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JAROSŁAW FIGAJ

Comparison of early and late selection of poplars exemplified by hybrid progeny *Populus maximowiczii* Henry × *P. pyramidalis* Roz.*

INTRODUCTION

The program of Poplar breeding and selection started in Kórnik in 1949. The aims and methods were presented by Białobok (1956) though they have changed somewhat in the course of the last twenty years. More detailed description of methods of selection, distribution of hybrid progenies in experimental plots as well as preliminary results on growth, inheritance of various characters etc. were provided in many publications (Pohl, 1962, 1964, Stecki, 1963 and others). A characteristics feature of the method of selection developed here was that every hybrid progeny was transplanted in full onto so called selection fields regardless of the number of seedlings and their height growth in the nursery. In other words not a single tree has been eliminated from the progeny even if it was the weakest after one or two years of growth.

Trees were spaced in the selection fields 3×3 m. Well known poplar cultivars, commonly used in this country were planted together as comparative standards. Trees were measured in the course of several years and a set of morphological characters was recorded. This long term selection was described in one of the previous papers (Stecki, 1963).

Different opinions could be found in literature concerning the duration of the process of selection. They are sometimes contradictory depending on the climatic conditions in which a particular method of selection was developed. Kopecki (1969) established a breeding and selection program for Hungary lasting no longer than 10 years. Eschner (1960) presented results of a clonal test obtained after 7 and 9 years whereupon the experiment was terminated and trees removed from the plot. In spite of that Muhle Larsen (1964) entitled one of his papers: „Breeding poplars is efficient but time is needed" (original in German). Zufa (1969) pointing to fragmentary results obtained in Canada by several breeding centres proposed a long term selection program. Rovskij and Sarkisova (1969) observed a large differentiation in height growth among the one

* Praca wykonana w ramach problemu węzłowego 09. 10.

year old hybrids (the coefficient of variability was as high as 41 - 45%) and no correlation between their height and the growth rate after transplantation. Selection of two year old plants was slightly more successful but still there were smaller or average plants which started to grow faster than the initially big ones. Sekawin (1972) considered correlations between diameters of plants in the nursery and in different ages in the plantations as being from moderate to good. Differences were however observed depending on the parent material. These correlations (between the diameters in the nursery and in the plot) in progenies of pure *P. deltoides* were satisfactory but in the progeny of *P.* × *euramericana* (*P.* × *canadensis*) they were quite low. The author concludes that early selection of poplar clones is efficient but needs special care with the hybrids of *P.* × *canadensis*. It must be always followed by large scale tests in plantation for a complete rotation. Wilkinson (1974) published results of comparison of fifty clones at the age of 1, 4, 9 and 15 years. This selected material was planted out several times from 1949 to 1952. Only the height of the trees was considered as a selecting criterion. To preserve all seven best performing clones (at the end of the experiment) from 44 to 88 percent of clones at the age of 1 year and from 29 to 50 at 9 years must be left on the plot.

A more detailed comparative presentation of the data obtained from literature will be made below in the discussion.

The present study is an example of an analysis of one hybrid progeny with respect to the possibilities or lack of them of early selection.

MATERIAL AND METHODS

The hybrid progeny No. PK 126 was obtained in 1954. The female partner was a *Populus maximowiczii* Henry specimen growing in Kórnik Arboretum since 1928. It is a tree which deviates significantly from other representatives of this species at last in one feature — its fruits ripen at the end of August (on other trees in the middle of June). For this reason seedlings at the end of the first year are very small and 1955 could be considered as the first full season of vegetation in the nursery. The obtained 233 seedlings were planted out onto a selection field in spring 1956. Seven of them dried out as a result of damaged roots (cockchafer grub). Up to 1962 only 3 dying trees had to be removed from the plot. In that year the canopy was dense enough to perform the first thinning. At the time 94 trees were taken away. Since that time additional 19 trees were cut in several years so that in 1975 and 1976 there were still 100 trees left on the plot.

Diameters (b.h.) were measured continously from 1956 to 1962. Every year trees were estimated visually, accordingly to their habit, growth vigour, healthiness and other characters by means of a five degree scale.

++ — very good (1 in calculations),
+ — good (2 in calculations),
+− — middle (3 in calculations),
− — weak (4 in calculations),
−− — negative (5 in calculations).

This estimation was applied to several progenies investigated at that time. Some of them were so bad in quality that only trees considered as weak (−) and negative (−−) were found during the first three years. Details of this estimation were published in one of the previous papers (S t e c k i, 1963; English issue, 1967).

