Differences in growth performance of four provenances of Giant Sequoia (Sequoiadendron giganteum (Lindl.) Buchh.)*)

By G. H. Melchior and S. Herrmann

Institut für Forstgenetik und Forstpflanzenzüchtung
der Bundesforschungsanstalt für Forst- und Holzwirtschaft,
Siekerlandstraße 2, 2070 Großhansdorf 2

(Received 8th January 1987)

Summary

Four provenances of giant sequoia (*Sequoiadendron giganteum* (Lindl.) Buchh.) originating from the counties Fresno, Calaveras, Tulare and from Sequoia National Forest in California were tested on three sites in the Federal Republic of Germany (Rengsdorf/Rhineland Palatinate; Reinhausen/Lower Saxony; and at Grosshansdorf/Schleswig-Holstein).

At age 14 years differences in survival between locations and provenances were ascertained. At the trial in Grosshansdorf survival was influenced particularly by frost damage in a frost pocket and a following infection by *Armillaria mellea* (Vahl) Karst. In spite of the small number of provenances there were significant differences in height, d.b.h. and diameter at half tree height between provenances and locations. The provenance Tulare which is known from other trials to perform well proved to have inferior growth and survival up to age 14 years. At the trial at Rengsdorf height growth was slightly negatively correlated with the altitude at the seed origin.

A prerequisite for establishing stands of giant sequoia at a commercial scale is the choice of frost hard (and well performing) provenances. Such stands might be promising at suited sites in the Federal Republic of Germany.

Key words: giant sequoia, variability, survival, growth performance, frost damage, damage by *Armillaria mellea*.

Zusammenfassung

Vier Provenienzen des Mammutbaumes wurden auf drei Standorten in der Bundesrepublik Deutschland geprüft. Im Alter von 14 Jahren wurden zwischen Standorten und zwischen Provenienzen Unterschiede in der Überlebensfähigkeit festgestellt. In einem Versuch in Großhansdorf konnten die Ausfälle insbesondere auf Frostschäden in einem Kältestau und wahrscheinlich nachfolgenden Hallimaschbefall zurückgeführt werden. Trotz der geringen Anzahl von Herkünften variierten die Wachstumsmerkmale Höhe, BHD und Mittendurchmesser gesichert zwischen den Herkünften und Standorten. Die bisher in anderen Anbauversuchen als günstig angesehene Herkunft Tulare erwies sich dabei den Provenienzen aus den Counties Fresno, Calaveras und Sequoia National Forest bis zum Alter 14 als unterlegen.

Das Höhenwachstum an einem der Versuchsorte (Rengsdorf) war schwach negativ mit der Höhenlage des Ursprungortes korreliert. Voraussetzung für den Anbau des Mammutbaumes in wirtschaftlichem Ausmaß ist die Auslese frostharter und wüchsiger Populationen. Solche Anbauten könnten auf geeigneten Waldstandorten in der Bundesrepublik Deutschland aussichtsreich sein.

Introduction

Since middle of the last century, giant sequoia has been introduced into Europe in about 600 occasions (Libby, 1981) from the small natural area of distribution along the Californian Sierra Nevada (Little, 1975). It has exhibited a good growth performance even in larger afforestations (Kleinschmit, 1984; Fuldner, 1968). Yet, only in the mid-sixties a provenance trial with 4 provenances was initiated by W. Langner on 3 sites in the Federal Republic of Germany. Prerequisite for these trials was knowledge about the culture of giant sequoia which was elaborated by Martin (1957/58). In this paper results of the 14 year old giant sequoia provenance trial are presented.

Material and Methods

The provenances originate from the counties of Tulare, Fresno, Calaveras, and from Sequoia National Forest in California, and several trees from each provenance were harvested. (*Tab. 1*). The trial areas were established with 3 resp. 4 year old plants in the forest districts of Rengsdorf (Rhineland Palatinate), Reinhausen (Lower Saxony) and at Grosshansdorf (Schleswig-Holstein). Some details concerning the trial areas are shown in *Table 2*. The previous vegetation on the trial areas were decidous trees (beech in Rengsdorf and Reinhausen and an apple orchard at Grosshansdorf). At Rengsdorf and Reinhausen a randomised

Tab. 1. — Sites of the seed origin of four provenances of *Sequoiadendron giganteum* and survival (%) as well as growth characters at 14 years of age.

