Eine vollständige Mischung ohne wiederholte Nachbarschaft ist auch theoretisch nicht möglich, da jeder der 81 Klone im Idealfall 80 Nachbarn hat. Bei Zugrundelegung der 9er-Gruppe wären also 10 Varianten erforderlich. Die neuen Nachbarn können aber nur aus 8 weiteren 9er-Gruppen kommen. Zumindest in den Varianten V bis VIII lassen sich die Auswirkungen abmildern, indem nach dem in *Abbildung 18* unten dargestellten Muster gepflanzt wird. Das gleiche Signum bedeutet gemeinsame Zugehörigkeit zu einem Zahlenkreis. Es bietet sich an, die doppelten Nachbarschaften in der Weise auszunutzen, daß man diejenigen Klone erneut zusammenbringt, die sich schwierig kreuzen lassen. In der Regel wird man aber nicht mehr als die ersten 4 Varianten ausführen. Nach gleichem Schema lassen sich auch 5 x 5er- und 7 x 7er-Matrix in 5er- bzw. 7er-Gruppen mischen.

Schlußbemerkung

Zur Gruppe der systematischen Mischungen gehört noch ein weiteres Verfahren, das die spätere Überführung der Plantage in einen plenterartigen Zustand erlaubt. Obwohl bereits praxisreif entwickelt und umgesetzt, muß die Vorstellung dieses Verfahrens aus Umfanggründen einem gesonderten Artikel vorbehalten bleiben.

Ein direkter Vergleich mit den praxisüblichen Verfahren konnte im Rahmen dieser Arbeit nicht erfolgen. Sie soll aber dazu anregen.

Literatur

NESTER, M. R.: Modulo Tile Constructions for Systematic Seed Orchard Design. Silvae Genetica **43** (5/6) 312–321 (1994).

Growth Performance and Wood Characteristics of Five *Pinus contorta* Progenies[1)][2)]

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Summary

In a 36-year old test plantation progenies of 5 open pollinated single trees of *Pinus contorta* DOUGLAS ex LOUDON from Washington (USA) and British Columbia (Canada) were investigated on a site in northern Germany. Several traits were measured or assessed in various years regarding height and diameter growth, branching, fresh weight of biomass as well as some wood characteristics as wood density, annual ring width, late wood percentage and content of soluble substances in the wood. In general, the differences between the progenies were small and not significant, although individual variation between the trees was found. The results correspond very well with the performance and wood traits of *Pinus sylvestris* L. trees of about the same age and on a comparable site.

Key words: Lodgepole pine, Scots pine, differences between progenies, growth characters, wood characters.

FDC: 232.11; 232.12; 181.6; 812; 165.43; 174.7 *Pinus contorta.*

Zusammenfassung

An 36jährigen Nachkommenschaften von 5 frei abgeblühten Einzelbäumen der Baumart *Pinus contorta* aus 2 Herkünften von Washington (USA) und British Columbia (Canada) wurden auf einem Versuchsstandort in Norddeutschland im Verlauf mehrerer Jahre Wuchs- und Holzeigenschaften untersucht. Dabei handelte es sich um Wuchshöhen, Durchmesser in verschiedenen Höhen, Astmerkmale, Frischgewicht ganzer Bäume, sowie um die Holzmerkmale Rohdichte, Jahrringbreite, Spätholzanteil und Anteil an löslichen Substanzen im Holz. Die Ergebnisse brachten trotz individueller Variation im Mittel nur geringe Unterschiede zwischen den Nachkommenschaften. Auch der Vergleich mit etwa gleichalten Bäumen von *P. sylvestris* ergab eine weitgehende Übereinstimmung zwischen diesen beiden Kiefernarten.

Introduction

Since the beginning of this century lodgepole pine (*Pinus contorta* DOUGLAS ex LOUDON) from western North America was increasingly planted in central Europe because of the very promising growth performance of this tree species in the Scandinavian countries (see e.g. review by STEPHAN, 1982). The aim of reforestations with *P. contorta* was to increase timber and cellulose production of forests. But for central Europe the plantations and trials showed in general the following results: The growth performance on poor sites was not comparable with Scandinavian results. The origin of the provenances used at that time was often unknown or from very limited regions of the natural range. The growth rate was only good on rich and humid soil, but the species competed on such sites with other native and more valuable tree species, mostly hardwoods. Additionally, *P. contorta* was extremely susceptible to the European pine shoot moth (*Rhyacionia buoliana* DEN. et SCHIFF.) and the trees were susceptible to storm events.