It should be mentioned that the 94 trees removed in 1962 were distributed in all categories. Two of them belonged at that time to the ++ group, 17 to + (7 trees from those groups were used for vegetative propagation), 46 to +−, 24 to − and 5 to −−. During the next years only one good tree was cut down, the last 18 belonged to lower categories.

In autumn 1975 and 1976 diameters of the trees were measured again and the estimation was undertaken according to the criteria developed ca 20 years ago. It is the aim of the present work to estimate the minimum time needed for a reasonable selection of a new clones promising good results in the future cultivation. Before the evaluation will be undertaken it must be assumed that:

1. A period of 20 years is a good rotation period for cultivation of poplars in this country.
2. The hybrid population used in this work is a good example for the analysis of balsam x black crosses but the results obtained must not be expected to serve as a universal recipe for all hybrid poplars or even those obtained in Kórnik.

RESULTS

OVERALL ESTIMATION

When applied to young trees this has been thought of as a comparison with an ideal tree which should exhibit the following characters: 1) maximum height and diameter in the population, 2) straight stem, 3) low branch density and fine branches, 4) regular crown structure, 5) fastigiate or nearly fastigiate habit. This last feature was considered only in those crossings where as here at last one parent belonged to the festigiate forms of *Populus* (see P o h l, 1964).

Maximal attention was paid to those morphological characters which are important economically (straight stem, fine branches etc.). Trees estimated as very good and good as well as a major part of middle ones were also healthy (according to visual judgement).

It should be mentioned however that the estimation criteria which were adequate to relatively young trees (up to ca 8 years) did not prove satisfactory when applied to older trees. Requirements, particularly with respect to the straigth stem and branching were to severe for 20 years old trees and specific corrections had to be made.

Overall estimates of the 100 trees still growing in 1976 were distributed in the following manner:

Table 1

PK 126 (*P. maximowiczii* × *P. pyramidalis*). Overall estimate in 1976

Estimate	++	+	+−	−	−−	Total
No. of trees	2	7	26	45	20	100

In course of time trees changed their estimates in different directions. Even a difference of 2 degrees between the estimates in two years for the same tree was sometimes observed (S t e c k i, 1963). Correlations between the estimates from several years of early selection and the final estimate are shown in Table 2.

Table 2

PK 126. Correlation coefficients between overall estimates made in different years of selection

	1957	1958	1959	1976
1956	0,76	0,52	0,57	0,13
1957		0,74	0,69	0,14
1958			0,71	0,45
1959				0,27

As it can readily be observed, there is a significant difference in coefficients between the final result and that obtained in the two first years of selection and those obtained in 1958 and 1959. It is rather interesting that in 1958, that is the third year of growth of the trees in the selection field, the estimate made a rather high correlation with the final result of selection.

Since coefficients are calculated from all individuals in population and in poplars only individual selection is of importance, the "curriculum vitae" of each tree in this hybrid progeny was analyzed separately. In the so called early selection two ways can be suggested:

1) negative selection — consisting of removing the worst specimens from the population in first years of selection (the percent of trees left for further selection relatively high),

2) individual (or positive) selection consisting of choosing only few best trees during first years of selection (relatively high saving of space and effort in observations and measurements to be performed in the future).

Selection carried out in both ways can be made with different intensities.

a. Negative selection

Selection intensity 1° = only trees with the estimate - - to be eliminated.

Selection intensity 2° = trees with estimates - - and - to be removed.

Effects of that selection are presented in Table 3.

The percent of trees which could be removed in different years (weak or negative) can be considered in two ways: as a percent of the number of trees remaining on the plot up to the end of selection or as percent of the total number considered before thinning.

It can be easily seen that the lower (1°) intensity of selection after 1957 (or even after 1956) is not reasonable. It gives little or almost no space and labour savings. Only in 1956 (first year on the selection field) there was a considerable reduction of the population (32%) and all very good as well as 6 of the 7 good trees remained up to the end of the investigation.

The greater (2°) selection intensity gave the most interesting result in 1958. With 40% of trees eliminated no ++ and only one + tree were lost in that selection. One year before, the percentage of trees which were to be eliminated is considerably bigger (67%) but the loss of 4 out of the 7 future + trees is not acceptable.

