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ABSTRACT

PARENTAL AND FAMILY SELECTION

IN PRUNUS SEROTINA EHRH.

By

John Alfred Pitcher

Tree improvement programs have relied on the selection of parents in natural stands as the basis for developing genetically improved strains. This study reports results of the effectiveness of this procedure in black cherry. Phenotypically superior parents were selected from 76 stands on two National Forests. Phenotypically average and inferior parents were selected in the vicinity of each superior parent. Open-pollinated seed from 199 parents was used to establish plantations in two locations, in each of two years.

Analysis of variance revealed highly significant differences between sources and between stands-within-sources. For example, Allegheny sources had smaller seed but grew better than Monongahela sources at all test locations. No differences were found to substantiate the hypothesis of positive results of parental selection on either height or form of offspring. Progeny of good, average and poor quality parents were similar in form. Some families grew faster than others but growth rate was not related to parent form.

The lack of parent-progeny correlation is most likely due to the inability of the multitrait scheme used to satisfactorily identify those traits under strong genetic control. Selection based upon an evaluation of the phenotype at one instant in its' life assumes equal opportunity for expression of all like genotypes within stands. Micro-environmental influences were possibly responsible for the wide differences noted in parent phenotypes. Under the more uniform conditions of the test plantations, the progeny from varied phenotypes failed to respond in a manner similar to their parents.

Evolutionary processes have probably contributed to a somewhat stable population as regards sources. The chance deviation from the source population norms, expressed in superior, mediocre and inferior parent quality, are probably due more to their relative position within a regenerating population than to the particular genetic constitution of the individual. Thus, in the absence of reliable heritability estimates, multitrait selection based upon parent phenotypes in wild stands has little chance to produce the desired results in terms of genetically improved progeny. These results agree with recent investigations by others in both conifers and hardwoods.

The author concludes that selection of individuals for height and form was not effective in producing superior offspring. He recommends representative sampling without regard to parent phenotype and evaluation of half-sib

John Alfred Pitcher

families as the primary step in the genetic improvement of black cherry. Family selection could increase growth rate by as much as 23 percent in black cherry. For development programs, the identification of geographic sources having above average growth characteristics provides an interim source of seed to satisfy planting stock requirements while seed orchards are being developed.

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CHAPTER I

INTRODUCTION

Black cherry (Prunus serotina Ehrh.) is a medium size tree which, under forest conditions, develops a form suitable for timber harvest. It is the only native member of the genus which is used for this purpose. In recent years, its value in the timber market has increased greatly. The properties of its wood, its density, machinability, color, grain and texture, have made it a favored species for the furniture and veneer industries. These industries are centered in the Northern Appalachian Mountains, where black cherry attains its optimum development as a timber tree, although its natural range is far more extensive. Considerable interest has been generated for the genetic improvement of this species within its high value range.

NOMENCLATURE

Rosaceae L. is one of the largest plant families and one of the most important in the commerce of the world.

The genus Prunus L. is the largest genus in the Prunoidae Focke subfamily. Over 175 species of trees and shrubs are recognized within the genus, including the cherries, peaches, plums, apricots and almonds important for their horticultural and ornamental values (Johnson, 1931.).

There are 77 species of Prunus in North America, with approximately 25 native to the United States (Sargent, 1922). Little (1953) lists 18 principal tree species, 4 varieties and 7 introduced species which have escaped cultivation and become naturalized in the United States. Of these only Prunus serotina Ehrh. is used extensively for timber. Prunus avium (L.) L. occasionally reaches large size as does Prunus pensylvanica L.f. but these species are rarely cut for wood products in this country. Prunus has been classified by Rehder (1940) as having six sections and twelve subsections. Prunus serotina is one of nine species belonging to section Padus (Moench) Koehne.

Range

Prunus serotina var. serotina, the typical black cherry, covers the entire Eastern half of the United States, along the Atlantic coast, from the Canadian Maritime provinces and southern extremes of Quebec and Ontario, to the northern half of Florida and westward along the Gulf of Mexico to Eastern Texas, and northward along the prairie grass range into Minnesota.

Little (1953) includes three varieties of the black cherry, all in the southern and western extremes of the range. P. serotina var. alabamensis (Mohr) Little is restricted to Georgia, northeastern Alabama and northwestern Florida, largely the southern Piedmont area outside of the Carolinas. Its distinguishing character is the hairiness of

the foliage, peduncles and calyx.

P. serotina var. eximia (Small) Little is unique in that it occupies a disjunct portion of the range in the Edwards Plateau and Balcones Escarpment of Central Texas.

The third variety, P. serotina var. rufula (Woot. and Standl.) McVaugh occurs along the Mogollon Plateau of Arizona and New Mexico, south to northern and central Mexico.

Another variety, P. serotina var. salicifolia (H.B.K.) Koehne, the Capulin black cherry, is native from central Mexico southeast to Guatemala.

Popenoe and Pachano (1922) report this variety to be a form of wild black cherry, occurring in the highlands of tropical America. The fruit is about the size of the Montmorency cherry, and is suitable for table use and cooking. In the Ecuadorian highlands, the fruit is marketed by the Indians. Popenoe and Pachano (1922) suggest that the Capulin cherry is a cultivated variety of P. serotina and that the fruit size and flavor are the result of selection over many centuries.

Silviculture.

While the natural range of black cherry is very large, its commercial range is restricted to the Allegheny Plateau along the southern tier of New York and northern Pennsylvania, extending southward along the Appalachian Mountains into extreme western Maryland and northern West Virginia and part of northeastern Ohio (Hough, 1960). A cool, moist,

temperate climate with adequate and well-distributed rainfall is strongly associated with the commercial range of black cherry. Within this range, black cherry is abundant at elevations of 1000' - 2600'. In the mountains of West Virginia, its best development is at elevations of 2500' - 3500'.

Black cherry sprouts readily from stumps and grows very rapidly, especially in openings in the forest. It is a shade intolerant species, requiring full sunlight for optimum growth. Seedlings under a forest canopy are unable to cope with the low light intensity and root competition. Such seedlings rarely survive more than three years before succumbing (Hough, 1960).

Under optimum conditions of light, soil, and moisture, cherry seedlings often achieve heights of 18 inches or more in the first growing season. In the nursery seedbed, heights exceeding three feet in one year are not uncommon.

Because of the need for light and moisture, mature black cherry stands are harvested in patches or blocks, creating the openings needed to encourage abundant natural regeneration. Seeds may lie dormant in the humus layer of the forest floor for many years. Once the stand has been removed, they germinate and the development of a new forest begins. However, rabbits and particularly the white-tailed deer extract a heavy toll from the seedling stands. A moderate amount of this browsing is beneficial in reducing

competition, but where animal pressures are high, practically all the black cherry reproduction may be destroyed.

Black cherry grows rapidly during its youth, overtopping competing vegetation. After 45 to 50 years, growth is gradually reduced. Within its optimum range, black cherry reaches a maximum height of 129 feet and age of 258 years (Hough, 1960). Heights of 80 to 100 feet and diameters of 20 to 24 inches are common at age 60. Normal rotation for sawtimber crops is 50 to 120 years, depending upon site conditions. Satisfactory growth rates of the dominant and co-dominant individuals in natural stands can be maintained by thinning the stand to favor the better members.

Yields in pure stands can be quite high, often exceeding 10,000 to 15,000 board feet per acre. In one 80 year-old stand, on a good site, there were 8,500 cubic feet or 24,000 board feet per acre. Translated into economic terms, this stand would have a value of \$2,640.00 per acre at an average stumpage rate of \$110.00 per thousand board feet.^{1/}

^{1/} Current rates for standing sawtimber on the Allegheny National Forest vary from \$40.00 to \$140.00 per thousand board feet depending on timber quality and markets.

PHENOLOGY, FLORAL STRUCTURE AND SEED CHARACTERISTICS

In Pennsylvania and places of similar latitude, raceme clusters of flowers appear from mid-May to early June, after the leaves are nearly fully grown. Each raceme bears an average of 35 perfect flowers, consisting of five pale green sepals, five white petals, a solitary pistil with two ovules and 15 to 20 stamens. The fruit is a 1-seeded drupe with thick fleshy pulp which is dark red to black when ripe. The "seed" is the stone or pit, a bony, smooth, nearly spherical light colored endocarp, encasing the embryo and endosperm. The endocarp has a distinct line encircling it, beginning and ending at the micropylar attachment.

Numbers of cleaned seeds per pound average 4800, ranging from 3100 to 8100 (Woody Plant Seed Manual, 1948).

In the study reported here, seed was collected from 269 individual trees, cleaned and weighed. The mean weight was 110.446 grams per 1000 cleaned seed and ranged from 68.6 to 180.0 grams. This is equivalent to an average of 4107 seeds per pound, ranging from a low of 2520 to a high of 6565 seeds per pound.

The pulp of the black cherry fruit is used for making jellies and wine. An extract is used in flavoring foods, particularly ice-cream. The flavor is quite distinctive.

Van Dersal (1938) reports that 33 species of birds ingest the fruits of black cherry. In some locations it constitutes a major autumn food for the prairie chicken. It is an important food of white-tailed deer, which feeds on the

young stems and leaves as well as the fruits in season, constituting a major problem in reestablishing the species following harvest of mature timber. The leaves and twigs contain cyanic acid, causing much distress and often death to live stock, but deer browse this species with impunity (Hough, 1960).

CHROMOSOME NUMBER

The basic chromosome number for Prunus is $x=8$ as reported by Darlington (1928). Kobel (1927) determined that the chromosome number of P. serotina was $2n=32$. Knight (1969) lists 38 diploid species with $2n=16$, seven triploids ($2n=24$), eleven tetraploids ($2n=32$) of which P. serotina and six of the eight other species of section Padus are representative, two pentaploid species ($2n=40$), four hexaploids ($2n=48$), two octaploids ($2n=64$) and one species, P. laurocerasus L., with a chromosome count ca. 170-180 (22-ploid).

HYBRIDIZATION IN THE GENUS PRUNUS

Knight (1969) abstracted numerous publications which indicate that all sweet cherries (P. avium (L.) L.) tested have proved to be completely self-sterile. The mechanism is actuated by inhibition of the pollen tubes, controlled by a sterility gene (S-gene) having many possible alleles. When the tube and style both have the same allele, growth of the pollen tube is terminated after a brief period of development. Interspecific fertility is high when crossing with

other cherry varieties, using sweet cherry as the mother.

In the sour cherries (P. cerasus L.) varying degrees of self-incompatibility are expressed, depending upon the varieties tested. The Duke cherries (P. cerasus x avium) are often self-fertile, depending again upon the horticultural varieties attempted.

Plums fall into three classes: entirely self-sterile, partially self-fertile and self-fertile. Peaches are generally self-fertile.

CROSSING IN BLACK CHERRY

Black cherry is apparently self-incompatible although this fact has not been established beyond doubt. Hauck (1968) isolated 18,000 flowers during a two-year study and obtained four seeds, none of which germinated. Control pollinations were not made. Thus the effects of bagging on the developing flowers is unknown. I isolated several hundred flowers and obtained no seed, either, even when flowers from the same tree containing anthers at anthesis were brushed over the bagged flowers. The technique was an imperfect attempt at controlled pollination.

Yeager and Meader (1958) report a single cross using P. serotina as the mother and Capulin cherry (P. serotina var. salicifolia.) as the pollen donor. A few seeds were obtained, two of which germinated. These germinants flowered in 1957 but set no fruit. This is the extent of the literature of authenticated species crossings within P. serotina.

OBJECTIVES OF STUDY

This study addresses itself to the practical problem of phenotypic selection of black cherry in wild stands as a starting point for the improvement of timber qualities in the species through breeding.

