Juvenile-Mature and Trait Correlations in Some Aspen and Poplar Trials

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(Received November 1978 1 June 1979)

Summary

With the evaluation of 15 F, Leuce progeny trials and 23 Aigeiros/Tacamahaca clonal trials, juvenile-mature correlations have been made for the traits growth potential and survival rate. Furthermore, trait correlations of exterior characters have been evaluated.

The results are as follows:

1) Differences in growth vigor of F, Leuce progenies can already be observed in the first years after planting in the field. In general this is true for survival rate too.
2) In F_1 Leuce progenies, a close positive correlation exists between D.B.H. and survival rate. For aspen and hybrid aspen there is a correlation between D.B.H. and form class in general. The better growing progenies tend to have straighter stem forms.
3) Differences in growth vigor as well as survival of Aigeiros/Tacamahaca clones can also be evaluated at relatively early ages. Yet statements about single clones should not be made before an age of 7 years, especially as growth potential and survival rate are uncorrelated.
4) A test interval of 8 years seems to be sufficient for F_1 Leuce progenies. For Aigeiros/Tacamahaca clones a test interval of 10 years seems to be appropriate.

Key words: F_1 Leuce progenies, AigeiroslTacamahaca clones, juvenile-mature correlations, trait correlations, early testing.

Zusammenfassung

Mit der Auswertung von 15 Versuchen mit F_1-Leuce-Nachkommenschaften sowie 23 Versuchen mit Aigeiros/Tacamahaca-Klonen sind auch Jugend-Alters-Korrelationen für die Merkmale Zuwachs und Überlebensprozent gerechnet worden. Weiterhin sind Merkmalskorrelationen von äußeren Merkmalen gerechnet worden.

Die erhaltenen Ergebnisse sind wie folgt:

1) Zwischen F_1-Leuce-Nachkommenschaften bilden sich Unterschiede in der Wüchsigkeit bereits im ersten Jahr nach der Pflanzung aus. Dies trifft in der Regel auch für das Merkmal Uberlebensprozent zu,
2) Bei F_1-Leuce-Nachkommenschaften besteht eine enge positive Korrelation zwischen den Merkmalen BHD und Uberlebensprozent. Bei Aspen und Hybridaspen sind in der Regel auch die Merkmale BHD und Stammform korreliert, wobei die gutwüchsigeren Nachkommenschaften meistens auch die geradschäftigeren sind.
3) Bei Aigeiros/Tacamahaca-Klonen tritt eine Differenzierung nach Wüchsigkeit sowie Uberlebensprozent ebenfalls bereits im frühen Alter ein. Es sollten jedoch Aussagen über einzelne Klone nicht vor dem Alter von 7 Jahren gemacht werden, besonders auch, da Zuwachsmerkmale und Uberlebensprozent nicht korreliert sind.
4) Bel F_1-Leuce-Nachkommenschaften erscheint eine Prüfdauer von 8 Jahren, bei AigeiroslTacamahaca-Klonen von 10 Jahren angebracht zu sein.

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Introduction

For the commercial registration of new Populus cultivars, test intervals of 10 years are prescribed in the Fed. Rep. of Germany, which corresponds to half of the usual rotation period. This age was established from past experience, i.e. it is commonly assumed that a cultivar has proven its good growth potential by this age. It is also assumed that it will maintain its growth potential.

However, as to later age-classes, exceptions to this rule are known for certain Aigeiros clones. For 'Robusta', RÖHRIG (1959) has observed a very good juvenile growth potential, which is equaled or surpassed by other clones at an age of 30 years. The same authors found for 'Harff' a low growth potential at young ages, which, however, showed increased height and thickness at later ages.

It was the aim of this paper to investigate the earliest age at which predictions could be made about new cultivars, and whether a test interval of 10 years really is appropriate. For this purpose, juvenile-mature correlations were established for F, progenies and hybrid progenies of the section Leuce on one hand, and for intra and interspecific clones of the sections Aigeiros and Tacamahaca on the other hand.

