ARBETSRAPPORT

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Study of survival, height growth, external quality and phenology in a beech provenance trial in southern Sweden

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Summary

Traits such as survival, height growth, external stem quality and phenology were studied after 1–10 years of growth in one beech provenance trial in southern Sweden. The trial included 33 provenances from different European countries and belong to a series of international beech provenance trials established throughout Europe.

Mean survival after 10 years of growth in field was modest (77%) and total height was in average 39 dm. The last 6 years (years 2002–2007) the height increment was almost 5 dm per year.

Significant differences among provenances were found for all traits studied except for autumn phenology and forking. So far the three Swedish provenances have behaved quite modestly indicating that the local material is not the most suitable one. It is interesting that the German provenance from Baden-Würtenberg, which is transferred from latitude 48.47 to 55.56 i.e. roughly 800 km north, was the best grower and one of the best survivors.

The correlations among the different traits were generally weak. However, the correlation between the spring phenology scored at three different years was strong (>0.68). This suggests that satisfactorily results for bud burst can be achieved by observations during one season. Furthermore, total height was strongly and positively correlated (0.82) with the presence of double stem above 1.3 m, indicating that good growers are more likely to get double stems than bad growers.

Introduction

Climatic adaptation is of great importance for practical forestry. If the reforestation material is not climatically well adapted to the plantation site, there will be a considerable risk for damage, which will reduce growth and deteriorate timber quality with economical loss as a result. Climatic adaptation is therefore one of the key traits for a successful establishment of high quality producing beech.

Today there is a lack of good Swedish indigenous forestry regeneration material of many broad-leaved species, which is compensated by importing material mainly from Poland and Germany. However, our knowledge about north transfer effects on survival, vitality and growth is limited, and might be crucial since the northern limit of natural distribution of many "noble hardwood" species is found in southern Sweden.

To increase the knowledge of the transferring effects of different beech material within Europe two series of international beech provenance trials (1993/95 and 1996/98) were established throughout Europe. One trial in each of the series was established in Sweden. The main objective is to provide northern Europe with better regeneration material of beech in the future, with emphasis on the probable climate change scenarios.

It will probably take another 15–20 years until reliable provenance and transfer recommendations can be achieved. However, in order to make as good recommendations in the future as possible it is essential to get information about traits associated with the establishment. Thus, the main objective with this study was to evaluate and present results for such traits for one of the Swedish beech provenance trials, and deliver data for a joint evaluation of a number of beech provenance trials all around Europe.

Material and methods

The study was based on one trial in southern Sweden, including plant material cultivated at the Institute for Forest Genetics and Forest Tree Breeding in Grosshansdorf, Germany. The Trial S21F9871313, included 33 European provenances (Table 1) planted on agricultural land in the very southern part of Sweden (Trolleholm, 55º 56'N, 13º 19'E, altitude 100 m). The two-year old bare-root seedlings were planted in spring 1998 in a randomised block design with 7 × 7 plants per provenance and plot in each of 3 blocks at a 1.25 × 1.25 m spacing.

The analyse refer mainly to measurements and scorings performed during year 2007. In table 2 the traits of concern are defined. In order to get correlations with previous measurements (Stener, 2002) some traits from the years 1999 and 2001 were included in the analysis as well (Table 3). Trees damaged by wild game (roe deer), trees with stem breakage and trees that were severely suppressed from other more fast growing trees (mainly birch) were excluded from the analyse (in total 37 trees).

Table 1.
Provenances included in the study sorted by country. Latitude and longitude are presented in decimal degrees and altitude in meters.

