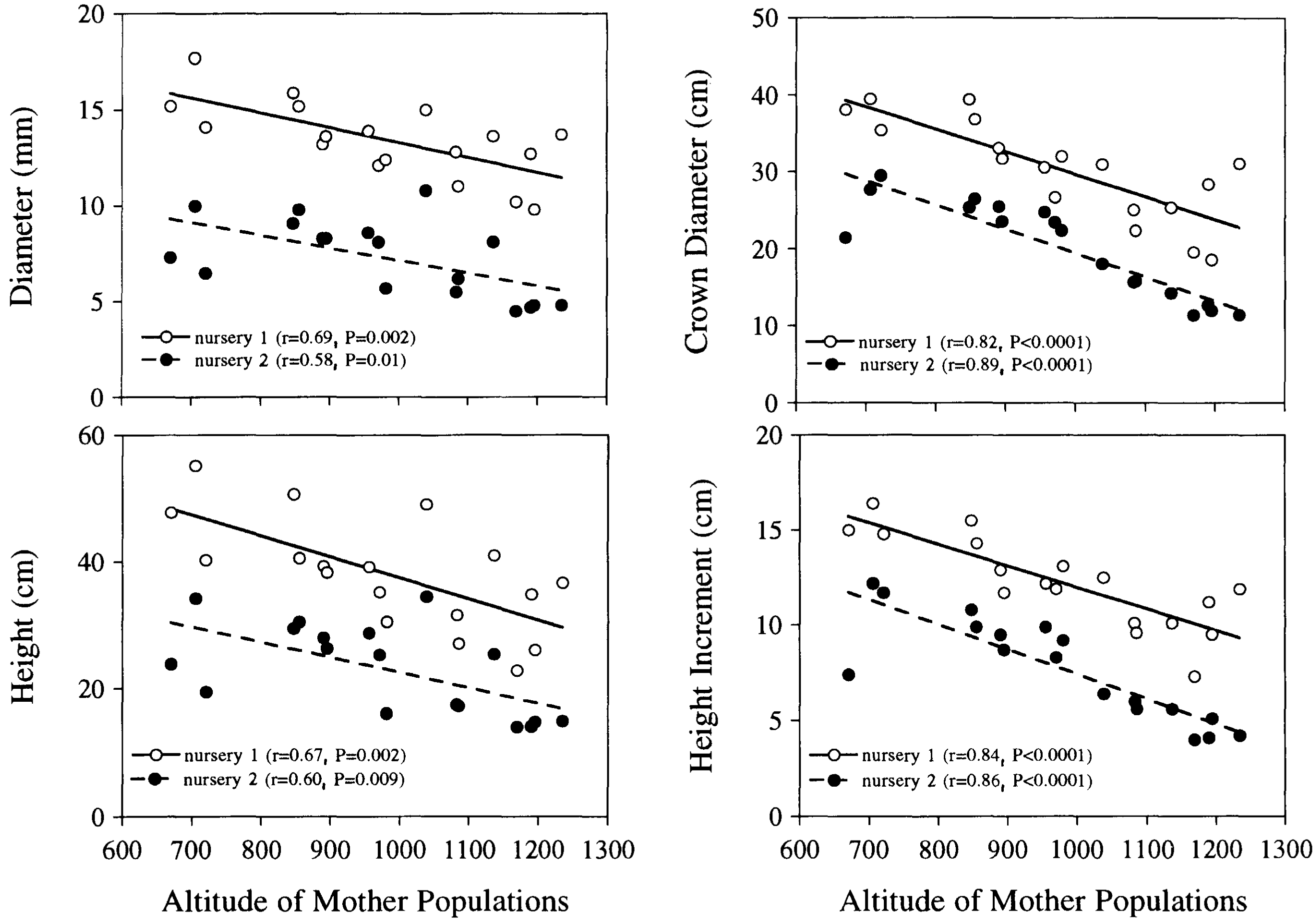

Figure 3. – Relationship between height, diameter, height increment and crown diameter of 5-year old spruce trees grown in 2 different nurseries and the altitude of mother populations.

Table 2. – Altitudinal deviations (m) estimated graphically for the studied populations.