Individual tree selection, phenotype selection, plus or superior tree selection, mother tree selection, all are synonymous terms. They relate to searching out and locating that one tree which is better than all the rest in the vicinity in one or a combination of desirable traits. Numerous publications of guides for selection in various species and geographical locations are available (Lindquist, 1948; Dorman, 1952; Anonymous, 1952; Isaac, 1955; Duffield, 1955; Rudolf, 1956; Joranson, 1957; Burch, 1959; Barber and Wakely, 1962; Dawson and Read, 1964; Limstrom, 1965; Schreiner, 1966; Anonymous, 1966; Pitcher and Dorn, 1967; Clausen and Godman, 1967; Beineke and Lowe, 1969; Trimble and Seegrift, 1970). They all emphasize economic traits. Some guides use a point score system in arriving at a value for the selected tree compared to three or five of the best dominant trees within the vicinity. Van Buijtenen (1969) gives some examples of point score systems (Table 1.) In discussing their value, he points out that such systems have merit in plantations and even-aged natural stands of conifers but lose much of their value if applied to trees in uneven-aged stands. They cannot be applied to all species and in particular to the hardwoods without

Table 1.--Example of Point Score on Loblolly Pines.

Trait	Score	
	<u>Minimum</u>	<u>Maximum</u>
Height	0	15
Volume	0	7
Crown	-2	5
Form point	-3	3
Straightness	0	5
Pruning ability	-3	3
Branch diameter	-2	2
Branch angle	-2	2
Specific gravity	-2	10
Age	0	<u>3</u>
Total Possible Points		55

reservation. Rather striking examples of extremes in the variation of certain traits have been given and illustrated frequently. This variability has been cited as the basis for phenotypic selection. Yet recent studies have pointed to weak parent-progeny correlations in height and vigor traits.

Yao, et al (1971) reported on the results of a provenance trial of red pine (Pinus resinosa Ait.) in Michigan, ten years old from seed. Included in this study of 292 seed collections from the range of red pine in Michigan, were collections from stands of phenotypic excellence, selected as seed production areas. At the time of measurement and analysis, these selected stands all produced offspring which were at or below average in height when compared to the plantation mean.

Canavera (1969) made 382 individual tree selections of jack pine (Pinus banksiana Lamb.) in 61 stands in the lower peninsula of Michigan, using height as one of the selection criteria. Average and below average trees were also selected as controls on the selection procedures. Three year nursery data showed that progeny heights were only slightly correlated with parental heights. Height growth of the good selections was 28.48 inches compared to 28.38 inches for the control group at three years of age. He concluded that mass selection for height growth in natural stands was ineffective.

Progeny trials of Scots pine planted in 1934 in southern Sweden and in 1946 to 1952 in central Sweden were measured in 1965 and 1966 and the results reported by Nilsson (1968). The progenies were derived from half-sib seed of individual mother trees selected for their rapid growth and good quality. Nilsson found that the correlation between various characteristics of the mother trees and their progeny was "rather weak." On data from 34 mother trees and progenies, the only significant correlation, was that of the crown length/tree height ratio of the mother tree to the crown length of the progeny.

Nilsson noted that the within provenance variation was sometimes greater than the between provenance variation, depending upon the trial error between different plantations and concluded that there was sufficient tree-to-tree genetic variation to justify plus tree selection for most characters. He was careful to point out that the mother trees used in his investigation did not represent extreme types of good or bad quality but represented instead the better part of the phenotypes. He suggested that selection of the more extreme stands would increase the inter-provenance variance to the point where it should exceed the individual variance, implying that selection of extremely good or bad mother trees would likewise reduce individual variance and produce more uniform progenies, either good or bad depending upon the selection direction.

This is the foundation principle of most forest tree

improvement programs now in existence, to select only the very best, the extremely good, in anticipation of producing uniformly good progenies.

In another study, open-pollinated seed was randomly collected from 100 longleaf pine (Pinus palustris Mill.) trees in a three county area in southern Mississippi in 1955 (Synder, 1969). Three comparison trees were also selected and measured along with each seed tree. At the end of eight years, the resulting plantation was measured and analyzed. Progenies from phenotypically selected parents averaged 12 percent taller than the population average indicating a positive advantage to selection. However by selection of the best 25 percent of the families it was possible to obtain a 35 percent gain, an increase of 23 percent over parental selection. Snyder concludes, "Thus, it appears that at this intensity of selection, progeny testing was almost three times as effective as individual-tree selection for height growth in longleaf pine."

The three best families came from parents that were "phenotypically unimpressive" and would have been lost to future breeding work were it not for the fact that they had been included in the progeny test as comparison trees. This is prima-facie evidence of the inability to estimate the genotype from evaluation of the phenotype.

The present study was undertaken to determine the extent to which selection of superior black cherry parental phenotypes is effective in producing superior offspring.

Outstanding parents for black cherry were rigorously selected as representing the upper range of desirable traits. Equally rigorous selection of extremely poor parents was practiced to select representatives of the opposite end of the scale. A third class of parents was included which approximated the median of the parental range, neither very good nor very bad, simply a good "woods-run" tree for the location.

Based on published results and selection guides, I would expect three distinct offspring groups, significantly different one from another, representing good, average and poor parents. These expected results would support superior tree selection efforts.

CHAPTER II

PARENTAL SELECTION AND HALF-SIB FAMILY VARIATION

METHODS

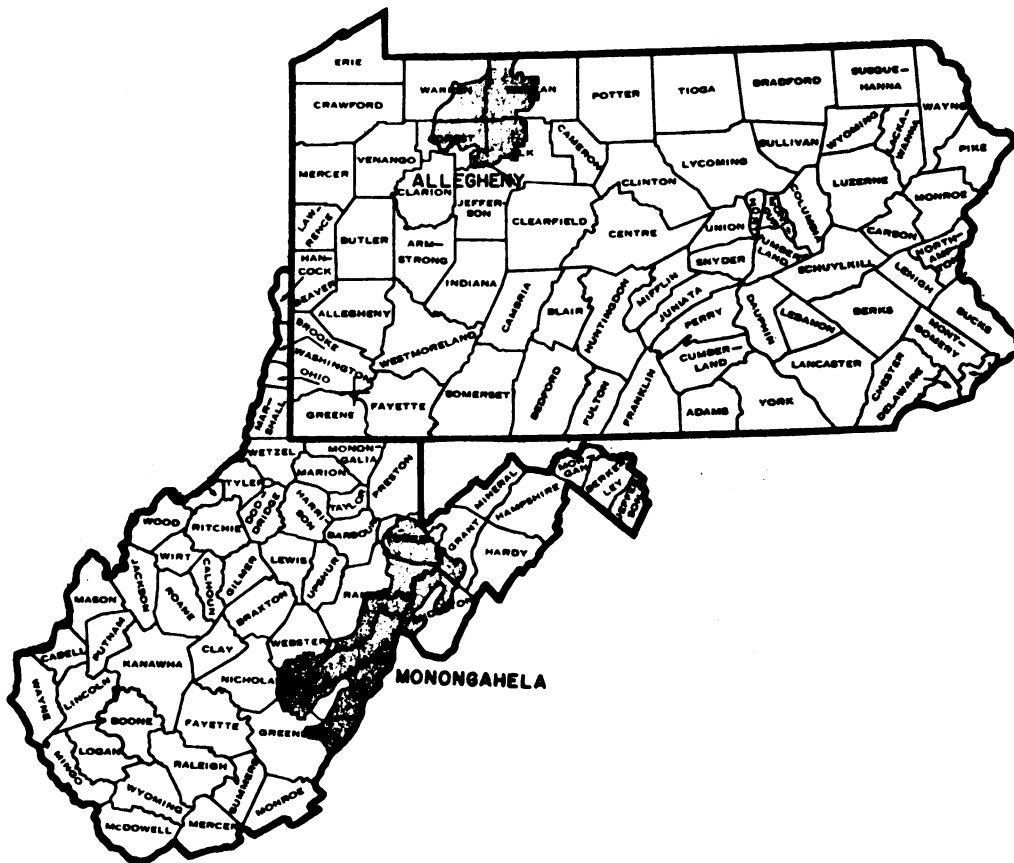
The methods described here were applied throughout the study with minor variations which are noted in the sections dealing with each plantation. The study was conducted in two separate years, using different parents selected in each year.

The Allegheny National Forest is located in the Northwestern portion of Pennsylvania and the Monongahela National Forest, in the east central portion of West Virginia (Figure 1). These two forests lie within the commercial range of black cherry and represent the geographic area of optimum development for the species. Parents were selected within these two National Forests.

PARENTAL SELECTION

Both the Allegheny and Monongahela National Forests have had an active program of superior tree selection since 1965 in connection with their tree improvement program for black cherry. During this period, a large number of "superior" trees had been located, using the standards developed

Figure 1.--Location of the Allegheny and Monongahela
National Forests.



SCALE
0 100 200 Miles

LEGEND

 National Forest

by Schreiner, et al (1965). The specific selection criteria were rapid growth rate, excellent timber form, disease and insect resistance, resistance to, or good recovery from ice damage, high veneer quality, particularly freedom from gum spot. Only trees of seedling origin were selected. Rapid growth rate was determined by measuring crown diameter and radial increment of the stem at DBH (4.5 feet above the ground). The ratio of crown diameter to radial increment is considered by Schreiner et al to be an index of the growth efficiency of the selected black cherry tree.

In addition, further selection criteria were added using the standards developed by Pitcher and Dorn (1967). These included total height, height to the first fork^{2/} on the main stem, merchantible height, roundness of bole in first log, freedom from sweep, crook and seams, and general form and vigor. Selections were compared to three of the best appearing trees within 66 feet of the selected tree.

^{2/} A fork is defined as: (a) the smaller of two adjacent branches exceeds one-third the diameter of the larger one or (b) the main stem is deflected more than 10 degrees from the perpendicular at the branch juncture or (c) the angle between the branch and the main stem is less than 30 degrees.

These comparison trees were also measured and their average values for height, diameter and Apical dominance^{3/} used to judge the "superiority" of the selected tree by the following equation:

$$\text{Superiority} = 100 \frac{\text{Value of selected tree}}{\text{Average Value of comparison trees}} - 100$$

In addition the selected tree had to be at least six inches in diameter at breast height on the stem, and have a percent superiority of at least 10 percent for height, 20 percent for volume and 15 percent for apical dominance and could not fork below 33 feet.

These selected trees represented as nearly as possible, the most desirable phenotypes as could be located in natural forest stands (Figure 2). The selection intensity was estimated by the author to be 1:50.

^{3/} Apical dominance: tendency to maintain a central stem measured as the point above ground where the central stem becomes divided into two or more dominant stems.

Figure 2.--Example of the typical parental selection
classified as GOOD in this study. Selection
is in Stand 73, U.S.F.S. Accession No. 28.



In each stand^{4/} where a superior tree had been selected, several trees were measured to determine a stand average for height and diameter. One tree, which approximated the median value for height and diameter and was judged to be average for form and defect was selected to represent the average phenotype for that location. Within the same locality, a search was made to locate a tree with forking low on the main stem, slow growth, and prominent defects; in general, a poor, scrawny, misshapen woods tree commonly termed a "cull" in timber stand improvement projects. This individual represented the poor parent class (Figure 3). Much effort was expended in selecting all parents to assure that extremes were well represented.

The average and poor phenotypes were usually located within one-half to 5-1/2 chains (30'-360') of the good phenotype, mostly within less than an acre, so that site and aspect factors were minimized.

Close spacing of parental selections within a stand raises the question of whether or not the selected trees might be half-sib to each other. This is a possibility that cannot be dismissed since, under natural conditions, seeds fall about the base of the mother trees, germinate,

^{4/} Stand. An aggregation of trees or other growth occupying a specific area and sufficiently uniform in composition (species), age arrangement, and condition as to be distinguishable from the forest or other growth on adjoining areas (Society of American Foresters, 1958).