Prov no	Provenance name	Country (region)	Lat	Long	Alt
35	Hinterstoder.	Austria	47.72	14.10	1250
13	Soignes.	Belgium	50.83	4.42	110
16	Gotze Delchev.	Bulgaria	41.57	23.73	1450
46	Domazlice-Vyhl.	Czech Rep.	49.40	12.77	760
48	Jablonec N.N..	Czech Rep.	50.80	15.23	760
49	Brumov-Sidonie.	Czech Rep.	49.05	18.05	390
51	Homi Plana-Ce.	Czech Rep.	48.85	14.00	990
64	Nizbor.	Czech Rep.	50.00	14.00	480
21	Grasten, F413.	Denmark	54.92	9.58	50
22	Alsted, F.603.	Denmark	55.40	11.65	50
1	Perche.	France	48.42	0.55	205
2	Bordure Man.	France	49.53	0.77	80
3	Picardie.	France	49.25	3.10	140
6	Plateaux du.	France	46.80	5.83	600
8	Pyreness Or.	France	42.92	2.32	670
17	Westfield (2002).	Great Britain	57.67	–3.42	10
18	BE 95 (4003).	Great Britain	51.72	–2.00	140
30	Belzig (ST).	Germany (Brandenburg)	52.05	12.42	140
31	Urach (BW).	Germany (Baden-Würtenb.)	48.47	9.45	760
28	Schulecht (HE).	Germany (Hesse)	50.35	9.68	535
26	Farchau (SH).	Germany (Schlesw.-Holst.)	53.65	10.67	55
37	Val di Sella.	Italy	46.02	13.50	1150
11	Heinerscheid.	Luxembourg	50.08	6.12	423
14	Aamink.	Netherlands	51.93	6.73	45
39	Jaworze.	Poland	49.83	19.17	450
40	Tamawa.	Poland	49.47	22.33	540
60	Sekowiec, 160b.	Poland	49.25	22.82	320
67	Bilowo 115, 116.	Poland	54.33	18.17	250
53	Postojna Masun.	Slovenia	45.63	14.38	1000
23	Torup.	Sweden	55.57	13.20	40
24	Trolle Ljungby.	Sweden	56.12	14.50	40
25	Gullmarsberg.	Sweden	58.37	11.65	25
34	Oberwil.	Switzerland	47.17	7.45	570

Table 2.
Description of basic traits used in the study.

Trait	Field age	Abbreviation	Description
Survival	10 years	Surv10	Survival in autumn 2007 for all trees. Scored as 0 (dead) or 1 (alive).
Height	10 years	Height10	Total height in dm in autumn 2007. Measured for all living trees.
Spring phenology	9 years	Sphen9	Phenology in May 1, 2007, i.e. after 9 years of growth in field. Scored in 6 bud burst classes based on the most developed bud, regardless the position within the crown. 1=winter state, 2=buds swelling, 3=first green visible, 4=leaves spreading, 5=leaves not fully unfolded, 6=leaves fully unfolded. Scored for all trees in three out of seven rows per plot (mostly rows 3–5). However, in plots where survival was poor, scoring was made in the three rows with the highest survival.
Autumn phenology	10 years	Aphen10	Phenology in October 1–2, 2007, i.e. after 10 years of growth in field. Scored on the basis of autumn leaf color of the entire crown in 6 classes. 1=All leaves still green, 2=1–5% of the leaves autumn colored, 3=6–50% of the leaves autumn colored, 4=51–99% of the leaves autumn colored, 5=100% of the leaves autumn colored, 6=All leaves felled. Class 6 was set as class 5 during evaluation, in consequence with the classification in other countries. Scored with a few exceptions on the same trees as for Sphen9.
Crookedness	10 years	Crook10	Crookedness in autumn 2007 scored in a scale of 1–5 for all living trees above 25 dm. 1=straight, 2=better than average, 3=average, 4=worse than average, 5=crooked.
Forking	10 years	Fork10	Number of forks in autumn 2007 scored for all living trees above 25 dm: 0=none, 1=1 fork, 2=two forks, 3=three forks. Double stems was not registered as a fork but was classified as a separate trait (see below). 3 forks were set to 2 forks during evaluation, in consequence with the classification in other countries.
Branch thickness	10 years	Brth10	Branch thickness in autumn 2007 was scored for all living trees above 25 dm, on the middle third of the tree height in three classes: 1=thin (approx < 25% of stem diameter), 2=average (approx 25 – 33% of stem diameter), 3=thick (approx 34– % of stem diameter).
Double stem 1	10 years	DbstA10	Double stem below 1.3 m in autumn 2007 was scored for all living trees in two classes: 0=none, 1=double stem.
Double stem 2	10 years	DbstB10	Double stem above 1.3 m in autumn 2007 was scored for all living trees in two classes: 0=none, 1=double stem.