Population	Bud setting index 1+2*	Flushing index 2	Diameter 2	Height 2	Diameter 5	Height 5	Height increment 5	Crown diameter 5	Roots dry matter 5	Average
1	- 22	- 40	- 92	- 172	- 276	- 200	- 208	- 212	- 185	- 156
2	- 14	- 76	+ 68	+ 12	+ 116	+ 208	+ 100	- 60	- 546	- 21
3	- 2	+ 22	+ 84	- 52	- 372	- 424	+ 28	- 72	- 85	- 97
4	+ 70	+ 62	- 28	+ 16	+ 68	+ 156	+ 136	+ 52	- 185	+ 39
5	+ 2	- 30	+ 100	+ 24	+ 84	+ 112	+ 56	+ 36	+ 95	+ 53
6	+ 56	+ 82	+ 132	+ 44	- 132	- 84	+ 12	0	- 352	- 27
7	- 2	+ 30	- 100	- 24	- 84	- 112	- 56	- 36	- 95	- 53
8	+ 104	+ 180	+ 320	+ 116	+ 8	+ 4	+ 64	+ 4	- 282	+ 58
9	+ 42	+ 130	+ 100	+ 68	- 132	- 148	0	- 48	- 280	- 30
10	+ 116	+ 240	+ 228	+ 144	- 288	- 456	+ 104	+ 24	- 15	+ 11
11	+ 48	+ 146	+ 92	+ 12	+ 320	+ 416	+ 20	+ 12	+ 55	+ 125
12	- 46	+ 20	- 92	- 24	- 176	- 280	- 60	- 68	- 70	- 88
13	- 94	+ 100	- 4	- 96	- 248	- 388	- 96	- 100	- 322	- 139
14	- 32	- 154	- 96	- 32	+ 144	+ 164	- 24	- 40	+ 120	+ 6
15	- 42	+ 180	- 60	- 108	- 340	- 448	- 184	- 112	- 284	- 155
16	+ 32	+ 154	+ 96	+ 32	- 144	- 164	+ 24	+ 40	- 120	- 6
17	- 42	- 64	- 28	- 64	- 344	- 340	- 20	- 86	- 200	- 132
18	+ 34	+ 14	+ 28	- 28	- 4	- 84	+ 96	+ 104	- 50	+ 12

*) Numbers 1, 2 and 5 denote the 1st, 2nd and 5th growing period

It may seem a paradox that populations 15 and 17, located close to the timberline (about 1250 m) appear adapted to higher altitudes. FIRBAS (cited in RUBNER and REINHOLD, 1953) claims, however, that until the 15th century the timber line in Karkonosze Mts. was 150 m to 200 m higher than today.

The spruce ecotypes transferred into drastically alien environments can be completely destroyed, e. g. by frost, snow or wind (RUBNER, 1936; ZOLL, 1958; ROHMEDER, 1964; SCHMIDT-VOGT, 1975, 1977). This may be what happened to some ecotypes imported to the Karkonosze Mts.. Usually, however, the introduced spruce populations have a chance of adaptation to the new site. Norway spruce populations, characterized by very high variability and heterozygosity (LUNDKVIST, 1979; KLEINSCHMIT, et al., 1981; GIERTYCH, 1985; GÖMÖRY and PAULE, 1993) may undergo an effective selection during one generation. The offspring of these populations are usually significantly different from the mother populations, especially in terms of ecologically important characteristics (BOUVAREL, 1974; HOLZER, 1988). The effectiveness of this process is increased by the inflow of pollen from neighboring native stands.

KRUTSCH (1992) claims that environmental tolerance and adaptability fo Norway spruce is much higher than that of Scots pine.

Thus, the high plasticity and adaptability of Norway spruce would explain the generally good adaptation of stands in Karkonosze Mts. in spite the possible foreign origin of some of them.

The results obtained suggest that valuable gene resources of the highly endangered spruce stands in Karkonosze Mts. should be protected. The author has estabilished in the vicinity of Kępno (much less polluted than the Sudety Mts.) an archive of the ecotypes identified in this study.

Conclusions

1. The investigated Norway spruce populations show, in general, good adaptation to the sites occupied by them in the Karkonosze Mts. and silviculturally they may be treated as indigenous.

2. Of 5 populations which show poorest adaptation, 4 have an inclination to higher, and 1 to lower altitude. Their average altitudinal deviations (125 m to 156 m) fit easily into the tolerance zones accepted in silviculture for seed transfer in the mountains (150 m to 300 m).

3. Because spruce stands in the Karkonosze Mts. generally behave like native ecotypes, and show high regeneration potential, they should be regenerated naturally wherever possible.

4. Seeds for artificial regeneration can be obtained in all seed producing adult spruce stands of the Karkonosze Mts. and used within the tolerance zones, because their adaptation seems satisfactory.