Figure 3.--Example of the typical parental selection classed as POOR in this study. Much effort was spent in locating parental selections which adequately represented the class extremes. Stand 63, U.S.F.S. Accession No. 10.



and given favorable conditions, mature. At least some of these mature trees are likely to be half-sibs. However, birds and mammals also play an important role in stirring up and redistributing seeds to new locations, often at some distance from the parent tree.

Prunus species are insect pollinated by a number of Hymenoptera, Diptera, and Lepidoptera genera. The common honeybee, Apis mellifera is, by far, the most frequent visitor to fruit blossoms (Hooper, 1920). Insect pollinators contribute to pollen mixing. This fact, plus the evidence of self-incompatibility in P. serotina and its control by the multiple S-allelic series in other Prunus species, leads this author to conclude that the incidence of selecting half-sibs in this study was low. The ages for all three selected parents within a stand were within seven years of one another. The data collected for the parents is given in Table 2.

A total of 199 parents, from 76 stands are represented in the study (Table 3).

Figures 4, 5, and 6 show the location and distribution of the 76 stands on the two National Forests. Each stand was assigned a number from 1 to 76 (Table 4).

Table 2.--Selection criteria for parents.

-
1. Total Height.
 2. Diameter Breast Height.
 3. Age.
 4. Diameter increment during last 10 and 20 years.
 5. Crown width.
 6. Height to 4" and 10" top.
 7. Height of ice damage.
 8. Height to first fork.
 9. Crown class.
 10. Direction of largest stem diameter, if eccentric.
 11. Evidence of gummosis (gum exudates along trunk).
 12. Evidence of black knot.
 13. Other disease or insect damage.
 14. Forest type (SAF).
 15. Site Index.
 16. Elevation.
 17. Slope percent.
 18. Stem volume (cubic feet).
 19. Apical dominance.
 20. Roundness ratio (stem).
 21. Lean.
 22. Sweep.
 23. Branch angle.
 24. Seed crop.
 25. Percent superiority.
 26. Distance and azimuth to Good Parent.
 27. Description of tree.

Table 3.--Numbers of parents selected by forest, year,
and stand.

National Forest	1967		1968		Totals ^{1/}	
	Parents	Stands	Parents	Stands	Parents	Stands
Allegheny	42	14	132	44	174	58
Monongahela	51	17	45	15	96	32
Totals	93	31	177	59	270	90

^{1/} Totals include 29 parents from 14 stands selected in 1967 and used again in 1968.

Figure 4.--Locations of stands in the southern part of
the Monongahela National Forest.

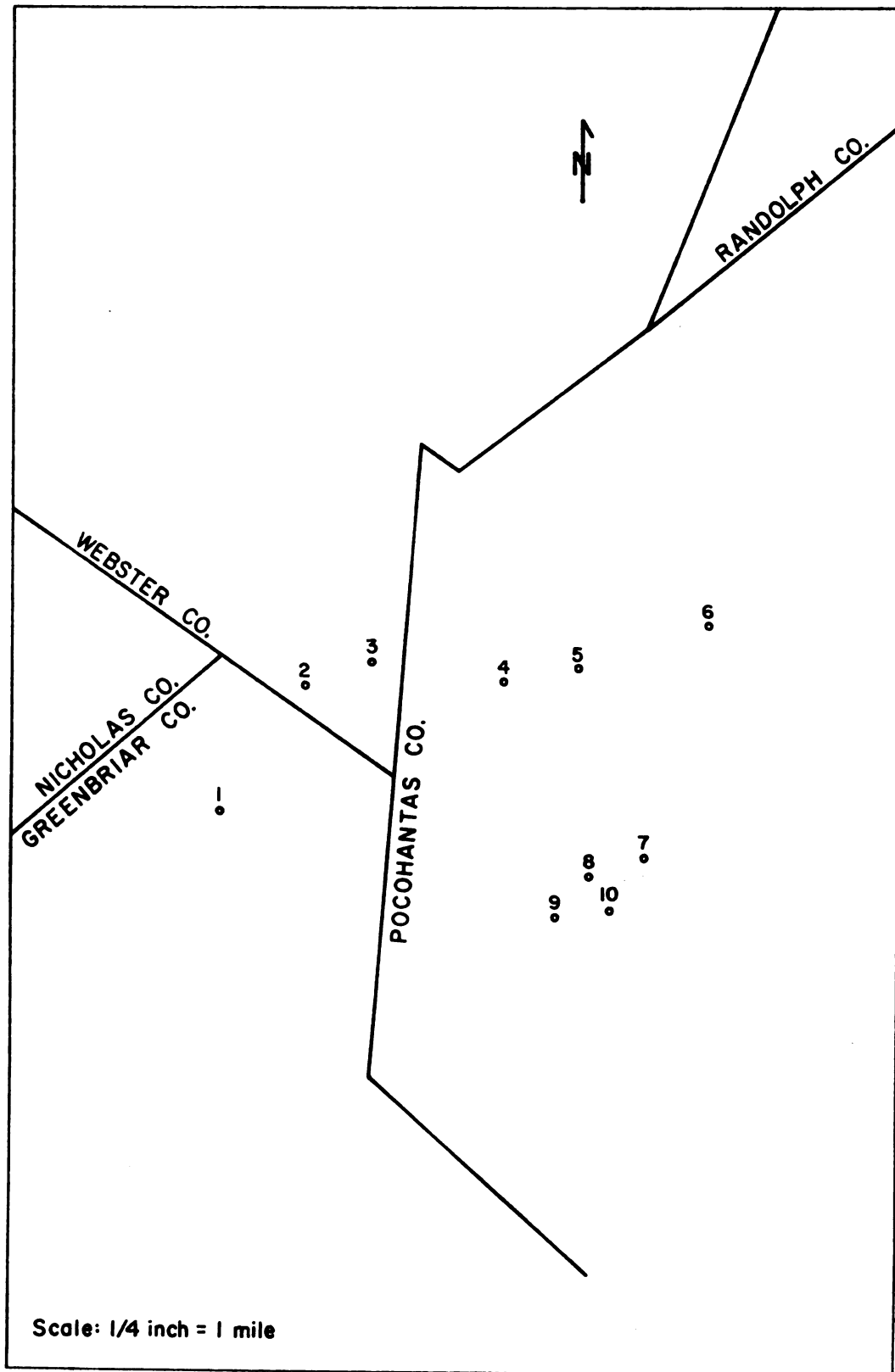


Figure 5.--Locations of stands in the northern part of
the Monongahela National Forest.

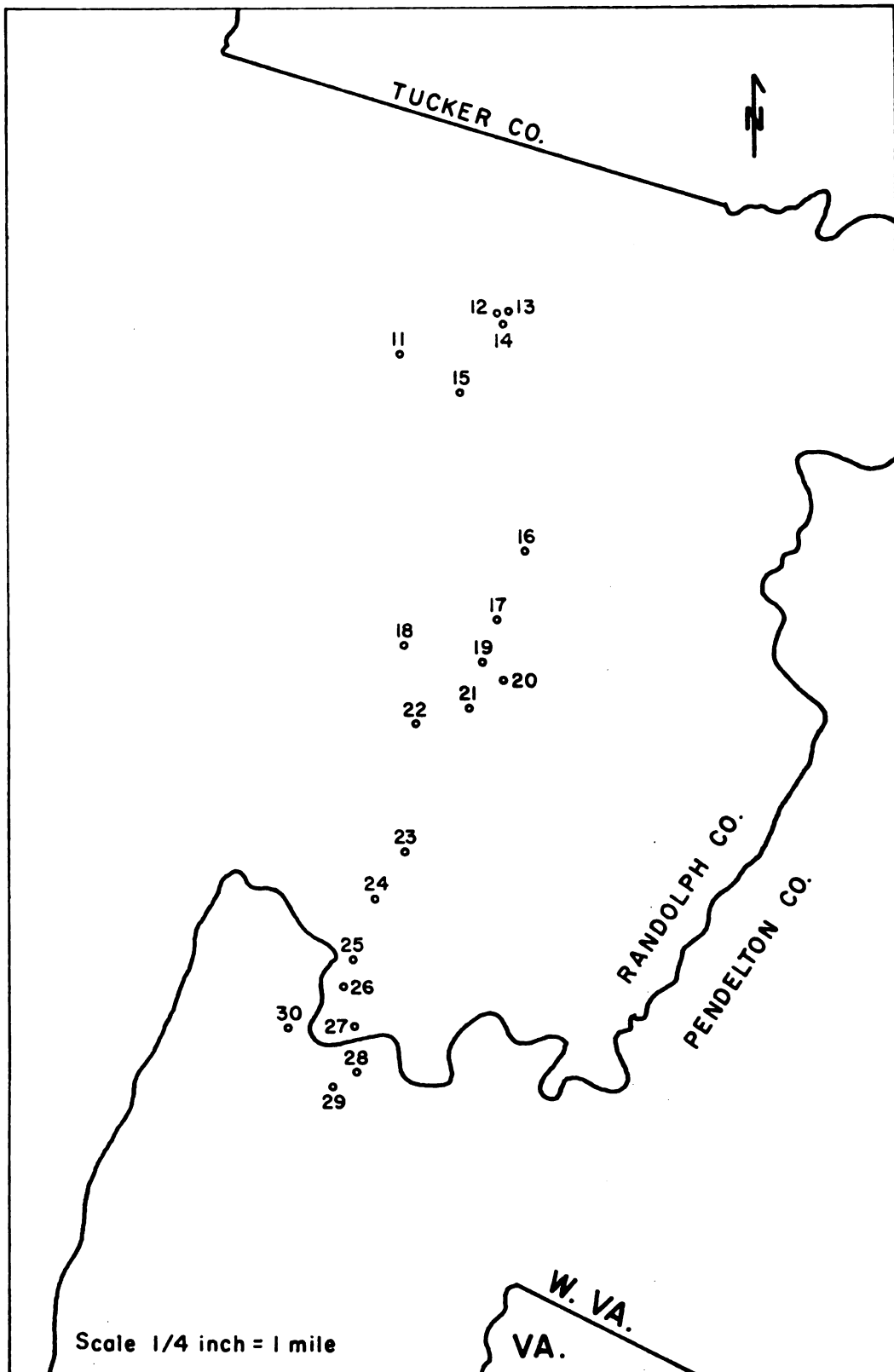


Figure 6.--Locations of stands in the Allegheny National
Forest.

