Intraspecific Variation in Virginia Pine, Results of a Provenance Trial in Maryland, Michigan and Tennessee[1])

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Introduction

Virginia pine (Pinus *virginiana* MILLER) is a common tree of eastern United States. It is characterized by two leaves (4—8 cm long) per fascicle; bloomy branchlets; oblong. dark brown, very rasinous buds; cones 4—8 cm long with prickles; and dark brown bark fissured into small scaly plates. It is a close relative of jack pine (P. banksiana LAMB.) of northern United States and of lodgepole pine (P. contorta ENGELM.) of western United States. As in those species the cones are persistent. Its form is similar to that of jack pine — widespread crown and crooked boles if grown in the open or straight but branchy if grown in dense stands.

The natural range of Virginia pine extends along the Coastal Plain from New York to Virginia and along the Appalachian Mountains from Pennsylvania to central Alabama, and west of the Appalachians to southern Indiana and northwestern Mississippi. Atlhough it occurs naturally in 16 states, half the commercial volume is in North Carolina and Virginia.

In 1922 SARGENT described Virginia pine as a scrub tree usually 30—40 ft tall (occasionally 100 ft) inhabiting poor soils, occasionally manufactured into lumber or used for firewood. At that time it was of little economic importance (SNOW, 1960). Then and for many years afterward any Virginia pine planting was done primarily to obtain a ground cover on eroded, sterile soils. But in recent years it has been recognized as an important pulpwood species north of the loblolly pine (P. taeda L.) zone. It can grow rapidly, especially in youth, on infertile sites and produces good pulpwood if grown in closed stands. Hence, several paper companies are now interested in development of better strains for practical use.

Research on racial variation of Virginia pine was started in Maryland by CRAIG D. WHITESELL who in 1957 started Trial No. 1, using trees grown from seed collected in 16 different parts of the natural range. These were found to differ in survival and growth rate (GENYS, 1966; GENYS and FORBES, 1973). Trial No. 2, with 21 seedlots, was started a year later and is the subject of this paper. The objectives of both trials were to determine the natural variation pattern, the extent of genetic variation in various traits, and regions giving the best seed for specific planting areas.

Material and Methods

In 1956 and 1957 seeds were collected from 21 natural stands located in 13 states from Pennsylvania to Alabama (WHITESELL, 1959; Table 1 of this paper). In each stand the seeds were collected from 6—20 trees. The stands ranged in elevation from 30—2,400 ft, both extremes occuring in Virginia.

The seeds were sown broadcast in unreplicated plots in the Maryland State Forest Tree Nursery at Harmans in April 1958. In 1959 and 1960 ten replicated test plantationc were established in Maryland, Delaware, Pennsylvania, Tennessee, Alabama, Michigan and West Virginia, using 1—0 or 1—1 stock. Because of hardwood competition, mouse damage, etc. five of the test plantations had very poor survival and have been discarded. Data on the remaining five, which had high survival and produced useful results, are summarized in Table 2.

Of the five most useful plantations, three in Maryland were measured during the winter of 1970—71 when the trees were 13 years old from seed. The two in Tennessee and Michigan were measured two years later, when the trees were 15 years old from seed. At the time of measurement, all plantations had closed canopies (except where mortality had been high), and the lower branches had died from shading.

Measurements included height and mortality at all places; diameter in all plantations except in Michigan; stem form in Maryland and Michigan plantations; and winter injury and cone production in Michigan. An analysis of variance was performed on each set of measurement data from a single plantation, using plot means as items and seedlot X replicate interaction as the error term.

Simple product-moment correlations were calculated between each of **34** variables, **6** relating to site of origin and 28 relating to growth measurements made in the planta-