5. Gene resources of local Norway spruce ecotypes in the Karkonosze Mts. deserve conservation.

Literature

BOUVAREL, P.: L'adaptation ecologique des arbres forestiers. Applications a la selection. In: Ecologie forestiere. P. Pesson (ed). Gauthier-Villars, Paris: pp. 155–173 (1974). — DORMLING, I.: Influence of light intensitiy and temperature on photoperiodic response of Norway spruce provenances. IUFRO Norway Spruce Meeting S 2.03.11–S 2.02.11, Bucharest. Publ. by Lower Saxony Forest Res. Inst. 486 pgs. pp 398–408 (1979). — FANTA, J.: Morphologische Variabilität der Fichte und Grundzüge der genetischen Rekonstruktion der Gebirgsfichtenwälder im Krkonoše Nationalpark (CSSR). Arch. Naturschutz u. Landschaftsforsch., Berlin **3**: 179–200 (1974). — GÄRTNER, E.: Beiträge zur Beurteilung der Jugendentwicklung von Fichtenprovenienzen. Mitt. Hess. Landforstverw. **15.** Sauerländer's Verlag, Frankfurt am Main. 114 pgs. (1980). — GIERTYCH, M.: Zmienność genetyczna polskich ras świerka (*Picea abies* (L.) KARST.). [Genetic variability of Polish spruce (*Picea abies* (L.) KARST.) races]. Arboretum Kórn. **21**: 189–211 (1976). — GIERTYCH, M.: Porównanie selekcji rodowej i proweniencyjnej u świerka (*Picea abies* (L.) KARST.) z Beskidu Śląskiego i Żywieckiego. [A comparison of progeny and provenance selection in Norway spruce (*Picea abies* (L.) KARST.) from the Silesian and Żywiec Beskid]. Arboretum Kórn. **30**: 241–255 (1985). — GÖMÖRY, D. and PAULE, L.: Isozyme polymorphism in Norway spruce (*Picea abies* KARST.) from Slovak Carpathians. Norway spruce provenances and breeding – Proceedings of IUFRO (S2.2–11) Symposium, Latvia, 1993, Riga. Publ. by Latvian Forestry Res. Inst. Silava. 263 pgs. pp 60–67 (1993). — HOLZER, K.: Die Vererbung von physiologischen und morphologischen Eigenschaften der Fichte. I. Sämlingsuntersuchungen. Mitt. Forstl. Bundes-Versuchsanst. Mariabrunn **71**: 185 pgs. (1966). — HOLZER, K.: Zur Identifizierung von Fichtenherkünften (*Picea abies* (L.) KARST.). Silvae Genetica **24** (5/6): 169–175 (1975). — HOLZER, K.: Die Kulturkammertestung zur Erkennung des Erbwertes bei Fichte (*Picea abies* (L.) KARST.). 4. Qualitative Merkmale. Cbl. ges. Forstwesen **2**: 65–87 (1981). — HOLZER, K.: About morphology, physiology and genetics at mountainous forest trees. Acta Biol. Mont. **4**: 47–56 (1984). — HOLZER, K.: Die Bedeutung der Genetik für den Hochlagenwaldbau. Proc. 3rd IUFRO Workshop P 1.07–00, 1984. Eidg. Anst. forstl. Versuchswes.. Ber., 270 pgs. pp 225–232 (1985). — HOLZER, K.: Die Vegetationszeitlänge bei Fichtensämlingen, ihre Bedeutung und ihre Beeinflußbarkeit durch Umweltfaktoren. Forum Genetik-Wald-Forstwirtschaft, Insbruck 1987. FBVA Berichte **28**: 73–86 (1988). — KLEINSCHMIT, J., LUNDERSTÄDT, J. and SVOLBA, J.: Charakterisierung von Fichtenklonen (*Picea abies* (L.) KARST.) mit Hilfe morphologischer, physiologischer und biochemischer Merkmale. (III). Silvae Genetica **30** (4/5): 122–127 (1981). — KLEINSCHMIDT, J., SAUER-STEGMANN, A., LUNDERSTÄDT, J. and SVOLBA, J.: Charakterisierung von Fichtenklonen (*Picea abies* (L.) KARST.). II. Korelation der Merkmale. Silvae Genetica **30** (2/3): 74–82 (1981). — KRUTZSCH, P.: IUFRO's role in coniferous tree improvement: Norway spruce (*Picea abies* (L.) KARST.). Silvae Genetica **41** (3): 143–150 (1992). — LÜDEMANN, G.: Die Rolle der deutschen Forstbaumschulen bei der Herkunftssicherung forstlichen Saat- und Pflanzgutes. Allg. Forstztg. **37**: 32–35 (1978). — LUNDKVIST, K.: Allozyme frequency distributions in four Swedish populations of Norway spruce (*Picea abies* (L.) KARST.). I. Estimation of genetic variation. Hereditas **90**: 127–143 (1979). — MATUSZKIEWICZ, W. and MATUSZKIEWICZ, A.: Zespoły róslinne Karkonoskiego Parku Narodowego. I. Zbiorowiska leśne. [Plant communities of the Karkonosze National Park (Western Sudety Mts.). I. Forestal communities.]