Growth Performance and Marssonina Attack of Populus deltoides Bartr. Grown in Northern Germany

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Summary

A total of 253 single tree seed lots of *Populus deltoides* Bartr. from Canada and USA have been tested for growth performance and *Marssonina brunnea* attack in various field trials of different age in Northern Germany. Although the selection procedure, the field design and therefore the evaluations varied between the different lots, some general conclusions can be drawn. The best D.B.H. was shown by seed lots from Northern and Central Illinois as well as from Minnesota, Ohio, and Wisconsin. These results (and results from other sources) indicate that the region around the Great Lakes seems to be suitable for eastern cottonwood selections to be introduced into Northern Germany. The region between 37° and 39° of northern latitude seems to form a border between populations of different genetic constitution. Good results have also been obtained from seed lots originating from the Central States Nebraska, Missouri, and Iowa. Well suited sources might be expected also in selections from Michigan and Vermont. Selections from the Northern States including the Canadian provinces Quebec and Ontario showed intermediate performance. Seed sources from the southern part of the USA seem to be unsuitable under the conditions of Northern Germany.

The *Marssonina* attack showed large differences between the seed origins. It seems that progenies from states south of the Great Lakes and from S. Dakota are less attacked than others, but that should not be generalized as infections are influenced strongly by environmental conditions, and can vary from year to year and from site to site.

In relation to breeding aspects of eastern cottonwood (also for *Marssonina* resistance) the selection within open pollinated progenies seems to be less promising than selection within artificial crossings of parents trees from promising provenances. To combine desired character performances it is necessary to test the combining ability of trees of well suited and fast growing provenances.

Key words: Eastern cottonwood, provenance trial, clonal test, D. B. H., *Marssonina brunnea*, breeding aspects.

Zusammenfassung

Insgesamt 253 Einzelstammabsaaten von *Populus deltoides* Bartr. aus Kanada und USA wurden auf ihre Wuchsleistung und *Marssonina brunnea*-Befall in verschiedenen Feldversuchen unterschiedlichen Alters in Norddeutschland untersucht. Auch wenn Auslese, Feldversuchsanlagen und demzufolge die Auswertung zwischen den Versuchen nicht identisch sein konnten, dürfen einige allgemeine Schlüsse aus den mehr als zehnjährigen Versuchen gezogen werden. Herkünfte von Nord- und Zentral-Illinois sowie Minnesota, Ohio und Wisconsin erwiesen sich als besonders wüchsig, wie ihr starker BHD ausweist. Die Region um die Großen Seen erscheint deshalb zur Auslese für Ansprüche in Norddeutschland besonders geeignet. Das Gebiet zwischen 37. und 39. Breitengrad scheint eine Grenze für das Vorkommen genetisch verschiedener Populationen zu bilden. Gute Ergebnisse wiesen auch Absaaten aus den Zentralstaaten Nebraska, Missouri und Iowa auf. Herkünfte aus Quebec und Ontario lagen auf mittleren, Herkünfte aus südlichen Staaten der USA auf unteren Rängen. Gutwüchsige Herkünfte dürften auch aus Michigan und Vermont erwartet werden.

Im *Marssonina brunnea*-Befall ergaben sich deutliche Herkunftsunterschiede. Offenbar werden Herkünfte aus Staaten südlich der Great Lakes sowie aus S. Dakota weniger befallen als andere. Dies sollte jedoch nicht verallgemeinert werden, zumal Infektionen in starkem Maße Umwelteinflüssen unterliegen und von Jahr zur Jahr und Ort zu Ort variieren können.

Bezüglich züchterischer Aspekte wird Auslese aus frei abgeblühten Nachkommenschaften als weniger aussichtsreich als Auslese aus kontrollierten Kreuzungen zwischen Eltern verschiedener geeigneter Provenienzen angesehen. Für die weitere Kreuzungszüchtung werden Untersuchungen über die Kombinationseignung von Bäumen gut angepaßter und schnell wachsender Provenienzen als notwendig erachtet.

1. Introduction

Among all poplar species, eastern cottonwood (*Populus deltoides* Bartr.) has gained most importance all over the world. This is due to its rapid growth rate, relatively high disease resistance, relative ease of vegetative propagation, wide range of genetic variation, ability to produce heterotic hybrids, coppicing ability, and wood quality. The geographical range of eastern cottonwood covers a large area of the North American continent, and there are a lot of different ecotypes which make this species suitable for many ecological different cultivation areas. Thus in the 1960's, provenance collections of eastern cottonwood have been made in order to study their performance and resistance in different European countries and elsewhere. The first experience in these countries have been presented during the Symposium on Eastern Cottonwood and Related Species in Greenville, Miss., in 1976 (cf. Thielges and Land 1976).