Furthermore, it seemed to be useful to estimate correlations between traits as well. By this e.g. the recording of a late manifesting trait might be ignored if it is closely correlated to a trait well expressed in young ages.

Material and Methods

The trials investigated in this paper had been laid out in order to test new bred Leuce progenies as well as Aigeiros and Tacamahaca clones. They are part of the Schmalenbeck breeding program in Populus, and the field trials in which the investigations of this paper were made, are presented by MOHRDIEK (1976). Trials As7 — As42, presented in table 1, contain intra and interspecific F, crossing progenies among the Leuce Duby species P. alba L., P. tremula L., P. X canescens SM., P. *tremuloides* MICHX., and P. *grandidentata* MICHX. Of the trials mentioned, As25—As42 contain progenies and hybrid progenies of P. tremula and P. tremuloides only. All progenies are part of the Leuce breeding program of which an evaluation of 337 F, progenies and backcrossings will be published afterwards (MOHRDIEK, 1979). The other trials in table 1, described by numbers 1a — 12, contain clones or hybrid clones of the sections Aigeiros Duby and Tacamahaca Spach. These clones are part of the clonal test program of which recently an evaluation of 236 clones was published (MOHRDIEK, 1978).

Juvenile-mature correlations are calculated for growth potential and survival rate. As to growth traits of poplars, it is well known that height and diameter growth are closely and positively correlated (WILKINSON, 1973; PETROV, 1974). An exception for any species without this close correlation is not known to the author. So D.B.H. and height growth were considered as corresponding indicators for growth potential, which could be put in auto-correlation. In agreement with this, former studies showed correlation coefficients between D.B.H. and height values were positively correlated and highly significant (MOHRDIEK, 1976).

Table 1. — Significances of juvenile-mature correlations for growth potential and survival rate.

trial	no. of progenies /clones	correlation base at the age of	measurements at earlier ages (correlated to correlation base) (numbers indicate ages): growth potential (height or DBH)	survival rate
Leuce progenies				
As7	10	22	12*** 3-	12*** 3-
As8	22	21	10*** 2-	10*** 2-
As9	15	20	13*** 10*** 3*** 2*** 1***	13*** 10*** 3*** 2** 1-
As11	16	20	14*** 11*** 2* 1*	14*** 11*** 2- 1-
As12	35	20	15*** 11*** 9*** 3*** 2** 1**	15*** 11*** 9*** 3*** 2*** 1***
As14	8	21	19*** 14*** 11***	19*** 14*** 11***
As25	25	18	10*** 7*** 6***	10*** 7- 6-
As29f	25	17	4*** 3*** 2***	-
As31	25	13	7*** 3*** 2*** 1***	7*** 3*** 2*** 1***
As35	17	10	5*** 2***	5*** 2***
As36	16	11	6*** 3***	6*** 3***
As39	20	11	5*** 2***	5*** 2***
As40	24	11	2**	2***
As41	20	11	5*** 2***	5*** 2*
As42	10	11	5*** 2***	5*** 2*
Aigeiros/Tacamahaca clones				
1a	11	13	7*** 4*** 1*	7** 4- 1-
1b	15	13	7*** 4*** 1*	7*** 4- 1-
2a	12	13	7* 4- 1-	7*** 4- 1-
2b	13	13	7* 4- 1-	7** 4- 1-
3a	21	11	3- 1-	3* 1-
3b	24	11	4** 3**	4* 3-
4a	21	12	7*** 4** 3** 2- 1-	7*** 4- 3- 2- 1-
4b	23	12	4** 1-	4* 1-
5	19	12	4* 1-	4*** 1-
6a	41	10	3*** 1**	3** 1-
6b	42	6	1***	1***
7a	18	9	1-	1-
7b	28	8	1-	1-
7c	23	8	1-	1-
8	21	8	1*	1***
9a	12	13	7*** 4** 3- 2- 1-	7** 4- 3- 2- 1-
9b	11	13	6*** 3**	6** 3**
10a	16	12	7*** 4*** 1*	7*** 4*** 1***
10b	13	11	4* 3-	4- 3-
11a	25	11	4*** 1***	4- 1-
11b	18	9	1-	1-
11c	21	6	1-	1***
12	12	11	4** 1-	4*** 1-

In the correlation analysis presented, stem height had been recorded until the age of 7 years. Afterwards only D.B.H. has been recorded in general. The data of stem height and D.B.H., recorded at earlier ages, were put in correlation to D.B.H. data recently recorded. For survival rate, correlations have been made by absolute numbers of surviving trees. Comparability of the traits was possible because all trials were randomized except trials As7 and As29f.

