PLUS-TREE SELECTION OF MICHIGAN JACK PINE
(*Pinus banksiana* Lamb.)

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Abstract.--After 13 to 15 growing seasons jack pine half-sib families from plus-trees performed 1.9, 2.2 and 4.8 percent better than controls for height, diameter and biomass respectively in three Michigan progeny test plantations. Use of family selection in these tests would have yielded performances roughly three to five times as great. Although plus-tree selection along does not appear to be a good approach to jack pine tree improvement, the incorporation of plus-tree selection into a progeny test program may be effective in achieving small additional gains in growth rate.

Additional keywords: Phenotypic selection.

Plus-tree selection as proposed for use in jack pine tree improvement programs usually follows provenance testing and is used in conjunction with progeny tests (Rudolph and Yeatman, 1982; Yeatman, 1978). Natural regeneration of jack pine frequently follows fire or clearcutting resulting in extensive even-aged stands. These stands often occupy level sites with little variation in soil type. The corresponding reduction in age and environmental variation within jack pine stands increases the efficiency of selection based on phenotypic comparisons among trees. Little data have been available, however, on whether the predicted potential of plus-tree selection in jack pine is being realized.

In 1965 a study was begun to assess the effectiveness of plus-tree selection of jack pine for growth and stem-form. This was done in conjunction with collection of a large number of half-sib families on which to base a long-term breeding program. Seed from plus and average jack pine parents located in the northern Lower Peninsula, of Michigan were collected under the supervision of Dr. David S. Canavera 2/ and Dr. Jonathan W. Wright. Provenance tests indicate that this is the best source to use for establishment of jack pine in the Lower Peninsula of Michigan (Canavera and Wright, 1973; Jeffers and Jensen, 1980).

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METHODS

Plus-tree selection of jack pine was begun in the northern Lower Peninsula of Michigan in the summer of 1965. A total of 202 selected parents were identified in 40 even-aged stands located on state forests of the Michigan Department of Natural Resources. Mean stand heights and ages averaged 46 feet (14.0m) and 57 years. Improvement thinnings had occurred in several stands prior to 1965.

Plus-trees were chosen on the basis of superiority in total height, length of the live crown and stem-form. Each trait was assessed separately so that a tree may have been judged superior for height growth without having had good live-crown length or stem-form. Selections were also made from trees with average performance for each trait to be used as controls. Increment cores were taken to confirm that selected trees were within 5 years of the stand average.

After selecting the parents, performance for all traits was recorded for each tree. The degree of parental superiority was judged by comparison to unselected trees growing within a 230 foot (61m) radius. Superiority of the selected tree was visually estimated for each trait. The following information was was recorded; (1) percent height superiority in relation to the comparison tree mean, (2) size of the population in which selected tree would have the greatest height (for instance population size "10" would indicate that parent was in the top ten percent of the comparison-tree population), (3) length of the live crown, (4) size of the population in which selected tree would have the longest live crown, (5) number of crooks, (6) the total number of inches a tree deviated from the center because of crooks, and (7) the size of the population in which the selected tree would have the best form.

When the three-month selection process was complete, the individual trait superiority of the parents ranged from none for the controls to 2.5 standard deviations above the mean for selections from the top one percent of the comparison-tree population (best in population size 100).

Parent trees were felled and cones collected by Michigan Department of Natural Resources personnel. Cones were kept separate by parent, seeds were extracted and sown in May, 1966 in the nursery at the Michigan State University Tree Research Center in East Lansing, Michigan using a randomized complete block design with four replications. Trees were lifted in the springs of 1968 and 1969 and planted at an 3 foot (2.5m x 2.5m) spacing in three test plantations using a randomized block design with 4 or 6 replications and 4-, 5-, or 10-tree row plots at each location. The two plantations planted in 1968 were located in the Lower Peninsula, while the 1969 plantation was planted in the Upper Peninsula of Michigan (Table 1.).