Nevertheless, *P. contorta* is, despite several disadvantages, an interesting forest tree species, especially as a pioneer species for afforestations, or for sites in the highlands endangered by immissions (LATTKE, 1990). Therefore, one should have a better knowledge about traits of growth, form and wood from populations grown outside the natural range. With the exceptions of Scandinavia (e.g. BJÖRKLUND, 1982; PERSSON, 1993) or the United Kingdom (e.g. BRAZIER, 1980) results about

[1)] Dedicated to Dr. G. H. MELCHIOR on his 70th birthday

[2)] A modified version of a paper presented on the IUFRO meeting on "Evolution of breeding strategies for conifers from the Pacific Northwest" at Limoges, France, August 1 to 4, 1995.

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those characters, particularly about wood traits, are scarce for central Europe.

In the present paper results are given of a 36-year old test plantation with progenies from 2 *P. contorta* provenances. These 2 provenances grew in one of the oldest German provenance trials established in Bavaria in 1931 (FABRICIUS, 1936; ROHMEDER and MEYER, 1952). Cellulose and lignin contents of the trees were investigated by SCHÜTT (1958), who selected 5 trees with high cellulose contents for a small progeny test at Grosshansdorf (Schleswig-Holstein, northern Germany).

Material and Methods

Plant material

In January 1959 seed samples from 5 open pollinated single trees were collected in the above mentioned provenance trial (at that time 30 years old) located in the Forest District of Schwabach (Bavaria) from a coastal provenance of Washington and from an interior provenance of British Columbia. The following details are available about the origin of the provenances (ROHMEDER and MEYER, 1952):

Provenance A: coast of Washington, 48° northern latitude, altitude up to 100 m; climatic section 19, more than 270 days without frost.

Provenance O: British Columbia at Kamloops, lower course of Fraser River, near the mouth of the Thompson River, 51° northern latitude, altitude 500 m; climatic section 110B, 110 to 150 days without frost.

According to CRITCHFIELD's (1957) taxonomical classification the coastal provenance A belongs to the subspecies *contorta,* the interior provenance O to the subspecies *latifolia.* Provenance A is represented in this trial by 1 tree (seedbook no. 3225) and provenance O by 4 trees (seedbook no. 3230 to 3233).

Seed was sown in the nursery of the institute in spring 1959.

Trial establishment and treatment

With 2-year old seedlings a field trial was planted in rows without replications at Grosshansdorf (Park Manhagen; 53°40' N, 10°16' E, 44 m above sea level) in spring 1961. Three progenies were planted with 112 trees each (7 x 16 plants of seedbook no. 3225, 3230, 3231), 2 progenies with 144 trees each (9 x 16 plants of seedbook no. 3232, 3233). Spacing was 0.5 m x 1 m. The site can be characterized as dilluvial moraine, slightly podzolic; site index: Scots pine II.

The progeny trial was thinned four times in the years 1968/1969, 1975, 1980, and 1986.

Measured or assessed traits

The following traits have been measured or assessed:

Height 1975, 1980, 1994;

Dbh 1975, 1980, 1985, 1986, 1994;

Number, length and thickness of branches of the 5th whorl from the top 1975, 1980;

Fresh weight of the tree biomass including timber, branches and needles 1980;

Wood density in various stem heights 1975, 1980;

Annual ring width up to 1975, and up to 1980;

Late wood in percentage of the annual rings up to 1975;

Content of extract of soluble substances after 24 hrs cooking in hot water in 1980.

Height (1994) and dbh (all years) have been measured for all trees, the other traits in a random sample of 2 trees/progeny in 1975 and 4 trees/progeny, respectively, in 1980.

In 1975, 1980 and 1994, sample trees of a local Scots pine stand (*Pinus sylvestris* L.), about 10 years older than *P. contorta,* adjacent to the progeny test and therefore under similar environmental conditions, were included in the studies.

Statistical analysis

Depending of the trait, single tree values or mean values of the respective progeny were used for the various calculations. Values and most graphs were calculated with the SAS Program package (SAS Institute Inc., 1989).

Results

Growth performance

Height and diameter growth

Until age 36 the *P. contorta* progenies have reached mean heights between 18 m and 22 m, and mean dbh values between about 17 cm and 23 cm (*Fig. 1, Table 1,* columns 3 to 6). Since age 17 (1975) the annual mean increment was about 54 cm in height and about 0.6 cm in diameter at a height of 1.3 m. The 5 progenies are very similar in their growth performance. The differences are statistically not significant, although the progeny no. 3225 from the coast of Washington had the lowest height and dbh values since age 17 (*Table 1, Fig. 1*). Unfortunately, a heavy storm damaged the progeny trial in January 1990 and the plot with progeny no. 3233 was completely lost. The residual trees of the other progenies are still vital, so that one can expect a further good growth development.

Table 1. – Growth traits of *Pinus contorta* at age 17 (1975; random sample of 2 trees/progeny) and at age 22 (1980; random sample of 4 trees/progeny). The values are average values for each progeny.