Data has been recorded since the first vegetation period after planting. The age at the time of recent data recording is given as "correlation base" in the third column of *table 1*. To the right of this column, ages are given for previous measurements. Significance or non-significance of the data to the correlation base is noted at these ages.

Trait correlations have been made for the traits D.B.H., survival rate, as well as form class, branchiness between whorls, branch angle, and forking. All but the first two traits have been recorded as classifications (MOHRDIEK, 1976).

All correlations were obtained from mean values of the progenies resp. clones. Significances were noted as follows: — for non-significance at $P = 0.05$, * for significance at $P = 0.05$, ** for significance at $P = 0.01$, and *** for significance at $P = 0.001$.

Results

Juvenile-mature correlations

In *table 1* the correlation coefficients for the ages of the correlation base and the earliest measurements are significant for growth potential in Leuce progenies. This is true for all trials except As7 and As8. For trials As9, As 11, As12, and As31, such significant coefficients even occur for the first year after planting. In the other trials the first data recording had been made only at later ages.

For growth potential of Aigeiros/Tacamahaca clones, there are significant coefficients in the first and third year after planting in eight of the 23 trials. In the other trials no significant coefficients are obtained at the ages of 1, 2, 3, or 4 years, but at ages of 4 and 7 years significant coefficients could be found.

As to survival rate in Leuce progenies, significant coefficients at the first measurements occur in half of the trials. In the other trials, there are no significant coefficients at ages of 1, 2, and 3 years. Trial As25 was not even significant at the age of 7 years.

For survival rates of Aigeiros/Tacamahaca clones, significant coefficients for the first year after planting were obtained in four trials. In seven trials the first significant coefficients are at ages of 3 and 4 years. In six trials the first significant coefficients only occur from the age of 7 years on.

It could be determined that, after the occurrence of significant coefficients in early ages, all juvenile-mature correlations always maintained significant coefficients in the following ages. With decreasing age difference from the correlation base they always become highly significant. In *table 2* this is demonstrated for trial As12.

Trait correlations

Significant coefficients did not regularly occur in the Aigeiros/Tacamahaca trials for any correlation, so only the results of the Leuce trials are reported.

The trait correlations of D.B.H. with survival rate and D.B.H. with form class for Leuce progenies show that the coefficients have equal signs over all trials *(table 3)*. D.B.H.-survival rate coefficients have a positive sign, and D.B.H.-form class coefficients have a negative one. The latter means that Leuce progenies with high D.B.H. values have straighter stem forms and vice versa.

In D.B.H.-survival rate correlations significant or highly significant coefficients occur in eight of fourteen trials. In the other trials, which are mostly those with lower degrees of freedom, except as in trial As8, the coefficients are relatively high.

In D.B.H.-form class correlations significant or highly significant coefficients occur in seven of fifteen trials. In the other trials, especially in As7, As8, As9, and As40, there are relatively low coefficients.

The differenciation of *table 3* into trials where grey poplar and aspen crossings are together, and trials with aspen crossings only, shows that there are different results in D.B.H.-form class correlations. In the six trials with grey poplar crossings a significant coefficient only occurred in trial As12. However, of the ten trials with aspen crossings only six have significant coefficients.

There were no regularly significant coefficients when correlating branchiness between whorls, branch angle, and forking with the other traits (Mohrdiek, 1976).

When correlating D.B.H., stem height, mean branch thickness, and mean branch length with each other (Mohrdiek, 1976), results of Leuce as well as Aigeiros/Tacamahaca trials show positive significant, mostly highly significant coefficients.