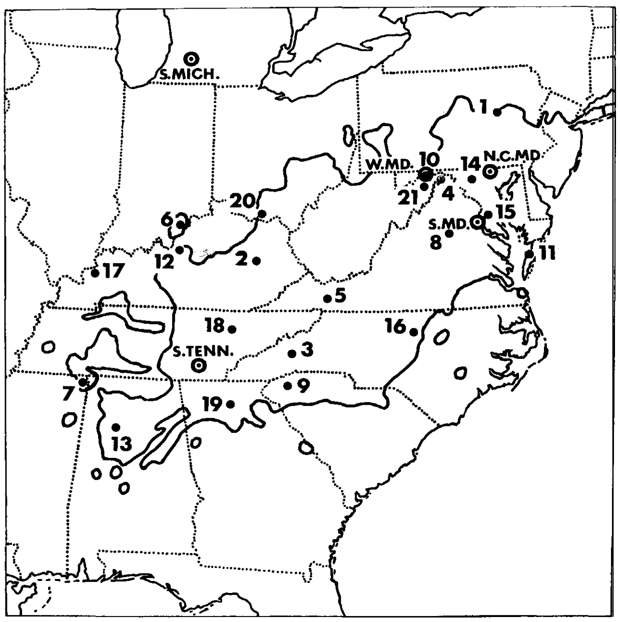

Figure 1. — Range of Virginia pine; numbered dots show the locations of seed sources, and circled dots stand for locations of research plantations (S. MICH. — Kalamazoo Co., Michigan; W. MD. — Alleghany Co., Maryland; N. C. MD. — Baltimore Co., Md.; S. MD. — Charles Co., Md.; and S. TENN. — Hamilton Co., Tennessee).

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Table 1. — Origin data for the 21 seedlots of Virginia pine used in the provenance test. The seedlots are arranged roughly from north to south.

Seedlot number, state and county of origin	North. Lat.	West Long.	Elev.	Total annual prec.	Length of frost-free season
	°	°	ft	in	days
1 PA Columbia	41.0	76.3	1,000	40	150
10 MD Alleghany	39.7	78.5	900	36	150
14 MD Frederick	39.5	77.3	620	40	170
15 MD Charles	38.6	76.8	200	42	200
4 WV Morgan	39.7	78.2	570	39	150
21 WV Hampshire	39.4	78.6	1,000	40	140
20 OH Adams	39.0	83.3	1,100	29	180
6 IN Clark	38.6	85.8	1,000	36	180
2 KY Wolfe	37.6	83.5	1,100	47	170
12 KY Bullitt	37.9	85.6	650	46	190
17 KY Crittenden	37.4	87.9	480	43	200
5 VA Smyth	36.9	81.5	2,400	40	150
8 VA Orange	38.2	78.2	—	43	170
11 VA Accomac	37.7	75.7	30	43	210
16 NC Orange	36.1	79.1	450	43	200
3 NC Buncombe	35.5	82.6	2,250	45	170
18 TE Anderson	36.1	84.1	960	48	190
9 SC Pickens	34.8	82.5	1,000	51	210
19 GA Dowson	34.6	84.2	1,380	50	220
13 AL Walker	33.5	87.3	380	50	200
7 MS Tishomingo	34.9	88.1	400	50	220

tions. Seedlot means were used as items in these calculations and degrees of freedom were 18 or 19.

Results

Mortality. Mortality varied from 11 to 34% in the five plantations. Except in the north-central Maryland plantation, where girdling by mice was a major cause of death, most of the mortality occurred the first year or two after planting, probably due to transplanting shock.

Two of the most southerly seedlots, 13 AL and 7 MS, suffered much heavier than average mortality in all plantations. That was expected in Michigan, where those two seedlots experienced noticeable needle injury the winter prior to field planting. These Alabama and Mississippi trees may also have suffered slight winter injury at the test site in western Maryland.

Mortality rates did not vary appreciably in the other 19 seedlots. Presumably high survival could be expected for any of them which were planted well on suitable sites.

Height. Average height was 18—25 ft at age 15 from seed in the most northerly (S. Mich.) and the most southerly (S. Tenn.) plantations, and 15—24 ft at age 13 in the three plantations in Maryland. Even greater differences might have been expected, considering the fact that the Michigan plantation is well north of the species' natural range or even the prospective commercial planting range.

In the most southerly plantation (S. Tenn.) there was a noticeable tendency for northern seedlots to grow at below average rates (*Table 3*). The expected opposite trend — for southern seedlots to grow most slowly in northern plantations — was also present but not nearly so noticeable. This opposite trend was evident mainly in the slower than average growth of seedlots 19 GA, 13 Al and 7 MS at northern test sites.