Table 3

Percentages of trees with final estimate middle or more which were left on the plot in the course of negative selection

1	2	3				
Intensity of selection	final estimate (1976) No. of trees	percent of trees from column 2 left on the plot in 1976 as result of selection				
		1956	1957	1958	1959	1960
1°	++ 2	100	100	100	100	100
	+ 7	85	85	100	100	100
	+− 26	69	96	100	100	100
% of −− trees at the moment of estimation		32	15	4	4	3
% of −− trees of the 100 remaining up to the end of selection		28	8	0	0	1
2°	++ 2	50	100	100	100	100
	+ 7	29	43	86	86	100
	+− 26	25	42	89	100	100
% of −− and − trees at the moment of estimation		76	67	40	29	22
% of −− and − trees of the 100 remaining up to the end of selection		77	62	34	17	14

b. Indiuviudal selection

Selection intensity 1° — only very good trees left.
Selection intensity 2° — good and very good trees left.
Results are given in Table 4.

It must be said on the basis of those results that any early hunting of very good and good specimens within this hybrid progeny was unsuccessful. Relative high space and material savings do not justify the losses in the best trees up to the fifth year after the progeny was transplanted onto the selection field. The displacement from one estimate class to another occurs quite often during first few years of growth.

Table 4

Percent of trees with ++ and + estimates found in course of individual selection

1	2	3				
Intensity of selection	final estimate (1976) No. of trees	Percent of trees from column 2 left on the plot in 1976 as result of selection				
		1956	1957	1958	1959	1960
1°	++ 2	0	0	0	50	50
	+ 7	0	0	15	29	29
	+− 26	0	0	4	8	69
% of ++ trees at the moment of estimation		0	1	3	6	8
% of ++ trees of the 100 remaining up to the end		0	0	4	10	14
2°	++ 2	0	0	50	100	100
	+ 7	0	15	43	43	43
	+− 26	0	8	23	46	69
% of ++ and + trees at the moment of estimation		2	6	14	22	32
% of ++ and + trees of the 100 remaining up to the end of selection		2	7	18	30	43

DIAMETERS

A comparison of stem diameters in different years can be made on a basis of deviation from progeny averages expressed in standard deviation units (s). At the end of the observation period (1976) diameters of the analyzed progeny were distributed normally as in Table 5.

No thicker tree than $x+3\ s$ was found. Among the 9+4 trees which belonged to the upper classes two were estimated in 1976 as ++, one as +, eight as +−, one as — and even one tree as −−. Selection of trees based on their diameter in young age was carried out similarily as the se-

Table 5

PK 126. Distribution of diameters in 1976

Interval	Deviated from the average ($\bar{x}$)					
	more than $-2s$	from $-2s$ to $-1s$	from $-1s$ to $\bar{x}$	from $\bar{x}$ to $+1s$	from $+1s$ to $+2s$	above $+2s$
No. of trees (= %)	3	12	36	36	9	4
Normal distribution (%)	3	13	34	34	13	3

lection of estimates i.e. individual or negative approach to it was considered. Both were done with two degrees of intensity.

No results were obtained with the positive selection. For the first time in 1961 among the seven trees with diameters above $x+2s$ the 4 thickest in 1976 appeared.

Negative selection is unsatisfactory in first two years (1956 and 1957). In the years from 1958 to 1962 the results were better and did not vary very much from year to year. About 50% of trees (from 46 to 52) with diameters below the average could be readily removed and always the four thickest and from 6 to 9 of the $x+1s$ to $x+2s$ group remained in the field.

MULTIPLE TRAIT ANALYSIS

Neither the overall estimate nor diameters and heights (recommended by several authors) gave satisfactory results in selection of the best individuals. Therefore an attempt was made to combine those three characteristics measured and estimated in the first years of growth and to compare the join result with the combination of estimates and diameters (heights were not measured) at age 20. Several patterns of behaviour could be distinguished here, including specimens which maintained their position steady (good or bad) and those ones which during the years 1956 - 1962 showed a deterioration or improvement of selection value. Among the 100 trees considered a few completely disappointing ones with no clear pattern were also found. Examples are presented in Table 6. A combination of the three characters mentioned gave a seven-degree scale different from the "overall estimate" described above. Degrees can be descri-

Table 6

Untypical behaviour of some trees within the PK 126 hybrid progeny

No. of tree	Multiple-trait estimate							
	1956	1957	1958	1959	1960	1961	1962	Final
13	1	1	2	2	2	2	2	5
57	2	4	4	6	6	6	4	1
81	6	5	4	4	4	4	4	1
113	4	4	5	6	6	6	6	2
132	4	5	4	6	6	6	6	2

bed as follows: 7 — excellent, 6 — very good, 5 — good, 4 — good to middle, 3 — middle, 2 — bad and 1 — very bad.