Table 3.
Description of traits from previous years of measurements.

Trait	Field age	Abbreviation	Description
Height	4 years	Height4	Total height in cm in spring 2002 for all living trees.
Spring phenology	1 years	Sphen1	Phenology in May 13, 1999 for all living trees in rows 2 and 5. Scored in 7 bud burst classes (Wühlisch, 1995b). Basically the same classes as those used during year 2007 (see above) except from class 6 and 7 where 6=not quite fully unfolded, 7=fully unfolded leaves. Classification to a certain class was made if at least 50% of the buds in the upper half of the crown had reached this stage.
Spring phenology	4 years	Sphen4	Phenology in May 9, 2002 for all living trees mainly in rows 3, 4 and 5 in each plot. However, rows 6–7 were added if the survival in the previous rows were low. Scored in 7 bud burst classes (Wühlisch, 1995b). Basically the same classes as those used in year 2007 (see above) except from class 6 and 7 where 6=not quite fully unfolded, 7=fully unfolded leaves. Classification to a certain class was made if at least 50% of the buds in the upper half of the crown had reached this stage.
Frost damage	1 years	Frost1	Frost damage observed in spring 1999 in classes 0= no damage and 1=frost damage.
Frost damage	4 years	Frost4	Frost damage observed in spring 2002 in classes 0= no damage and 1=frost damage.
Stem form	4 years	Form4	Stem form for all living trees mainly in rows 3, 4 and 5 in each plot. However, rows 6–7 were added if the survival in the previous rows were low. Scored in 1–5 scale based upon apical dominance and straightness in spring 2002. The higher classes the better stem forms.

Calculations

The statistical analyses of all traits were performed by Proc Glm (SAS, 1996) and were based upon plot means. The following model was used:

$Y_{ijk} = \mu + b_i + p_j + e_{ijk}$, where,

Y_{ijk} = Observation ijk

μ = Mean value

b_i = Fix effect of block i

p_j = Fix effect of provenance j

e_{ijk} = Random error term for observation ijk, with expected mean 0 and variance σ^2

As survival, phenology and external stem quality traits did not display normal distribution they were transformed prior analysis. This was carried out by transforming the individual observations within each block to normal-score values prior to statistical analysis (Gianola & Norton, 1981). Since these transformations only resulted in marginally differences in the results compared to the original data, it was decided to base all analysis on original, untransformed data. Tukey test was used for test of significance between individual provenances. Correlation coefficients among traits were estimated as Pearson correlations based on plot means (SAS, 1996).

Results and discussion

Means for each provenance and an overall mean for all traits assessed in year 2007 are presented in table 4 and 5. Mean survival was modest (77%) but has not decreased since previous assessment in year 2002. Actually it has increased slightly (1.1%), which probably is an effect of mistakes during the inventory in year 2002. Growth was in average quite good, with a mean height of 39 dm. It shall be noted that the first 6 years from seed the mean height increment was around 20 cm/year and the last 6 years (2002–2007) it was 46 cm/year.

Significant differences among provenances were found for all traits studied except for autumn phenology and forking (Table 4). So far the three Swedish provenances have behaved quite modestly, indicating that the local material is not the most suitable one. Several of the most southern provenenances had high survival and growth and were not significant different from the Swedish provenances. The German provenance 31, which is transferred from latitude 48.47 to 55.56 i.e. around 800 km north, was the best grower and one of the best survivors (Table 5). The results indicate that beech is a very plastic species, i.e. it is very adaptable to different climates.

If there is an interest in the future to establish new seed orchards or seed stands of beech in Sweden, the trials can be of great value by selection of the phenotypically best individuals within the best provenances.

Table 4.
Means, standard deviations, number of observations and significance levels (P>F) from analysis of variance for different traits.