From the practical standpoint it is probably more important to note that seedlots 16 NC and 18 TE grew at well above average rates in all five test plantations. For example, seedlot 16 NC was tallest in both southern Michigan and southern Tennessee and ranked no lower than fifth from tallest at the intermediate locations.

It is often assumed that local seed is the best to use in any particular area. That was true in the southern Maryland plantation, where seedlot 11 VA from a nearby part of Virginia was tallest. In the other four plantations, the seedlot originating closest to the planting site was only 4th to 10th tallest.

Diameter. Average diameter ranged from 2.9 to 4.6 inches at age 13 from seed in Maryland and it was 4.9 inches at 15 years in Tennessee. The tallest strains also tended to have the largest diameters (*Table 3*). The correlations between height and diameter were r = .79, .90, .88 and .82 for the W MD, NCent Md, S Md and S Tenn plantations respectively. There were no statistically significant dif-

Table 2. — Location and description of the test plantations.

Plantation name and location	Planted	Stock age	Plot size	Number of replications	Spacing	Survival
	date				ft	%
S MICH W. K. Kellogg Forest, Kalamazoo Co, 300 ft elev.	4/11/60	1—1	4-tree	10	7 × 7	71
W MD Green Ridge State For., Allegany Co., 1,200 ft elev.	5/5/60	1—1	2-tree	20	8 × 8	82
NCent MD Prettyboy Reservoir, Baltimore Co., 800 ft elev.	Apr. 59	1—0	2-tree	20	8 × 12	73
S Md Gen. Smallwood State Park, Charles Co.	4/9/59	1—0	4-tree	16	6 × 10	89
S TENN Frienship Exper. For., Hamilton Co., 1,000 ft elev.	4/9/59	1—1	2-tree	20	6 × 10	66

Table 3. — Survival, height and diameter of 21 Virginia pine seedlots tested in 3 plantations at age 13 in Maryland (Md), and in 2 plantations at age 15 in Michigan (Mich) and Tennessee (Tenn).

Seedlot number & state	Average survival	Relative height					Relative diameter			
		S Mich	W Md	NCent Md	S Md	S Tenn	W Md	NCent Md	S Md	S Tenn
	%	% of plantation mean					% of plantation mean			
1 PA	79	104	101	97	97	100	101	91	95	96
10 MD	81	103	101	92	92	89	102	87	89	84
14 MD	82	106	103	100	102	98	98	104	99	93
15 MD	76	107	107	107	103	94	105	109	107	104
4 WV	82	100	96	94	94	94	95	91	94	86
21 WV	81	100	96	94	94	—	103	86	87	—
20 OH	83	—	—	—	98	98	—	—	98	101
6 IN	81	103	103	100	104	99	102	96	104	94
2 KY	73	105	103	98	95	98	97	99	95	96
12 KY	78	103	107	97	102	96	111	95	100	94
17 KY	74	97	92	100	98	98	82	94	95	95
5 VA	80	101	99	98	98	98	111	95	94	92
8 VA	81	100	111	101	103	96	110	105	107	97
11 VA	74	100	101	105	110	100	98	105	111	109
16 NC	81	110	107	104	103	114	108	106	107	113
3 NC	75	93	94	100	96	98	87	103	94	99
18 TE	78	104	109	106	104	107	113	110	104	111
9 SC	80	102	97	101	101	104	104	110	108	106
19 GA	81	99	90	111	100	109	91	112	106	121
13 AL	55	89	97	103	105	106	92	108	105	112
7 MS	58	81	95	93	101	102	89	91	98	95
$LSD_{0.5}$	12	9	14	11	6	8	19	n.s.	9	18
Actual mean ht., ft		18.2	15.3	19.6	23.5	24.9				
Actual mean diam., in							2.9	4.6	4.3	4.9

ferences in the height/diameter ratio, which averaged about 59 feet/feet.

Leaf length. Average leaf length of the seedlots, as measured in the S Md plantation, ranged from 44 to 56 mm. There was a general tendency for southern trees to have the longest leaves, the correlation was r = —.63 between latitude of origin and leaf length, significant at the 1% level.

However, there was no apparent relation between leaf length and growth rate. The correlations between leaf length and height in the five plantations varied from r = —.36 to +.44, all non-significant.