. Prace Wrocławskiego Tow. Nauk., B 135, Wrocław. 100 pgs. (1967). — MODRZYŃSKI, J.: Stan naturalnego odnowienia świerka (*Picea abies* (L.) KARST.) w Karkonoskim Parku Narodowym na tle warunków przyrodniczo-leśnych. [The state of natural regeneration of spruce (*Picea abies* (L.) KARST.) in the Karkonosze Mts. National Park on the background of natural and forestal conditions.]. PTPN Prace Komis. Nauk Rol. Leś. **46**: 101–116 (1978). — MODRZYŃSKI, J.: Dynamika naturalnego odnowienia świerka (*Picea abies* (L.) KARST.) w drzewostanach położonych na różnych wysokościach nad poziomem morza w Karkonoskim Parku Narodowym. [Dynamics of spruce (*Picea abies* (L.) KARST.) natural regeneration in the stands situated at different altitudes in the Karkonosze Mts. National Park.]. PTPN Prace Komis. Nauk Rol. Leś. **48**: 113–132 (1979). — MODRZYŃSKI, J.: Środowiskowe przystosowanie i pochodzenie świerka pospolitego (*Picea abies* (L.) KARST.) w Karkonoskim Parku Narodowym. [Ecological adaptation and origin of Norway spruce (*Picea abies* (L.) KARST.) in Karkonosze Mts. National Park.]. Roczniki AR Pozn. rozpr. nauk. 192, 103 pgs. (1989). – MOULALIS, D.: Untersuchungen über das Austreiben der Baumart Fichte (*Picea abies* (L.) KARST.) in Bayern und die Züchtung auf Spätfrost-Resistenz. Dissertation, München. 149 pgs. (1971). — NATHER, J.: Pflanzenqualitätsmerkmale bei Gebirgsherkünften. Forum Genetik-Wald-Forstwirtschaft, Insbruck 1987. FBVA Berichte **28:** 97–102 (1988). — PEŘINA, V. and SAMEK, V.: Sposoby zagospodarowina lasów sudeckich. [Ways of management of the forests in the Sudety Mts.]. Sylwan **5/6:** 34–49 (1958). — PRAVDIN, L. P. and ROSTOVTSEV, S. A.: Norway spruce provenance experiments in the USSR. IUFRO Norway spruce Meeting, S 2.03.11 – S 2.02.11, Bucharest. Publ. by Lower Saxony Forest Res. Inst. 486 pgs. 85–99 (1979). — ROHMEDER, E.: Die Bedeutung der Samenherkunft für die Forstwirtschaft im Hochgebirge. In: Forstsamengewinnung und Pflanzenzucht für das Hochgebirge. BLV, München-Basel-Wien. 17–35 (1964). — RUBNER, K.: Beitrag zur Kenntnis der Fichtenformen und Fichtenrassen. Parey, Berlin. Thar.-Forstl.-Jb. **87:** 101–176 (1936). — RUBNER, K. and REINHOLD, F.: Das natürliche Waldbild Europas. Parey, Hamburg, Berlin. 288 pgs. (1953). — SCHMIDT, H.: Die Gütebeurteilung von Forstpflanzen. BLV, München. 171 pgs. (1961). — SCHMIDT, W.: Results with Norway spruce provenances using rapid tests for the distinction of seedlots. IUFRO Norway spruce Meeting S 2. 03. 11 – S 2. 02. 11, Bucharest. Publ. by Lower Saxony Forest Res. Inst. 486 pgs. pp 464–467 (1979). — SCHMIDT-VOGT, H.: Analyse der Fichtenbestände nach Provenienzen und deren ökologisches Verhalten. Allg. Forstzeitschrift **30**, 2 pgs. (1975). — SCHMIDT-VOGT, H.: Die Fichte. Bd. I. Paul Parey, Hamburg, Berlin. 647 pgs. (1977). — SCHMIDT-VOGT, H.: Monographie der *Picea abies* (L.) KARST. unter Berücksichtigung genetischer und züchterischer Aspekte. Forstwissenschaftliches Cbl. **6:** 281–302 (1978). — SOKOŁOWSKI, A.: Phyto-sociological characteristics of seed producing spruce stands. In: S. TYSZKIEWICZ (ed.). Population studies of Norway spruce in Poland. Forest Research Institute, Warsaw. pp 100–106 (1968). — TRANQUILLINI, W., LECHNER, F., OBERARZBACHER, P., UNTERHOLZNER, L. and HOLZER, K.: Über das Höhenwachstum von Fichtenklonen in verschiedener Seehöhe. Mitteilungen der Forstlichen Bundes-Versuchsanstalt **129:** 7–25 (1980). — Zoll, T.: Podstawowe zagadnienia zagospodarowania lasów górskich w Sudetach. [Basic problems of managing the Sudety Mts. forests.]. Sylwan **5/6:** 9–33 (1958).