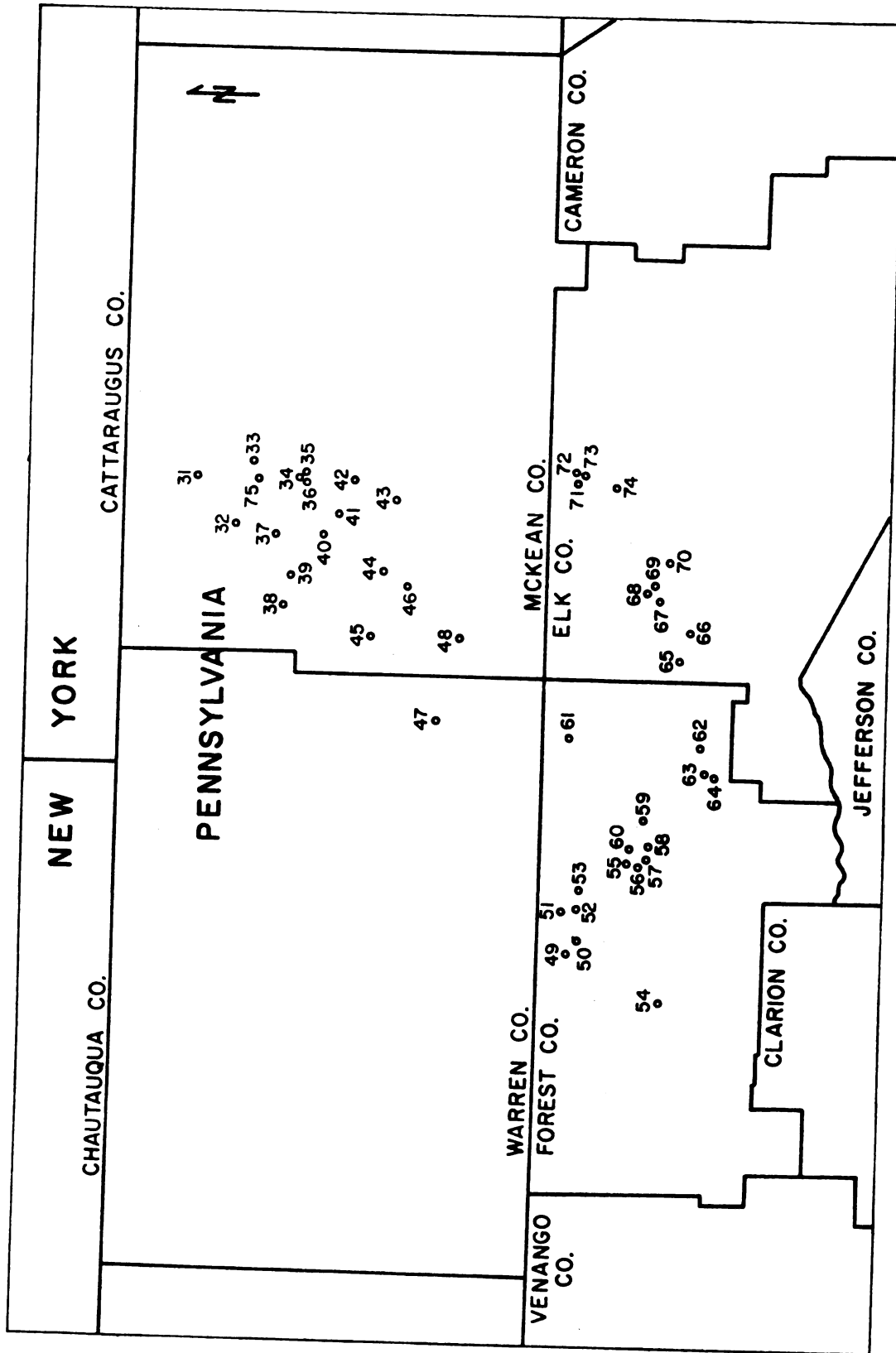


Table 4.--Stand, tree and U.S.F.S. accession numbers.

Stand Number	Tree Number	U.S.F.S. Acc. No.	Stand Number	Tree Number	U.S.F.S. Acc. No.
1	MO-47	369	23	MO-4	90
2	MO-32	78	24	MO-2	89
3	MO-30	86	25	MO-7	394
4	MO-29	396	26	MO-10	395
5	MO-31	85	27	MO-5	392
6	MO-43	366	28	MO-11	256
7	MO-26	80	29	MO-23	255
8	MO-25	79	30	MO-24	82
9	MO-45	367	31	B-4	38
10	MO-46	368	32	NE-4	34
11	MO-3	391	33	B-5	14
12	MO-12	263	34	B-9	39
13	MO-13	264	35	B-10	40
14	MO-14	265	36	B-11	41
15	MO-6	393	37	B-24	151
16	MO-18	262	38	B-21	388
17	MO-22	249	39	B-19	72
18	MO-16	261	40	B-16	64
19	MO-19	257	41	B-13	44
20	MO-8	253	42	B-2	35
21	MO-20	258	43	B-18	69
22	MO-21	81	44	R-6	371

Table 4 (cont'd.)

Stand Number	Tree Number	U.S.F.S. Acc. No.	Stand Number	Tree Number	U.S.F.S. Acc. No.
45	S-12	57	61	M-15	51
46	R-14	30	62	M-14	43
47	S-8	52	63	NE-6	10
48	R-16	70	64	NE-7	11
49	M-17	12	65	M-7	7
50	M-8	8	66	R-15	50
51	M-2	51	67	R-8	3
52	M-18	60	68	R-18	76
53	M-20	62	69	R-21	295
54	M-12	27	70	R-13	29
55	M-24	152	71	NE-1	15
56	M-23	294	72	NE-8	26
57	M-22	387	73	TV-2	28
58	M-9	9	74	R-22	150
59	M-4	4	75	B-6	1195
60	M-13	42	76	MO-42	1196

MO = Monongahela National Forest

B = Bradford District, Allegheny National Forest

M = Marienville District, Allegheny National Forest

NE = Northeastern Forest Experiment Station

R = Ridgeway District, Allegheny National Forest

S = Sheffield District, Allegheny National Forest

TV = Tennessee Valley Authority

USFS Acc. No. = Accession Number assigned to select tree
in register of Superior Trees maintained by the United
States Forest Service, 633 W. Wisconsin Ave, Milwaukee.

SEED COLLECTION AND HANDLING

Collection of ripe seed began on August 28, 1967 and was completed by September 29, 1967. In 1968 the collection period extended from September 3 to September 30. The fruits were usually gathered by climbing each tree with ladders and ropes and plucking the ripened fruits. On some occasions, particularly with the poor parents when seed in the crown was sparse, the entire tree was felled and collection made from the downed top. On other occasions, large plastic tarpaulins were spread about the base of the tree, a climber sent into the upper crown area, and the entire tree shaken vigorously to dislodge the ripened fruit. The fruits were then gathered by lifting and folding the tarpaulin edges in a manner which caused the cherries to roll into the center. The fruits were then guided into large plastic bags by manipulating the tarpaulins to form a crease or channel and a spout.

At least 200 dark red fruits were collected from every one of the good, average, and poor parents. Not all trees reach ripeness at the same time and it was necessary to return to some locations a second time to collect from one or more of the parents. However, this differential phenology is not uncommon and has been documented by Huntzinger (1968). He states that the fruits at any given time will vary in ripeness from tree to tree, and even on the same tree.

The 1967 collection of seed was depulped within a few

days after collection by maceration in a food mill under running water. In 1968, the seed was depulped in a mechanical cleaner as described by Dorn and Flick (1969). The cleaned seed was surface dried, 100 seeds counted out and their weight in grams recorded. This work was done at the Forestry Sciences Laboratory near Warren, Pennsylvania. The seed was stored there in a refrigeration unit at 35° F in individually sealed plastic (polyvinyl) bags.

STRATIFICATION AND GERMINATION

The 1967 Collections

Early in January, 1968, each of the 93 seedlots were divided into three sublots. Moist (saturated and squeezed dry) paper toweling was added to each subplot bag and the bags clearly labeled both inside and outside. One subplot of each seedlot was shipped to Michigan State University, and Elkins, West Virginia, near Parsons, for stratification. The shipments arrived at their destination on January 11-12, 1968, and were put, at once, under refrigeration. One subplot was held at Warren for stratification. Periodic checks were made of the condition of the seed in stratification.

The subplot at Elkins showed radicle emergence prior to April 30, 1968, but sublots at East Lansing and Warren were still dormant.

Bench space was rented at a commercial greenhouse in Elkins. Peat pots (Jiffystrip No. 515) were filled to within 1/4 inch of the top with good potting soil. Plastic

retainer trays (Jiffytrays No. J 150) were used to hold the peat pots. At Elkins, 72 seeds showing radicle emergence were sown for each seedlot, one seed per pot. The seeds were then covered with 1/4 inch of fine sand, the trays labeled and set out in random order on the benches, where they were watered to near saturation twice each day. Germination was rapid and essentially complete within three weeks. Total germination was tallied on June 10, 1968, 33 days after sowing. Of the total 93 seedlots, 24 failed to germinate and 15 had less than 10% germination; 27 seedlots had 50% or better germination. (Table 5)

Greenhouse space was also provided at Michigan State University and the procedures there were the same as described for Elkins, except that only 48 seeds per seedlot were sown on May 21-22, 1968. Germination counts were made on June 13, 21 days after sowing. At East Lansing, 22 seedlots failed to germinate (17 of these were the same lots that failed at Elkins), 10 seedlots had 10% or less germination at Elkins, and 39 had 50% or more germination. Unfortunately, watering was neglected during an extremely hot period early in June and many seedlots were killed. Of the original 93 seedlots sown, only 32 had sufficient seedlings remaining to establish the nursery portion of this study.

At Warren, one-half of each seedlot was removed from refrigeration the first week in May and sown under shade screens in a nursery plot on the Kane Experimental Forest

Table 5.--Total numbers of seedlots sown by location and year and numbers of seedlots showing zero, less than 10 percent and more than 50 percent germination by location and year.

Plantation Location	Total Seedlots Sown		Seedlots with germination of:					
			0%		<10%		> 50%	
	1968	1969	1968	1969	1968	1969	1968	1969
West Virginia	93	177	24	6	15	13	27	121
Michigan	93	177	22	4	10	11	39	137
Pennsylvania	93	177	43	76	8	41	20	7

near Kane, Pennsylvania. The remaining half of each seedlot was sown in peat pots and placed in the greenhouse facilities at Warren. Germination counts were made on the greenhouse seedlots 30 days after sowing. Of the 93 seedlots sown, 43 failed completely to germinate (17 were the same seedlots which failed at both Elkins and East Lansing), eight seedlots had 10 percent or less germination (seven of these had the same results at the two other locations) and 20 seedlots germinated at least 50 percent. Germination in the nursery plots on the Kane Experimental Forest was similar to that in the greenhouse. Only 18 seedlots had sufficient seedlings with which to set up the field plantings, and so this portion of the study was terminated.

The 1968 Collections.

Immediately after seed cleaning, the 177 seedlots from the 1968 collections were divided into three sublots. One subplot was shipped to Michigan State University and put into moist cold storage about October 15, 1968. The other two sublots for each family were fall sown in nursery beds at Clearfield, Pennsylvania, (Dague State Forest Nursery) and Parsons, West Virginia (Parsons State Forest Nursery). The sowing was done on November 6-8 and 18-21, 1968. Fall sowing is a standard nursery practice where seeds require stratification.

The sublots at Michigan State University were put into polyvinyl bags containing moist peat moss and a fungicide and

1

2

stratified at 34 F for 170 days. Radicle emergence commenced at about the 140th day and germination was essentially complete at the time of sowing. Only four seedlots out of 177 failed to germinate and 11 seedlots had less than 10 percent germinants. In many cases, germination was over 90 percent.

The seedlots sown at Clearfield failed to germinate almost completely. The explanation for this is not clear but was probably due to a combination of seedbed location, preparation and adverse winter conditions which exposed the seeds to repeated freezing and thawing. Consequently, this portion of the study was terminated.

The seedlots sown at Parsons germinated well with only six lots showing complete failure. Of these, four were from good parents and two from average parents. There were no poor parents which failed to germinate and grow.

