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Comparison of French and German sessile oak (*Quercus petraea* (Matt.) Liebl.) provenances

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Abstract

Provenances originating from French and German sessile oak seed sources were analysed 23 years after planting at nine different locations in Northwest Germany. In general, German provenances are better adapted to the prevailing conditions of the test sites showing a better survival. Differences between the provenances in measured growth characters (“DBH”, “height”) were less pronounced than in observed quality parameters (“form”, “crown”). Five of the German provenances showed a better stem form; only three French provenances exceeded the overall mean. Variation in phenotypic stability between provenances could be observed as well as rank changes of provenances measured at different ages. Observed variation in stability was mainly attributable to single provenances, however, no pattern of variation could be detected. Besides the German seed sources “Bundesgebiet”, “Spessart” and “Göhrde” some French provenances (“Reno Valdieu”, “Bertranges”, “Darney” and “Der”) can be recommended as substitute in low crop years.

Key words: Q. petraea, provenance, test, adaptation, stability.

Introduction

In Germany about 3306 seed stands of sessile oak are registered for harvesting, which cover an area of nearly 32.000 ha (FEDERAL OFFICE FOR AGRICULTURE AND FOOD 2008, available at www.ble.de). There is an average amount of harvested acorns of about 233 tons per year over a ten-year period (FEDERAL OFFICE FOR AGRICULTURE AND FOOD 2010, available at www.ble.de). However, seed stands in Germany fructificate irregularly. Furthermore, the acorns cannot be stored for a sufficiently long time to bridge the gap between subsequent harvests. In order to provide sufficient seed and seedlings, research on optimal storage conditions of acorns (HOFFMANN, 1990; GUTHKE and SPETHMANN, 1993; LIESEBACH and ZASPEL, 2004) or mass propagation of superior seedlings (JÖRGENSEN, 1994) has been done.

Oak stands of excellent quality grow in France and due to favourable climatic conditions, these stands often show a prolific seed production whereas in Germany only rare harvests are possible. In order to overcome local bottlenecks and to provide practical forestry with sufficient seedlings it would be interesting to know if French oaks were suitable for cultivation in Northern German.

Unfortunately, only little information was available about the performance of French provenances under German conditions. With the intention of getting more information associated with French provenances the former Lower Saxony Forest Research Institute established a provenance trial with provenances from French *Quercus petraea* stands. It was intended to compare French and German provenances under near practice conditions, so cultural treatments were comparable to the recommendations valid for practical forestry at the time of trial establishment

Materials and Methods

Seedlings from eleven French stands were obtained by the private German nursery Rahte, and as a basis of comparison, six German provenances and one progeny

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Table 1. – List of tested provenances.

No	name	Provenance / Progeny		State	Latitude	Longitude	Seedling age
		code	region				
1	Forêt Domaniale de Boulogne	QPE 106	Secteur ligérien	F	47°36'N	01°28'E	1 + 0
2	Forêt Domaniale Saint Sauvant	QPE 311	Charentes - Poitou	F	46°22'N	00°04'E	2 + 0
3	Forêt Domaniale Hez Froidmont	QPE 102	Picardie	F	49°22'N	02°20'E	1 + 0
4	Forêt Domaniale Fontainebleau	QPE 105	Sud Bassin parisien	F	48°24'N	02°42'E	1 + 0
5	Forêt Domaniale des Abbayes	QPE 107	Berry-Sologne	F	46°55'N	02°22'E	2 + 0
6	Forêt Domaniale de Dreuille	QPE 411	Allier	F	46°28'N	02°52'E	1 + 0
7	Forêt Communale Reichshoffen	QPE 204	Nord-Est gréseux	F	48°58'N	07°40'E	1 + 0
8	Forêt Domaniale de Der*	QPE 212	Est Bassin parisien	F	48°33'N	04°50'E	1 + 0
9	Forêt Domaniale des Bertranges	QPE 422	Morvan - Nivernais	F	47°11'N	03°05'E	2 + 0
10	Forêt Domaniale de Darney	QPE 203	Nord-Est limons et argiles	F	48°03'N	06°03'E	1 + 0
11	Forêt Domaniale de Reno Valdieu	QPE 104	Perche	F	48°32'N	00°39'E	1 + 0
12	FA Göhrde, "Göhrde"	03 3 818 03 022 2	Heide and Altmark	D	53°05'N	10°56'E	1 + 0
13	FA Liebenburg, "Liebenburg"	03 4 818 07 723 2	Harz, Weser- and Hessisches Bergland without Spessart	D	52°09'N	10°15'E	1 + 0
14	FA Rothenbuch, "Spessart"	09 1 818 10 094 4	Spessart	D	49°58'N	09°25'E	1 + 0
15	FA Dassel, "Seelzerthurm"*	818 07	Harz, Weser- and Hessisches Bergland without Spessart	D	51°44'N	09°56'E	1 + 0
16	Elmstein-S, Hinterweidenthal-W	818 08	„Pfälzerwald"	D	Mixture	Mixture	1 + 0
17	FA Liebenburg, "Bundesgebiet"**	03 1 818 07 001 4	Seed orchard with plustrees selected in regions 02, 03, 06, 07, 08, 09	D	52°09'N	09°47'E	1 + 0

* not officially registered; ** formerly „Berkel".

from a seed orchard were included in the trials. Detailed information on the "provenances" is given in *Table 1* and *Fig. 1.* Entry 16 is a mixture of stands and is not displayed in *Fig. 1.*

The experiment was planted in eight locations in 1984 and in one location in 1985, all on forestland. Prior to planting, all locations were cleared. Six trials are located in the northern lowlands; three locations are in the hilly regions of Northwest Germany (*Fig. 2*). Both planting and replanting one vegetation period after planting was done by hand. Weed control happened mainly mechanically, herbicides were used only in two locations. During the first years tending focussed on removal of competitors to young oak seedlings. No clearances within the trials were made until age 23 and 22, respectively. The experiments were planned for a long operating time, so the trials were established with large-sized plots. Description of the locations and the specific field trial layouts are specified in *Table 2*.