Only tree No 13 could be considered as lost being definitely displaced in the analysis, but its final result was also not the best. This tree was estimated + in 1976 and its diameter was 32 cm. The whole progeny had at that time an average diameter 26.19 cm with a standard deviation of 4.82 cm.

DISCUSSION

Three of the previous works from the literature list could be compared in a broad sense with the present study. Table 7 shows the material used in them, methods applied, conclusions and other main characteristics.

One feature is common in all those works. They started to observe and estimate the selected material at once, either in the nursery (hybrid seedlings) or directly after the planting of unrooted cuttings.

Table 7

Studies on the selection of poplar hybrid progeny found in the literature

Author Issue date	Country	Material used in the study	Characters correlated or compared	Main conclusions
Rovskij a. Sarkisova 1969	USSR Middle Asia	Hybrid progeny of *Populus alba*, *P. bolleana*, *P. nigra*	Heights of one and two year old plants with 5 year old trees in a plantation	One year old seedlings show very poor correlation with 4 or 5 year old plants. Selection can be first performed after 3 or 4 years, but the main one between 10 and 20 years
Sekawin 1972	Italy	80 clones of *Leuce*, *P. deltoides* and *P.* × *canadensis*	Diameters of 1 and 2 year old trees in a nursery to girths of trees after 4, 8 and 12 years from transplantation	Early estimates of *Leuce* and *Deltoides* hybrids vere valid. Not so in *P.* × *canadensis*. The effects of early selection decrease with the age of plantation. In some groups selection must be confirmed by a full rotation experiment
Wilkinson 1974	US Massachusetts	50 clones of hybrid poplars in 4 replicates. Experiment repeated 5 times	Heights of 1, 4 and 9 year old trees compared with final height at 15	Clones selected in the 1-st and 4 year had negative selection differentials. Gain from selection after 4 years is 60 to 80 percent of that at the end of trial. Early rouging can cause losses of superior genotypes

In the present study one and a half year of nursery life was completely ignored as useless for the purposes of selection.

Studies presented in the table below deal with only one character used as a basis for selection. In the presented analysis of the data obtained here. not only diameters but a synthetical overal estimate and also part-

ially heights were used for comparison. An attempt of a multi-trait evaluation of those features was also done.

Application of the overall estimate proved useful when negative selection was performed. After three years of growth in the selection fields and use of the 2° degree selection intensity 40% of the trees could be removed from the plot. In the fourth year this percent decreased to 29. Almost no losses were then observed among the best ortets. When comparing this result with that of Wilkinson (1974) the superiority of the estimate against the heights as a criterium of selection is evident. This same can be said about the results obtained by Rovskij and Sarkisova (1969) who wrote that even after 5 years of selection the fast growing trees went suddenly over to the group of those slowly increasing their height.

Results obtained here with the estimate are confirmed by the results obtained with diameters when the negative selection was carried out. By using a multi-trait evaluation of three characters observed and measured, only one of 100 trees was substantially misjudged.

Sekawin correlated diameters of young trees with girths of older trees. The coefficients obtained by him were from 0.337 to 0.670 in those taxa where his selection succeded and nearly 0.0 in *P* ×*canadensis*. In order to evaluate those coefficients he utilized the estimations of Nanson (ref. Sekawin, 1972). According to them they should be considered: r — 0.0 to 0.50 as moderate, 0.51 to 0.71 as middle, 0.72 to 0.86 as fair, and 0.87 to 1.00 as excellent. So, the results of Sekawin are between moderate and fair.

Correlations presented in this paper, concerning the overall estimate (Table 2) belong to moderate only but differences between the results of 1956 - 1976 and 1957 - 1976 and those of 1958 - 1976 and 1959 - 1976 are evident. The coefficient for 1958 - 1976 ist the best one better than that for 1959 - 1976. Sekawin also obtained a decreasing correlation (after first 4 years) with the increasing age of selected progeny. As an explanation of in he suggests an increasing influence of environmental factors in relation to the genetic ones.

SUMMARY

One hybrid progeny, PK 126 (*P. maximowiczii* × *P. pyramidalis*) was raised from seed in 1954. In 1956 after 1 and a half vegetation seasons 223 plants were planted onto a selection field. Diameters, heights and morphological characters important from the economical point were measured and observed in the course of several years (1956 - 1962). After a period of ca 20 years in 1975 and 1976 measurements of diameters and a synthesis of morphological observations called overall estimate were repeated.

Over a half of the trees were removed from the plot, with the majority thinned at once (94) in 1962. Since 100 trees remained on the plot up to the end of investigation the "curriculum vitae" of them as investigated individually and correlations between their characters in young and mature age were evaluated.