In the 1960's the Institute in Schmalenbeck also received seed collections of eastern cottonwood provenances, which have been used for the establishment of field trials in the surroundings of Hamburg. The objective of the study was to find out which provenances were suited for selection of fast growing clones for cultivation in northern Germany. First results concerning the selection in the nursery and the performance in D.B.H., mortality, and *Marssonina* attack in field trials in the Hamburg area are presented in this paper.

2. Materials and Methods

2.1 *Seed lots*

Between 1962 and 1969 seed of 253 single trees of *Populus deltoides* has been obtained from USA and Canada. Seedlings were obtained from 212 seed lots in the nursery at Schmalenbeck. The progenies were classified on the basis of states of USA and Canadian provinces. From the seedlings of the USA-collection in 1962 and 1963 all seedlings of each progeny, from the 1963 Canada-collection 100 plantlets and from seedlots of the following years a maximum of 360 plantlets were transplanted.

2.2 *Clonal trials and collection (Pa 51 and Pa 52)*

From the 1962/63 material by various selection procedures (results on nursery trial 'Kiesgrube' will be published elsewhere), considering height performance, form, rust attack, frost resistance, and rooting ability resulted the clonal trial Pa 51 and the clonal collection Pa 52, in which the residual clones with less than a total of eight ramets were planted.

2.3 *Provenance trials (Pa 46 and Pa 50)*

Two provenance trials, Pa 46 and Pa 50, were established with the later received seed lots near the institute at Schmalenbeck. These lots are known only by the region where they originated from.

2.4 *Description of the trials*

Trial Pa 46: Progenies planted at Reinbek in spring 1968 with 1 + 1 year old seedlings. Soil: sand to loamy sand. Design: randomized complete block design with four replications and 3 or 6 plants per plot, spacing 2 × 2 m.

Trial Pa 50: Progenies planted at Ahrensburg in spring 1970 with 1 + 3 year old seedlings. Soil: pseudogley. Design: completely randomized with 2—33 single-tree plots per progeny, spacing 2 × 2 m.

Trial Pa 51: Clonal trial established at Curslack in autumn 1973 with 1/5 year old cuttings. Soil: loamy sand. Design: randomized complete block design with four replications and 2 plants per plot, spacing 2 × 2 m.

Trial Pa 52: Residual clones of trial Pa 51 (clonal collection) established at Curslack in autumn 1973 adjacent to trial Pa 51 with 1/5 year old cuttings. Unreplicated planting of 3—5 trees per clone in rows, spacing 2 × 2 m.

The trials Pa 51 and Pa 52 were established with clonal material from the trial 'Kiesgrube'. The different plant numbers reflect the large variation in the plantlets obtained, the differences of survival after transplanting, and the different selection intensities between USA- and Canada-collections. A large variation in the available number of seedlings or rooted cuttings was a reason for unfavourable designs in the field trials. Differences in plant numbers and designs between trials rendered a comparison of provenances and progenies more complicated. Additionally the plant material of trial Pa 52 originally was determined for clonal collection only and not for testing. But in this paper it is presented together with the results of trial Pa 51. This is justified, because the ANOVA did not result in a trend of the soil, the collection (Pa 52) is at the same age as trial Pa 51, located adjacently, and the plant material was treated equally. The four old-stock hybrid clones 'Gelrica', 'Grandis', 'Harff', and 'Löns' are included as standards. Trials Pa 46, 50, 51 and 52 cannot be examined as parallel trials.

2.5 *Measured traits*

The following traits were tested in the field trials: D.B.H., mortality, and *Marssonina* attack. D.B.H. data has been measured in trial Pa 46 in spring 1976 (age 8), in trial Pa 50 in autumn 1978 (age 9), and in trials Pa 51 and Pa 52 in autumn 1979 (age 6). At the same time the mortality could be calculated. Leaf attack by *Marssonina brunnea* (Ellis et Everh.) Magn. has been recorded in all four field trials in autumn 1978 as mean of each tree using the following scale: 1 = no leaf spots, 2 = small number of leaf spots (less than 5 per leaf), 3 = medium number of leaf spots (about 10 per leaf), 4 = large number of leaf spots (more than 20 per leaf). The year 1978 was well suited for scoring *Marssonina* attack, because according to Butin (1979) this year showed a beginning of a severe epidemic in Germany. Therefore, the results seem to be representative for our area.

2.6 *Evaluation methods*

The percentage values of mortality and the absolute values of *Marssonina* attack have been evaluated by r × c contingency tables (Sachs 1978). The data of diameter of the field trials were evaluated by analyses of variance and correlation analyses. Data computed were trials mean values of progenies resp. clones.

In trial Pa 51, D. B. H. data were furthermore compared by Duncan's range test at 5% level. Significances were noted as follows: +, ++, +++ significance at the 5%, 1% and 0.1% level respectively; − for non-significance.