Species	Seedbook no.	Height		Dbh		Length of branches of the 5. whorl from top		Branches	Branch thickness	Weight of biomass
		1975 [m]	1980 [m]	1975 [cm]	1980 [cm]	1975 [cm]	1980 [cm]	1980 n	1980 [mm]	1980 [kg]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
P. contorta ssp. *latifolia*	3233	8.9	13.1	7.0	12.2	121	112.8	4.75	14.8	131.8
P. contorta ssp. *latifolia*	3232	8.2	12.5	6.3	10.9	111	78.6	5.5	10.4	99.9
P. contorta ssp. *latifolia*	3231	9.1	13.8	7.1	11.2	90	102.6	5	12.5	108.9
P. contorta ssp. *latifolia*	3230	10.0	13.4	7.1	9.6	104	74.9	5	9.6	58.8
P. contorta ssp. *contorta*	3225	9.2	11.5	6.9	9.5	81	60.5	5.5	7.1	64.5
P. sylvestris	--	--	14.1	--	12.8	--	89.3	6	11.2	111.6

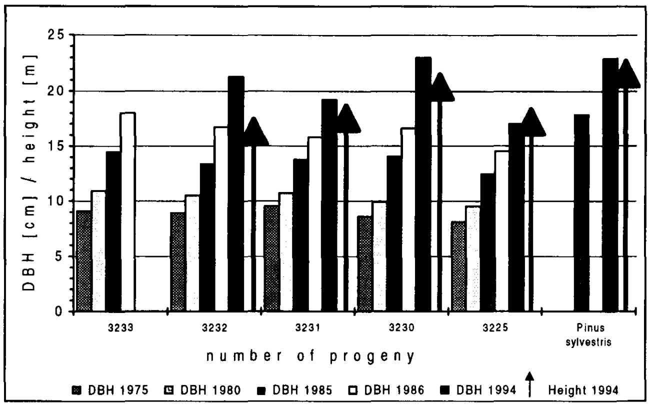

Fig. 1. – Diameter and height growth of *Pinus contorta* progenies at age 17, 22, 27, 28, and 36. Mean values of a 10 years older *P. sylvestris* population are given for comparison.

The stem form of nearly all trees was straight and showed no differences between progenies. There was also no striking damage by the European pine shoot moth. Regarding the stem form the relation between length of stem and stem diameter at different heights was investigated. The stem diameter is usually thick at the stem butt, decreases slightly from 1.3 m to about 8 m to 9 m height, and then quicker to the top (*Fig. 2*). There were only little differences in the stem diameter relation between the progenies.

Branches

The formation of 2 whorls in one vegetation period is typical for the species *P. contorta*. The trees are branchier than for instance Scots pine. This disadvantage is combined with a high flexibility of the branches, which avoids the natural pruning of the stems. Less and thin branches could therefore overcome these problems. Measurements or assessments of the branches at age 17 (1975) and 22 (1980) resulted in a great variation between and within the progenies (*Table 1*, columns 7 to 10). The length of branches of the 5th whorl from the top varies in the mean between 81 cm and 121 cm in 1975 and between 60 cm and 113 cm in 1980. After 5 years the absolute length of branches of the at that time 5th whorl had decreased, probably because of the denser stand of the trees.

The number of branches was about 5 per whorl in all progenies (*Table 1*, column 9). But the mean thickness of the branches near the stem varied between 7 mm and 14 mm (*Table 1*, column 10). Also in these traits the coastal progeny (no. 3225) had in general the lowest mean values. The British Columbia progeny no. 3233 had the thickest branches and ranked first. Though, the differences between the progenies were not significant.

Fresh weight of the biomass

After felling four trees per progeny in 1980, the total fresh weight of the single trees without roots was ascertained (*Table 11*, column 11). The average fresh weight of the 5 progenies varied between about 59 kg and 132 kg per tree. The ranking of the progenies corresponded very well with the traits of the branches and with the dbh: progeny no. 3233 had generally the highest values, progeny no. 3225 low mean values with less than half of the fresh weight (*Table 1*).