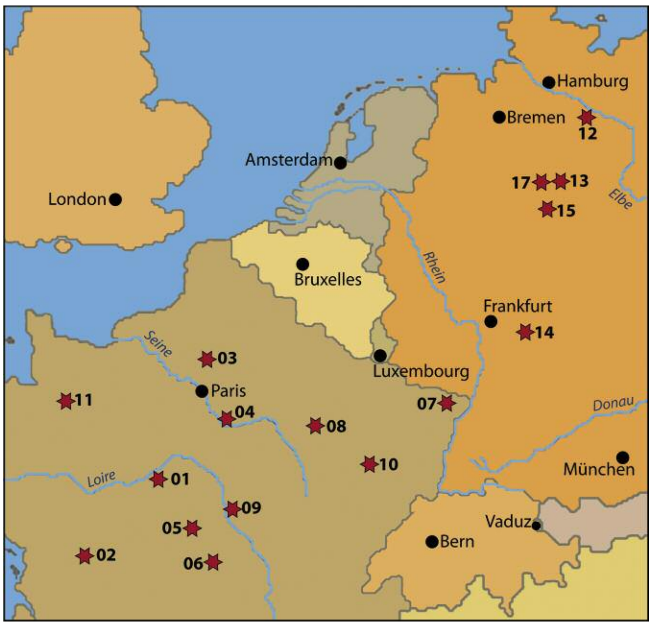

Figure 1. – Location of seed sources.

Figure 2. – Location of test sites.

Statistical design in all trials is a randomized complete block design with two or three replications, respectively. Assessments and measurement were carried out 23 and 22 years, respectively, after planting. In order to economize evaluation effort, trees in the six center-rows of the generally existing twelve rows per plot i.e. rows 4 to 9, were used for evaluation. Only dominant and co-dominant trees were measured (i.e. Kraft classes 1–3).

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Table 2. – Characteristics of test location; field trial layout. (Names in brackets were used by KLEINSCHMIT and SVOLBA (1995, 1996)).

Region Forest district	Elevation asl	Temp. (°C) year	 5-9	Pr. (mm) year	 5-9	Site class	Repl.	Plot size (m)	Spacing (m)	stems / ha	Measured Rows (max. plant/row)
Lowlands											
Harsefeld (Osterholz-Scharmbeck)	23	8,5	14,0	760	370	Pseudogley, mesotroph	2	24 x 20	2,0 x 0,4	12500	6 (50)
Oerrel	65	8,5	15,0	606	296	Loam above sand	3	24 x 22	2,0 x 0,5	10000	6 (44)
Rotenburg	40	8,3	14,7	687	328	Rich, humid soil with perched water	2	24 x 22	1,8 x 0,4	13888	6 (55)
Ahlhorn, comp. 1356 (Syke)	38	8,4	14,5	699	326	Poor brown soil	3	22 x 18	1,5 x 0,4	16666	6 (55)
Ahlhorn, comp. 12	46	8,6	14,8	760	360	Para brown soil-Pseudogley	3	24 x 18	2,0 x 0,4	12500	6 (44)
Neuenburg (Hasbruch)	38	8,2	14,3	730	340	Rich sandy soil	3	22 x19	2,0 x 0,4	12500	6 (48)
Hilly region											
Clausthal (Liebenburg)	160	8,0	14,5	670	320	Poor brown soil on gravel	2	24 x 22	2,0 x 0,5	10000	6 (44)
Wolfenbüttel (Schöningen)	210	8,0	14,7	725	350	Pseudogley	2	24 x 18	2,0 x 0,4	12500	6 (44)
Grünenplan	275	8,0	16,0	850	240	Gley soil	3	24 x 22	2,0 x 0,5	10000	6 (44)

Assessed traits were survival and diameter at breast height (DBH) within the measurement rows. Single tree height was additionally measured on the first five callipered (diameter measured) trees/row (i.e. max. 30 trees/plot). Status of tree was scored on all trees within measurement rows at a four level scale where 1=fully alive, 2=alive with constraints, 3=dead or missing, 4=not planted. Stem straightness and type of crown were visually scored on all callipered trees per plot according the following scheme:

score	stem straightness (form)	beginning of branching (crown)
1	totally straight, very good fit for silvicultural use	continuous main shoot
2	benched slightly, good fit for silvicultural use	at ¾ total tree height
3	benched slightly to medium, fit for silvicultural use	at ½ total tree height
4	benched medium to strong, marginal fit for silvicultural use	at ¼ total tree height
5	benched strong to very strong, unfit for silvicultural use	no real main shoot, shrub

Survival was calculated as fraction of fully alive trees (score 1) to planted trees within the measurement rows. The number of stems per hectare was calculated as:

$n_{ha} = n_m * 10\,000$ / sample area and
sample area $= n_l * s$, where

n_m = number of measured trees (DBH)

n_l = number of planted trees within measurement rows

s = growing space of single tree in m^2.

For statistical analysis, quality traits were grouped into positive and negative proportions. In order to get a dichotomous decision of the positive fraction only the trees with scores 1 and 2 for stem straightness and type of crown were used to calculate "form (%)" and "crown (%)", respectively. The determination of negative quality (improper quality) was made by calculating the percentage of trees with either stem form scores greater than 3 or trees scored for type of crown in class 4 or 5. For statistical analysis, plot means were used.

Volume was determined on single tree and hectare basis. A form factor was calculated for each single location using all measured DBH-height relations within that location. For every pair of DBH-height values the linear coefficient of regression b_0 was calculated in each trail as:

$$h = a + b_0 \cdot DBH$$

In each plot, an absolute term (a_{pl}) was estimated from plot mean h_{pl} and DBH_{pl} as:

$$a_{pl} = h_{pl} - b_0 \cdot DBH_{pl}$$

Missing tree heights in each plot were estimated as:

$$h = a_{pl} + b_0 \cdot DBH$$

This procedure offers the advantage, that even with few pairs of values per plot easy, but robust estimates of missing heights are possible. With estimated heights for each callipered tree and the form factor calculated for each location a single-tree volume can be calculated. The volume per hectare is estimated with average volume per tree and calculated number of stems per hectare with the volume function according to BERGEL (1974).

The program package SAS was used for all statistical analyses. On each site, plot means were subjected to a two-way analysis of variance with PROC MIXED according to the following linear model:

$$x_{ij} = m + \gamma_i + \rho_j + \epsilon_{ij}$$

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Where x_{ij} is the observed value of entry i (provenance i) in replication j, m is the general mean, γ_i is the effect of entry i, ρ_j the effect of replication j and ϵ_{ij} is the residual deviation. The factor replication was considered as random. One progeny ("Spessart") was planted twice (two plots per replication) in six locations. Therefore, adjusted progeny means (LSMEANS) per location were calculated and used for further analysis.