3. Results

3.1 *Nursery trial ('Kiesgrube')*

The final number of USA and Canada clones selected in the trial 'Kiesgrube' are recorded in *Table 3* (see also no. 2.2).

3.2. *Field trials*

3.2.1 *Mortality*

The mortality of the progenies is relatively high after 8 and 9 years respectively *(Tables 1* and *2)*. The average mortality is 50% in trial Pa 46 and about 70% in trial Pa 50. In general good growing progenies have a 10% lower mean mortality.

The lowest mortality is 16% for the two progenies from Minnesota in trial Pa 50, but in trial Pa 46 eleven other Minnesota progenies have a mortality rate of 37%. Progenies from S. Illinois, Louisiana, Mississippi, Tennessee, and Texas have totally died away in trial Pa 50. Progenies of three of these states also occur in trial Pa 46 *(Table 1)*, where they have survived in parts: S. Illinois 61% mortality, Mississippi 87%, and Texas 97%. High mortality also has been shown in both progeny trials by Kansas (82% and 93%), and furthermore S. Dakota (67% and 78%). The range of variation of mortality is considerable *(Table 2)*, showing a large within-state variability of the progenies studied.

The mortality of the clones is obviously lower than that of the progenies *(Table 3)*. There is an average mortality of 13% over all *P. deltoides* clones.

In clonal trial (Pa 51) the mortality range is relatively small (0 to 50%), it is broad in the clonal collection (0 to 100%, *Table 3)*. But the according mean mortality values in general are relatively small, ranging from 0% to 24%; only N. Carolina died away with 75%. This indicates that the large range of variation is not as important as it looks

Table 1. — Results of provenance trial Pa 46 (D.B.H. data at age 8, mortality and *Marssonina* data at age 11).

state	no. of progenies	no. of outplanted trees	mean mortality (%)	range	mean D.B.H. (cm)	var. coeff. (%) +	% fast growing trees ++)	no.of fast growing progenies ++)	mean Marssonina attack	range	% trees without attack
N. Illinois	29	616	35	4- 67	4.9	14	42	5	2.7	2.0-3.8	8
Quebec	1	24	21	-	4.8	-	37	0	2.6	-	11
Nebraska	3	44	36	25- 42	4.7	26	36	1	1.6	1.5-1.7	46
Minnesota	11	215	37	13- 89	4.5	27	41	2	2.6	2.0-3.2	14
Missouri	18	394	43	25- 83	4.4	13	33	2	2.0	1.5-2.6	29
Vermont	1	71	30	-	4.3	-	29	0	1.7	-	47
Ontario	1	23	30	-	4.3	-	44	0	2.5	-	19
S. Illinois	3	71	61	39- 74	4.1	16	24	0	2.1	1.9-2.4	25
Montana	1	23	30	-	3.5	-	11	0	1.8	-	35
S. Dakota	3	57	67	33- 83	3.4	5	21	0	1.9	1.5-2.4	37
Kansas	1	11	82	-	3.0	-	-	-	2.0	-	0
Mississippi	9	197	87	28-100	3.0	52	20	-	3.1	2.8-4.0	8
Oklahoma	1	23	70	-	2.6	-	0	0	3.0	-	0
Texas	9	184	97	88-100	2.3	60	0	-	3.2	1.0-4.0	17
sum	91	1953						10			
average			50		3.8		26		2.4		19

+ calculating mean values of progenies; ++ fast growing progenies and trees: equal or superior to 120 % of the trial mean value of D.B.H.

like. E.g. of the 20 clones from Minnesota: 15 do not have any mortality, four have a mortality of 12.5%, one of 20%, and another clone of 37.5%.

The results of a contingency test of the mortality rate show significant differences between the states of origin *(Table 4)* with Minnesota and Wisconsin as outstanding regions of low mortality in the progeny test (37/16% and 29% mortality resp.; *Table 1, 2)* and in the clonal trial with nearly 0% *(Table 3).* That is true also for the Wisconsin clones in the clonal collection (8%), whilst one Minnesota clone had a somewhat higher mortality (20%).

3.2.2 *Growth performance*

In *Tables 1* to *3* the states are ranked according to the mean D.B.H. of all progenies resp. clones of a state. Although the numbers of progenies or clones per state varies very strongly the following results can be obtained.