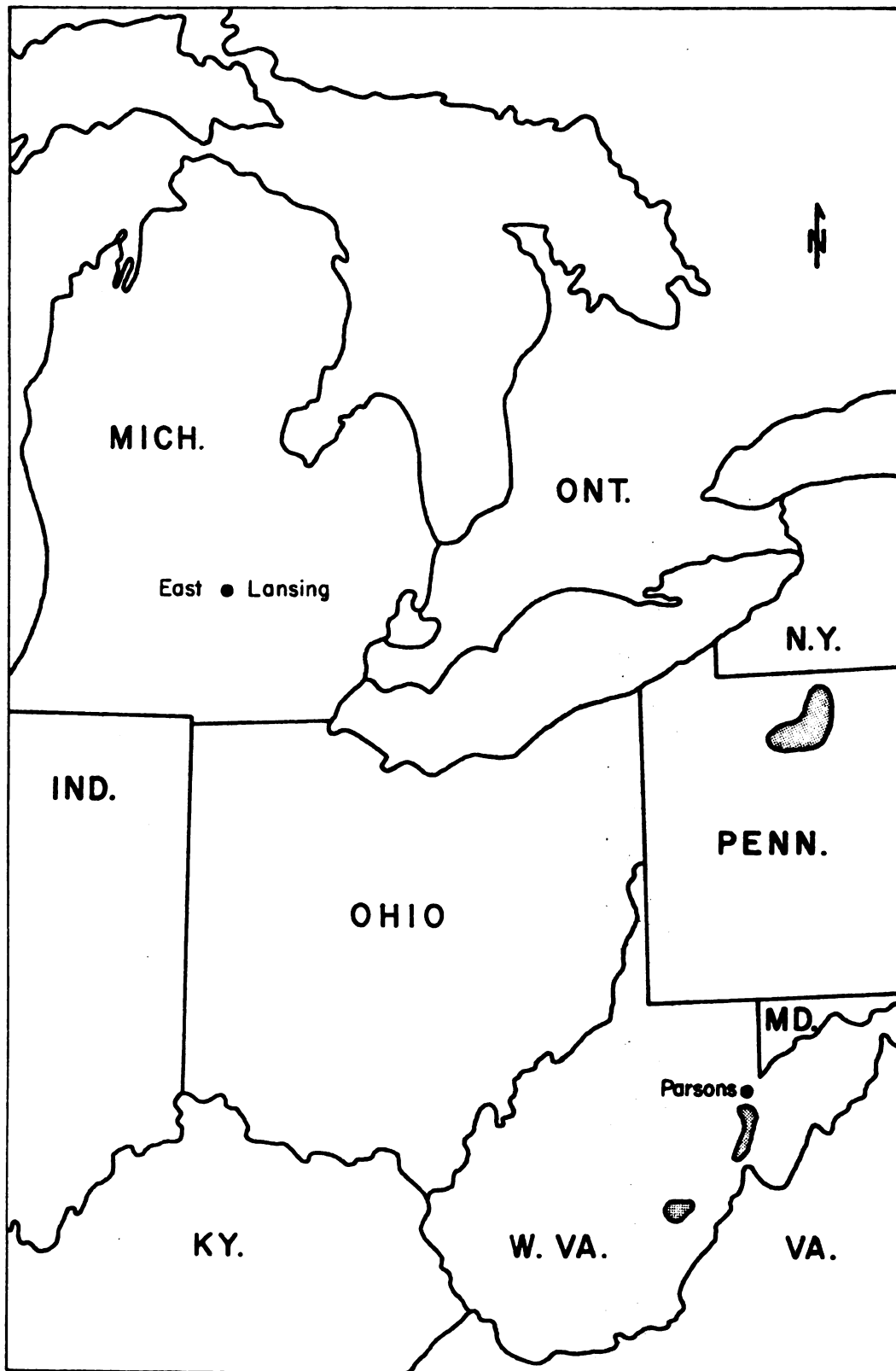
DESCRIPTION OF PLANTATIONS

Plantations were located at Parsons, West Virginia and the Tree Research Center at Michigan State University, East Lansing, Michigan (Figure 7). All plantations were established on nursery soils and received supplemental irrigation during the growing season.

Three different planting designs were used in the study to accommodate the areas available for planting.

Plantation 1-69 was put in at Parsons, adjacent to the Timber and Watershed Management Research Laboratory of the U. S. Forest Service. The site is located within the West

Figure 7.--Location of the plantations at East Lansing, Michigan and Parsons, West Virginia, and the geographic areas represented by parental selections in these plantations.



Virginia State Nursery, situated at the confluence of the Blackwater and Shavers Forks of the Cheat River. The soils are deep, relatively uniform loamy sands of alluvial origin. The plantation consisted of 15 randomized complete blocks with 42 single tree plots randomized in each block. Spacing between trees was 12 inches by 12 inches. Three complete rows of border trees of black cherry surplus to the study were planted at the same spacing interval (Appendix Figure A1).

The germinated seedlings in their peat pots, still attached in strips and in plastic trays, were taken from the greenhouse in Elkins and transported to the nursery. The strips were then cut into individual peat pots and replicates prepared. Actual planting was started the same day, June 11, 1968, and completed the following day. Survival counts were made November 8, 1968, and some replacements made using border trees of the same seedlot. Overall survival was excellent. Of 630 trees planted 613 (97.3 percent) were still alive on October 13, 1970 when final measurements were made.

Plantation 1-69 was established at the Tree Research Center at Michigan State University. It consisted of two randomized blocks. Block 1 had 59 randomized split-plots while Block 2, because of incomplete germination had 54 randomized split plots. The major plots were stands of origin. Three minor plots within each major plot were offspring from good, average and poor parents. Minor plots each had 10 trees spaced 12 inches apart in the row and 12 inches between rows (Appendix Figure A2).

Peat pots were also used to establish this plantation. The germinated seeds were potted in the greenhouse on April 3, 1969, and moved into the planting area at the Tree Research Center on May 19-22, 1969. Survival was excellent, 95.7 percent after two years.

Webb (1969) has pointed out the importance of uniform seedling density in progeny testing of hardwoods. The efficiency of the progeny test was found to be highly dependent upon the uniformity of seedbed densities. In one study using half-sibs from 15 sweetgum (Liquidambar styraciflua L.) parents, he found a strong, negative relationship between root collar diameter and numbers of seedlings per square foot. Seedling height, however, was found to be independent of seedling density. Densities reported were 10, 20, 30, and 40 seedlings per square foot, considerably higher than the one and four seedlings per square foot for the black cherry studies reported here.

When root collar diameter in the nursery beds was related to the height of plantations at age five, nursery effects were still apparent although not statistically significant. Survival in all black cherry plantations was excellent.

Plantation 2-69 followed a randomized complete block design. There were three blocks, each containing offspring of one good, one average and one poor parent from each of 59 stands (177 families total). Thirty-seven of the 59

stands were completely represented in all three blocks.

(Appendix Figure A3).

Nonstratified seed was sown in a standard 4.0 foot width nursery bed on November 21-22, 1968. Seventeen seeds from each seedlot were sown in each row plot across the width of the bed. Initial spacing was three inches between seeds in plots and six inches between plots.

Following germination, the plots were thinned by hand, on June 17-18, 1969, to no more than eight uniformly spaced seedlings per row plot. Bed densities were reasonably uniform but not as good as with the method of setting out germinated seedlings in peat pots.

PLANTATION 1-68, PARSONS

RESULTS AND DISCUSSION

At the end of the third growing season, height and form data were collected and analyzed. Height was measured in class intervals of 0.2 foot, which approximated 1/27 of the range between extremes. Plantation mean height was 3.20 feet and mean heights of offspring from good, average, and poor parents were 3.28, 3.18, and 3.14 feet respectively.

Mean heights of offspring in feet

National Forest	Form of Parent			Forest Mean
	Good	Average	Poor	
Allegheny	3.57	3.38	3.50	3.48
Monongahela	2.98	3.02	2.86	2.95
Plantation	3.28	3.18	3.14	3.20

Analysis of variance

Source	d.f.	M.S.	F.
Stand of origin	15	7.37	5.0 **
Form of parent	2	1.03	.7
Error	24	1.47	

The analysis of variance showed no significant differences in height growth after three years due to parental selection but there was a significant difference due to stand of origin. The Allegheny sources had a mean height of 3.48 feet compared to a mean of 2.95 feet for the Monongahela sources.

There was no significant difference in mean heights between stands of origin or offspring of good, average or poor parents in the Monongahela sources. Within the Allegheny sources there was a highly significant difference between stands. However, when the quality of the parent was compared to the growth rate of the offspring, no significant relationship could be detected.

Form of offspring was scored on a rating scale of 10 points. Trees of the best form in the planting were scored as 1. Trees without forks were scored from 1 to 5, points being added as form quality decreased. Trees having at least one fork were scored beginning with 6 and points added for limbness, additional forking and crooks. Thus the rating scale was additive. Mean values below 5.0 indicate generally

good form, while those above would indicate generally poor form (Table 6).

Analysis of variance for Table 6

<u>Source</u>	<u>d.f.</u>	<u>M.S.</u>	<u>F</u>
Stand of origin	15	0.1809	0.792
Form of parent	2	0.0052	0.023
Error	24	0.2284	

Seed from the Monongahela National Forest was significantly heavier than seed from the Allegheny National Forest. However, trees grown from the Allegheny seed were taller at age-3. Within either the Monongahela or Allegheny National Forests there were no significant differences in seed size between good, average and poor trees, or between stands. Seed weight had a negative covariance with 3-year height and the correlation coefficient in this study was $r = 0.58$, with 42 d.f. (Figure 8).

The negative relationship of seed weight to three-year height is due largely to geographic variation. Allegheny sources were, with few exceptions, above the plantation mean height at all locations, while few, if any, Monongahela sources exceeded the plantation mean height.

In the study group at Parsons, the 10 tallest families were all Allegheny sources, while the shortest 10 families were all Monongahela sources (Table 7). However, when

Table 6.--Comparison of form of parent and form of offspring for 42 families in 16 stands of origin, tested at Parsons.

Stand of Origin	Form of Parent	Form of Offspring (1 = Good; 10 = Poor)
<u>4</u>	Aver	5.36
<u>4</u>	Poor	5.67
<u>4</u>	Good	6.33
<u>11</u>	Poor	5.69
<u>11</u>	Aver	5.78
<u>11</u>	Good	5.80
<u>15</u>	Good	4.78
<u>15</u>	Aver	6.78
<u>19</u>	Aver	5.29
<u>19</u>	Poor	5.64
<u>19</u>	Good	5.78
<u>21</u>	Poor	5.20
<u>21</u>	Good	5.78
<u>25</u>	Aver	4.75
<u>25</u>	Poor	5.80
<u>25</u>	Good	6.20
<u>26</u>	Aver	5.00
<u>26</u>	Poor	5.31
<u>26</u>	Good	5.41
<u>28</u>	Aver	5.54
<u>28</u>	Poor	5.69
<u>29</u>	Aver	5.36
<u>29</u>	Good	6.07
<u>34</u>	Good	4.87
<u>34</u>	Poor	5.25
<u>34</u>	Aver	5.78
<u>36</u>	Poor	5.13
<u>36</u>	Aver	5.18
<u>36</u>	Good	5.20
<u>47</u>	Good	5.71
<u>47</u>	Poor	5.92
<u>64</u>	Poor	5.38
<u>64</u>	Aver	5.50
<u>65</u>	Aver	5.81
<u>65</u>	Good	6.00
<u>65</u>	Poor	6.53
<u>72</u>	Poor	5.33
<u>72</u>	Good	5.75
<u>72</u>	Aver	6.27
<u>75</u>	Good	5.50
<u>75</u>	Poor	5.78
<u>75</u>	Aver	5.88

Figure 8.--Relationship of seed weight to three-year height of black cherry from 48 families and 16 stands of origin, tested at Parsons.