Table 4A. Basic traits assessed in year 2007.

Trait	Unit	Mean	Std dev	No of obs	P>F Block	P>F Prov
Surv10	%	77	17.9	99	0.0400	<0.0001
Height10	dm	39	7.5	99	0.0073	<0.0001
Sphen9	1–6	3.47	1.08	99	0.0004	<0.0001
Aphen10	1–5	2.74	1.00	99	0.0010	0.1131
Crook10	1–5	2.69	0.36	99	<0.0001	<0.0001
Fork10	0–2	1.67	0.20	99	<0.0001	0.0927
Brth10	1–3	2.39	0.22	99	0.0040	0.0040
DbstA10	%	41	12.4	99	0.0477	0.0280
DbstB10	%	63	17.5	99	0.0017	0.0001

Table 4B.
Traits from assessments in year 1999 and 2002.

Trait	Unit	Mean	Std dev	No of obs	P>F Block	P>F Prov
Height4	cm	126	26.6	99	0.1121	<0.0001
Form4	1–5	3.51	0.24	99	0.9563	0.0012
Sphen1	1–7	2.69	0.90	99	0.0015	<0.0001
Sphen4	1–7	4.28	1.07	99	0.0130	<0.0001

Provenances from areas close to the coast (maritime climate) flushed later then provenances originating from regions of more continental climate, i.e. a higher temperature sum is needed for the maritime materials to initiate growth in spring. Any pattern for growth cessation was not found since autumn phenology was not significant different at all (Table 4). Previous studies have shown that beech provenances from eastern regions or from higher altitudes initiate growth earlier than populations from lower elevations or from regions affected by the closeness to the Atlantic (Muhs, 1985; Madsen, 1995; von Wuehlish et al., 1995a). This is in agreement with the results in the present study.

The phenotypic correlations are presented in Table 6 and they were generally weak. However, the correlation between the spring phenology scored at three different years was strong (>0.68), irrespective of differences in definitions (Table 2). This is in accordance with other beech studies such as von Wühlisch et al. (1995a, 1995b), where bud burst was found to be highly heritable and also stable in ranking over time. This suggests that satisfactorily results for bud burst can be achieved by observations during one season.

Furthermore, height was strongly and positively correlated (0.82) with double stem above 1.3 m (DbstB10), indicating that good growers are more likely to get double stems than bad growers. Strong correlations were expected between survival and growth. However, height was only modestly correlated with survival (0.57 and 0.63).

The correlation between stem form in spring 2001 and the external stem quality traits (Crook10, Fork10, Brth10) was weak, indicating that a very early scoring of stem quality is of little value.

The phenology traits could of course only be scored on plants that were alive at the time of classification. So, plants that died during the first year after establishment due to climatic adaptation problems (too early flushing or too late winter hardening) were not included. Therefore, there might be a risk that the phenology estimations are somewhat biased.

One of the main objectives with this study was to produce data to a joint evaluation of a number of beech provenance trials all around Europe. Since Sweden is located at the border of the distribution area of beech such data will be of great value. Such data has been sent to Georg von Wühlisch, coordinator of the COST project: Action E52: Evaluation of beech genetic resources for sustainable forestry.

Table 5.
Means for survival, total height, phenology and external quality traits for each provenance sorted by country. Results from Tukey test (Tu) are given for each trait. Provenances where any of the Tukey letters are similar for a specific trait (column) are not significant ($p < 0.05$). There are no Tukey values for Aphen10 and Fork10 since no significant effect for provenances was found in the ANOVA (see Table 4).