Winter injury. In the Michigan plantation, which is well north of the species' natural range, winter injury has been evident after exceptionally cold winters. The symptoms were brown needles on upper branches and occasional twig dieback. In the most severely damaged trees 10—15% of the foliage was affected. No trees died as a result of the damage.

Such injury was observed several years but measured only once, after the 1960—61 winter (*Table 4*). At the time, the damage was slight on northern seedlots and moderate to servere on southern seedlots; the correlation between latitude of origin and number of trees affected was r = —.61, significant at the 1% level.

Flowering and fruiting. As with other members of Subsection *Contortae*, Virginia pine is a precocious flower producer. Flowers can occur on 2—3 year-old seedlings. In this experiment, cone production was studied in the Michigan plantation only. Cone counts were made in each of 4 years, starting at age 5 from seed. The average number of trees producing female flowers increased with age, as shown in the following tabulation.

Age from seed, years	5	6	7	14
Trees with female flowers, %	3	6	40	58

Table 4. — Differences among 21 Virginia pine seedlots in leaf length (measured in S Md), winter injury and cone production (measured in S Mich) and stem form (measure in Maryland and Michigan).

Seedlot number & state	Leaf length	Trees with winter injury	Trees with cones	Weighted average number or amount of stem crooks
	mm	%	%	% of mean
1 PA	50	0	32	111
10 MD	50	0	48	84
14 MD	49	12	48	89
15 MD	51	20	25	104
4 WV	46	8	40	93
21 WV	48	8	32	82
20 OH	44	—	—	114
6 IN	51	32	25	93
2 KY	51	35	30	97
12 KY	49	0	35	97
17 KY	55	32	20	82
5 VA	46	12	35	91
8 VA	53	20	35	103
11 VA	50	32	17	123
16 NC	51	50	25	108
3 NC	53	58	25	99
18 TE	57	62	17	84
9 SC	55	82	12	107
19 GA	56	25	17	93
13 AL	52	32	10	124
7 MS	56	35	12	109
$LSD_{0.5}$	8.8	32	20	23
Mean	51	38	27	See text

The average number of cones per fruiting tree increased from 3 to 7 between ages 6 and 7. No exact counts were made at age 14, but at that time many trees had 50+ cones each.

In the southern Michigan plantation the frequency of coning was highest in the northern trees, although the number of cones per fruiting tree was nearly the same in all seedlots. The same tendency was noted in eastern white pine *(Pinus strobus* L.). It is probable that southern trees, even those with no visible symptoms of winter injury, suffered hidden damage to their growing points sufficient to prevent flower bud formation.

After age 5, male flowers were present in abundance but were not counted. Occasional inspections showed that most cones were producing sound seed. Also, even though the southern Michigan plantation is outside the species' natural range, there is considerable natural reproduction along the edges and in the openings where trees have died.

Stem form. Virginia pine, especially when grown in the open, is apt to be crooked. Therefore, improvement in stem form is desirable. To obtain data on this point, a total of six sets of measurements were made on the S Mich, NCent Md and S Md plantations. The average results for all seedlots are presented below:

Average offset per tree due to crook, S Mich	0.6 ft
Forks per tree, S Mich	.2
S Md	.6
Crooks per tree, S Md	1.0
Total stem defects per tree, NCent Md	1.4
S Md	1.3

There were positive but relatively weak correlations among these six sets of measurements. Also, correlations between form and other growth characters or climate at place of origin were weak, most being between r = —.4 and +.4.

For presentation, all the form data were reduced to a single set of weighted averages. To calculate those, all seedlot means in each set of data were reduced to percentages of the plantation mean. Then the deviations from 100% were weighted inversely to the error mean square, full weight being given to the set of data having the lowest error mean square. The results are presented in *Table 4.*

The weighted averages for different seedlots varied by an approximate 3-to-2 ratio, the lowest being 82% *(Table 4).* Thus, the straightest seedlots had about 4/5 as many crooks or other types of stem defects as the plantation averages shown in the above tabulation. In other words, even the best seedlots did not produce straight, single-stemmed trees such as are typical of many pine species. On the other hand, there was considerable variation which indicates a possibility of improvement in Virginia pine stem form.