After the single trial evaluation, a combined two-way analysis of variance was run with PROC MIXED on individual data according to the following linear model:

$$x_{ijk} = m + \gamma_i + \delta(\gamma)_{j(i)} + \epsilon_{ijk}$$

Where x_{ijk} is the observed value of entry j within country-group i in the location k, m is the general mean, γ_i is the deviation to the general mean attributable to country-group i, $\delta(\gamma)_j$ is the deviation to the general mean attributable to the entry j within the country-group i and ϵ_{ijk} is the residual deviation. The Sidak t test, provided by the SIDAK option in PROC MIXED, is used for comparison of provenance means versus overall mean. Box and whisker plots produced by PROC BOXPLOT express the variation between locations and provenances, respectively. The mean rank difference (HÜHN, 1979) calculated with all possible pair wise rank differences averaged across location was used to measure provenance stability. PROC CORR was used to determine correlations between traits measured at age 10 and 23, respectively.

Results

Locations

Analyses of variance for observed traits in single locations verified provenance effects and the results are presented in *Table 3*. Significant provenance effects were

Table 3. – Analyses of variance for single locations; Asterisks indicate significant F-values for provenance effects at 0.05 (*), 0.01 (**) and 0.001 (***) level. ns = non-significance at 0.05 level.

Region Location	Trait								
	Survival (%)	DBH (cm)	Height (m)	Form (%)	Crown (%)	improper quality (%)	Stems (n/ha)	Vol/tree (dm^3)	Vol/ha (m^3)
Lowlands									
Harsefeld	ns	*	*	*	ns	ns	ns	**	ns
Oerrel	***	ns	**	***	***	**	***	ns	***
Rotenburg	ns	ns	ns	**	ns	**	ns	ns	***
Ahlhorn_1356	**	*	ns	ns	***	*	***	ns	ns
Ahlhorn_12	***	**	**	***	*	**	***	**	***
Neuenburg	**	ns	ns	**	ns	*	**	ns	ns
Hilly region									
Clausthal	*	ns	ns	***	*	***	*	ns	ns
Wolfenbüttel	***	ns	ns	**	ns	***	***	ns	*
Grünenplan	**	ns	ns	*	ns	ns	**	ns	*

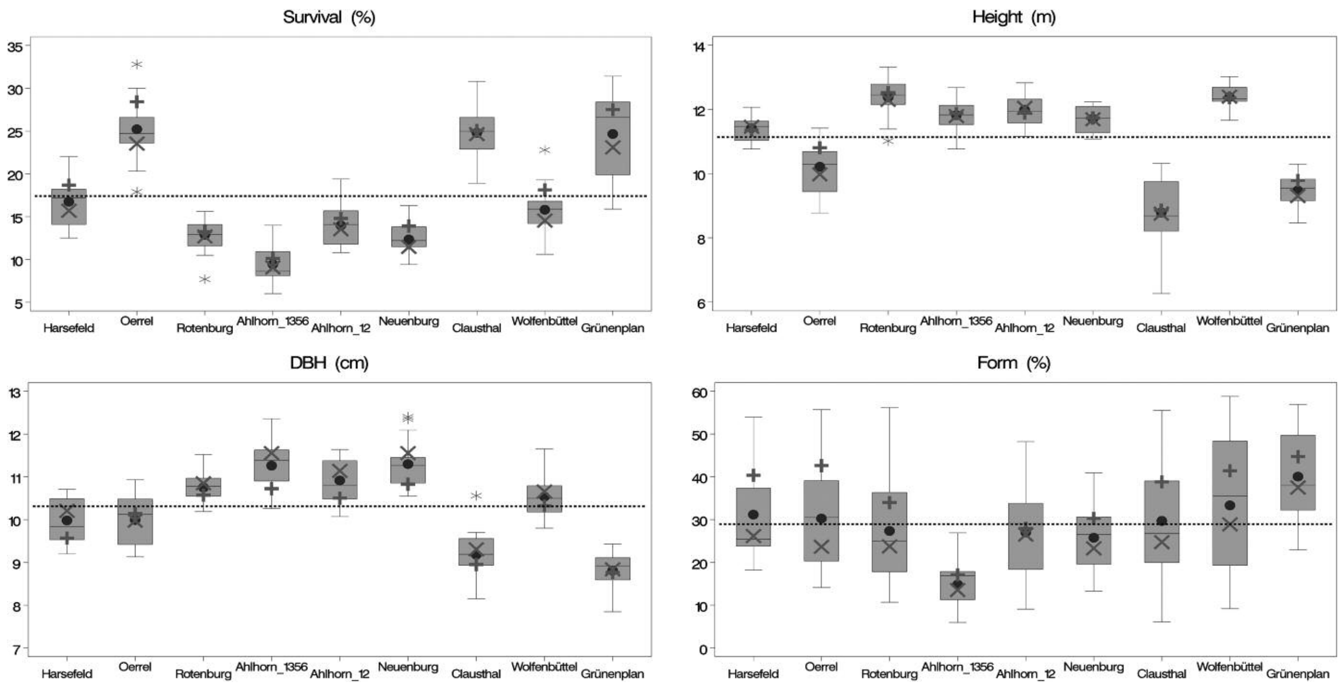

Figure 3. – Boxplot of the different sites; with series mean (dotted line), site mean (dot in box), site median (line in box), mean of provenances (german = "+", french = "x" in box).

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present in eight and seven trials for "survival" and "form", respectively. On growth characters ("height", "DBH"), however, significant provenance effects were evident only at three locations in lowlands.

Mean performance and variation at each location is illustrated by Box and Whisker plots in *Fig. 3*. Overall mean per trait is represented by a dotted line, location mean and location median by a dot, and a line within the box, respectively. Symbols indicate the group means of French ("x") and German entries ("+"). At two of the hilly locations provenances displayed a similar reaction in growth characters, however, at the third (Wolfenbüttel) they perform similar to the lowland tests. Greatest site effects occur in "survival" and "height" where eight of the boxes do not touch the dotted line of the series mean. "Survival" was higher in tests with lower plant density (i.e. higher spacing). Traits associated with quality, especially "form", seemed to be less affected by site conditions and plant density. "Ahlhorn_1356" is the location with highest plant density, however, with poorest forms. Tests in "Oerrel" and "Clausthal" were established with different number of replications and located in different regions; however, provenances presented similar form in both locations.