Table 2. — Correlation coefficients showing the relationship between growth potential resp. survival rate at the age 20 (correlation base) with that a younger ages (trial As12: Grey poplar and aspen crossings).

age	15	11	9	3	2	1
growth potential	0,952***	0,934***	0,828***	0,554***	0,483**	0,462**
survival rate	0,973***	0,954***	0,941***	0,894***	0,886***	0,886***

Table 3. — Trait correlations in Leuce trials.

trial	no. of progenies	age	correlation coefficients DBH/survival rate	correlation coefficients DBH/form class
grey poplar and aspen crossings together				
As7	10	22	0,854***	-0,156^{-}
As8	22	21	0,169^{-}	-0,161^{-}
As9	15	20	0,781***	-0,199^{-}
As11	16	20	0,530*	-0,456^{-}
As12	35	20	0,666***	-0,390*
As14	8	21	0,549^{-}	-0,304^{-}
aspen crossings only				
As25	25	18	0,484*	-0,526**
As29f	25	17	-	-0,344^{-}
As31	25	13	0,702***	-0,432*
As35	17	10	0,685**	-0,714**
As36	16	11	0,468^{-}	-0,796***
As39	20	11	0,747***	-0,501*
As40	24	11	0,394^{-}	-0,006^{-}
As41	20	11	0,380^{-}	-0,659**
As42	11	10	0,291^{-}	-0,253^{-}
As63	13	7	0,637*	-0,801**

Discussion

The results of juvenile-mature correlations show that the differences in growth potential of single F_1 Leuce progenies are almost distinguishable in the first years after planting. Furthermore, no considerable interactions are occurring between the progenies. That the correlation coefficient of growth potential tends to increase as age is increasing is confirmed by Wilkinson (1973) for hybrid poplars and by Ying and Bagley (1976) for *P. deltoides*.

Bialobok (1963) has stated for Leuce hybrids that one can safely eliminate in the first or second year all the shortest and thinnest members of a progeny. The individuals of average size, however, should be observed for at least 5 — 7 years before final evaluation of their growth potential. The selection of the fastest growing individuals could be helped by the knowledge of the stem girth ratio, which was proportional to the final size and did not alter significantly over a period of 10 years.

In another paper Bartkowiak and Bialobok (1965) confirm these results with Leuce crossings, and for Aigeiros and Tacamahaca crossings as well. The earliest significant coefficients were found at the age of 3 years, however, most coefficients were not significant until the age of 4—8 years. Thus they consider the 5th — 7th year after planting as the earliest age for selection within poplar progenies.

Sekawin (1972) computed correlation coefficients between the diameters of poplar saplings in the nursery and their girths at different ages in the populetum. After 12 years there was a fair degree of correlation for the section Leuce and for the species *P. deltoides*, for which early selection seemed to be efficient.

Several authors working with *P. deltoides* progenies and clones came to similar results (Mohn and Randall, 1971; Woessner, 1973; Ying and Bagley, 1976). They all found performances at 5 — 7 years correlated to those at 1 — 2 years. Wilcox and Farmer (1967) also found that diameter and height in the second year were highly correlated to their performances one year before. But the second year's increase in diameter and height were not correlated with their previous season's increment. Thus the authors suggest that an accurate evaluation of the inherent juvenile growth of individual *P. deltoides* clones may require more than 1 year's performance.

As to Aigeiros/Tacamahaca clones the results of this paper show that in some cases the correlation coefficients are significant in the first 3 years after planting, but the conditions do not seem to be the same as in Leuce progenies. Here a longer test interval seems to be more appropriate, and Hyun and Son (1976) recommend an age of 7 years.

Wilkinson (1973) has found similar results for hybrid poplar clones. He assessed that a selection for height and diameter after nine growing seasons would result in the greatest gains, whereas selection for 1-year height would be the least effective. On the other hand SEKAWIN (1972) has only found very low or non-existent correlation coefficients for Aigeiros clones even at an age of 12 years. Thus he concluded an early selection to be ineffective.