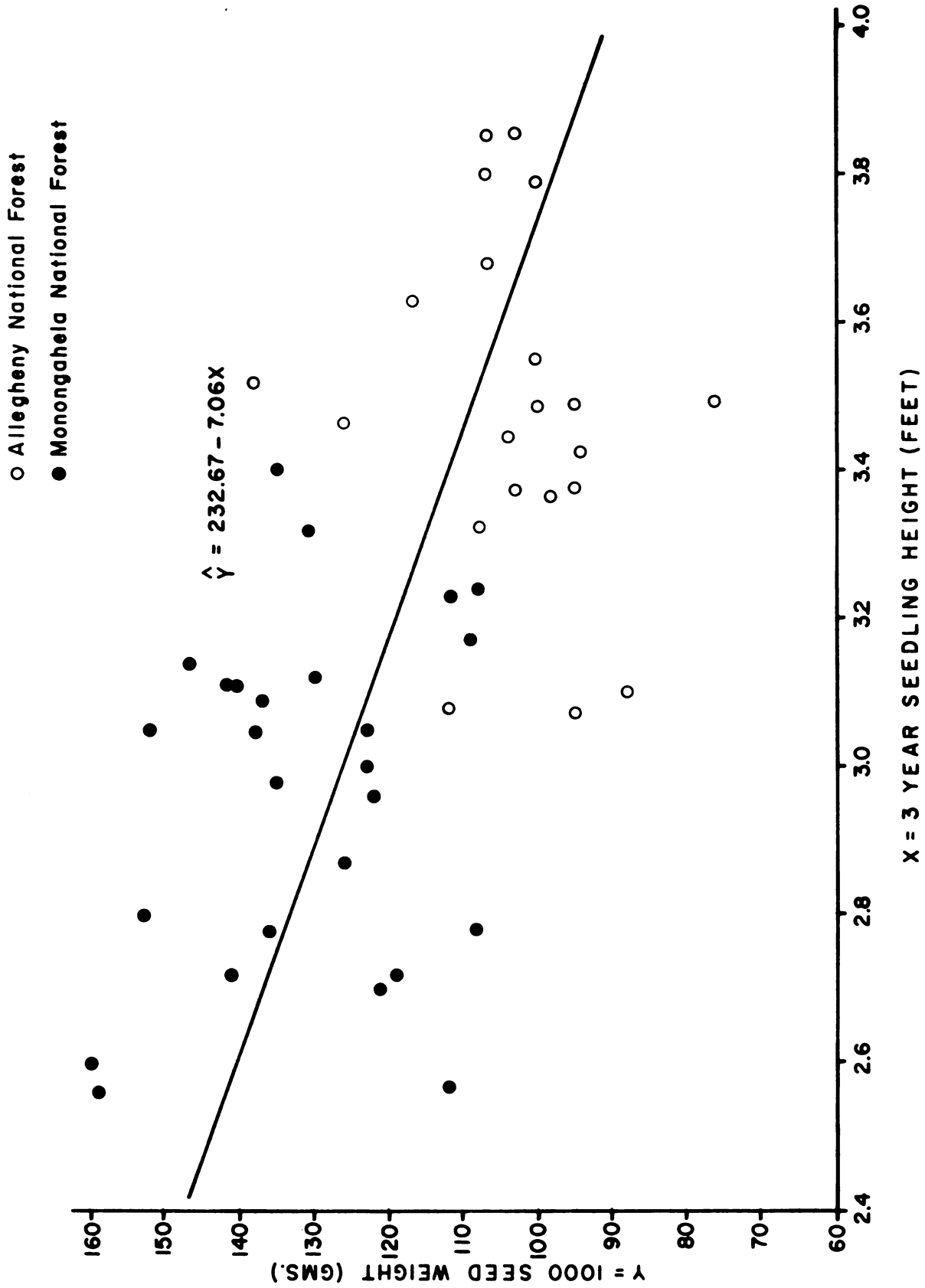


Table 7.--Comparison of height of offspring, form of parent and National Forest stand of origin for 48 families and 16 stands, tested at Parsons.

National Forest	Stand of Origin	Mean height as percent of plantation mean	Form of parent
Allegheny	75	121	Poor
Allegheny	36	121	Good
Allegheny	34	119	Good
Allegheny	75	119	Good
Allegheny	65	116	Good
Allegheny	36	114	Poor
Allegheny	64	111	Aver
Allegheny	65	110	Poor
Allegheny	47	110	Poor
Allegheny	47	109	Aver
Allegheny	47	109	Good
Allegheny	72	109	Poor
Allegheny	34	108	Aver
Allegheny	34	107	Poor
Monongahela	25	107	Aver
Allegheny	65	106	Aver
Allegheny	75	106	Aver
Allegheny	36	106	Aver
Monongahela	28	104	Aver
Allegheny	64	104	Good
Monongahela	29	102	Aver
Monongahela	26	102	Good

Table 7 (con'd).

National Forest	Stand of Origin	Mean height as percent of plantation mean	Form of parent
Monongahela	15	100	Good
Monongahela	15	99	Poor
Monongahela	4	98	Good
Monongahela	15	97	Aver
Monongahela	25	97	Poor
Allegheny	64	97	Poor
Monongahela	4	97	Aver
Allegheny	72	97	Aver
Allegheny	72	97	Good
Monongahela	19	96	Good
Monongahela	29	96	Poor
Monongahela	28	96	Good
Monongahela	26	94	Aver
Monongahela	25	93	Good
Monongahela	21	93	Poor
Monongahela	29	90	Good
Monongahela	11	88	Poor
Monongahela	21	87	Aver
Monongahela	28	87	Poor
Monongahela	11	85	Good
Monongahela	11	85	Aver
Monongahela	19	85	Poor
Monongahela	26	82	Poor
Monongahela	21	82	Good
Monongahela	19	81	Aver
Monongahela	4	80	Poor

ranked by form (Table 6), the distribution was equal with 5 families each from the Monongahela and Allegheny in the top 10, and 6 Monongahela to 4 Allegheny in the lowest 10. By parental selection classes, the ten tallest families, all Allegheny sources, were split 5 good, 1 average, 4 poor with the tallest family springing from a poor parent. This parent was of extremely poor form, growing near the edge of a small opening in a sparsely wooded portion of the forest. The trunk was rough and crooked and divided into several stems at a point only three feet above the ground. Diameter of the stem below the fork was 15.3 inches, and the height of the highest point on the several stems was 62 feet. Several other poorly formed, rough, cull-trees were nearby in the small opening.

The good parent was 254 feet away in a group of trees of better quality. It was described as having an unusually straight stem and a small symmetrical crown. Total height of the good parent was 72 feet at age 46, with a stem diameter of 12.4 inches. This tree ranked fourth in height in the plantation at Parsons. The average parent in this stand ranked sixteenth.

In form, there were 3 good, 4 average and 3 poor parental selections having offspring in the top ten ranking with the best form being offspring from an average parent.

This average parent was 79 feet tall and had a stem diameter of 11.8 inches. At a point 18 feet above ground, the trunk was forked. The good parent in this stand ranked 38th

in form in the plantation. It was 82 feet tall with a stem diameter of 17.9 inches. The stem was straight and clean for a distance of 35 feet, with a fork at 43 feet.

Stand 36 offspring ranked 5 (poor parent), 6 (average) and 7 (good) in form. The poor parent in this stand forked at 26 feet with multiple forking above that point. The average parent forked at 45 feet while the good parent had a perfectly clear stem up to 53 feet where it forked. It thus had over twice as much clear length of stem as the poor parent. The form ranking of the offspring in the plantation was the complete opposite of the parental quality. At age 3, there is no apparent relationship between parent phenotype and the form of the half-sib progeny.

PLANTATION 1-69, EAST LANSING

RESULTS AND DISCUSSION

At the end of the second growing season height data were collected and other traits measured and analyzed. Height was measured in 0.3 foot class intervals, which approximated 1/21 of the range between extremes. Statistical analysis was done using the height of the five tallest trees in each minor plot to calculate plot means.

Mean height of offspring in feet

National Forest	Form of parent			Forest Means
	Good	Aver	Poor	
Allegheny	3.42	3.47	3.40	3.43
Monongahela	3.57	2.55	2.61	2.91
Plantation	3.42	3.43	3.37	3.41

Mean height of the Allegheny sources at two years was 3.43 feet compared to 2.91 feet for all Monongahela sources. This difference was significant when using the "t" test on source means.

Analysis of variance showed that there were significant differences in height of the black cherry seedlings at age-2 associated with stand of origin but not with parent within stand.

Analysis of variance

Source	d.f.	M.S.	F
Block	1	2848.00	66.3 **
Parent	71	46.91	1.1
Stand of origin	23	88.49	2.1 **
Parent within stand	48	26.99	0.6
Error	71	42.94	

There were also large differences among blocks in this experiment. Block I was next to a windbreak planting whereas Block II was 13 to 23 feet away. Moisture was possibly more abundant closer to the windbreak where air movements were moderated and surface evaporation retarded. Shade provided by the windbreak reduced soil and leaf temperatures favoring lower transpiration and respiration rates. Block II was more open and exposed to wind and sun. A nursery tree crop was removed from the area just before Block II was planted.

The split-plot design which was used gave rather low precision as regards detection of differences among progenies

from different stands, but high precision as regards testing of differences among offspring of different trees within a stand.

Although these results seemed to indicate that the parental selection was ineffective in controlling progeny height, it was desirable to check this point in another manner by calculating the correlation between parental and progeny height. The parents were of different ages, so it was necessary to convert all the heights to an age-50 basis by using the black cherry site index curves developed by Defler (1937). The correlation was calculated with data from 69 parents and their offspring. The correlation was not significant, with $r = .02$.

In the plantation at East Lansing, nine of the ten tallest families were all from the Allegheny National Forest, but seven of the ten shortest were also from the Allegheny (Table 8). The ten tallest families included offspring of five good, two average and three poor parents.

Seeds collected from an average parent on the Marienville District, Allegheny National Forest, produced the tallest family in the plantation. The parent was described as having a pronounced crook at 22 feet with heavy branches and dead wood in the top of the crown, with a diameter of 20.4 inches, age of 70 years and height of 79 feet. The good parent in that stand was 297 feet northwest. It had a diameter of 23.5 inches, and was 100 feet tall at 72 years

Table 8.--Mean height of offspring by stand of origin,
ranked by height in Plantation 1-69, East Lansing.

Mean height as percent of plantation mean	Stand of origin	Mean height as percent of plantation mean	Stand of origin
166.6	60	96.0	36
141.9	54	95.5	23
129.7	62	94.8	37
128.8	43	93.8	3
122.8	65	93.4	22
121.3	61	93.4	35
121.0	58	93.4	67
118.9	53	93.1	2
113.7	76	93.1	47
113.2	33	92.9	10
113.2	49	92.8	7
113.2	52	91.4	30
110.4	45	89.9	44
109.8	50	89.0	66
109.8	57	88.6	46
108.9	56	88.5	39
108.1	51	88.3	21
108.1	59	86.4	32
106.9	64	86.2	31
106.3	55	85.6	24
103.7	5	85.0	69
103.4	38	83.9	6
103.2	1	83.0	41
103.2	40	79.5	8
102.3	72	79.4	74
101.7	34	78.1	48
101.2	71	77.8	42
98.6	73	74.4	63
97.7	9	64.4	68
97.1	70		

of age. It was described as having an unusually straight bole and symmetrical crown. Offspring of this good parent ranked 14th in height at age 2.

Seed weight per 1000 seeds ranged from 73.1 to 171.1 grams. There were no significant differences associated with National Forest of origin, stand of origin or quality of parent tree. The correlation between seed weight and progeny height was calculated for the sources from the Allegheny National Forest only. The correlation was weak, $r = .05$.

Form was scored in this study but based upon observations that differences were not apparent, and that within plot variation was judged to be as great as between plot variation, was not included in the analysis.

A condition of chlorotic leaf margins of varying severity was noted and measured. It was not associated with sources, stands or parents. The pattern within the plantation was erratic and widely distributed, and not associated with any discernible differences in soil or environment.

PLANTATION 2-69, PARSONS

RESULTS AND DISCUSSION

Height growth was measured on October 12, 1970, at the end of second growing season. A class interval of 0.2 foot was used which approximated 1/29th of the range between extremes.

Mean height of offspring in feet

National Forest	Form of parent			Forest mean
	Good	Average	Poor	
Allegheny	2.80	2.74	2.84	2.79
Monongahela	2.34	2.37	2.27	2.33
Plantation	2.73	2.68	2.74	2.72

Analysis of variance

<u>Source</u>	<u>d.f.</u>	<u>M.S.</u>	<u>F</u>
Blocks	2	516.01	79.26 **
Form of parent	2	3.34	.51
Stand of origin	36	20.88	3.21 **
Parent x Stand	72	7.35	1.13
Error	220	6.51	

Again, as was the case also in the plantation at East Lansing, there was a highly significant difference in 2-year height due to blocks and stands of origin. The variance in height due to parents was again not significant. The differences due to blocks in this plantation are the result of nursery seedbed treatments. Block I was closest to the road. Any soil treatments such as fumigation or fertilizer, is often applied more heavily at the ends of the nursery beds than farther along, as the equipment attains or reduces momentum. The seed in this experiment was fall-sown and covered with sawdust mulch overwinter. In applying mulch, the equipment operator occasionally varies his speed and applies a heavier mulch at the ends of the beds.