Wood characteristics

The thinning of the progeny trial in the years 1975 and 1980 offered a good opportunity to investigate a few traits of the

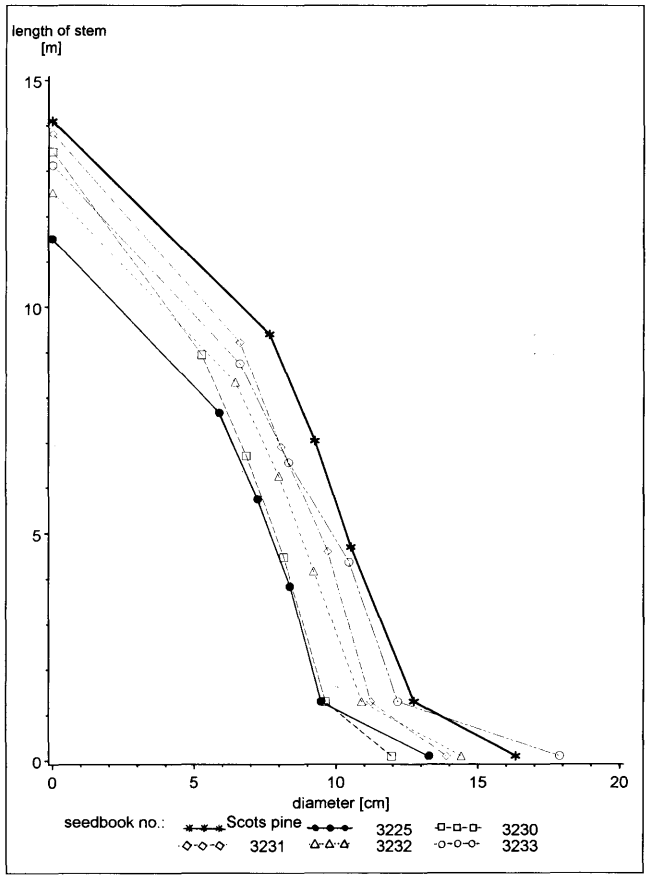

Fig. 2. – Stem diameter at different stem heights of 5 progenies of *Pinus contorta* (age 22) and 1 population of *P. sylvestris* (age about 32). The values are averages of 4 trees/progeny.

wood in a random sample of trees. The main results are summarized in the following.

Wood density

The wood density was measured in sample trees of the five progenies in 1975 in breast height (1.3 m) and in 1980 in various tree heights. The mean values at breast height vary between the progenies and the years between 0.374 g/cm^3 and 0.413 g/cm^3 (*Table 2*, columns 3 and 4). Generally, one could find the highest wood density values in the coastal progeny (no. 3225) from Washington. In 1980, when the trees were 5 years older, the wood density values of the stems were higher than in 1975, with the exception of progeny no. 3230.

Table 2. – Wood traits of *Pinus contorta* at age 17 (1975; random sample of 2 trees/progeny) and at age 22 (1980; random sample of 4 trees/progeny). The values are average values for each progeny. Wood samples were taken at the height of 1.3 m (dbh) of each tree stem.

Species	Seedbook no.	Wood density		Annual ring width		Late wood	Content of extract
		1975 [g/cm³]	1980 [g/cm³]	up to 1975 [mm]	up to 1980 [mm]	1975 [%]	1980 [%]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
P. contorta ssp. *latifolia*	3233	0.381	0.388	3.3	3.8	29	3.8
P. contorta ssp. *latifolia*	3232	0.376	0.386	3.0	3.5	26	3.8
P. contorta ssp. *latifolia*	3231	0.374	0.387	3.3	3.6	30	3.5
P. contorta ssp. *latifolia*	3230	0.391	0.387	3.4	3.1	31	3.9
P. contorta ssp. *contorta*	3225	0.408	0.413	3.4	3.2	29	3.3
P. sylvestris	--	--	0.402	--	2.7	--	3.6

The wood density varied along the tree stems. Measurements at different heights of a tree showed the highest values above 0.40 g/cm^3 at the stem ground, a gradual decrease up to one third or to one half of the tree height respectively, and then again a slight increase up to the two thirds height (*Fig. 3*). The largest changes along the stem were observed in progeny no. 3225 from the Washington coast. Very similar and parallel was the behaviour of the 2 progenies no. 3231 and 3233 (*Fig. 3*).