As to the results of this paper, an early selection on survival rate of Leuce progenies also seems to be effective. When regarding each trial, significant coefficients occurred in some cases even from an age of 2 — 10 years. But PAULEY (1963) has described a hybrid aspen progeny of which at the age of 7 years more than 90% of the trees died in a single year and over different trials.

The results of survival rates of the Aigeiros/Tacamahaca clones also show significant coefficients in the first years in some trials, but in most trials at ages of 4 — 7 years. For *P. deltoides*, WOESSNER (1973) stated that selection for survival was ineffective with 1-year-old plants grown in the nursery, but effective when grown out for 1 year in the field.

As to trait correlations in F_1 Leuce progenies, there seems to exist a close connection between D.B.H. and survival rate. The high value of the correlation coefficients and their significances show that normally fast growing progenies have high survival values and vice versa. For correlation of D.B.H. and form class it became obvious that significant coefficients nearly all occur in trials As25 — As42, which contain aspen and no grey poplar crossings. Thus it can be assumed that in aspen hybrid crossings the better growing progenies in general are the straighter formed ones. Similar observations were made by SCHÖNBACH (1960) and WEISGERBER (1976).

Conclusion

It has become obvious for F_1 Leuce progenies' growth potential and survival that predictions are possible in the first years after planting. As these two traits are closely and positively correlated, only the recording of height or, in later years, D.B.H. would be necessary, and survival rate would not have to be recorded. Certainly a definite final prediction of growth vigor after a few years would be too early because other important characters like form class or branchiness are not fully developed yet. The evaluation has shown that inspite of mostly significant coefficients between D.B.H. and form class, there are superior growing progenies with deficient stem form values. But the poorly growing progenies might be screened at ages of about 4 years as experience has shown that they subsequently never improve their growth rate. For selections among the better growing progenies, longer terms seem to be necessary. According to the results of this paper, in support of other authors, a test interval of 8 years seems to be required. This is true for normal-term rotations of about 20 — 30 years as well as for short-term rotations.

For Aigeiros/Tacamahaca hybrid clones similar early predictions do not seem to be possible. Here an age of 7 years would be the minimum limit for early tests. LANGNER (1971) had evaluated a part of the Schmalenbeck clonal test program and found after 8 years similar results as those after 13 years (MOHRDIEK, 1978). Thus for clonal tests in Aigeiros/Tacamahaca poplars test intervals of 10 years seem to be well suited. At the same age the survival of a clone should be recorded also, because it is not correlated with growth traits, but is clonal specific (HATTEMER, 1967; MOHRDIEK, 1978). This test interval is valid for rotations of about 20 years. As much longer rotations are unusual today, investigations about interactions at older ages (RÖHRIG, 1959) do not seem to be necessary.

Besides correlations of growth traits estimated in field trials, there is further need for other methods of preliminary tests. This is most evident for advanced crossings like most Aigeiros/Tacamahaca clones. In the following, two possible ways are described which also seem to be suited for predicting future growth potential of hybrid poplars.

SANTAMOUR (1961) made anatomical determinations on the roots and stems of 25 hybrid clones. The root bark percent determined on the roots of trees 1-year-old from cuttings was found to be inversely correlated to a high degree of significance with height, diameter, and volume growth of the same clones in 9-year-old replicated outplantings at two different locations. Furthermore, highly significant positive correlations were obtained between the characteristic percentage of the root bark area occupied by fibers and growth variables.

HENNESSEY and GORDON (1974) compared 3 clones of different sections, grown at two field locations and in the growth chamber over 3 years. The rankings of chamber and field growth were similar for stem height and diameter as well as for other variables. Results indicated that growth chambers can be used for initial rapid selection of poplar clones for field trials.

Acknowledgements

Thanks are due to the Deutsche Forschungsgemeinschaft for supporting the Leuce research at the institute. The technical assistance of Mr. A. GRIMM, Ing.Grad., is gratefully acknowledged.