Prov	Region	Country	Surv10		Height10		Sphen9		Aphen10		Crook10		Fork10		Brth10		DbstA10		DbstB10	
			%	Tukey	dm	Tukey	1–6	Tukey	1–5	Tukey	1–5	Tukey	0–2	Tukey	1–3	Tukey	%	Tukey	%	
35	Hinterstoder.	Aus	80	ABC	36	DEFGHI	4.20	BCDEFG	3.03		2.16	F	1.61		2.12	AB	33	AB	59	AB
13	Soignes.	Bel	65	ABC	45	ABCDE	2.25	L	2.45		2.85	ABCDEF	1.81		2.41	AB	34	AB	79	A
16	Gotze Delchev.	Bulg	78	ABC	41	ABCDEFGHI	5.22	AB	2.60		2.19	EF	1.81		2.38	AB	55	AB	75	AB
46	Domazlice-Vyhl.	Cze	61	ABC	38	BCDEFGHI	5.08	ABC	2.69		2.28	DEF	1.66		2.22	AB	32	AB	72	AB
48	Jablonec N.N..	Cze	84	ABC	41	ABCDEFGHI	4.60	ABCDE	2.51		2.36	CDEF	1.60		2.34	AB	33	AB	71	AB
49	Brumov-Sidonie.	Cze	90	ABC	42	ABCDEFGH	4.09	BCDEFGH	2.36		2.70	ABCDEF	1.71		2.30	AB	39	AB	79	A
51	Homi Plana-Ce.	Cze	87	ABC	32	EFGHI	4.90	ABCD	3.70		2.18	EF	1.59		2.44	AB	38	AB	51	AB
64	Nizbor.	Cze	78	ABC	32	EFGHI	3.47	EFGHIJKL	3.15		2.57	ABCDEF	1.61		2.48	AB	37	AB	54	AB
21	Grasten, F413.	Denm	50	C	37	CDEFGHI	2.99	GHIJKL	2.33		2.84	ABCDEF	1.63		2.69	A	34	AB	53	AB
22	Alsted, F.603.	Denm	77	ABC	43	ABCDEFGH	2.71	IJKL	2.28		2.70	ABCDEF	1.45		2.54	AB	28	B	59	AB
1	Perche.	Fr	94	AB	50	ABC	2.83	HIJKL	1.52		2.77	ABCDEF	1.78		2.17	AB	30	AB	79	A
2	Bordure Man.	Fr	68	ABC	35	DEFGHI	2.75	IJKL	3.53		3.06	ABC	1.65		2.58	AB	48	AB	45	AB
3	Picardie.	Fr	70	ABC	45	ABCDE	2.57	JKL	2.31		2.89	ABCDE	1.74		2.27	AB	38	AB	78	A
6	Plateaux du.	Fr	65	ABC	35	DEFGHI	2.41	L	2.89		2.72	ABCDEF	1.67		2.60	AB	45	AB	58	AB
8	Pyreness Or.	Fr	82	ABC	32	EFGHI	3.40	EFGHIJKL	2.68		2.60	ABCDEF	1.74		2.63	AB	56	AB	51	AB
17	Westfield (2002)	GB	52	BC	40	BCDEFGHI	2.83	HIJKL	2.35		2.73	ABCDEF	1.70		2.54	AB	47	AB	66	AB
18	BE 95 (4003).	GB	89	ABC	44	ABCDEF	2.60	JKL	1.96		3.07	AB	1.81		2.34	AB	46	AB	75	AB
30	Belzig (ST).	Ger-BB	83	ABC	43	ABCDEFG	2.51	KL	2.25		2.90	ABCD	1.57		2.48	AB	43	AB	61	AB
31	Urach (BW).	Ger-BW	95	A	54	A	2.30	L	1.46		3.24	A	1.87		2.09	B	64	A	76	A
28	Schulecht (HE).	Ger-HE	84	ABC	42	ABCDEFGHI	3.69	DEFGHIJK	2.36		2.55	ABCDEF	1.76		2.44	AB	40	AB	73	AB
26	Farchau (SH).	Ger-SH	99	A	51	AB	4.24	BCDEFG	2.46		2.96	ABCD	1.74		2.26	AB	36	AB	80	A
37	Val di Sella.	Ita	96	A	43	ABCDEFGH	5.77	A	3.53		2.76	ABCDEF	1.53		2.26	AB	41	AB	63	AB
11	Heinerscheid.	Lux	48	C	30	GHI	2.23	L	3.10		3.00	ABC	1.70		2.52	AB	41	AB	32	B
14	Aamink.	NL	93	AB	42	ABCDEFGHI	2.73	IJKL	2.65		2.84	ABCDEF	1.85		2.33	AB	46	AB	71	AB
39	Jaworze.	Pol	90	ABC	46	ABCD	4.98	ABC	2.69		2.37	BCDEF	1.74		2.19	AB	39	AB	74	AB

Table 5.
Continuation.