In the provenance trials Pa 46 and Pa 50 Northern and Central Illinois progenies have shown best mean D.B.H. results, which differ only to a small extent to the next following states. Good growth in both trials can be observed also in progenies of Minnesota, Missouri *(Table 1),* and Ohio *(Table 2).* Progenies of Quebec *(Table 1)* and Wisconsin *(Table 2)* show also good results, but only a few progenies could be compared. Nebraska progenies and those from Vermont showed the widest variation between the two sites. They show good growth in one but intermediate performance in the other site. Other intermediate growing progenies originate from Ontario and Southern

Table 2. — Results of provenance trial Pa 50 (age 9).

state	no. of progenies	no. of outplanted trees	mean mortality (%)	range	mean D.B.H. (cm)	var. coeff. (%) +	% fast growing trees ++)	no. of fast growing progenies ++)	mean Marssonina attack	range	% trees without attack
C. Illinois	16	406	69	35-87	9.0	23	35	3	2.6	1.8-3.0	6
Ohio	11	272	54	39-82	8.6	16	33	2	2.5	1.8-2.9	6
Wisconsin	3	68	29	25-33	8.5	17	27	0	3.1	2.9-3.2	0
Vermont	7	137	50	33-83	8.5	28	35	1	2.6	1.7-3.7	16
Minnesota	2	31	16	13-19	8.3	1	31	0	2.4	1.8-3.1	16
Kansas	4	118	93	89-93	8.2	20	25	0	2.9	2.0-4.0	0
Iowa	5	133	46	32-68	8.0	17	28	0	3.0	2.5-3.5	3
Nebraska	5	136	66	59-80	7.7	22	24	0	2.6	2.2-2.8	8
Michigan	2	29	47	44-50	6.9	4	19	0	2.4	2.0-2.5	0
S. Dakota	3	58	78	71-93	6.7	24	15	0	2.4	1.0-2.7	8
S. Illinois	8	123	99	-	6.1	-	-	-	-	-	-
Louisiana	10	135	100	-	-	-	-	-	-	-	-
Mississippi	11	190	99	-	9.4	-	-	-	-	-	-
Tennessee	7	174	100	-	-	-	-	-	-	-	-
Texas	3	7	100	-	-	-	-	-	-	-	-
sum	97	2017						6			
average			73		8.4		27		2.7		7

+ calculating mean values of progenies; ++ fast growing progenies and trees: equal or superior to 120 % of the trial mean value of D.B.H.

Table 3. — The final number of USA and Canada clones selected from the trial 'Kiesgrube', and the results of clonal trial Pa 51 and clonal collection Pa 52 (D.B.H. and mortality data at age 6, *Marssonina* data at age 5).

clones and provenance regions	no. of seedlots	total no. of clones	no. of outplanted trees	mean mortality (%)	range of mortality (%)	mean D.B.H. (cm)	var. coeff. D.B.H. (%) +	mean D.B.H. related to mean of standard clones (%)	no. of fast growing clones ++	mean Marssonina attack
standard clones										
'Gelrica'	-	1	8	13	-	13.7	-	117	1	1.0
'Löns'	-	1	8	0	-	11.6	-	99	0	1.0
'Grandis'	-	1	8	0	-	10.9	-	93	0	1.0
'Harff'	-	1	8	13	-	10.4	-	89	0	1.0
sum		4	32						1	
average				7		11.7		100		1.0
Pa 51 (clonal trial)										
Ohio	1.	1	8/clone	0	-	13.7	-	117	1	1.0
Minnesota	1.	8	"	3	0- 13	9.6	12	82	1	1.0
	2.	12	"	5	0- 38	10.0	18	85	0	1.0
Wisconsin	1.	9	"	4	0- 13	9.4	10	80	0	1.0
	2.	15	"	4	0- 25	8.9	23	76	2	1.0
Ontario	1.	2	"	0	-	5.0	4	43	0	1.0
	2.	12	"	9	0- 50	7.3	15	62	0	1.0
	3.	1	"	13	-	7.4	-	63	0	1.0
	4.	5	"	8	0- 25	9.0	8	77	0	1.0
	5.	3	"	0	-	7.7	13	66	0	1.0
Nebraska	1.	3	"	8	0- 13	6.6	10	56	0	1.0
	2.	15	"	14	0- 38	8.1	18	69	0	1.0
sum	12	86	688						4	
average				6		8.6		73		1.0
Pa 52 (clonal collection)										
Minnesota	1.	1	5	20	-	9.0	-	77	0	1.0
Ohio	1.	9	31	0	-	8.9	18	76	1	1.0
Wisconsin	1.	3	13	8	0- 20	9.5	20	81	0	1.0
Nebraska	1.	3	11	18	0- 33	6.1	12	52	0	1.0
	2.	3	11	18	0- 67	7.3	6	62	0	1.0
Ontario	1.	26	84	17	0-100	6.3	16	54	0	1.0
	2.	40	143	11	0-100	7.4	20	63	0	1.0
	3.	28	79	24	0-100	7.2	17	62	0	1.0
	4.	41	153	8	0- 67	8.7	15	74	1	1.0
	5.	49	150	16	0-100	7.5	16	64	0	1.0
N. Carolina	1.	1	4	75	-	7.0	-	60	0	1.0
sum	11	204	684						2	
average				20		7.7		66		1.0