Correlations between traits measured at age 10 and age 23, are given in *Table 4*. As could be expected for each trait, there was a highly significant correlation between measurements taken at different ages. The only exception is the correlation between different ages in "survival" at the three hilly locations, where the coefficient reached only half the amount of the lowland trials. Stem form at age 10 was averaged over the score

Table 4. – Pearson correlations between traits measured at age 10 and 23. (Asterisks indicate significance at 0.05 (*), 0.01 (**) and 0.001 (***) level. ns = non-significance at 0.05 level.

Lowlands (n=102)		Age 23: Survival (%)	DBH (cm)	Height (m)	Form (%)	Crown (%)	improper form (%)
Age 10	Survival (%)	0.71 ***	-0.43 ***	-0.26 **	0.47 ***	0.14 ns	-0.32 **
	DBH (cm)	-0.56 ***	0.67 ***	0.76 ***	-0.30 **	0.07 ns	-0.02 ns
	Height (m)	-0.21 *	0.37 ***	0.83 ***	0.02 ns	0.31 **	-0.38 ***
	Form (mean)	-0.20 *	0.07 ns	-0.28 **	-0.61 ***	-0.14 ns	0.71 ***

Hilly region (n=51)		Age 23: Survival (%)	DBH (cm)	Height (m)	Form (%)	Crown (%)	improper form (%)
Age 10	Survival (%)	0.32 *	-0.24 ns	0.16 ns	0.48 ***	0.76 ***	-0.31 *
	DBH (cm)	-0.31 *	0.66 ***	0.65 ***	-0.20 ns	0.20 ns	0.14 ns
	Height (m)	-0.47 ***	0.61 ***	0.87 ***	0.07 ns	0.54 ***	0.03 ns
	Form (mean)	0.34 *	-0.43 **	-0.78 ***	-0.48 ***	-0.59 ***	0.40 **

Table 5. – Combined analysis of variance; Mean Squares. Asterisks indicate significant F-values for provenance effects at 0.05 (*), 0.01 (**) and 0.001 (***) level. ns = non-significance at 0.05 level.

Source	DF	Survival	DBH (cm)	Height (m)	Form (%)	Crown (%)	Improper quality (%)	Vol/tree (dm^3)	Vol/ha (m^3)
Location	8	621.40 ***	13.22 ***	29.34 ***	776.86 ***	1938.78 ***	893.72 ***	3326.22 ***	5453.27 ***
Group	1	199.23 ***	6.28 ***	0.73 ns	3412.72 ***	25.20 ns	1183.76 ***	549.99 ***	895.25 *
Prov(Group)	15	32.73 ***	0.16 ns	1.14 ***	707.51 ***	395.87 ***	341.15 ***	42.66 ns	1187.67 ***
Residual	128	5.47	0.23	0.27	45.07	36.46	40.77	27.85	150.91

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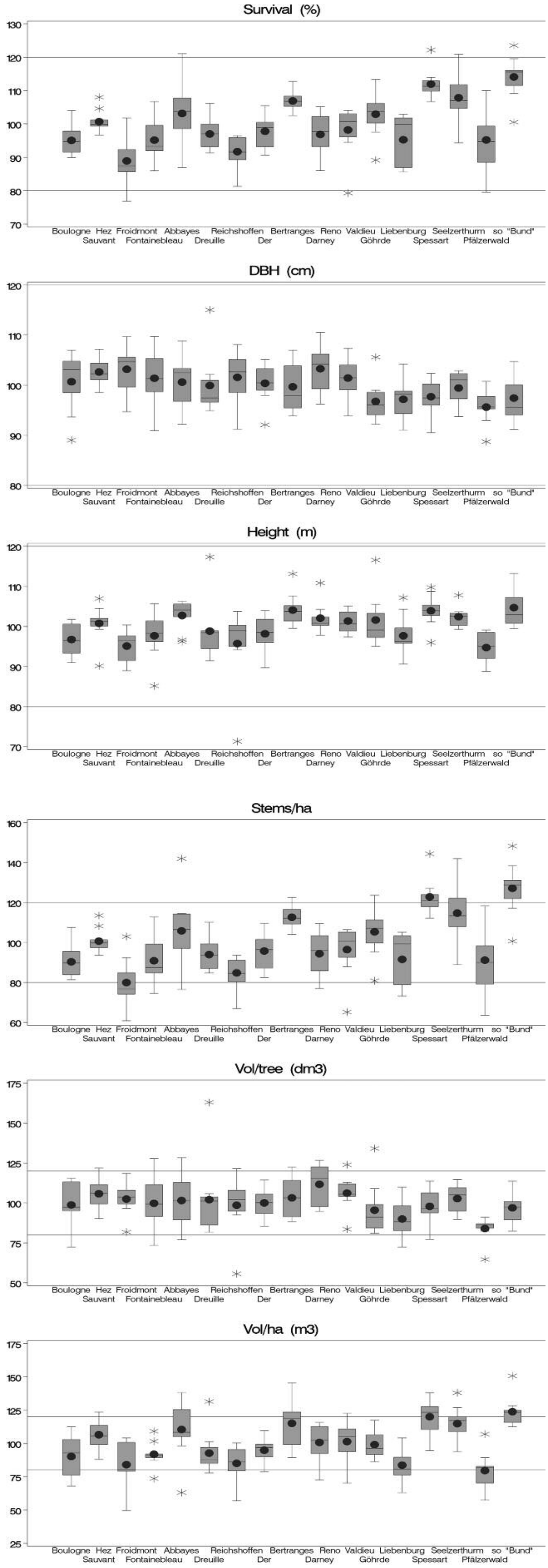