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Female flowering in Scots pine (Pinus sylvestris L.) crowns in relation to the trunk and cardinal directions*)

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(Received December 1978 / April 1979)

Summary

The distribution of conclets was studied on Scots pine (*Pinus sylvestris* L.) shoots in various positions on the previous year's apex relative to the cardinal directions and tree trunk. It was found that more flowers are induced in buds located distally on an apex than in those located closer to the trunk regardless of crown zone. This is true on all sides of the crown suggesting that direct insolation is not the differentiating factor. The possible role of nutrient transport and gravimorphism in the attainement of this strobile distribution most advantageous for cross pollination is discussed.

Key words: flowering, light intensity, gravimorphism, nutrition, growth rate, *Pinus sylvestris*.

Zusammenfassung

Bei *Pinus sylvestris* L. wurde die Verteilung der an den vorjährigen Triebspitzen vorhandenen Zapfenanlagen in verschiedenen Kronenbereichen in Bezug auf die vier Haupthimmelsrichtungen untersucht. Es wurde gefunden, daß auf der Außenseite der Triebe mehr blühinduzierte Knospen platziert sind als im Inneren der Baumkrone, wobei die absolute Höhe innerhalb der Krone ohne Bedeutung ist. Das gilt zugleich für die verschiedenen Himmelsrichtungen, woraus geschlossen wird, daß die direkte Sonneneinstrahlung kein differenzierender Faktor ist. Die Bedeutung des Nährstofftransports und des Gravimorphismus für die günstige Blütenknospenverteilung wird diskutiert.

Introduction

In a recent study it was demonstrated that shading of individual Scots pine buds from the south reduces floral induction relative to shading from the north (Giertych and Królikowski 1978). This study did not consider the position of the treated buds within the crown. It was often observed that there develop more female strobiles on the side of the crown which is more exposed to direct sunshine, this being the eastern, southern or western exposition depending on the time of day when skies are most commonly clear during the time of floral induction (Smith and Stanley 1969, Jackson and Sweet 1972 and others). Together with the observations that there are more cones on tree tops and on edge trees the rather obvious conclusion is usually reached that direct insolation is instrumental in the induction process.

We know of no report on the distribution of female strobiles on pine shoots in relation to the axis of the previous year's shoot and to the trunk. If insolation is the dominant external factor determining floral induction the shading effected by individual buds upon each other within a stem apex should be reflected in the distribution of flowers on shoots derived from those buds. It was the purpose of this study to consider this distribution.

Materials and Methods

The observations were conducted in August and September 1978 on bundles of shoots all derived from buds on a single 1977 shoot apex. Except for the terminal shoot of the bundle the others will be referred to here as whorls. Several dozons of these were selected in various parts of crowns of three Scots pine (*Pinus sylvestris* L.) grafts growing in the Kórnik seed orchard. These three grafts (K-01-22, K-01-22' and K-01-16 2 clones) were treated as replicates. The crowns of these three trees were divided into four sectors corresponding to the cardinal directions N, S, E and W. The same split up was made of the shoots on each of the studied whorls, and these sectors similarily corresponded to cardinal directions however they were also designated as being in a distal (D), proximal (P), left (L) or right (R) position relative to the tree trunk *(fig. 1)*. Since most of the shoots no longer had a vertical stance but were in various stages of bending away from the trunk towards a horizontal or even drooping position, it was not their present orientation that was considered but their presumed position in buds on the previous year's shoot when the latter was still in the vertical position in June 1977.

Note was taken which sectors of the whorls had female strobiles in 1978. Only flowering whorls were considered, and when there were more than one shoot per whorl-sector only a single score was made of the presence or absence of flowers in that sector. A note was made of the position of the observed whorls relative to height in the crown and in which of the crown-sectors it grew. In all 332 whorls were investigated, 86, 111, and 135 from the three trees respectively. The data from each tree each crown-sector and each whorl-sector was pooled together and the result presented as the percentage of whorl-sectors with flowers per number of whorl-sectors with shoots. The height in the crown was not a factor considered in the statistical analyses due to insufficient numbers from the upper zones of the crown. The percentage values were treated by the arcsine trans-

*) This study was supported by grant FG-Po-342 from the US Department of Agriculture under PL-480.