+ calculating mean values of clones; ++ fast growing clones: equal or superior to the mean of standard clones (11.7 cm)

Illinois (only a few progenies tested, *Table 1),* and from Kansas and Iowa *(Table 2).* Kansas also is represented between the poorest progenies *(Table 1)* accompanied by South Dakota on both sites, Montana, Mississippi, Oklahoma, and Texas in trial Pa 46 *(Table 1)* and Michigan in Pa 50. In the same trial progenies from Southern Illinois, Louisiana, Mississippi, Tennessee and Texas at least totally died away *(Table 2).*

The clonal material of trial Pa 51 and the clonal collection Pa 52 originates from 1 to 5 progenies *(Table 3).* Best mean D. B. H. values are obtained by clones from Ohio, closely followed by Minnesota, and Wisconsin (Pa 51). In Pa 52 clones from Ohio and Wisconsin have changed their ranks. Compared with these, clones from Nebraska, Ontario, as well as a single one from North Carolina have considerable lower mean D.B.H.

In order to investigate the differences among the progenies resp. clones of the same state, in *Table 1—3* furthermore the variation coefficients of the mean values of D.B.H. are presented. Mississippi and Texas progenies show important within-state variation; N. Illinois and Missouri *(Table 1)* as well as Ohio progenies *(Table 2)* have relatively low variation coefficients.

In the analysis of variance of the field trials only those states were considered of which more than one progeny resp. clone could be investigated. The results for mean D.B.H. show highly significant differences ($p = \leq 0.1\%$) between the states in trial Pa 46, but no significant differences in trial Pa 50.

For further interpretation of the results also the percentage of fast growing trees per state origin and the number of fast growing progenies was evaluated. The percentage of fast growing trees indicates the percentage of trees per progeny which have a D. B. H. performance equal or superior to 120% of the trial mean value (in relation to the number of surviving trees). The average percentage of fast growing trees is 26% and 27% *(Tables 1* and *2).* The ranking of the states according to their percentage of fast growing trees is similar to the mean D.B.H. ranking. N. Illinois and Minnesota (and Ontario, with only one progeny) show the best results with 41% to 44% of fast growing trees. The number of fast growing progenies varies between zero and five *(Tables 1* and *2).*

In the clonal trial Pa 51/52 the mean D.B.H. of the clones is related to the mean of the standard clones 'Gelrica', 'Grandis', 'Harff', and 'Löns' (= 11.7 cm). There are two faster growing clones each from Ohio and Wisconsin, and one each from Minnesota and Ontario *(Table 3).*

3.2.3 *Attack by Marssonina brunnea*

Attack by the leaf spot causing pathogen *Marssonina brunnea* showed great differences between the trials as well as between the states. No infections at all could be observed in the clonal trial Pa 51/52 *(Table 3).* In progeny

Table 4. — Comparison of the mortality (%) of regions in 1975 in provenance trial Pa 50, evaluated by a contingency test, in which the number of outplanted and still surviving trees were considered (level of significance: 5 %).

		Minnes. (16)	Wisc. (29)	Michig. (45)	Iowa (46)	Vermont (50)	Ohio (54)	Nebraska (66)	C.Ill. (69)	S.Dak. (78)	Kansas (93)
Minnesota	(16)		-	+	+	+	+	+	+	+	+
Wisconsin	(29)			-	+	+	+	+	+	+	+
Michigan	(45)				-	-	-	-	+	+	+
Iowa	(46)					-	-	+	+	+	+
Vermont	(50)						-	-	+	+	+
Ohio	(54)							+	+	+	+
Nebraska	(66)								-	-	+
C. Illinois	(69)									-	+
S. Dakota	(78)										+
Kansas	(93)										

trials Pa 46 and Pa 50 attack was medium to heavy with mean values of 2.4 and 2.6 respectively *(Tables 1* and *2).*

In trial Pa 46 *(Table 1)* the lowest attack, ranging from classifications 1 to 2 had progenies from Nebraska, Vermont, S. Dakota, and Montana. Progenies of the first three of these states also occur in trial Pa 50, but mean infection rates were somewhat higher *(Table 2).* The highest *Marssonina* attack could be observed in progenies of Texas, Mississippi, and Oklahoma in trial Pa 46 *(Table 1),* and Wisconsin, Iowa, and Kansas in trial Pa 50 *(Table 2).*

The within-state variation of *Marssonina* attack was highest between progenies from Texas *(Table 1)* and Vermont *(Table 2),* lowest between Nebraska *(Table 1)* and Wisconsin progenies *(Table 2).*

Regarding *Marssonina* infection the results of contingency tests showed highly significant differences ($p \leq 0.1$ %) between the states.