Origin :				
No.	(2)	(1)	(3)	(4)
County	Tulare	Fresno	Calaveras	Seq.Nat.For.
Latitude (apr.)	36°26′	36°45′	38°15′	36°15′
Altitude (m)	1830	1830	1433	1220
Survival (%) :				
Reinhausen (Niedersachsen)	48	72	67	59
Rengsdorf (Rheinland-Pfalz)	55	83	69	73
Average	52	77	68	66
Großhansdorf (Schlesuig-Holstein)	-	56	87	81
Average	-	75	70	68
Growth characters :				
Height (cm)	362	399	418	426
DBH (cm)	8.1	9.4	9.5	10.6
MD* (cm)	5.8	6.3	6.4	7.0

* Diameter at half tree height.

*) Dedicated to Prof. Dr. W. Langner's 80th birthday.

Tab. 2. — Some soil and climatic characteristics at the trial areas.

Trial area	Soil characteristics	annual average temperature (°C)	annual average precipitation (mm)
Reinhausen (Niedersachsen)	sandy loam, variegated sandstone	7.2	607
Rengsdorf (Rheinland-Pfalz)	sandy loam, brown earth	8.8	750
Großhansdorf (Schleswig-Holstein)	sandy loam - loamy sand, ground moraine	8.1	739

block design was established with 4 replications and 16 trees per plot. At Grosshansdorf the remaining material with 3 provenances, replications and 4 trees per plot were planted.

At age 5 and 14 years height and diameter at breast height as well as at half the tree height were measured and at age 14 years the survival rate. Frost damage on the site at Grosshansdorf was estimated at age 13 and 16 years. At age 13 the attack of *Armillaria mellea* was first observed. Calculating of the metric characters were done by analysis of variance (random-model) and survival rate with the χ^2-test. Correlations were calculated by using Spearman's rank correlations.

Results

Survival: Between the trial areas significant differences were found with the highest survival rate at Rengsdorf (*Table 1*). Also among the provenances there are significant differences in survival rate. Noticeable are the large losses of the seed source Tulare. Between the three trial areas and the provenances there seems to be an interaction. In Reinhausen and Rengsdorf the provenance Fresno survived well, whereas at Grosshansdorf there were considerable losses. Accordingly, the provenances Sequoia National Forest and Calaveras reacted vice versa.

Damage by Frost and Armillaria mellea: At the trial in Grosshansdorf the damages which occurred between the ages 13 and 16 were investigated more closely. A distinct red-brownish coloring of the needles beginning at the bottom of the crown was observed. Later the color turned grey. Damaged and undamaged parts of the crown could easily be distinguished allowing an easy identification of these damages as being due to frost.

In *Figure 1* the frost damages are shown irrespective of the provenance but dependent of the position of the trial area. Trees growing in the frost pocket in the northern part of the area (replication IV) were damaged most.

Giant sequoia is known to be slightly resistant against *Armillaria mellea* (Vahl) Karst.. It occurs frequently and in its virulent stage on sites previously covered with deciduous trees (Schwerdtfeger, 1981, Phillips and Burdekin, 1982). At Grosshansdorf *Armillaria mellea* occurred frequently after trees were damaged by frost. It was not possible to find out yet if the attack occurred as a primary attack on these trees. However, the fungus was found only on trees which were damaged by frost. On the other trial areas no such damages could be found.

Growth Performance: Figure 2 shows significant differences between the trials in height, in d.b.h. and in diameter at half the tree height (see also *Table 1* and 3). In Rengsdorf height growth was better than in Reinhausen and Grosshansdorf. The sensitive reaction of giant sequoia to the trial area becomes perceptible in the differences between the repetitions of a trial. Between provenances there are significant differences, which are demonstrated by inferior growth of the provenance Tulare and the superior growth of the provenance Sequoia National Forest (*Figure 2, Table 3*).

The different provenances seem to react differently to the nursery conditions and/or to planting shock. For instance, Tulare showed its inferior growth already after the first growing period. However, this provenance effect decreases to about 9% after 10 years in the field while the effect of the site increases to about 76% (*Table 3*). The differences in growth between provenances become more similar with time. Thus, the provenance Tulare increased in height since age 5 in Rengsdorf about 8-fold and in Reinhausen about 5 in Rengsdorf about 8-fould and in Reinhausen about 5-fold. The other provenances maintained a very similar increase at Reinhausen as Tulare (4.4- to 5-fold, *Fig. 2*), however a marginal increase at the climatic better site in Rengsdorf (5.9- to 7.6-fold).