Trees were measured in the Upper Peninsula plantation in the fall of 1981 after 13 growing seasons since planting. The Lower Peninsula plantations were measured in the summer of 1982 during their fifteenth growing season. Measurements on each tree included height, DBH, and the presence or absence of poor form. A crooked tree was defined as one which had at least one crook with a deviation from the center of the bole greater than one-half the diameter of the bole at that point.

Table 1.--Jack pine progeny test plantations in Michigan.

Plantation number	County	Number of families	Acres (ha)	Ave dbh in.(cm)	Ave height ft.(m)	Age when measured
----------Lower Peninsula plantations----------						
5,6,7-68	Allegan	192	11.1 (4.5)	4.3 (10.9)	20.0 (6.1)	15
13,14-68	Antrim	194	7.1 (2.9)	4.2 (10.7)	19.0 (5.8)	15
----------Upper Peninsula plantation----------						
11-69	Mackinac	169	3.7 (1.5)	4.3 (10.9)	20.3 (6.2)	13

Analysis Of Progeny Measurements

Total tree oven-dry biomass in kilograms was calculated from height and diameter measurements using a regression equation developed from data collected in Minnesota, Ontario, and Quebec (Green and Grigal, 1978)3/ The percentage of crooked trees in each plot was calculated and transformed using an arcsin-squareroot transformation. Plot means were calculated for height, diameter, biomass, and the transformed stem-form data and expressed as a percent of the block mean in order to remove block and plantation effects. Plot percentages were analyzed as a completely randomized design in order to extract variance components for stand and family-within-stand.

For each trait, family averages over all three test plantations were calculated. The performance of each family over all plantations was adjusted to reflect its performance in relation to the other families collected from

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3/Total live oven-dry biomass(kg)=0.0601*Dbh(cm)^2.090*Height(m)^0.490

the same stand. This was done by averaging the performances of all families within a stand and then expressing the performance of each family as a percent of the stand mean. The adjusted (within-stand) family performances were checked for normalilty before being subjected to correlation analyses with parental data.

Analysis Of Parental Measurements

Individual-trait selection intensity for each tree is estimated by the "popluation size" data. The size of the population from which each parent could be considered the best was converted to a standardized selection differential (Becker, 1975). These selection differentials are estimates of the number of standard deviations above the mean each parental selection was for total height, live-crown length, and form. All parental data were non-normally distributed and transformations to achieve normality were unsuccessful. Simple correlation coefficients between parent and progeny measurements were calculated in order to evaluate the significance of the parent-progeny correlations. Since the parent-progeny measurements do not conform to a bivariate normal distribution, r (the simple correlation coefficient) cannot be used to judge the amount of variation accounted for in the correlation and can only be used to assess wheether a significant non-zero correlation exists (Snedecor and Cochran, 1967). Mean progeny performances of plus-trees were compared to controls in order to judge the strength and practical importance of the parent-progeny relationships.

RESULTS

Progeny Test Results

Survival in all plantations exceeded 94 percent. The form of the trees was very good except for some defect caused by snow damage. The criterion used for assessing poor form was quite rigorous and many of the trees recorded as crooked are expected to have little defect by the time they reach harvestable size. The number of crooked trees averaged 64 percent over all three plantations. All plantations were essentially disease and insect free.

Stand and family-within-stand differences were significant for height, diameter, and biomass at the p=.01 level of probability (Table 2.). The amount of variation accounted for by family-within-stand was greater than that attributable to stand for all three traits. No stand differences were found for form, but family-within-stand differences were significant at the p=.01 level. When Canavera (1975) measured this same material in the nursery he found significant family-within-stand (p=.01), but no stand differences in height.

Table 2.--Mean squares and F-values for analyses of variance of half-sib families of jack pine growing in Michigan.