The average percentages of trees without any *Marssonina* attack at the time of observation is very different in the two progeny trials *(Tables 1* and *2),* presumably because of the differences of infection rates at the two locations. In trial Pa 46 nineteen % of the trees of the different state origins are free of *Marssonina* attack, but only 7% in trial Pa 50. In both trials Vermont had the highest percentage of unattacked trees, followed by progenies of Nebraska in Pa 46 *(Table 1)* and Minnesota in Pa 50 *(Table 2).* In trial Pa 46 Oklahoma and Kansas do not have any unattacked tree at all, which is also true for Wisconsin, Kansas, and Michigan in trial Pa 50. Summarizing the results one can say that progenies from states south of the Great Lakes were generally less attacked by *Marssonina* than progenies from Canada and the southermost US states.

3.2.4 *Comparison of the best progenies resp. clones*

In *Table 5* the single data of the fast growing progenies and clones are presented. These progenies and clones originate from Northern and Central Illinois, Minnesota, Missouri, Nebraska, Ohio, Ontario, Vermont, and Wisconsin. The average mortality of the progenies of trials Pa 46 and Pa 50 is 44%, ranging from 17% to 83%. The clones had no mortality. The average D.B.H. variation coefficient is 41% for the progenies and 12% for the clones. The average *Marssonina* attack is 2.6 for the progenies, which is a value between low and medium attack. The mean *Marssonina* attack ranges from 1.6 to 3.4. The clonal trial had no *Marssonina* infection at all as mentioned above.

When calculating the D.B.H. values of the ramets in the clonal trial Pa 51 by analysis of variance there are highly significant differences between the clones ($p \leq 0.1\%$). Regarding D.B.H. the first 20 clones of this trial are ranked in *Table 6.* The results of the Duncan test show that four clones are significantly superior to the mean of the four standard clones, and four clones are not significantly different to the standard mean. The two fastest growing clones are standard clone 'Gelrica' and Ohio no. 3987/3, followed by two Wisconsin clones. In the next following group there are standard clone 'Löns' and three Minnesota clones. The other two standard clones, 'Grandis' and 'Harff', are among other clones from Minnesota and Wisconsin, being significantly inferior to the standard mean. From the other states including 18 clones from Nebraska and 23 clones from Ontario, no one is among the first 20 clones.

The trait correlations in *Table 7* show highly significant coefficients in both trials for mean D.B.H. and percentage

Table 5. — Data of fast growing progenies (upper part of table) and clones (bottom part of table).

state	county	location	north latitude	west longitude	altitude (m)	trial	seed book no.	mortality (%)	mean D.B.H. in % of trial mean*	var.coeff. D.B.H. (%)	mean Marssonina attack
N.Illinois	-	-	-	-	-	Pa46	4227	54	122	41	2.6
	-	-	-	-	-	Pa46	4237	21	135	44	2.5
	-	-	-	-	-	Pa46	4239	33	139	42	2.8
	-	-	-	-	-	Pa46	4241	17	130	47	2.9
	-	-	-	-	-	Pa46	4243	58	126	59	2.7
C.Illinois	Mason	Topeka	40°20'	89°55'	153	Pa50	5574	83	146	43	2.8
	Mason	Havana	40°20'	90°05'	151	Pa50	5577	61	123	37	2.9
	McLean	Heyworth	40°20'	89°00'	223	Pa50	5616	62	129	42	2.6
Minnesota	-	-	-	-	-	Pa46	4192	42	120	40	2.9
	-	-	-	-	-	Pa46	4193	29	122	36	2.3
Missouri	-	-	-	-	-	Pa46	4211	17	124	32	2.6
	-	-	-	-	-	Pa46	4225	50	120	31	2.6
Nebraska	-	-	-	-	-	Pa46	4167	33	133	36	1.6
Ohio	Fulton	Whitehouse	41°45'	83°45'	25	Pa50	5592	41	124	43	2.8
	Cujahoga	Gates Mills	41°30'	81°25'	354	Pa50	5606	53	120	34	1.8
Vermont	Chittenden	Essex Junct.	44°23'	73°04'	104	Pa50	5665	43	127	41	3.4
average progenies								44	-	41	2.6
Minnesota	Ramsey	Clev.Ave.Bdg.	-	-	335	Pa51	3989/23	0	100	6	1.0
Ohio	Athens	T9N R14W	39°19'	82°06'	210	Pa51	3987/3	0	118	11	1.0
	Athens	T9N R14W	39°19'	82°06'	210	Pa52	3987/8	0	101	19	1.0
Ontario	-	Lowbanks	42°53'	79°29'	-	Pa52	3996/7	0	106	10	1.0
Wisconsin	Wasau	Wisc.River	45°00'	89°30'	430	Pa51	3992/12	0	106	17	1.0
	Wasau	Wisc.River	45°00'	89°30'	430	Pa51	3992/42	0	108	7	1.0
average clones								0	-	12	1.0

* mean D.B.H. of clones is in percentage of mean of standard clones.