Prov	Region	Country	Surv10		Height10		Sphen9		Aphen10		Crook10		Fork10		Brth10		DbstA10		DbstB10	
			%	Tukey	dm	Tukey	1–6	Tukey	1–5	Tukey	1–5	Tukey	0–2	Tukey	1–3	Tukey	%	Tukey	%	
40	Tamawa.	Pol	72	ABC	35	DEFGHI	3.81	CDEFGHIJ	3.66		2.71	ABCDEF	1.68		2.43	AB	43	AB	54	AB
60	Sekowiec, 160b.	Pol	58	ABC	31	FGHI	4.30	BCDEF	3.06		2.37	BCDEF	1.78		2.39	AB	47	AB	59	AB
67	Bilowo 115, 116.	Pol	64	ABC	29	HI	2.51	KL	2.81		2.70	ABCDEF	1.58		2.62	AB	37	AB	41	AB
53	Postojna Masun.	Slov	85	ABC	32	EFGHI	3.97	BCDEFGHI	4.37		2.16	F	1.59		2.30	AB	45	AB	49	AB
23	Torup.	Swe	70	ABC	29	I	2.71	IJKL	2.44		2.92	ABCD	1.39		2.51	AB	25	B	43	AB
24	Trolle Ljungby.	Swe	76	ABC	37	CDEFGHI	3.13	FGHIJKL	3.41		2.72	ABCDEF	1.53		2.33	AB	50	AB	57	AB
25	Gullmarsberg.	Swe	81	ABC	35	DEFGHI	2.25	L	3.04		2.74	ABCDEF	1.48		2.35	AB	37	AB	51	AB
34	Oberwil.	Switz	85	ABC	45	ABCDE	4.37	BCDEF	2.71		3.10	A	1.86		2.32	AB	44	AB	76	A
Total			77		39		3.47		2.74		2.69		1.67		2.39		41		63	

Table 6.
Correlations among different traits. Bold figures are statistically significant ($p < 0.05$).

	Frost1	Height4	Sphen4	Frost4	Form4	Sphen9	Aphen10	Height10	Crook10	Fork10	Brth10	DbstA10	DbstB10	Surv10
Sphen1	0.04	0.04	**0.68**	–0.04	**0.21**	**0.70**	**0.33**	0.06	**–0.39**	0.01	–0.18	0.10	**0.22**	**0.34**
Height4			–0.04	**–0.39**	**–0.30**	0.19	**–0.37**	**0.94**	**0.22**	**0.35**	**–0.43**	0.15	**0.72**	**0.63**
Sphen4				–0.08	0.17	**0.87**	**0.30**	–0.08	**–0.51**	–0.01	**–0.20**	0.03	0.12	**0.20**
Frost4					0.00	–0.18	0.07	**–0.38**	–0.01	**–0.30**	**0.22**	**–0.32**	**–0.34**	**–0.28**
Form4						0.09	0.04	**–0.20**	**–0.21**	**–0.26**	**0.25**	**–0.32**	–0.04	**–0.22**
Sphen9							**0.22**	0.11	**–0.53**	0.04	**–0.28**	0.07	**0.26**	**0.35**
Aphen10								**–0.45**	–0.14	–0.15	0.16	**0.28**	**–0.29**	0.02
Height10									**0.22**	**0.46**	**–0.42**	0.11	**0.82**	**0.57**
Crook10										0.17	0.11	0.17	0.07	0.04
Fork10											–0.04	**0.43**	**0.65**	**0.28**
Brth10												0.06	**–0.30**	**–0.36**
DbstA10													0.14	**0.35**
DbstB10														**0.51**

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