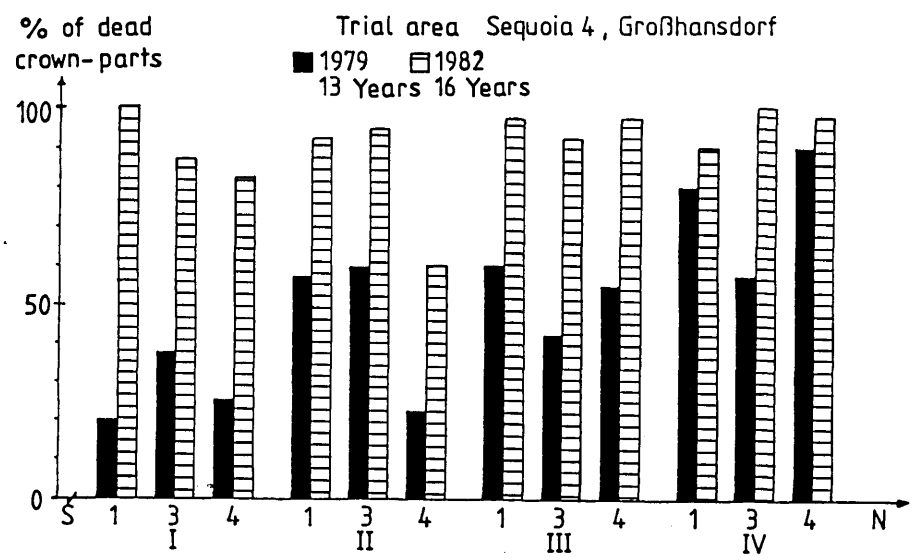

Fig. 1. — Dead parts of the crown due to frost damage (%) in 3 provenances (1, 3,, 4) from south (Repl. I) to north (Repl. IV).

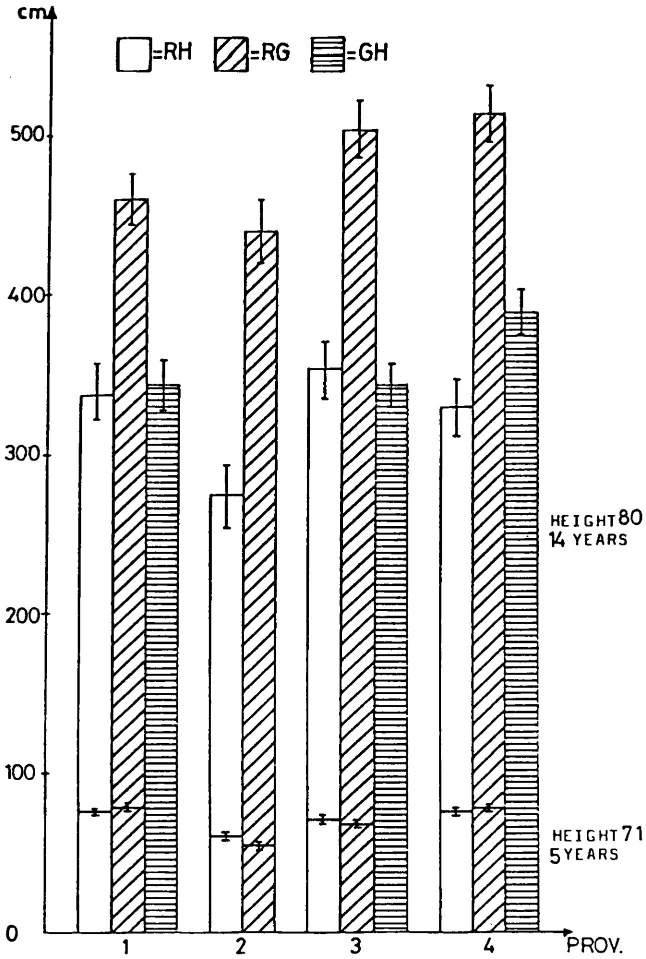

Fig. 2. — Average heights by provenances at trial areas.

Correlations: Significant correlations were found between height, d.b.h. and diameter at half tree height (*Table 4*). The positive correlation between survival at age 14 and height at age 5 proved to be significant only for the provenance Fresno in the trial at Rengsdorf when survival of the remaining plants is correlated to their height at age 5.

Apparently the growth characters are negatively correlated with the height a.s.l. of the place of origin of seed source (*Table 1*). At the trial area Rengsdorf an increase in altitude of the seed source of 100m involves a decrease in tree height about 10 cm and a decrease in d.b.h. of about 3.7 cm. At Grosshansdorf and Reinhausen such a relationship could not be found.

Discussion and Conclusions

The natural area of distribution of giant sequoia extends only little in north-south direction. So, it may be assumed that the variation of the species is small. However, the

Tab. 3. — Relative variance components for growth characters at the age of 5 (1971) and 14 (1980) years.