Blocking in this plantation was effective since mean heights in Block I were 3.21 feet at age-2 compared to 2.48 and 2.46 in Blocks II and III.

The plantation mean height was 2.72 feet, with the offspring of good, average and poor parents having mean heights of 2.73, 2.68, and 2.74 feet respectively. Needless to say, heights did not differ significantly between offspring of different qualities of parents. The poor parent offspring was actually 0.01 foot taller than the good parent offspring.

As in the other two experiments, trees grown from Allegheny seed were taller than the Monongahela trees at age-2. Offspring of average Monongahela parents had slightly greater height than the offspring of good or poor parents from the same forest. That difference, while small was large compared with the very slight superiority of the offspring of the poor Allegheny parents.

The ten tallest families were all Allegheny offspring, results similar to the other two experiments. The distribution by parent quality class was three good, four average, four poor with one good and one poor tied for tenth position. The bottom of the rankings were mixed with four Allegheny and six Monongahela sources represented in the shortest ten progenies. Four good, three average and three poor parents were represented, with the bottom of the rank held by offspring of an Allegheny good parent. Thus both the tallest and the shortest families were grown from seed collected from good quality Allegheny parents.

The best stands of origin were 52, 36, and 56 in that order (Table 9). Offspring of the poor parent in stand 52 were third tallest in this plantation, while average parent offspring were sixth and offspring of the superior tree were tenth.

The tallest family was 133.4 percent better than the plantation mean and came from a good parent in stand 61. The second and third tallest families were both from poor parents in stands 51 and 52. They were 132.7 and 130.8 percent of the plantation mean.

The good parent in stand 61 was 22.1 inches in stem diameter and 97 feet tall at age 87. The trunk forked at 45 feet above ground, where it divided into two distinct stems. The trunk below the fork was very straight and well formed.

The offspring from the average and poor parents in this stand were well below the plantation mean at 89.8 and 87.6 percent.

Table 9.--Mean heights of offspring as percent of plantation mean by stand of origin, Plantation 2-69, Parsons.

Mean height as percent of plantation mean	Stand of origin	Mean height as percent of plantation mean	Stand of origin
125.8	52	101.1	57
120.7	36	100.0	48
118.8	56	99.4	64
117.0	65	98.7	58
116.2	54	98.0	53
115.9	51	97.4	6
112.8	50	96.9	38
112.5	60	95.4	10
110.9	45	94.5	8
110.6	33	93.8	46
110.3	62	93.5	76
109.6	72	93.2	23
109.3	70	93.1	41
108.9	35	92.5	44
107.9	63	92.2	1
107.4	43	91.6	67
105.9	47	91.4	21
105.4	69	90.7	39
104.9	68	89.8	66
104.8	74	89.1	24
104.4	55	87.7	3
104.0	40	87.2	5
103.9	42	86.5	22
103.6	61	86.0	9
103.2	32	85.2	30
102.8	37	78.8	31
102.8	59	77.9	49
102.6	34	73.4	2
102.0	71	63.9	7
102.0	73		

CHAPTER III

CONCLUSIONS AND RECOMMENDATIONS

Mass selection is effective when environmental effects are small and heritability is high for the character or characters under selection (Wright, 1962). In modifying characters such as yield, growth rate and height, that are controlled by many genes and cannot be accurately judged on the basis of the appearance of an individual, the technique of mass selection has not been effective.

The studies and results described here lead to the same conclusion: mass selection of parents in wild black cherry stands is not the most efficient approach to breeding of the species for timber. Allard (1960) has succinctly stated the case for mass selection:

"The most effective way of distinguishing among single plants whose superiority is environmentally induced and those whose superiority stems from superior genotypes is by progeny testing. . . . The most common procedure is merely to harvest open-pollinated seed from the selected plants and use it to establish the progeny plots. . . . The plants . . . are then selected on the basis of the performance of their progeny, rather than on their own phenotypic appearance."

This is the procedure followed in this thesis, with the one addition that selected parents included not only superior but also inferior phenotypes.

The results of the investigations reported here agree with previously reported results in jack pine (Canavera, 1969), Scots pine (Nilsson, 1968), longleaf pine (Snyder, 1969), and red pine (Yao, et al, 1971). Parental selection, as currently practiced in black cherry, fails to fully identify useful genotypes. There was no relationship between parents and their half-sib families at two or three years of age. These results could possibly change as the offspring mature. However, the complete lack of association between parent and offspring is very strong. The distribution of offspring in all plantations was completely independent of parental selection (Table 10).

The lack of a significant parent-progeny relationship for height indicates that this character is not under strong genetic control in black cherry. Height growth in black cherry trees is most likely under the control of several genes, which under favorable environmental conditions can produce the desired phenotype. But in this species the favorable gene combinations must segregate with the result that parents of superior height and form can produce inferior progenies. Conversely, phenotypically inferior parents may produce superior progenies as well as mediocre and inferior progenies. This situation is also the result of the inability of the tree breeder to adequately identify genotype in wild stands by evaluation of the phenotype. Confounding this evaluation is the relatively long life span of the

Table 10.--Comparison of the distribution of the numbers of families of good, average and poor parents which were above and below the plantation mean height.

Parent	Good	Average	Poor	Total
Above mean	62	65	60	187
Below mean	58	60	70	188
Total	120	125	130	375

Chi-square = 1.098

species, making it virtually impossible to reconstruct the many environmental and site factors which have acted upon the individual tree over a period of years to bring it to its present form at the moment of observation.

Individual tree selection might be more productive in plantations, where plants were established at the same time, spacing was uniform, and gross environmental factors could be considered to have operated equally on all plants. Unfortunately, until very recently, there has been no consideration given to artificial reforestation of black cherry. No plantations were available to test this approach to selection.

Agronomists can make their selections under relatively uniform field conditions. Foresters and tree breeders seldom have such an opportunity. In fact, some early guidelines for forest tree improvement programs actually discouraged selection in plantations, preferring natural stands because of their demonstrated fitness for the local conditions.

Even though the distribution of offspring was apparently independent of parental selection, there were significant differences in the way in which certain seedlots performed at the different plantation locations (Table 11). Of 157 seedlots compared, 49 were above the plantation mean height at both locations, a number higher than would be expected on the basis of a normal distribution. Parental selection was not responsible for this deviation from expected since those 49 seedlots were from 17 good, 15 average, and 17 poor parents.

Table 11.--Numbers of seedlots having same or different degrees of superiority at two planting sites.

Mich.	W. Va.		
	Top 50%	Bottom 50%	Sums
Top 50%	49	25	74
Bottom 50%	38	45	83
Sums	87	70	157

Chi-square = 6.61 *

It is interesting to note that of the 49 seedlots which were above the plantation mean heights at both Parsons and East Lansing, 47 of these were Allegheny sources. Of the 45 seedlots below the means at the two locations, 20 were Monongahela sources. Thus while parental selection was not effective in producing superior progeny, it is evident that geographic source differences do exist and can be exploited to advantage in the genetic improvement of black cherry. Apparently, evolutionary forces have produced in the Allegheny population, a provenance well adapted to the test conditions and one worthy of further investigation.

Some tentative conclusions can be drawn regarding which stands are likely to be most productive in yielding seedlings of above average height growth for use in reforestation programs (Table 12). Stands 43, 54, 60, 62 and 65 are good prospects for seed collection since the offspring as a group were well above average. Rigorous culling of the seedlings produced from these stands would assure that nursery stock was of the best attainable from wild stands that were sampled.

There appears to be little basis for collecting only from the good parents in these stands. The tallest families in each of the five best stands of origin were offspring of two good parents, two average parents and one poor parent.

Table 12.--Comparison of stands of origin based on relative height at three locations.

Stand No.	Relative height as percent of plantation mean				
	Parsons 1-68	E. Lans 1-69	Parsons 2-69	Pooled	
1		103.2	92.2	97.7	
2		93.1	73.4	83.3	
3		93.8	87.7	90.8	
4	91.8			91.8	
5		103.7	87.2	95.4	M
6		83.9	97.4	90.6	
7		92.8	63.9	78.4	O
8		79.5	94.5	87.0	
9		97.7	86.0	91.8	N
10		92.9	95.4	94.2	
11	86.2			86.2	O
12				--	
13				--	N
14				--	
15	98.6			98.6	G
16				--	
17				--	A
18				--	
19	87.2			87.2	H
20				--	
21	87.2	88.3	91.4	89.0	E
22		93.4	86.5	90.0	
23		95.5	93.2	94.4	L
24		85.6	89.1	87.8	
25	99.2			99.2	A
26	92.6			92.6	
27				--	
28	95.7			95.7	
29	95.8			95.8	
30		91.4	85.2	88.3	
31		86.2	78.8	82.5	A
32		86.4	103.2	94.8	L
33		113.2	110.6	111.9	L
34	111.6	101.7	102.6	105.3	E
35		93.4	108.9	101.2	G
36	113.5	96.0	120.7	110.1	H
37		94.8	102.8	98.8	E
38		103.4	96.9	100.2	N
39		88.5	90.7	89.6	Y
40		103.4	104.0	103.6	
41		83.0	93.1	88.1	
42		77.8	103.9	90.8	
43		128.8	107.4	118.1	*
44		89.9	92.5	91.2	

Table 12.--Continued

Stand No.	Relative height as percent of plantation mean				
	Parsons 1-68	E. Lans 1-69	Parsons 2-69	Pooled	
45		110.4	110.9	110.6	S
46		88.6	93.8	91.2	O
47	109.4	93.1	105.9	102.8	U
48		78.1	100.0	89.1	R
49		113.2	77.9	95.6	C
50		109.8	112.8	111.3	E
51		108.1	115.9	112.0	S
52		113.2	125.8	119.5	
53		118.0	98.0	108.0	
54		141.9	116.2	129.1	*
55		106.3	104.4	105.4	
56		108.9	118.8	113.8	
57		109.8	101.1	105.4	
58		121.0	98.7	109.8	
59		108.1	102.8	105.4	
60		166.6	112.5	139.6	*
61		121.3	103.6	112.5	
62		129.7	110.3	120.0	*
63		74.4	107.9	91.2	
64	107.8	106.9	99.4	104.7	
65	110.7	122.8	117.0	116.8	*
66		89.0	89.8	89.4	
67		93.4	91.6	92.5	A
68		64.4	104.9	84.6	L
69		85.0	105.4	95.2	L
70		97.1	109.3	103.2	E
71		101.2	102.0	101.6	G
72	100.6	102.3	109.6	104.2	H
73		98.6	102.0	100.3	E
74		79.4	104.8	92.1	N
75	115.3			115.3	Y
76	113.7	93.5	103.6		Monon.
n	100.2 16	100.3 59	99.8 59	99.6 67	

* = Stands which exceed plantation means by more than 15 percent at two or more locations.

Family mean height as percent of plantation mean height			
Stand No.	Form of parent		
	Good	Average	Poor
43	96.2	114.6	127.2
54	129.5	--	128.6
60	142.9	133.8	141.8
62	112.4	136.1	123.4
65	114.8	128.9	116.1

It should be interesting to compare the realized gain attained by including all parents (good, average and poor) to the gain realized by selecting only the good parents. Since all parent classes were represented in the plantings, the plantation mean heights should be a reliable estimate of the population mean height at two years.