Table 6. — Ranking of the first 20 clones in trial Pa 51 (total number: 90).

rank	clone	seed book no.	mean D.B.H. (cm)	Duncan test	significance in relation to mean of standard clones
1.5	'Gelrica'	-	13.7		
1.5	Ohio	3987/3	13.7		significantly superior
3	Wisconsin	3992/42	12.6		
4	Wisconsin	3992/12	12.3		
5	Minnesota	3989/23	11.7		
6	'Löns'	-	11.6		no significant differences
7	Minnesota	3990/41	11.5		
8	Minnesota	3990/79	11.4		
9	Minnesota	3990/8	11.1		
10.5	'Grandis'	-	10.9		
10.5	Minnesota	3990/66	10.9		
12.5	Minnesota	3990/42	10.7		
12.5	Wisconsin	3991/34	10.7		
14	Wisconsin	3992/69	10.6		significantly inferior
16	Minnesota	3989/19	10.5		
16	Minnesota	3990/18	10.5		
16	Wisconsin	3992/20	10.5		
19	Wisconsin	3992/27	10.4		
19	Wisconsin	3991/75	10.4		
19	'Harff'	-	10.4		

Table 7. — Results of trait correlations (upper coefficient is of trial Pa 46, bottom coefficient is of trial Pa 50).

	% fast growing trees	mortality	mean Marssonina attack	% unattacked trees (Marss.)
mean D.B.H.	0.82 ** 0.85 **	-0.79 *** -0.31 -	-0.50 - 0.29 -	-0.07 - 0.12 -
% fast growing trees		-0.26 - -0.28 -	0.10 - 0.21 -	-0.28 - 0.23 -
mortality			0.76 ** 0.18 -	-0.31 - -0.19 -
mean Marssonina attack				-0.87 *** -0.47 -

of fast growing trees. There seems to be a negative correlation between mean D. B. H. and mortality, but the coefficient in trial Pa 50 is not significant. In trial Pa 46 mortality and mean *Marssonina* attack are highly significantly correlated, but uncorrelated in trial Pa 50. There is also a highly significant negative correlation between mean *Marssonina* attack and percentage of unattacked trees in trial Pa 46, which is not significant in trial Pa 50.

4. Discussion

The large variability within eastern cottonwood could be demonstrated in these trials in spite of several disadvantages regarding different designs, different numbers of trees per progeny, and missing of true parallel trials. Nevertheless the results show which regions are important within the natural distribution area for selecting suited provenances resp. clones for the north German climate.

In the trials investigated the large variability of eastern cottonwood could be expected before when regarding the ecologically different origins of the seeds. Results of D.B.H. and mortality in all trials confirm in that way that progenies or clones originating from Northern and Central Illinois as well as from Ohio, Wisconsin, and Minnesota have performed best *(Table 6, 7).* Selected clones of another seed collection from Massac County, Illinois, are already known to be of good growth vigour in Germany (Weisgerber 1976). Three clones of this collection, 'Lincoln', 'Marquette', and 'Peoria' are the only registered eastern cottonwood clones in Germany. The origin Illinois seems to be suited for the climatic conditions in the Netherlands as well (Koster 1976a).

The results obtained indicate that provenances from the region around the Great Lakes seem to be especially suited for the conditions in Northern Germany. Provenances from the southern parts of Illinois and Ohio do not seem to be suited the same way, which might indicate the occurrence of two populations of different genetic constitution along the scope between 37° and 39° of northern latitude. When investigating the trait "mean number of branches per meter of stem length" Koster (1976a) also found a differentiation in the scope of this latitude. Marcet (1961) investigated the trait "gland numbers" and separated a northern and a southern ecotype of eastern cottonwood, which he assumed to be both migrated in western direction. Following this theory, the origins from the northern and central part of Illinois and Ohio might be the most southerly situated ones of the northern ecotype. But investigating other morphological traits Ying and Bagley (1976) found the geographical variation in eastern cottonwood appearing to be clinal rather than ecotypic. A majority of the traits investigated had stronger east-west than north-south differentiation.

Good results also have been obtained by seedlots from Nebraska, Missouri, and Iowa, which belong to the Central states like Illinois and Ohio. The origins of the northern states including the Canadian provinces Quebec and Ontario seem to be of intermediate growth vigour when cultivated in Northern Germany. This would suggest that well suited sources might be selected also in Michigan and Vermont. To a limited extent this seems to be also true for S. Dakota and Kansas in the North to Middle West region. The origins of the southern part of USA seem to be unsuited under the proved conditions. According to our results this would apply to S. Illinois, Oklahoma, Tennessee, N. Carolina, Texas, Lousiana, and Mississippi.