There was no relation between stem form and climate at the place of origin or other measured growth traits. Of the two tallest seedlots, 18 TE was 3rd from straightest and 16 NC was 15th from straightest.

Theoretical Implications

From error variances. At the bottom of each set of measurement data is an LSD .05 (= least significant difference at the 5% level), which was calculated as 3.2 × the standard error of a seedlot mean.

These LSD's were relatively high in relation to the total range of between-seedlot means. That may be due to the culture given the plantations or to a relatively large amount of genetic variation among individual trees. Whatever the cause, the relatively large error terms necessitate caution when interpreting geographic trends.

From correlation. Certain broad geographic trends can be recognized by inspection of *Tables 3 and 4.* In the two most northern test plantations (S Mich and W Md),

Southern seedlots 19 GA, 13 AL and 7 MS grew most slowly,

Southern seedlots 13 AL and 7 MS suffered heaviest mortality,

and

Southern seedlots generally suffered heaviest winter injury and fruited least.

Altogether a total of 34 × 32/2 = 561 simple correlation coefficients (r) were calculated to give mathematical expression to those generalizations. Those for the northern test plantations can be summarized as:

Characteristic of habitat at place of origin	Survival	Height	Winter injury	Fruiting
	r	r	r	r
North latitude	.6 to .7	.3 to .5	—.6	.4 to .8
West longitude	—.3 to —.7	—.3 to —.6	.2 to .4	—.2 to —.6
Total ann. prec.	—.6	—.3 to —.5	—.2 to .8	—.2 to —.7
Length, frost-free season	—.3 to —.5	—.1 to —.3	.3 to .6	—.1 to —.8

Values of r greater than .5 and .6 were statistically significant at the 5 and 1% levels, respectively.

Such results indicate that there are general north-south trends but the correlation coefficients do not differ sufficiently to allow us to decide which site characteristics were most responsible for the evolutionary differentiation. Also, the statistical significance of some of the correlations seems due mostly to the inclusion of seedlots 19 GA, 13 AL and 7 MS. Without those seedlots, some trends disappear.

In the southern plantations, southern seedlots grew fastest and had the longest needles. It is hard to say whether those facts are causally related. Correlations between those traits and environmental traits which vary in a north-south manner ranged between .6 and .7 (significant at 1% level).

Even the highest correlations accounted for only 35—40% of the total variance in seedlot means. It is possible that the correlation would have been much closer to 1 if the experimental error had been less. But that is far from certain and it must also be remembered that the size of the correlations in several instances is due primarily to a few seedlots from extreme parts of the range.

From interactions. Survival and height were the two traits measured in all plantations. The correlations between plantations in these traits varied from —.1 to +.7; 5 of the 20 possible correlations being above .5, and 4 being below 0. Thus the statistical results indicate more agreement than disagreement between results at various test sites.

But a non-statistical look at *Table 3* indicates that some interaction occurred. For example, northern seedlots in general grew more slowly in the S Tenn plantation than elsewhere.

On the other hand, there is even stronger evidence in favor of the view that some seedlots grew well (16 NC and 18 TE) at all test sites and that some others grew poorly (4 WV, 21 WV, 17 KY and 5 VA) at all places. And two seedlots (13 AL and 7 MS) survived poorly at all places. It is difficult to reconcile such obvious lack of interaction with the concept that natural selection has produced Virginia pine genotypes particularly well adapted to specific habitat conditions.

From other species. Squillace (1966) studied geographic variation in slash pine (*P. elliottii* Engelm.), sampling the range intensively from South Carolina to Louisiana and south to southern Florida. Within the Florida population he found a south-north cline in several traits, and there was considerable genetic variation. But elsewhere in the range there were only 10—20% differences among the offspring of different parental stands and it was difficult to detect any pattern to the variation.

Wells and Wakely (1966) summarized their own considerable research on geographic variation in loblolly pine (*P. taeda* L.) and that of previous workers. Trees originating west of the Mississippi River differed from more eastern trees in several respects and trees from the extreme northern part of the range were consistently slow growing if planted in the south (the reverse was true in northern plantations).