In plantation 2-69 at Parsons, the mean height of the good parental families was 2.73 feet and the plantation mean was 2.72 feet. Realized gain was 0.4 percent in height as a consequence of selection of good parents. As East Lansing, the mean of all the families was 3.42 feet compared to 3.43 feet for the families of parents selected as good. There was 0.3 percent realized gain because of parental selection.

However, if the mean of the upper half of the plantation families are compared to the plantation mean, as is the generally accepted procedure in roguing progeny tests to develop seedling seed orchards, then the realized gains in height are 15.6 percent for the plantation at East Lansing and 12.2 percent for plantation 2-69 at Parsons.

If the top 25 percent of the families are included, regardless of parental selection, the realized gains increase to 22.9 percent in the plantation at East Lansing and 19.5 percent for plantation 2-69 at Parsons.

Realized gain (percent) under different selection criteria		
Criteria	Plantation	
	E. Lansing 1-69	Parsons 2-69
Family selection from superior trees	0.3	0.4
Upper half all families	15.6	12.2
Upper quarter all families	22.9	19.5

In these comparisons, it is pertinent to point out the contributions to realized gains provided by the families of the average and poor parents. If the current procedures for parental selection in tree improvement programs were followed, these parents would not have been tested because of their unimpressive phenotype. Thus while the gains realized in this study are only moderately better than those of programs testing only superior trees, several families which appear promising would not have been discovered.

TREE IMPROVEMENT PROGRAMS INVOLVING BLACK CHERRY

There are currently at least four tree improvement and research projects underway involving black cherry (Ettinger and Gerhold, 1968). These are, the Seed Orchard Program for the Allegheny and Monongahela National Forests, which forms the basis for this study; the Tennessee Valley Authority's Hardwood Tree Improvement Program; the Forest Tree Improvement Program at the State University College of Forestry at Syracuse University; and a Black Cherry Provenance Trial, under the direction of Franklin Cech, Division of Forestry, West Virginia University.

One of the prime considerations in the improvement of black cherry must be rapid initial or juvenile growth. Black cherry is recognized as an extremely rapidly growing species in its youth, a characteristic common to intolerant species (Hough, 1960). Growth rate culminates at age-45 or less, even on the best sites and continues to decline thereafter. The species responds poorly to release, even when young which is further evidence of the strong association of juvenile growth to the total height which the species attains at maturity.

Form and wood quality are quite susceptible to manipulation under intensive silviculture. There is a definite trend to shorter rotations because of increased demand for products. Yet this demand must be satisfied from an

ever-shrinking land base. Consequently, timber production is likely to become concentrated and far more intensive than is currently being practiced. The need is for raw material in the form of an improved species capable of fully utilizing the better sites where intensive forestry can be practiced economically.

Current parental selection standards for black cherry are highly artificial and mostly without basis in fact. All of the traits selected and evaluated are related to their economic desirability. For example, growth rate, straightness and symmetry of bole, height of first fork, branch angle, epicormic branching, apical dominance, freedom from insect and disease attack, and specific gravity all relate to the merchantability of the tree in the lumber market. Value judgments are applied to each trait and priorities set which may result in a certain numerical value being assigned to the trait. The sum of the values for each trait then indicates the tree's utility in a tree improvement program. There is some value in this method after heritability estimates for the species traits have been derived.

For the hardwoods and in particular for black cherry, there is no published information on heritabilities for height, growth rate, form, or other similar characteristics. Thus any selection guides or standards proposed are simply and completely based around the ideal timber tree without regard to the influence of genotype X environment interactions. This

interaction is the very reason that selection in wild stands will seem to be so productive on the surface, yet so frustrating in results obtained. The series of studies reported in this thesis are evidence of the futility of parental selection without basis in fact.

While improvement will be possible and significant genetic gains realized through identification of parental selections based on progeny tests, a great deal of time and money will have been invested in searching out superior parents, measurement and judgment of the value of the selected tree, in returning to collect seed and scions, in establishing progeny tests and in their measurement and analysis. Rather than approach improvement by this route, a first step might well be a sampling of the population genotypes to determine ecotypic variation.

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VITA
JOHN ALFRED PITCHER



John Pitcher was born May 28, 1935, at Amsterdam, New York and raised in the village of Canajoharie, an agricultural - industrial community on the banks of the Mohawk River in upstate New York. His early education was gained in the public schools there. He entered Hope College, Holland, Michigan, in September, 1952, on an accelerated program having completed his junior year in high school with sufficient credits to matriculate. At Hope College, he followed a Liberal Arts curriculum, majoring in Biology. At the completion of his college sophomore year, he transferred to the State University College of Forestry at Syracuse University, graduating from this institution in June, 1957, with the degree of Bachelor of Science in Forestry. His major course

of study as an undergraduate was in the area of general forest management. While at Syracuse, he was introduced to the field of Forest Genetics through the late Dr. Frederick U. Klaehn.

His first professional assignment was with the United States Forest Service, Olympic National Forest, Shelton, Washington, where he personally established the Dennie Ahl Seed Orchard, the first Douglas-fir seed orchard developed by the U.S. Forest Service. His appetite whetted by this experience, he returned to Syracuse in 1958, to pursue graduate work under Dr. Klaehn completing the requirements for a Master of Science in Forest Genetics in 1960. His MS thesis involved interspecific grafting within four tree genera.

In March, 1960, he was reassigned by the U.S. Forest Service to the Gifford Pinchot National Forest, as assistant nursery superintendent at the Wind River Nursery near Carson, Washington. His duties there included nursery stock production and tree seed processing.

Transfer to the Regional Office at Portland, Oregon, followed on April, 1962, where he was assigned as staff specialist in tree improvement and nurseries in the Division of State and Private Forestry. In February, 1963, he was transferred to the Regional Headquarters at Milwaukee, Wisconsin, to take charge of the Region's Forest Genetics program.

He entered the Graduate School of Michigan State

University, in September, 1966, under the Government Educational Training Act, PL 85-507, and completed a course of study in Forest Genetics, leading to the degree of Doctor of Philosophy. Returning to Milwaukee at the conclusion of his studies, he continued his assignment as Regional Geneticist with additional responsibilities for programs involving tree seed and nursery management.

In April, 1971, he moved to the Regional Headquarters of the U.S. Forest Service at Albuquerque, New Mexico, where he is responsible for the tree improvement programs in the Southwestern Region.

Author and co-author of several publications in his field, his most recent is: Tree Improvement Opportunities in the North Central States as Related to Economic Trends, published by the North Central Forest Experiment Station as Research Paper NC-40, 1970.

He is a member of the Society of American Foresters, Xi Sigma Pi, American Association for the Advancement of Science and several professional committees.

John Pitcher married Ann Dykhuizen at Canajoharie, New York, on September 8, 1956. They have five children. Wesley Giles was born November 28, 1957, at Shelton, Washington; Nola Ann, November 19, 1959, at Syracuse, New York; twin boys Eric John and Erin George, June 28, 1961, at Portland, Oregon; and Lisa Louise, November 9, 1966, at Lansing, Michigan.

APPENDIX

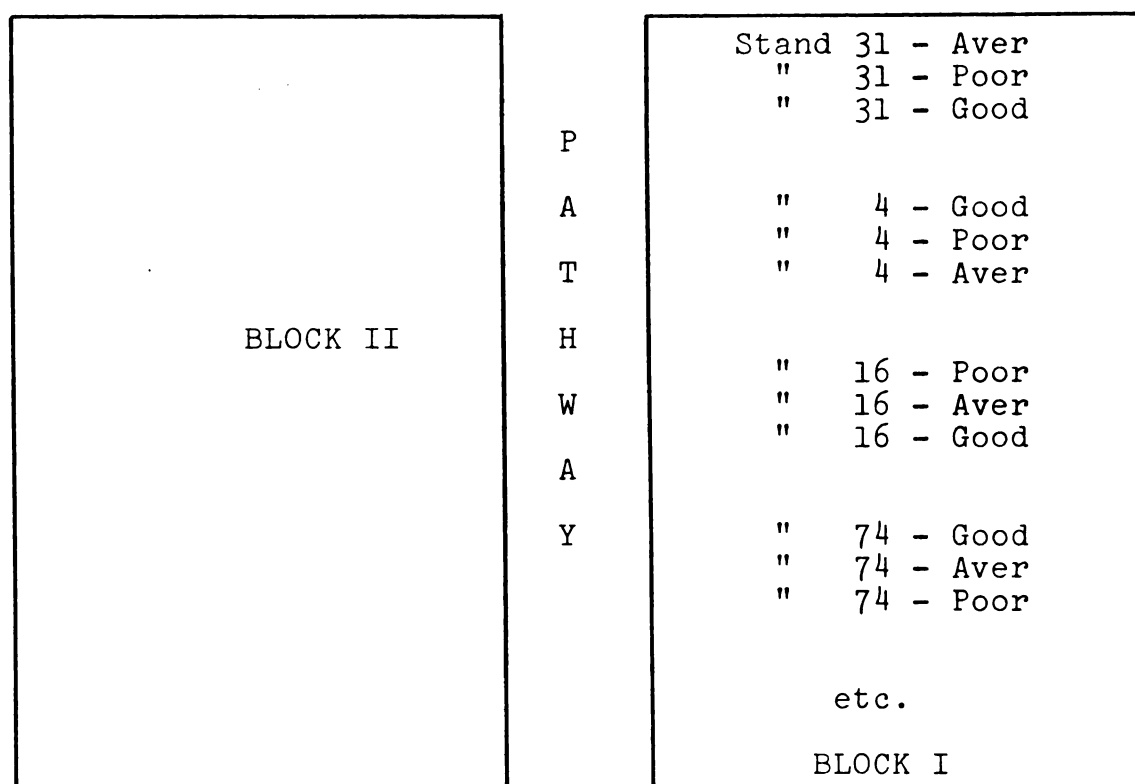
Figure A.--Planting design, Plantation 1-68, Parsons,
West Virginia

	B O R D E R T R E E S					
B O R D E R	V	IV	III	II	I	B O R D E R
	VI	VII	VIII	IX	X	
	XV	XIV	XIII	XII	XI	
	B O R D E R T R E E S					

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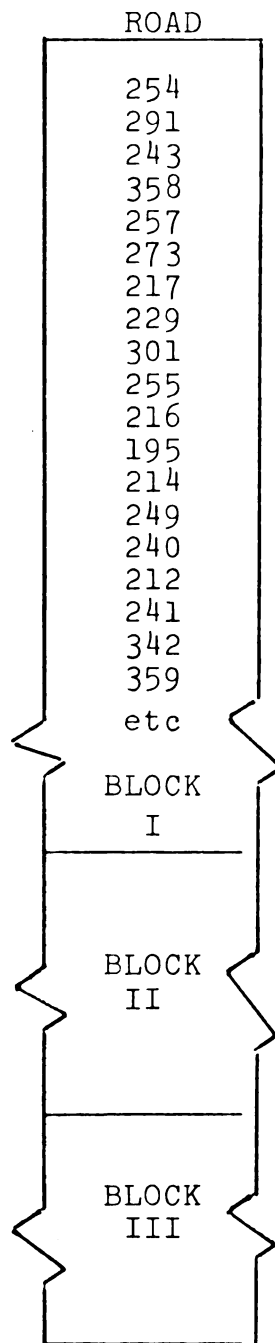
Spacing - 1 ft. X 1 ft.

Figure A2--Planting design, Plantation 1-69, East Lansing,
Michigan.



Spacing - 1 ft. X 1 ft.

Figure A3--Planting design, Plantation 2-69 Parsons,
West Virginia.



Numbers refer to
seedlots.

Spacing 6 in. X 6 in.



Figure A4.--Superior tree (TV-1), near stand 48, Allegheny National Forest.



Figure A5.--Good parent selected in stand 51, Allegheny National Forest.



Figure A6.--Poor parent selected in stand 51, Allegheny National Forest.

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