Source of variation	Df	Expected mean squares	Height	Diameter	Biomass	Form
			Mean square(% of block mean) F-value			
Family	201					
Between stands	39	$\sigma_e^2 + 9.5\sigma_{f(s)}^2 + 47.8\sigma_s^2$	275.2 2.8**	456.9 1.9**	2241.1 2.0**	3493.2 1.2ns
Within stands	162	$\sigma_e^2 + 9.5\sigma_{f(s)}^2$	96.9 2.1**	238.3 2.5**	1144.2 2.6**	3034.4 1.5**
Error	1708	σ_e^2	46.3	96.1	446.4	2068.1
Total	1909					

**=Significant at the 0.01 level of probability.
ns.=non-significant.

Parent-progeny correlations

Based on correlation analyses, the selection differentials for total height and live-crown length are better indicators of progeny growth rate than either percent height superiority or length of the live-crown. The selection differential for total height was significantly correlated with all three growth traits at the p=.05 level of probability (Table 3.). The selection differential for live-crown length was also correlated with progeny height at the p=.05 level, but for diameter and biomass the correletions were significant at the p=.01 level. None of the parental form measurements were correlated with the form of the progeny.

Selection for growth rate

Based on the results presented in Table 3., it appears that the parental selection differentials for height and live-crown length may be useful for predicting progeny growth rate. For this reason, the adjusted (within-stand) progeny performances for plus and average parents were compared using both the total height and live-crown length selection differentials as selection criteria (Table 4.). The maximum performance that could be achieved through family selection for each trait is included for comparison. Plus-trees were defined as those parents which had selection differentials equal to or greater than two standard deviations. The parental live-crown control group was used as the "unselected" families for use in comparisons with the "selected" families based on family performance in the progeny test. Performances of families selected on the basis of progeny test results were significantly greater than those selected on the basis of parental phenotype.

Table 3.-- Simple correlation coefficients for comparisons of parental phenotypic measurements and progeny performance of Michigan jack.

Parental measurement	Progeny performance for: Height	Diameter	Biomass
Height selection differential	0.16*	0.16*	0.15*
Live-crown length selection differential	0.16*	0.19**	0.18**

*=significant at the 0.05 level of probability
**=significant at the 0.01 level of probability

Table 4.-- Progeny superiority of jack pine parents selected on the basis of phenotypic or family performance as compared to unselected controls.

	Percent superiority of progeny using				
	Plus-tree selection for		Family selection for		
Progeny trait	Total Height	Live-crown length	Total height	Diameter	Biomass
Height	1.2	1.9*	5.9**	4.2**	4.6**
Diameter	2.0*	2.2*	6.6**	10.0**	9.9**
Biomass	4.2*	4.8	15.6**	21.8**	22.0**

*=differences between selected families and controls sig. at the .05 level.
**=differences between selected families and controls sig. at the .01 level.

DISCUSSION

Phenotypic superiority of jack pine parents in natural, even-aged stands can be related to progeny growth rate. Measurements of both parental total height and live-crown length were significantly correlated with progeny height, diameter, and biomass. These correlations, however, appear to be quite low. In this experiment, parental plus-tree selection for total height and live-crown length were roughly equal in their ability to predict progeny growth rate. Progeny from live-crown plus-trees performed 1.9, 2.2, and 4.8 percent better than the controls for height, diameter, and biomass respectively on a within-stand basis. Family selection could have achieved performances of 5.9, 10.0, and 22.0 percent for each of these traits. Use of family selection based on progeny test results is obviously much better than use of plus-tree selection alone. Genetic gain could be roughly three to five times as great using family selection.

These results indicate that plus-tree selection used in conjunction with progeny tests may be beneficial for improving growth of jack pine. The performance. increase attributable to plus-tree selection, however, may be fairly small and genetic gains are expected to be even smaller. There is the potential that the effectiveness of plus-tree selection could be improved through better, more intensive field techniques or more rigorous selection, but this might raise the costs of selection considerably. Collecting only plus-tree for inclusion in a progeny test rather than collecting from average individuals will raise the cost of the improvement program. Whether the added cost is justified based on the expected gains will depend on the magnitude of the cost increase.

Parental stem-form was uncorrelated with form of the progeny. This result may be due in part to the high stocking levels of both the parental stands and progeny test plantations lowering the expression of poor form in the trees.

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