Performance of 43 *Pinus pinaster* Ait. Provenances on 5 Locations in Central Spain

By R. ALIA[1]), L. GIL[2]) and J. A. PARDOS[2])

(Received 13th September 1993)

Summary

The paper present results of a 5-location all range *Pinus pinaster* provenance study in Spain, conducted in four-replicated complete block design provenance tests. Total height, diameter, survival and stem form were analysed at age 19 years. An analysis of variance over locations was made and two methods of studying stability of provenances were used, ecovalence and joint regression analysis.

For stem form, provenance was the most important effect, and site was statistically not significant. For height and diameter, site was the predominant effect, but high provenance – site interaction was present. Significance of interaction and implications on the use of the species were discussed.

Key words: Provenance x environment interaction, provenances experiments, genotypic stability, *Pinus pinaster.*

FDC: 232.12; 165.5; 174.7 *Pinus pinaster;* (460).

Introduction

Maritime pine (*Pinus pinaster* AIT.) is one of the most important forest species in the Occidental Mediterranean basin and the Atlantic coastal region of Southern Europe. It grows in natural stands on an extremely wide range of soil types and a variety of climatic conditions which characterize the plains, coastal regions and mountain slopes in an altitudianl range of about 2.000 meters.

Maritime pine is commonly planted at all conditions within its range and was intensively used in production and protection plantings. In Spain, 780,000 ha were afforested with this species between 1940 and 1982.

The performance of maritime pine provenances has been studied on numerous occasions, mainly in atlantic climates, (RYCROFT and WITCH, 1947; SWEET and THULIN, 1963; HOPKINS, 1964; MOLINA, 1965; BELLEFONTAINE, 1975, 1979; MATZIRIS, 1982); and it is considered a highly plastic species (HARRIS, 1966; BUTCHER, 1974; MATZIRIS, 1982) in the sense that the best genotypes or provenances usually display superior performance in a wide variety of conditions. On some occasion the species has been cited as an example of stability (ZOBEL et al., 1987).

However, when the diversity of locations tested or the number of provenances involved increase, stability ceases to be a general feature. Susceptibility to frost (BOUVAREL, 1960; ILLY, 1966) and drought (GUYON and KREMER, 1982; SARRAUSTE, 1982; NGUYEN and LAMANT, 1989) varies according to provenance, and therefore performances in diverse conditions are not homogeneous.

Because of the great genetic variability displayed in this species, which has been subdivided into 18 elementary geographical races (BARADAT and MARPEAU, 1988), and the different performance of provenances, it is necessary to study the behaviour of maritime pine in mediterranean conditions.

This paper examines the performance of 43 provenances of *Pinus pinaster* in 5 sites in West-Central Spain, located in mediterranean phytoclimates. The importance of the factors site and provenance are analysed, likewise the interaction of these, for survival, height, diameter and stem form. Stability of the provenances for each of the traits is also examined.

Material and Methods

A series of trials was planted at 5 locations in 1967 with 1-0 seedlings for the purpose of evaluating performance of maritime pine provenances. *Figure 1* shows the location of the provenance tests under analysis, and details of the sites included in this study are presented in *table 1.*

Each plantation followed a randomized complete block design with 16-tree plots and 4 replications. Spacing was 2.5 m x 2.5m. They include as many as 52 provenances of the species, 43 of which were chosen for this study.

Seeds were collected both in natural stands and plantations (*Table 2*), covering the entire range of the species (*Figure 1*).

Three response variables were measured on each surviving tree in each plot; i.e.: height (HTOT), diameter at breast height (DBH) and stem form (FORM, on a subjective scale from 1-good quality- to 9-poor quality- according to straightness and verticality), and the survival (SUR) of each plot was evaluated. Acebo, Cabañeros and Riofrío plantations were measured 18 years after planting, and Miravete and Espinoso tests were measured after 19 years. For height and diameter in Acebo,

[1]) Dpto. Sistemas Forestales, CIT-INIA, Aptdo. 8.111, E-28080 Madrid (Spain)

[2]) Dpto. Silvopascicultura, ETSI MONTES, Ciudad Universitaria s/n, E-28040 Madrid (Spain)