The results of this investigation concerning *Marssonina* attack can be compared with those of Koster (1976b) in the Netherlands, who evaluated the percentages of trees being unattacked by *Marssonina brunnea* and *Melampsora larici-populina.* There are some differences in the behaviour of the progenies of various states. Some states had much more unattacked trees in our trials than did in the Dutch ones, others had less. Several explanations are possible for these contrary results. Koster (1976b) combined both *Marssonina* and *Melampsora* attack, whereas in our trials only *Marssonina* was determined. The differences between sites influenced by local environmental conditions can be considerable, what has been shown also between our different trials. Further, the within-state variation was in some cases very great. So one cannot compare mean values of the states only, but should check the respective provenances, progenies or clones, if possible.

According to the results of clonal trial Pa 51, a successful selection of fast growing clones being selected out of open pollinated progenies seems to be possible. But still a problem is the exterior habit of selected clones, which mostly show deficient stem forms and branching as well as much taper. So far for the establishment of well suited cultivars the controlled combination of parent trees with desired characters seems to be a more convenient way than selection within open pollinated progenies. Another advantage of such crossings would be the possibility of obtaining heterotic provenance hybrids as found by Dhir and Mohn (1976). Mohrdiek (1979) reported a very fast growing

progeny of eastern cottonwood with excellent form habit, which was established by controlled crossing. The exact origin of the parent trees could not be identified. They originated from one or more of the following states: Kansas, N. Dakota, and Ontario. In a six-year old clonal trial, one clone of this progeny had no mortality and showed a D.B.H. growth vigour, which was 198% of the mean of the standard clones 'Gelrica', 'Grandis', 'Harff', and 'Lönns' (MOHRDIEK 1978). When compared with 'Gelrica' only, its D.B.H. was 246%.

For breeding of eastern cottonwood, the selection within open pollinated progenies seems to be less promising than selection within controlled crossings of parent trees from different provenances. In such crossings trees from fast growing provenances like Illinois or Ohio should be used; it is therefore necessary to test also the combining ability of trees of good suited and fast growing provenances. Parent trees with desired character performances should be selected for crossings in factorial and polycross designs. Using this approach, parent trees with a superior combining ability might be selected like e.g. mother tree "D60", which already has proven its high heritability in growth vigour and form habit (MOHRDIEK 1979). Furthermore, the crossing with other species like e.g. *Populus nigra* L. (MOHRDIEK 1979) and *Populus trichocarpa* TORR. et GRAY are promising as well (KOSTER 1976b, MOHRDIEK *et al.* 1979, STETTLER *et al.* 1980).

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Seventeen-year performance of Pinus flexilis and P. strobiformis progenies in eastern Nebraska

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Summary

First and 17-year survival percentages were 32 and 15 for *Pinus flexilis* and 85 and 72 for *P. strobiformis* trees. Thirteen *P. flexilis* and 1 *P. strobiformis* progenies died during the test period. Surviving *P. flexilis* trees attained a mean height of 2.5 m; surviving *P. strobiformis* trees attained a mean height of 7.1 m. Differences in survival and heights were significant between species, but not among progenies within species. *Pinus flexilis,* except for low elevation, easternmost sources, is of little value in Great Plains plantings because of low survival and slow growth. *P. strobiformis* shows good potential for Great Plains use, if seed is collected at elevations of 2,300 m or higher in central Arizona and New Mexico. Genetic age-age correlations indicate that early selection is reliable.

Key words: *Pinus flexilis, P. strobiformis,* progeny testing, survival, height growth, genetic correlations.

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Zusammenfassung

In einem Anbauversuch von *Pinus flexilis* und *Pinus strobiformis* in Nebraska wurden im Jahre 1964 49 Nachkommenschaften, darunter 28 aus Einzelbaumbeerntung, ausgepflanzt, nachdem diese im Jahre 1961 in einer Baumschule in East Lansing, Michigan, ausgesät worden waren. Bei *Pinus flexilis* überlebten im Alter 1 32% und im Alter 17 15%, bei *Pinus strobiformis* dagegen 85% im Alter 1 und 72% im Alter 17. Weitere 13 *P. flexilis* Nachkommenschaften und eine von *P. strobiformis* starben während der Untersuchungsperiode ab. Überlebende *Pinus flexilis* erreichten im Durchschnitt eine Höhe von 2,5 m; überlebende *P. strobiformis* eine Höhe von 7,1 m. Die Überlebens- und Größenunterschiede zwischen den beiden Arten waren also bedeutsam, nicht jedoch unter den einzelnen Nachkommen der Arten. Bei *P. flexilis* eignen sich östliche Herkünfte aufgrund geringer Überlebensprozente und langsamen Wachstums wenig für den Anbau in den Great Plains (Prärie). *P. strobiformis* kann für den Anbau in der Prärie gut verwendet werden, wenn die Herkünfte aus Höhen über 2300 m in Zentral-Arizona und New Mexico stammen.