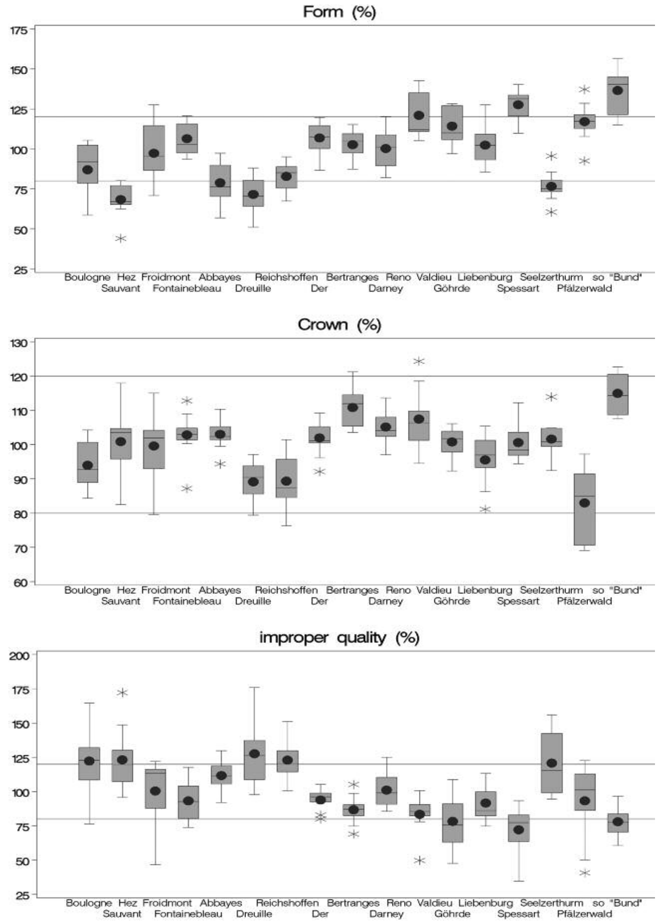

Figure 4. – Boxplot of provenance values relative to single location means.

values. Due to the fact that lower mean values indicate better stem forms, the coefficient between form means at age 10 and "form" at age 23 is negative. In lowlands, the magnitude of estimated correlation in "form" is similar to "DBH" and "height", respectively. However, in hilly region the correlation between different ages in "form" is minor. "Survival" at age 10 has an influence on growth character measured at age 23 in lowlands. At hilly locations, however, such a correlation could not be detected.

Provenances

Mean squares calculated by combined analysis across locations are presented in *Table 5*. Significant location effects were obtained in all traits and significant group effects between French and German entries were found in any trait other than "height" and "crown". In "height" no significant difference appears between groups and mentionable differences in this trait emerge only at the locations "Oerrel" and "Grünenplan" (cf. *Fig. 3*). Effects of provenances within groups are highly significant in most of the traits.

Provenance means averaged over locations are shown in *Table 6* and *Fig. 4* presents box plots of provenance values relative to single location means. Horizontal lines

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delimitate a range of 20% above and below the average, respectively and facilitate comparisons among provenances and traits. Three German and the French provenance "Bertranges" significantly exceeded the overall mean in "survival", whereas two French provenances displayed significantly lower values. In growth characters ("height", "DBH") minor differences between provenances occurred. Significant group differences were evident in "DBH" (*Table 5*), however no significant single provenance deviation from overall mean could be verified. In "height", two provenances ("Hez Froidmont" and "Pfälzerwald") performed significantly poorer than the overall mean.

A clear differentiation between provenances in quality characters is possible. Most of the significant deviations from overall mean could be obtained in "form". "Seelzerthurm" is the only German provenance with significantly and poorer quality than the overall mean. Four German progenies exhibit significantly good quality and the seed orchard "Bundesgebiet" (abbreviated in *Fig. 4*: so "Bund") is top ranking. Among French provenances "Reno Valdieu" is the only one with significant and positive deviation from overall mean.

The length and position of the box plots (*Fig. 4*) demonstrate variation within provenances. Growth characters verified small variation as only one value ("Reichshoffen") fell below the 80% border in "height". The French provenances have higher mean values in "DBH" than the German ones (conf. *Table 5*). For "survival" a higher degree in variability is expressed by boxes of varying length and position. "Saint Sauvant", "Bertranges", "Spessart" and "Bundesgebiet" have small boxes and "Bertranges" displayed no outlier.

Large variability was detected in quality parameters, especially "form", where three groups could be differentiated: provenances that generally develop stem forms that were more than 20% above the average ("Reno Valdieu", "Spessart" and "Bundesgebiet"); a group of provenances that displayed forms more than 20% below the average ("Seelzerthurm", "Saint Sauvant", "Abbayes" and "Dreuille"). The remaining provenances were in between and the whiskers of some provenances almost touch ("Der", "Darney") or overstretch ("Hez Froidmont") the borderlines.

Stability

Stability across locations is verified by similarity between provenance ranks in different locations. For each provenance, stability was analysed according to HÜHN (1979) by calculating all possible pair wise rank differences across locations. Rank differences of provenances for five characters are presented in *Fig. 5*. Low columns indicate high stability and numbers displayed at the bottom of the columns described mean values

Table 6. – Provenance means and ranges for different traits. Means averaged over nine sites at age 23; (significant deviations (Sidak) above (+) and below (-) overall mean).