Source of variation	H 71	H 80	DBH 80	MD 80
Sites (S)	0 n.s.	76***	65***	57***
Replications in Sites	9***	14***	23***	27***
Provenances (P)	84***	9***	11***	16***
S x P	7	0	0	0

Tab. 4. — Rank correlations between different characters of 5 and 14 year old *Sequoiadendron giganteum* provenances.

Characters	Height 71	Height 80	DBH 80	MD 80
Survival 80	0.3446 *	0.5231 **	0.5336 **	0.4419 **
Height 71	-	0.0636 n.s.	0.1826 n.s.	0.0351 n.s.
Height 80		-	0.9647 ***	0.9436 ***
DBH 80			-	0.9185 ***

growth characters showed significant differences which were found not only in the nursery but up to the age of 14 years. The provenance Tulare which has up to now been viewed as a particularly well growing one has proven to be inferior in growth up to this age. However its increase in growth is higher than in other provenances at the warmest trial site at Rengsdorf. It is about equal to the other provenances in Reinhausen. So this different result to former ones (Anon., 1982) may be due to the fact that most stands of giant sequoia in this country were established on warmer sites, where Tulare with the time could overcome other provenances. Since also in survival rate significant differences were found, further investigations are necessary to find provenances which in all probability are well adapted (Guinon *et al.*, 1982). The survival of all provenances past the time in the nursery proves that giant sequoia is suitable for various forest sites in the Federal Republic of Germany (see also Libby *et al.*, 1975). However, sites with frost pockets (or with strong winter frosts) should be excluded.

Significant differences in frost hardiness were not found in this investigation. But because only few provenances and trees were tested, they may be assumed to exist (Guinon *et al.*, 1982). If there is such damage an attack by the weak parasite *Armillaria mellea* must be expected especially if previously decidous trees were growing on the site as was the case on the trial area at Grosshansdorf (see also Schwerdtfeger, 1981; Phillips and Burdekin, 1982).

Testing the suitability of provenances and the avoidance of frost damages would be the prerequisite before giant sequoia could be used for larger afforestation in suited areas. If a relationship between altitude of the seed source and growth potential (and frost tolerance) could be further verified the selection of suitable provenances could be simplified considerably. The correlation found here gives a first indication of the existence of such a relationship.

Acknowledgement

We thank Dr. Ostrom, former director of the Timber Management and Research Bureau, USDA, Forest Service, Washington, for his endeavour for supplying seed sources to this institute, and to the directors of the forest districts of Rengsdorf and Reinhausen Dres. Stöhr and von Lüpke as well as the waterworks of the city of Hamburg for leaving the areas for this trial. The technical assistance of Mrs. A. Philipowski and aid in statistical analysis by Mr. Krusche is gratefully acknowledged.

Literatur

Anonymus: *Sequoiadendron giganteum* (Lindl.) Buchh.. Merkblatt über fremdländische Baumarten, LÖLF Nordrhein-Westfalen. 3 pp. (1982). —— Fuldner, R.: Zur forstlichen Bedeutung des Mammutbaumes. Holz-Zbl. **108**, 1555—1558 (1968). —— Guinon, M., Larsen, J. B. and Spethmann, W.: Frost resistance and early growth of *Sequoiadendron giganteum* seedlings of different origins. Silvae Genetica **31**, 173—178 (1982). —— Kleinschmit, J.: Der Mammutbaum (*Sequoiadendron giganteum* (LINDL.) BUCHHOLZ), nur eine faszinierende Exotenart? Beih. z. Schweiz. Z. f. Forstwesen Nr. **72**, 61—72 (1984). —— LIBBY, W. J., KAFTON, D. and FINS, L.: California conifers (Conservation of gene resources). FAO Report on pilot study on the methodology of conservation of forest genetic resources. FO/Misc./75/8: 41—54 (1975). —— LIBBY, W. J.: Some observations on *Sequoiadendron* and *Calocedrus* in Europe. Calif. Forestry and Forest Products **49**, 12 pp. (1981). —— LITTLE, JR., E. L.: Rare and local Conifers in the United States. Conservation Research Rep. No. **19**, USDA Forest Serv., Wash. DC, 25 pp. (1975). —— MARTIN, E. I.: Die Sequoien und ihre Anzucht. Mitt. Dtsch. Dendrol. Ges. **60**, 3—62 (1957/1958). —— PHILLIPS, D. H. and BURDEKIN, D. A.: Diseases of forest and ornamental trees. The Macmillan Press Ltd., London and Basingstoke, 435 pp. (1982). —— SCHWERDTFEGER, F.: Die Waldkrankheiten. 4. Aufl., Verlag P. Parey, Hamburg und Berlin, 486 S. (1981).