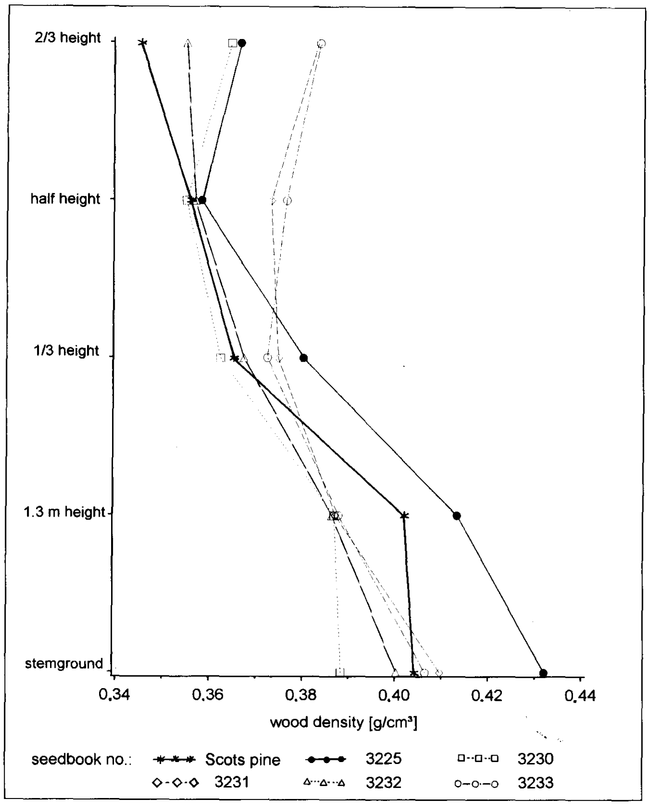

Fig. 3. – Wood density in different stem heights of 5 progenies of *Pinus contorta* (age 22) and 1 population of *P. sylvestris* (age about 32). The values are averages of 4 trees/progeny.

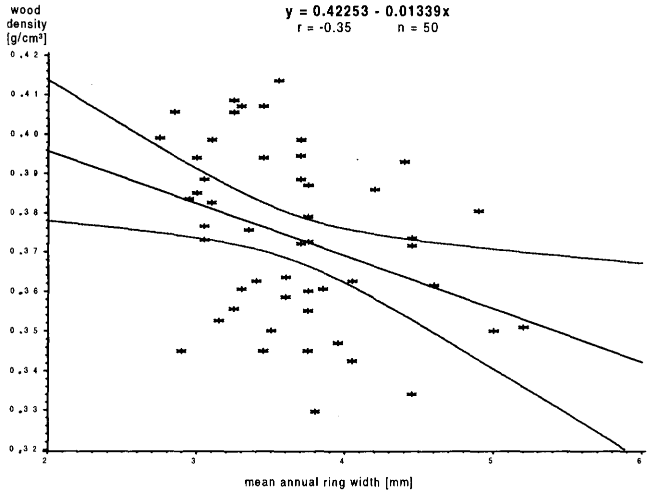

Fig. 4. – Relation between wood density and mean annual ring width up to age 17 in 50 wood samples of together 10 trees of 5 *Pinus contorta* progenies on basis of a regression analysis with confidence limits (95%).

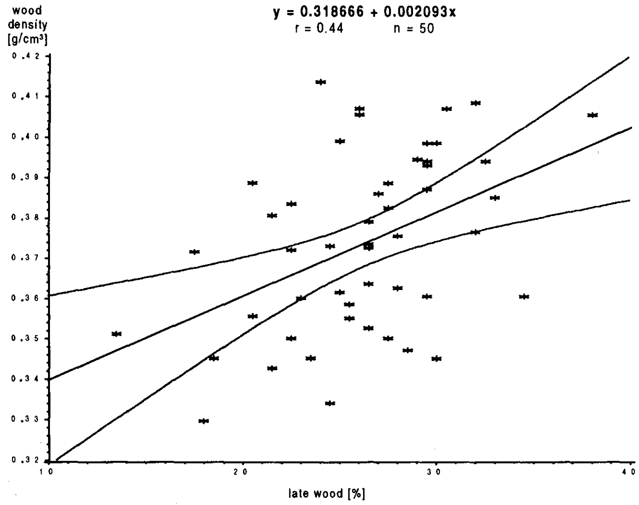

Fig. 5. – Relation between wood density and late wood content percentage of 50 wood samples of together 10 trees of 5 *Pinus contorta* progenies (age 17) on basis of a regression analysis with confidence limits (95%).

Annual ring width

The annual ring width of the 5 *P. contorta* progenies is given in *table 2* (columns 5 and 6) as mean values of all rings measured in wood samples in breast height (1.3 m). The rings were about 3.0 mm to 3.8 mm wide and were highly significantly correlated with the dbh values as was to be expected. There was an obvious, but very weak negative correlation ($r = -0.35$) between the annual ring width and the wood density compared for the 50 trees studied (*Fig. 4*). With increasing annual ring width the wood density decreased and vice versa.

Late wood

The distinction between sapwood and heartwood is not easy in *P. contorta,* because the wood colour is very similar and the limit not very marked. Heartwood was not yet developed in the relatively young trees of the *P. contorta* progenies. But the late wood could be investigated as portion of the annual ring. Also the border between late wood and early wood is difficult to see. Nevertheless, during the studies in 1975 the percentage of late wood was estimated (*Table 2,* column 7). In average, about 30% of the annual rings of the 17 years old trees were late wood. There were distinct differences between single trees, but only slight differences between the average values of the progenies tested. On basis of all 50 wood samples studied over five heights in together 10 trees of the 5 *P. contorta* progenies one can detect a weak positive correlation ($r = 0.44$) between late wood content and wood density (*Fig. 5*). With increasing late wood content also the wood density increased.