Progeny	Survival (%)	DBH (cm)	Height (m)	Form (%)	Crown (%)	Improper quality (%)	Stem/ha	Vol/tree (dm^3)	Vol/ha (m^3)
Boulogne	16.0 7.8 – 26.6	10.4 7.8 – 12.1	10.8 8.2 – 12.4	22.1 6.0 – 34.4	53.5 31.3 – 76.3	31.0 (+) 9.0 – 56.8	1849.7 1296.5 – 2670.5	43.5 15.0 – 63.5	74.0 36.9 – 98.4
Saint Sauvant	17.5 9.1 – 29.1	10.6 9.0 – 11.6	11.3 7.9 – 12.8	13.8 (-) 6.1 – 25.2	59.4 42.2 – 77.6	31.0 (+) 18.1 – 48.9	2045.4 1548.0 – 2817.2	46.1 18.9 – 63.0	87.7 45.1 – 112.7
Hez Froidmont	14.0 (-) 7.7 – 25.6	10.6 9.1 – 12.4	10.6 (-) 8.5 – 12.4	27.3 8.4 – 50.5	58.4 33.8 – 75.2	23.0 3.4 – 45.5	1631.2 (-) 1089.3 – 2556.8	44.0 20.6 – 66.7	68.2 (-) 40.6 – 92.0
Fontainebleau	15.9 8.1 – 24.8	10.5 9.1 – 12.4	10.9 8.8 – 12.2	31.0 16.9 – 43.4	61.4 28.0 – 76.8	18.9 8.9 – 38.7	1856.2 1171.9 – 2474.7	42.7 20.1 – 61.8	75.0 47.2 – 102.6
Abbayes	18.2 11.5 – 28.4	10.4 9.1 – 11.7	11.5 8.5 – 12.9	18.1 (-) 9.1 – 28.3	61.4 32.2 – 73.8	25.6 18.8 – 38.5	2134.9 1446.8 – 2842.2	43.8 17.0 – 64.2	90.7 52.7 – 122.8
Dreuille	16.5 8.1 – 27.3	10.3 8.6 – 11.5	11.0 8.7 – 12.2	15.2 (-) 9.2 – 27.1	49.5 (-) 23.7 – 69.8	32.8 (+) 21.1 – 42.9	1920.0 1345.5 – 2732.1	42.6 17.4 – 57.1	74.3 49.9 – 95.1
Reichshoffen	14.6 (-) 8.6 – 22.9	10.5 8.4 – 11.8	10.8 6.3 – 12.5	19.7 (-) 13.0 – 34.4	49.5 (-) 26.5 – 69.8	31.0 (+) 14.0 – 49.9	1712.1 (-) 1325.8 – 2291.7	43.7 11.7 – 61.3	71.7 29.1 – 94.2
Der	16.3 9.1 – 25.6	10.3 8.9 – 11.6	10.9 9.1 – 12.7	31.9 17.9 – 49.7	60.4 35.9 – 74.5	19.7 9.1 – 31.9	1925.6 1532.1 – 2588.4	42.3 21.9 – 56.4	78.3 43.5 – 102.8
Bertranges	19.5 (+) 10.9 – 30.4	10.3 9.4 – 11.0	11.6 9.8 – 13.3	29.1 18.0 – 38.1	67.1 (+) 49.0 – 77.3	16.6 6.8 – 24.2	2284.7 (+) 1707.2 – 3042.9	43.2 23.7 – 56.9	92.4 67.4 – 116.3
Darney	16.3 8.1 – 24.7	10.7 8.8 – 12.3	11.3 9.5 – 12.4	27.3 20.0 – 42.1	63.3 34.7 – 79.4	21.3 21.6 – 27.7	1919.4 1200.8 – 2481.1	48.2 (+) 20.3 – 69.0	83.5 37.2 – 110.2
Reno Valdieu	16.5 8.4 – 26.1	10.5 8.6 – 11.8	11.3 8.7 – 13.0	38.6 (+) 17.8 – 52.9	64.3 51.0 – 78.1	15.9 3.6 – 32.7	1943.4 1397.2 – 2613.6	46.3 17.5 – 62.9	85.1 36.1 – 108.4
mean of French provenances	***16.5***	***10.5***	***11.1***	***24.9***	***58.9***	***24.3***	***1929.3***	***44.2***	***80.1***
Göhrde	18.2 8.9 – 30.6	10.0 8.3 – 11.1	11.3 9.2 – 12.3	35.7 (+) 13.5 – 45.8	59.4 36.7 – 67.0	13.8 (-) 5.3 – 30.8	2133.6 1515.1 – 3068.2	39.9 17.9 – 55.7	80.8 52.5 – 103.0
Liebenburg	15.8 6.9 – 26.6	10.0 9.1 – 10.7	10.9 8.0 – 12.9	29.1 17.5 – 45.8	54.5 34.3 – 67.2	18.1 7.9 – 36.2	1857.6 1161.9 – 2664.1	38.3 18.5 – 52.4	69.1 (-) 38.2 – 101.8
Spessart	21.3 (+) 11.5 – 30.8	10.1 8.3 – 11.0	11.6 8.4 – 13.0	43.5 (+) 17.1 – 56.9	59.4 37.9 – 73.3	12.4 (-) 1.8 – 37.3	2496.8 (+) 1801.2 – 3077.7	42.0 16.7 – 55.7	99.3 (+) 48.4 – 135.0
Seelzerthurm	19.8 (+) 11.5 – 32.8	10.3 8.9 – 11.1	11.4 8.8 – 12.8	17.4 (-) 7.0 – 28.0	59.4 38.6 – 65.4	29.1 (+) 18.2 – 41.5	2324.5 (+) 1595.1 – 3282.8	44.1 18.8 – 58.0	95.1 (+) 50.5 – 133.5
Pfälzerwald	16.4 6.0 – 29.4	9.9 8.1 – 11.0	10.6 (-) 7.8 – 12.3	36.6 (+) 20.6 – 49.0	44.5 (-) 18.3 – 65.1	20.5 2.4 – 41.1	1882.7 1010.0 – 2935.8	36.5 (-) 13.6 – 49.8	64.1 (-) 42.4 – 80.2
Seed orchard „Bundesgebiet"	21.7 (+) 14.0 – 32.8	10.0 8.4 – 10.6	11.6 9.5 – 12.7	47.5 (+) 26.9 – 58.8	70.8 (+) 48.6 – 80.0	13.1 (-) 5.3 – 20.8	2556.3 (+) 2025.5 – 3282.8	40.8 20.1 – 57.8	102.4 (+) 59.1 – 145.8
mean of German provenances	***18.9***	***10.1***	***11.2***	***35.0***	***58.0***	***17.8***	***2208.6***	***40.3***	***85.1***
Overall mean	**17.3**	**10.3**	**11.1**	**28.5**	**58.6**	**22.0**	**2027.9**	**42.8**	**81.9**

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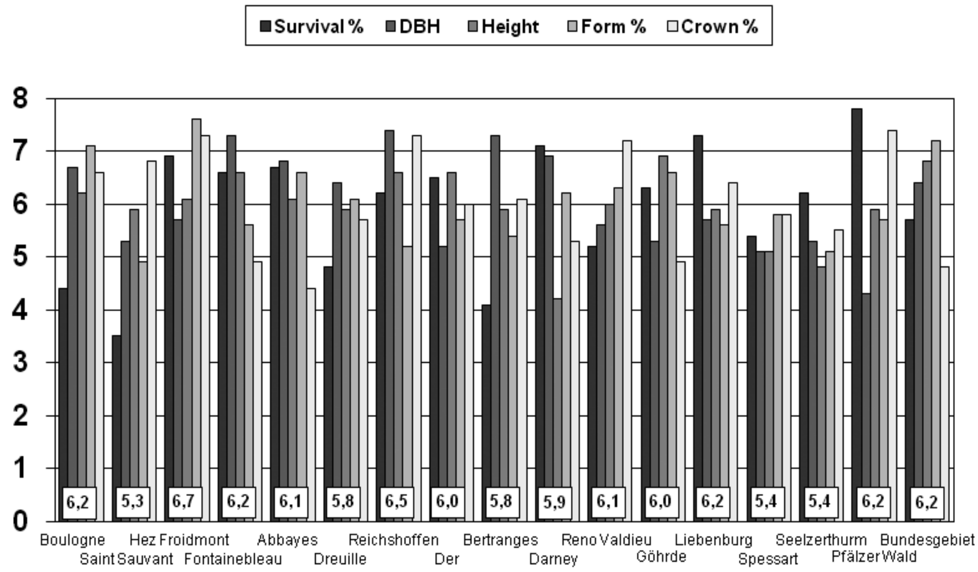