Within the rest of the range they found a modest amount of genetic variation and were not able to establish strong correlations between tree characteristics and characteristics of the climate or soil at the place of origin. There was a stronger tendency for certain seedlots to excel whereever planted than for a seedlot to excel at one place and do poorly at another.

Genys (1968) and Wright (1970) summarized the results of two series of provenance tests of eastern white pine (*P. strobus* L.). Over a wide range of test conditions from Georgia north to Pennsylvania and southern Michigan, trees from the southern part of the range grew faster than trees from the north and to date have not suffered appreciable winter injury. In other words, there were general north-south trends. But there were very important exceptions to those trends. One such exception is the rather poor growth rate of trees originating in a sizeable portion of Virginia. The differences in growth rate among seedlots originating in the general area from Pennsylvania south to northern Georgia were on the order of 10—20%.

The consensus from the work on Virginia pine and the three other pines from southeastern United States is that:

1. Genetic, geographic differences of 10—20% exist in several traits,
2. North-south trends can be proven statistically if all data are considered, but often can not be detected if the extremes are excluded,
3. Important exceptions to the general trends exist and are difficult to explain in terms of adoptation to any characristic of the native habitat, and
4. Some seedlots tend to excel on a wide variety of sites.

Practical Implications

Virginia pine will probably be planted more in the south central states than in the north central states typified by the S Mich and W Md test plantations. In view of the facts that (1) correlations between growth traits and climatic characteristics accounted for less than half the total variance and (2) only the most extreme genotype-environment interactions were significant, practical recommendations are best based upon average performance. Accordingly, the following three seedlots are recommended for general planting.

Seedlot	Average growth rate	Average stem form
18 TE	Good everywhere	Good
16 NC	Good everywhere	Poor
19 GA	Good in south only	

The exact parental stands which yielded those seedlots can be used as *pro stem* seed orchards for limited amounts of seed. For extensive planting, more seed is needed, and that should be obtained by collecting as close to the abovementioned stands as possible.

Use of seed from those natural stands should result in an approximate 4—5% gain in rate of height growth.

Virginia pine fruits at a relatively early age. Also, the ratio of within-stand to between-stand genetic variation is probably high. Thus the recommended next step in improvement is a series of large half-sib progeny tests, to include the offspring of a few hundred selected (and some average) trees from many different stands. It would be well to sample intensively those stands (18 TE, 16 NC and 19 GA) already proven superior as well as others in the south-central region where those stands are located.

Such an experiment may yield more information on geographic variation and inheritance. But even if such information is non-definite, superior half-sib progenies can be identified. Those can be favored in thinning operations to leave the plantations as practical seed orchards for large scale production of improved seed. Costs would be small and improved seed would be available within 6 years.

Summary

Seeds were collected from several average trees in each of 21 natural stands of Virginia pine, located in all parts of the species' range. The resulting seedlings were grown in 5 replicated plantations located in southern Michigan, three parts of Maryland, and southern Tennessee. They were measured periodically until 13—15 years of age. Mortality was similar (17—26%) in all except two seedlots from Alabama and Mississippi, which averaged 42—45% dead. In northern plantations, southern trees suffered most winter injury, fruited least and grew slowest. In southern plantations, southern trees had the longest leaves and grew most rapidly. The correlations between growth traits and climatic variables, although statistically significant in some instances, generally accounted for 35—50% of the total variance. From the practical standpoint, three seedlots (18 TE, 16 NC and 19 GA), which grew well at several places, are recommended for planting.

Key words: ***Pinus virginiana***, Virginia pine, geographic variation, intraspecific variation, strains, provenance study, growth rates.

Zusammenfassung

In 21 natürlichen Beständen von *Pinus virginiana* aus allen Teilen ihres Verbreitungsgebietes wurde Saatgut von mehreren Durchschnittsbäumen geerntet. Die entstandenen Sämlinge waren in Süd-Michigan, 3 Gebieten von Maryland und in Tennessee angebaut worden und wurden bis zum Lebensalter 13—15 periodisch gemessen. Die Sterblichkeit war überall ähnlich (17—26%) mit Ausnahme von 2 Samenproben von Alabama und Mississippi, die 42—45%

Ausfälle hatten. In den nördlichen Pflanzungen erlitten die südlichen Absaaten die meisten Winterschäden, fruchteten am wenigsten und wuchsen am langsamsten. Auf den südlichen Anbauflächen zeigten die südlichen Absaaten die längsten Nadeln und waren sehr raschwüchsig. Die Korrelationen zwischen Wuchsmerkmalen und Klima-Variablen waren zwar in manchen Beispielen statistisch signifikant, erklärten aber im allgemeinen nur 35—50% der Gesamtvarianz. Für die Praxis werden nur 3 Saatgut-Proben zur Pflanzenanzucht empfohlen, deren Wachstum auf mehreren Flächen gut gewesen war.