Content of soluble substances

Cooking of wood samples in hot water caused a loss of weight of about 3% to 4% (*Table 2,* column 8). The content of soluble substances varied between trees and progenies. There was no clear relation between content of extract and any other wood trait. A weak relation seemed to exist with the late wood percentage as the progeny (no. 3230) with the highest percentage of late wood content had also the highest value of soluble extracts.

Comparison between Pinus contorta and Pinus sylvestris

In close neighbourhood of the *P. contorta* progeny trial a *P. sylvestris* stand of unknown, but presumably local origin is growing. For comparing growth performance and wood traits of the 2 pine species, measurements or assessments were taken also in this Scots pine stand in 1975, 1980 and 1994. Considering all these traits one can state that the about 10 years older Scots pines were only slightly different from *P. contorta*. The higher diameter and height growth values can be explained with the higher age of the trees (*Fig. 1, Table 1*). The same is also true for the fresh biomass weight (*Table 1,* column 11). The length of branches and their thickness was about the average of the *P. contorta* progenies (*Table 1*, columns 7 to 10). The number of branches in the 5th whorl from top was with an average of 6 negligibly higher. However, with only 1 whorl per year *P. sylvestris* differed markedly from *P. contorta*.

Summarizing the wood characteristics of Scots pine, one can state that the wood density at breast height was with about 0.402 g/cm^3 comparable to the average of all *P. contorta* progenies (*Table 2*, column 4). The wood density at different heights showed as in *P. contorta* the highest values at the stem ground, a gradual decrease up to the half height and unlike *P. contorta,* a further decrease of wood density up to the two thirds height (*Fig. 3*) with values of about 0.34 g/cm^3. The annual ring width was the smallest, and the content of soluble substances was with about 3.6% comparable to the average of the *P. contorta* progenies (*Table 2*, columns 4, 6 and 8).

Discussion

Pinus contorta is in Scandinavia a highly interesting tree species, which can produce in stands of approximately 50 years a 20% to 50% higher volume yield than the local *P. sylvestris* (LÄHDE et al., 1982). In Germany, *P. contorta* is not a significant exotic forest tree species for afforestations, so far. However, it is planted occasionally as a pioneer species because of its fast juvenile growth and its favorable humus formation. The most suitable provenances have their origin along the coast of Oregon, Washington and southern British Columbia as well as in the interior of southern British Columbia as shown in provenance trials (STEPHAN, 1976, 1982), and particularly in trials with the large IUFRO seed collection of 1971/1972 (STEPHAN, 1980; STEPHAN et al., 1993). In the present field trial 5 single tree progenies of 2 provenances from these coastal and interior regions were investigated for more detailed informations about growth performance and wood characteristics, and the results were compared with the respective traits of a local *Pinus sylvestris* stand. The results show clearly that on the test location the differences between *P. contorta* progenies and between the 2 pine species, *P. contorta* and *P. sylvestris,* are not very distinct.

Regarding yield ROHMEDER and MEYER (1952), and regarding the content of cellulose and lignin SCHÜTT (1958) did not find significant differences between the 2 provenances, of which 5 progenies were investigated in the present study, although there was a distinct individual variation between the trees. It is worth to mention that under better site conditions volume production of *P. contorta* is as good or sometimes even better than that of *P. sylvestris,* at least under environmental conditions in northern Germany (STRATMANN, 1988; KRASMANN, 1991). With respect of height and diameter growth these findings correspond also with results obtained in the above mentioned progeny trial.

The mean values of wood density were a little lower in the progenies than the values which are normally found in *P. contorta.* In another 18 years old provenance trial coastal provenances from Washington had values around 0.42 g/cm^3, and those from the interior of British Columbia around 0.43 g/cm^3; in comparison, *P. sylvestris* had wood density values of about 0.38 g/cm^3 (STEPHAN, 1982). Higher values between 0.36 g/cm^3 and 0.57 g/cm^3 could also be found with a very great variation in various southern and northern German *P. contorta* stands (SCHÜTT, 1962). Under natural conditions in North America *P. contorta* logs possessed wood densities around 0.5 g/cm^3 (MULLINS and MCKNIGHT, 1981; Anonymous, 1986; SCHWAB, 1992).

The differences between wood density values of wood samples from the stem along the radius and along the stem from the ground to the top can generally be observed in conifer species (KNIGGE and SCHULZ, 1966). The very distinct low value at half stem height is typical for *P. contorta* (see also BJÖRKLUND, 1982). This observation could be confirmed by the present investigation.