Figure 5. – Pair wise rank differences in five traits and mean values of differences at the bottom of the columns.

averaged over traits. "Saint Sauvant" showed the highest averaged stability caused by lowest rank difference values in "survival" and "form". Next in stability were "Spessart" and "Seelzerthurm", provenances with good and poor performance, respectively. Low rank differences in "Seelzerthurm" can be seen in "form" and "height", which are in accordance with small variation ranges in *Fig. 4*.

Stability in time is expressed by rank changes between age 10 and age 23. KLEINSCHMIT and SVOLBA (1995, 1996) calculated ranks at age 10 for mortality, height and form. A high mortality was related to a low rank, i.e. high rank scores. At age 23, we calculated survival and therefore high values were associated with high ranks, i.e. low rank scores. Rank changes between first and second assessment are presented in *Fig. 6*. Changes were predominantly directed towards lower ranks at age 23. "Abbayes", "Hez Froidmont" and "Darney" showed distinct shifts to low ranks. The first provenance exhibited the highest decrease in one character ("form") and the latter expressed rank changes of all three traits aligned in the same direction. The same applies to "Seelzerthurm" and, with an opposite orientation to higher ranks, to "Spessart". "Liebenburg" and the seed orchard "Bundesgebiet" were the only entries with minor differences in just one character.

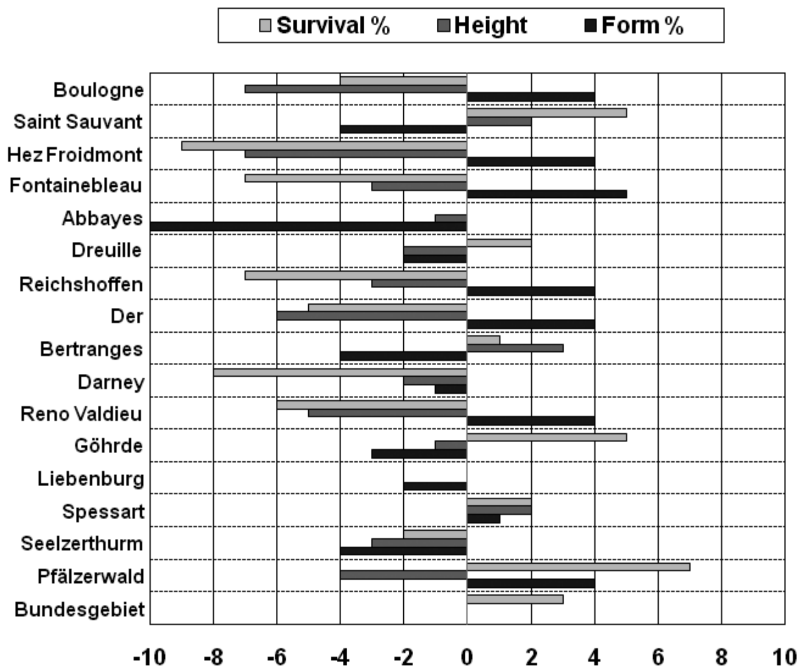

Figure 6. – Rank changes between age 10 and age 23.

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Discussion

In Germany, sessile oak is a problematic species for artificial cultivation. Main reason is the inadequate supply with sound seeds from native German stands, because of irregular flowering and low seed production of seed stands. An alternative approach to make superior oak material available for planting in German forests was initiated by KLEINSCHMIT in the early 1980ies. He proposed to use well performing French oak stands for seed production in low crop years. Prior to utilization and recommendation of French material, he established a trial series under practice conditions of Northwest Germany in order to test his proposal and to compare some of the best German seed sources with provenances from French oak stands.

Varying test characteristics of single tests, e.g. replication, stems/ha, seemed to have no influence on provenance performance here. However, region of test location within Northwest Germany do affect provenances. The number of planted seedlings per hectare did not significantly influence "form". Distinct provenance effects for "form" could be obtained in all locations except "Ahlhorn_1356" (formerly "Syke"), where trees were planted with highest density.

The present assessment of the French-German oak series was the first one that allows yield calculation and reliable score of quality. The first evaluation at age 10 revealed no clear differences between German and French provenances in survival and height (KLEINSCHMIT and SVOLBA, 1995). At age 23, however, we obtained significant group effects between French and German provenances in "survival", "DBH" and "form".

Performance and stability

Occurrence of group effects is in correspondence with results of authors, who described geographical clines concerning yield traits (JENSEN, 2000) and phenology (DUCOUSSO et al., 1996; JENSEN and HANSEN, 2008). As these clines are linked with traits of interest, the authors recommend foresters to use local seed sources for artificial cultivation. KRAHL-URBAN (1957) mentioned effects of provenances on growth-rate, phenology and susceptibility to frost. Various analyses of different oak provenances at a given site revealed different results, thus it is challenging to explain the role of provenances.

The same is true in the present investigation. French provenances that performed significantly better than the overall mean were "Reno Valdieu" and "Bertranges" in "form" and "survival", respectively. "Darney" combined good measurements in "height" and "DBH" and therefore the calculated value in "Vol/tree" significantly surpasses the overall mean. "Fontainebleau" and "Der" showed no significance in either direction. Other French entries were significantly inferior to the overall mean in at least one character.

Visually scored and measured values for German provenances "Seelzerthurm" and "Pfälzerwald" in "form" and "height", respectively, were significantly below average. Plants of "Pfälzerwald" originated from stands in two forest districts (Elmstein-Süd and Hinterweidenthal) and had been stored temporarily several times prior to distribution on test locations (KLEINSCHMIT, 1995). This could explain their low survival and poor initial growth.