Some Experimental Results concerning Age Dependency of Different Components of Variance in Testing Norway Spruce (Picea abies (L.) Karst.) Clones

By M. HUEHN*), J. KLEINSCHMIT**) and J. SVOLBA**)

(Received 19th December 1986)

Summary

A Norway spruce clonal test, established with 5 clones on 5 extremely contrasting sites in 1967 and remeasured for plant-height 10 times until 1981 has been used to estimate the relative importance of the components of variance for "locations", "clones", "locations × clones", "blocks", and "experimental error" dependent on the time. The results show, that in this study "blocks" and "interaction" are of minor importance, accounting to less than 5% of the total variation. Clones account for roughly 10%. These three sources of influence remain more or less constant over time. Considerable changes however occur in the components for "locations" and "experimental error". The first one increases quickly until it reaches a plateau at about 70%, the last one decreases correspondingly and ends up after few years at 15%. All values are quite stable at the end of the time of measurement. These results are discussed on a more general background.

Key words: Norway spruce, clonal test, components of variance, early testing.

Zusammenfassung

Eine Fichten *(Picea abies)*-Klonprüfung, die 1967 mit 5 Klonen auf 5 extrem unterschiedlichen Standorten begründet worden war und seither bis 1981 10 mal für das Merkmal Pflanzenhöhe aufgenommen worden ist, wird verwendet, um den Beitrag der Variationsursachen „Anbauorte", „Klone", „Anbauorte × Klone", „Blöcke" und „Versuchsfehler" in Abhängigkeit von der Zeit zu schätzen.

Die Ergebnisse zeigen, daß in diesem Versuch „Blöcke" und „Interaktion" mit weniger als 5% einen unbedeutenden Beitrag zur Gesamtvariation leisten. „Klone" erklären rd. 10% der Variation. Diese 3 Variationsursachen bleiben über die Zeit mehr oder weniger konstant. Erhebliche Veränderungen treten aber im Laufe der Zeit bei den Varianzkomponenten „Anbauorte" und „Versuchsfehler" ein. Erstere nimmt rasch zu, bis sie nach wenigen Jahren ein Plateau bei rd. 70 % erreicht, letztere nimmt entsprechend ab, bis sie sich bei etwa 15% stabilisiert. Erstaunlich ist die Stabilisierung aller Varianzkomponenten bereits nach wenigen Jahren.

Die Ergebnisse werden vor einem breiteren Hintergrund diskutiert.

Herrn Professor Dr. W. LANGNER zum 80. Geburtstag gewidmet.

*) Institut für Pflanzenbau und Pflanzenzüchtung der Universität Kiel, Olshausenstraße 40-60, D-2300 Kiel

**) Niedersächsische Forstliche Versuchsanstalt, Abteilung Forstpflanzenzüchtung, D-3513 Staufenberg 6

Introduction

Testing clonal material under different site conditions resulted repeatedly in pronounced differences of variance components depending on time. During the first years after test establishment site influences play a minor role and clonal influences are predominant. These are still strongly under the influence of the nursery site. Only after some years the site influences increase and finally by far the biggest part of variation can be explained by site influences, the clonal component decreases simultaneously.

This rule is not only true for clones but for other plant material as well. HUEHN (1974) could show for Norway spruce single tree progenies and controlled crosses, measured from 1959—1971 for tree height, that the variance components for progenies considerably decreased while variance components for planting sites increased correspondingly. The component for interaction did not change much. In this study the different variation components seem to approach fixed values asymptotically.

Finally the plateau-values reached 25% for progenies, 60% for locations, roughly 8% for interaction and 7% for experimental error.

NICHOLS (1965) already describes a change of variance components for *Pinus radiata* wood characteristics depending on age in 1965.

LEWARK (1981) found for the same clonal material used in this study strong annual fluctuations for variance components of annual ring width, basic density and other wood characters. The consequences resulting from these findings for early selection are discussed by LEWARK and elsewhere (KLEINSCHMIT and KNIGGE 1967).

In clonal tests these components of variance can be partly interpreted genetically.

For a judgement on the silvicultural use of clones the time of evaluation plays due to the influences discussed above a considerable role. Valid conclusions can be drawn only after the components of variance have been stabilized.

The following three questions have to be answered:

1. Do the components of variance stabilize sufficiently at all? Theoretically a continuous fluctuation during growth development would be possible too.
2. If the components of variance stabilize, in which age can this be expected?