The observed correlation between wood density and annual ring width or late wood content, respectively, are typical characters in conifer species, although the correlations are mostly stronger (KNIGGE and SCHULZ, 1966). The higher the content of late wood in the wood volume, particularly by thick-walled and minute poroid cells, the heavier is the wood. This can also explain the heavier wood weight of wood with small annual rings compared with wood containing wider rings. The values of the annual rings were relatively wide in these young trees. In mature trees the distances are between 0.6 mm and 2.2 mm (SCHWAB, 1992).

Summarizing the results one can say that despite of some disadvantages of *P. contorta* the potential of this species is worth to be used by the forestry practice on suitable sites. The differences in wood traits between *P. contorta* and *P. sylvestris* can probably be neglected for the use in the pulp and paper industry.

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References

Anonymous: Neue Importholzkunde. Teil III. Nordamerika: Lodgepole pine. Holzzentralblatt **112**: 1528 (1986). — BJÖRKLUND, T.: Kontortamännyn puutekniset ominaisuudet. (Technical properties of lodgepole pine wood). Folia Forestalia **522**: 1–15 (1982). — BRAZIER, J. D.: A report on the effects of provenance on the timber properties of lodgepole pine. In: *Pinus contorta* as an exotic species. Sveriges Lantbruksuniversitet, Inst. f. Skogsgenetik, Garpenberg. Rapporter och Uppsatser No. 30: 181–207 (1980). — CRITCHFIELD, W. B.: Geographic variation in *Pinus contorta*. Maria Moors Cabot Foundation, Publ. no. 3, 118 pp. (1957). — FABRICIUS, L.: Die Murrayskiefer, *Pinus murrayana* BALFOUR. Forstwiss. Cbl. **58**: 214–229 (1936). — KNIGGE, W. und SCHULZ, H.: Grundriß der Forstbenutzung. P. Parey, Hamburg, Berlin. 583 pp. (1966). — KRASMANN, O.: Anbauerfahrungen mit der Drehkiefer. Diplomarbeit, Fachhochschule Hildesheim/Holzminden. 50 pp. (1991). — LÄHDE, E., NIEMINEN, J., ETHOLÉN, K. and SUOLAHTI, P.: Varttuneet kontortametsiköt suomen eteläpuoliskossa. (Older lodgepole pine stands in southern Finland). Folia Forestalia **533**: 1–38 (1982). — LATTKE, H.: Kiefernarten für die immissionsgefährdeten Hochlagen der Mittelgebirge. Beiträge für die Forstwirtschaft **24**: 155–160 (1990). — MULLINS, E. J. and MCKNIGHT, T. S.: Canadian woods – their properties and uses. University of Toronto Press, Canada (1981). — PERSSON, A.: Wood properties of *Pinus contorta*. In: LINDGREN, D. (Ed.): *Pinus contorta* – from untamed forest to domesticated crop. Department of Forest Genetics and Plant Physiology, Umeå, Sweden. Report **11**: 38–59 (1993). — ROHMEDER, E. und MEYER, H.: 23jährige Anbauversuche in Bayern mit *Pinus contorta* Douglas (*Pinus murrayana* BALFOUR) verschiedener Herkunft. Forstwiss. Cbl. **71**: 257–272 (1952). — SAS Institute Inc.: SAS/STAT User's Guide. Version 6, Fourth Edition, Volume 1. Cary, NC: SAS Institute Inc. 943 pp. Volume 2. Cary, NC: SAS Institute Inc. 846 pp. (1989). — SCHÜTT, P.: Schwankungen im Cellulose- und Ligningehalt bei einigen in Westdeutschland angebauten *Pinus contorta*-Herkünften. Silvae Genetica **7**: 65–69 (1958). — SCHÜTT, P.: Individuelle und bestandesweise Schwankungen der Holzdichte und der Faserlänge bei *Pinus contorta*. Das Papier **16**: 671–675 (1962). — SCHWAB, E.: Eigenschaften importierter kanadischer Nadelhölzer. Holz als Roh- und Werkstoff **50**: 416 (1992). — STEPHAN, B. R.: Zur intraspezifischen Variation von *Pinus contorta* auf Versuchsflächen in der Bundesrepublik Deutschland. I. Ergebnisse aus der Versuchsserie von 1960/61. Silvae Genetica **25**: 201–209 (1976). — STEPHAN, B. R.: Zur intraspezifischen Variation von *Pinus contorta* auf Versuchsflächen in der Bundesrepublik Deutschland. II. Ergebnisse aus der IUFRO-Versuchsserie von 1971/72. Silvae Genetica **29**: 62–74 (1980). — STEPHAN, B. R.: Herkunftsversuche mit *Pinus contorta* in der Bundesrepublik Deutschland. Forstwiss. Cbl. **101**: 245–259 (1982). — STEPHAN, B. R., LIEPE, K. and VENNE, H.: Results of *Pinus contorta* provenance experiments in western Germany. In: LINDGREN, D. (Ed.): *Pinus contorta* – from untamed forest to domesticated crop. Department of Forest Genetics and Plant Physiology, Umeå, Sweden. Report **11**: 100–108 (1993). — STRATMANN, J.: Ausländeranbau in Niedersachsen und den angrenzenden Gebieten. Schriften aus der Forstlichen Fakultät der Universität Göttingen und der Niedersächsischen Forstlichen Versuchsanstalt **91**: 76–79 (1988).