Phenotypic stability and genotype by environment interactions are strongly related to the dynamic concept of stability (BECKER and LÉON, 1988). Univariate nonparametric stability statistics offers several advantages over parametric ones. They are easy to use and to interpret and they do not need any assumptions about distribution of observed values or of variance homogeneity. Furthermore, nonparametric methods reduce the bias caused by outliers. Provenance stability evaluated as mean rank differences and performance of provenances are obviously not linked in the test series examined here. Averaged across five characters "Saint Sauvant" and "Hez Froidmont" presented best and worst stability, respectively. No pattern of reaction in stability was detectable and varying stability in specific characters was observed even in provenances originating from locations lying closed together, e.g. "Abbayes" and "Dreuille".

Development of provenances between age 10 and 23 seemed to vary with location of test and origin of provenance. "Survival" and, although to lesser extent, "form" presented a strong relationship between different ages, however, in hilly tests this correlation is less distinctive. Different correlation coefficients for "survival" at age 10 with other characters were an indication of different provenance reaction in lowlands and hilly tests. Rank changes between different assessments demonstrated variability between the tested provenances. At age 10 KLEINSCHMIT and SVOLBA (1996) found poor form values for a group of six provenances "Reichshoffen", "Boulogne", "Hez Froidmont", "Dreuille", "Saint Sauvant" and „Fontainebleau". At age 23 "Seelzerthurm" and "Abbayes" joined this group instead of "Hez Froidmont" and "Fontainebleau".

A considerable variation between single populations even in nearby located stands was described by BARZDAJN (1993) that might superimpose geographic effects. Population and geographic effects can interfere so that the diversity within species is not structured along an ecological gradient (BACILIERI et al., 1995). After reviewing several provenance and progeny tests, KLEINSCHMIT (1993) mentioned the difficulty to separate genetic and environmental components of the phenotypic variation between and within provenances. However, he stated, that the choice of the provenance could be important for a successful economic plantation. In agreement with this statement KREMER et al. (2002) argued, that for traits of interest in forestry there is no significant correlation between belonging to lineages or haplotypes, respectively, and the performance of provenances. Therefore, there is a need for testing stands within provenances to detect valuable seed sources.

The phenology of oak can affect quality traits. In general, under the climatic conditions predominating at the nine test locations, the German provenances show a higher proportion of trees with good stem forms, which is in agreement with KLEINSCHMIT and SVOLBA (1996). These authors described, that in Northwest Germany

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French provenances have an earlier bud burst and a later growth cessation than German ones, thus being more endangered by frost.

Other investigations on oak in France (DUCOUSSO et al., 1996) verified a relationship between altitude, latitude and phenology of bud burst for West European oak populations. In general, northern populations and those close to the sea level show late bud burst. Frost tolerance and the susceptibility to spring and autumn frosts vary between provenances and are vice versa correlated with stem form (KLEINSCHMIT and SVOLBA, 1979; LIEPE, 1993; JENSEN and DEANS, 2004).

Provenances from locations near the coast or with early flushing and late growth cessation tend to be more damaged by frost than those with a shorter growth period. The distance of origin to the sea seemed to be of no influence on performance here. Among the French group, "Reno Valdieu" originates closest to the sea and revealed the best stem forms within the French group. However, originating from a similar distance to coast, "Saint Sauvant" has poor stem form. Among the German entries, there is a clear ranking. "Bundesgebiet" presented best forms, followed by "Spessart". "Seelzerthurm" is the worst German progeny concerning stem form.

Conclusion

By far the best entry concerning productivity and quality is the progeny of the seed orchard "Bundesgebiet". This orchard includes grafted plustrees from six German regions of provenience (mostly "07" and "03") and was approved in the category tested basic material. However, this seed orchard is only one hectare in size and KLEINSCHMIT (1986) noticed the limited contribution of seed orchards in oaks under practical silvicultural conditions. Seven grafts of that orchard originated from "Pfälzerwald". The provenance "Pfälzerwald" was also tested in this study. Although normally good performing in several provenance tests, plants of this provenance could not compensate sustained disturbances in early seedling stages. "Seelzerthurm" demonstrated good survival and productivity, however, at least in this study it could not fulfil the requirements in quality characters.

Combining yield and quality, the other German provenances, especially "Spessart" and "Göhrde" are the first choice under prevailing Northwest German conditions. Descendants from the Spessart seed source are good in yield as well as in quality. On typical *Q. robur* sites JENSEN (1993) already described the good performance of a *Q. petraea* entry, which was harvested from the Spessart provenance (*Kleinschmit*, 1999). In general, the observed high variation between provenances and test locations makes it difficult to appoint particular provenances for use at specific locations. Furthermore, transfer of provenances from a milder climate to another can result in frost damages and slower growth. Therefore, KLEINSCHMIT (1993) suggested intensive testing and selection of single trees and populations to detect broadly adaptable provenances. "Spessart" seems to approximate to this demand. It combines good growth characteristics and good quality.

The French provenances were apparently more sensitive to local test conditions than the German ones. After evaluation at age 10, KLEINSCHMIT and SVOLBA suggested a group of five French provenances ("Reno Valideu", "Bertranges", "Darney", "Der" and "Abbayes") as an substitute for German provenances. After the latest assessment at age 23, however, "Abbayes" should not be considered any longer, but "Fontainebleau" could be an option instead. "Reno Valdieu" is still the best performing provenance within French group and, together with "Bertranges", "Darney" and "Der" might be an alternative in low crop years. It seems that up to now other French provenances were apparently not qualified for Northwest German conditions.

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Genetic Variation and Tree Improvement of Konishii fir (*Cunninghamia lanceolata* (Lamb.) Hook. var. *konishii*) in Taiwan

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Abstract

We analyzed a 21-year old progeny test of Konishii fir (*Cunninghamia lanceolata* (Lamb.) Hook. var. *konishii*) involving 75 families. Tree height and diameter at breast height (DBH) were periodically recorded. At age 21, average height, DBH, and volume were 15.2 m, 20.2 cm, and 278 dm^3, respectively. At this age, family accounted for 9, 12, and 11% of the total variance in height, DBH and volume, respectively. Also at age 21, individual tree heritability was 0.35, 0.49, and 0.45 for height, DBH and volume, respectively, and family heritability was 0.53, 0.69, and 0.66 for the three respective characteristics. The age trend for all genetic parameters was more stable for DBH than for height and volume. Family (backward) selection for DBH at age 21 resulted in a 9.6% gain and indirectly 5.1 and 21.0% gains for height and volume, respectively, compared to 5.2 and 20.1% gains for height and volume, respectively, when selection for these characteristics is done directly. DBH

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