Results obtained in this study enable following conclusions:

1. Results of selection carried out in the course of several years after transplantation of plants onto a selection field depend on the age of the trees and the characters used as selection criterion.

2. First two years of selection brought unsatisfactory results. After 3 or 4 years all weak and negative trees (nearly 40% of the investigated progeny) could be removed from the plot with sufficient confidence that no losses will be caused in the superior material.

3. Overall estimate used as a criterium of selection could give good results when applied several years continously. Detailed analysis of the distribution of diameters supports the results. Heights of the trees as a criterium of selection ar of less value.

4. Selection depending on the choice of only best specimens failed. The only realiable method is the so called negative selection depending on elimination of worst trees.

Institute of Dendrology
Kórnik nr. Poznań

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JAROSŁAW FIGAJ

Porównanie wartości selekcji wczesnej i ostatecznej na przykładzie rodu mieszańcowego PK 126 (P. maximowiczii Henry × P. pyramidalis Roz.)

Streszczenie

Na jednym rodzie mieszańców *P. maximowiczii* × *P. pyramidalis* (PK 126) przeprowadzono analizę zastosowania jako kryterium selekcji takich cech jak: ocena ogólna, średnice i częściowo wysokości drzew. Wyniki selekcji przeprowadzanej w pierwszych 5 latach po posadzeniu drzew na pola selekcyjne porównywano z wynikiem ostatecznym (po 20 latach). Obliczono korelacje badanej cechy „ocena ogólna" w różnych latach i przeprowadzono analizę przemieszczania się drzew w klasach selekcyjnych. Celem analiz było określenie najbardziej właściwego wieku dla przeprowadzenia selekcji o wystarczającym stopniu trafności.

Wynik przeprowadzonych badań i analiza podobnych prac Rowskiego i Sarkisowej (1969), Sekawina (1972) i Wilkinsona (1974) prowadzą do następujących wniosków:

1. Wyniki selekcji zależą od wieku drzewek, na których dokonuje się selekcji i od cech, które przyjmuje się jako kryteria selekcji.

2. W pierwszych dwóch latach po posadzeniu nie można przeprowadzić dobrej selekcji. Po 3 lub 4 latach można z pola usunąć drzewa ocenione jako złe i bardzo złe (40% drzew w badanym rodzie), nie narażając się na straty w najlepszym materiale genetycznym.

3. Tak zwana „ocena ogólna" jako kryterium selekcji daje dobre wyniki jeśli stosuje się ją przez kilka lat pod rząd. Analiza średnic uzupełnia to kryterium. Wzrost na wysokość ma mniejszą wartość jako cecha selekcyjna.

4. Selekcja polegająca na wyborze tylko najlepszych osobników jest nie do przyjęcia. Jedynie tak zwana „selekcja negatywna" może być stosowana z dobrymi rezultatami.

ЯРОСЛАВ ФИГАЙ

Сравнение достоинства раннего и окончательного отбора на примере рода гибридов РК 126 (P. maximowiczii Henry × P. pyramidalis Roz.)

Резюме

На одном гибридном потомстве *P. maximowiczii* × *P. pyramidalis* (РК-126) был проведен анализ применения в качестве критерия отбора таких признаков как „общая оценка", диаметр и частично высота деревьев. Результаты отбора, проведенного в первые пять лет после посадки деревьев на селекционные участки, сравнивались с окончательным результатом (спустя 20 лет). Были высчитаны корреляции оценки разных лет и сделан анализ перехода деревьев из одной качественной группы в другую в этом

гибридном потомстве. Целью проведенных анализов являлось определение наиболее походящего возраста для проведения отбора с достаточной степенью точности.

Результаты проведенных нами исследований и анализ работ по схожей тематике Ровского и Саркисовой (1969), Секавина (1972) и Вилькинсона (1974) ведут к следующим выводам:

1. Результаты отбора зависят от возраста деревьев и от признаков, которые принимаются как критерий отбора.

2. В первые два года после посадки нельзя провести достаточно хороший отбор. После 3 или 4 лет можно с селекционного участка удалить деревья, обозначенные как плохие и очень плохие (в данном случае около 40%) не опасаясь потерь в лучшем генетическом материале.

3. Так называемая „общая оценка", как критерий отбора дает хорошие результаты если применяется несколько лет подряд. Анализ диаметров дополняет этот критерий. Рост в высоту менее пригоден в качестве критерия при отборе.

4. Селекция, в основе которой лежит отбор лучших особей неприемлема. Лишь так называемый „отрицательный отбор" может применяться с хорошими результатами.