Geographic Variation of *Abies grandis*-Provenances Grown in Northwestern Germany[1])

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Summary

In 3 field trials in northwestern Germany height and diameter growth as well as mortality of 52 provenances of Grand fir (*Abies grandis* LINDL.) up to the age of 15 years were investigated. Fast growing provenances originate from the East of Vancouver Island and the Olympic Peninsula, the West of the Cascade Range and – with exceptions – from the coastal regions of Oregon. But provenances from the South of the last mentioned region show the highest plant losses and a high percentage of forked trees. In general a rather large variation within provenances was observed. The estimated correlation coefficients between height at age 15 and some geographic variables are weak. In the years after planting pronounced rank changes occurred. Height growth seems to stabilize at a plant age of about 7 or 9 years. Finally wood properties of Grand fir and the silvicultural possibilities to influence them are discussed.

Key words: Grand fir (*Abies grandis*), provenances, height and diameter growth, mortality, correlations, rank changes, wood properties and silviculture.

FDC: 232.11; 232.12; 165.5; 174.7 *Abies grandis;* (430).

Zusammenfassung

Auf 3 nordwestdeutschen Versuchsorten wurde das Höhen- und Durchmesserwachstum sowie die Mortalität von 52 Küstentannen-Provenienzen bis zum Alter von 15 Jahren untersucht. Raschwüchsige Provenienzen stammen vor allem aus folgenden Regionen: Ostseite von Vancouver Island und Olympic Peninsula, Westseite der Kaskaden und – mit Ausnahmen – Küstenregion Oregons. Herkünfte aus dem südlichen Teil der zuletzt genannten Region zeigen aber die höchsten Pflanzenausfälle und den höchsten Anteil an zwieseligen Stämmen. Innerhalb von Provenienzen ist eine ausgeprägte Differenzierung feststellbar. Die geschätzten Korrelationskoeffizienten zeigen nur schwache Zusammenhänge zwischen der Höhe im Alter von 15 Jahren und einigen geographischen Variablen. In den Jahren nach der Versuchsbegründung findet eine ausgeprägte Rangverschiebung der Provenienzmittelwerte statt. Etwa ab dem Alter von 7 oder 9 Jahren scheint sich das Höhenwachstum zu stabilisieren. Abschließend wird auf die Holzeigenschaften der Küstentanne eingegangen und die waldbaulichen Möglichkeiten einer Beeinflußung derselben diskutiert.

Introduction

Grand fir (*Abies grandis* LINDL.) was first introduced to Germany some 120 years ago (KILLIUS, 1931) and several stands have shown good to excellent growth. Some examples: HEWICKER (1988) reported on a Grand fir stand in northern Germany on poor sandy soils, where the tallest trees had at an age of 56 years a height of 33 m. DONG et al. (1990) compiled growth and yield data of a Grand fir stand mixed with Douglas fir in southern Germany. At the age of 58 years Grand fir had reached mean heights of 35.9 m and was 5 m taller than the Douglas fir. In a review leaflet on Grand fir the opinion is issued that on good sites at an age of 80 years heights of 50 m and breast height diameters of 100 cm can be expected (Anonymus, 1987).

In the natural habitat the species performs well on different types of sites (QUERENGÄSSER, 1959; HERMANN, 1981), but it does not grow well on compacted soils with stagnant water and oxygen deficiency. German investigations have revealed that on these sites Grand fir is not able to develop an appropriate tap root system (KREUTZER et al., 1988) and it is therefore not able to replace our indigenous silver fir (*Abies alba* MILL.), which has been destroyed by air pollution in several regions. Grand fir is to a limited extent used as well as Christmas tree and early returns are gained by selling branches for covering or ornamental purposes. But nevertheless a large scale planting is generally not recommended. In Schleswig-Holstein, the northernmost state in Germany, planting recommendations are limited to poor sandy soils which are influenced by ground water. These sites are too poor for Norway spruce and too cold for Douglas fir, and Scots pine may suffer from a needle cast disease (ROEHRING, 1988). In Lower Saxony 2 management goal

[1]) Dedicated to Dr. G. H. MELCHIOR on his 70th birthday.