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Rooting Cuttings from Physiologically Mature Black Cherry

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Introduction

Rooting juvenile black cherry *(Prunus serotina* EHRHART) via mist propagation is a relatively simple procedure (FARMER and HALL, 1969), but cuttings taken directly from older trees generally exhibit low rootability. In breeding programs, however, it is frequently necessary to clone selected mature trees for retention as parent stock. To date, grafting has been used successfully, but is relatively expensive and presents the breeder with the problems of stock-scion relationships. We have, therefore, used a combination of "rejuvenated" material and high concentration of indolebutyric acid (IBA) to root cuttings of selected genotypes.

Methods

Scions from eight clones in the Tennessee Valley Authority's breeding collection were grafted to seedling stock and lined out in a nursery near Norris, Tennessee. All clones were random selections with respect to knowledge of rooting potential. Ortets of two clones were from western Pennsylvania, two were from western Virginia, and the remaining four were selected in middle and eastern Tennessee. After several years' growth, when the plants were 2 to 3 m. tall, they were pruned heavily in early spring, and shoots originating from subapical buds were used in preliminary propagation trials. In these trials, IBA-talc mixes (.8 to 1.6%) proved moderately effective to ineffective depending upon clone. In February 1973, three to seven ramets from each of six clones and one ramet from two clones were again pruned heavily. In addition, all visible buds were removed from the branches of approximately one half of the pruned ramets. This was done to induce development of shoots from suppressed or adventitious buds which might exhibit greater juvenile rooting capability than shoots from visible buds (SHREVE and MILES, 1972). Fifteen-centimeter-long greenwood cuttings were taken in mid-May. Leaves were pruned to about two-thirds of original length, and cuttings were placed in water for immediate transportation to greenhouse. Entire cuttings were subsequently immersed in an aqueous slurry of 0.1% benomyl (FIORINO *et al.*, 1969) for five minutes before receiving one of the following four rooting treatments:

1. 1.6% IBA and 10% benomyl in talc
2. 1% IBA, 1% 1-phenyl-3 methyl-5 pyrazolone (PPZ), 10% powdered sucrose, 10% Captan, 1% N-dimethylaminosuccinamic acid (B-9) in talc (HARE, 1974)
3. 1.5% IBA in 95% ethyl alcohol
4. 1.5% IBA, 0.1% catechol, 0.1% thiamine in 95% alcohol

The basal 2 cm. of cuttings assigned to Treatments 1 and 2 were dipped in the rooting mix. A five-second quick-dip was used for Treatments 3 and 4. After treatment, cuttings were planted in flats filled with a peat : perlite (1 : 1) mix and placed in a greenhouse mist bed supplying six seconds of mist every three minutes during daylight hours. One six-cutting replicate (individual flat) from each of a clone's ramets was assigned to each of the four rooting treatments. Thirty-one flats of each treatment were randomly located within the mist bed. Rooting was evaluated after a four-week propagation period.

Results

Treatment 3 produced significantly (.05 level) higher rooting than the other three treatments *(Table 1)*. Cuttings in Treatment 1 had significantly lower rooting percent than those in Treatments 2, 3, and 4. Rooting percents for Treatment 1 were similar to those observed in previous work with rejuvenated material from these clones.

Clonal variation in rooting was statistically significant and followed a pattern which had been previously noted in this group of clones: Clones 2103 and 2108 from Pennsylvania have consistently exhibited poor rooting, while Clones 2109 and 2172 from middle Tennessee are relatively easy to propagate. The clone × treatment interaction, which resulted from variation in the degree of response to treatment, was also significant.

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