Conclusion

Two-dimensional paper chromatography shows promise for identifying pitch × loblolly pine hybrids. The large amount of variation in chromatographically identifiable substances in both pitch pine and loblolly pine requires more complete understanding before these methods can be practiced at the operational level. The genetic inheritance of the compounds that appear to be repeatable hybrid plant markers needs considerable study before variation in chromatographic profiles of hybrids can be fully understood. Identification of the chemical structure of markers would be advised.

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Altitudinal Variation in juvenile Characteristics of southern Appalachian black Cherry (Prunus serotina Ehrh.)*

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By P. E. Barnett and R. E. Farmer, Jr. **)

Summary

Open-pollinated families of *Prunus serotina* Ehrh. from high- and low-elevation provenances in the southern Appalachian mountains were grown for five years in replicated reciprocal plantings. In the low-elevation planting, height superiority of high-elevation seedlings, established during first-year growth in the nursery, was eliminated after five years, resulting in no significant source differences. In the high-elevation test, material from high-elevation parents was superior in height and survival to low-elevation material. Low-elevation families exhibited earlier spring budbreak and began flowering earlier in ontogeny than high-elevation trees most of which had not flowered at five years.

Key words: shoot growth, flowering, budbreak

Zusammenfassung

Mit frei abgeblühten Familien von *Prunus serotina* Ehrh. aus dem Hoch- und Tiefland der Südappalachen wurde ein wiederholter, reziproker Versuch angelegt und fünf Jahre lang beobachtet. In der Tieflandpflanzung wurde an Hochland-Sämlingen schon im ersten Jahr im Gewächshaus Überlegenheit im Höhenwachstum festgestellt, die aber nach fünf Jahren verschwunden war, so daß keine signifikanten Unterschiede mehr bestanden. Im Hochland-Test war das aus dem Hochland stammende Pflanzenmaterial dem aus dem Tiefland in Wuchsleistung und Überlebensfähigkeit überlegen. Familien aus dem Tiefland trieben im Frühjahr eher aus und begannen auch während der Ontogenese früher zu blühen, als die aus dem Hochland, von denen auch mit fünf Jahren noch keine zu blühen begonnen hatte.

Introduction

In eastern Tennessee the phenotypic quality of black cherry (*Prunus serotina* Ehrh.) from high elevations (800+ m) is apparently better, in terms of growth, form, and pest resistance, than that of cherry from low elevations. As a consequence, most selections from natural populations made in genetic improvement programs have been from high elevations. If high elevation material retains superior qualities on low-elevation sites, its use on such sites could expand opportunities for planting this high-value species. Earlier experiments (Farmer and Barnett, 1972a, b) have demonstrated altitudinal variation in seed and flowering characteristics. In this study we have examined variation in 5-year heights and other characteristics in a reciprocal planting at high- and low-elevation sites, with special emphasis on the performance of high-elevation material at the low- elevation planting site.

Methods

Seed collections were made in the summer of 1969 from 87 trees at altitudes of 275 to 1370 m in Monroe and Anderson Counties, Tennessee. Six replications of 87 families were planted in the TVA Norris Nursery, where seedling growth characteristics were evaluated in 1970 (Farmer and Barnett, 1972a). In the spring of 1971, a low-elevation (275 m) planting was established on Jones Island in the Clinch River below Melton Hill Dam in Anderson County, Tennessee, where the soil varies from silt loam to sandy loam. A fescue sod cover was reduced by discing and

**) The authors are respectively Geneticist and Plant Physiologist, Division of Land and Forest Resources, Tennessee Valley Authority, Norris, Tennessee 37828.

Table 1. — Description of plant material and percent survival in a black cherry altitudinal provenance test.

Source Group	Source Area	Source Altitude Range, m	Number Families		Percent Survival	
			Jones Island	Tellico	Jones Island	Tellico
A	Anderson Co., TN	275-425	13	8	95	72
B	Monroe Co., TN	275-425	14	10	94	72
C	Anderson Co., TN	460-730	7	6	92	89
D	Monroe Co., TN	460-730	13	9	92	65
E	Anderson Co, TN	760-1160	13	12	95	97
F	Monroe Co., TN	760-1035	10	8	95	95
G	Monroe Co., TN	1065-1370	16	14	95	99

herbicide treatment during the summer and fall of 1970. A high-altitude (1130 m) planting was established near Stratton's Meadow in the Tellico Ranger District, Cherokee National Forest, Monroe County, Tennessee. This site, characterized by a deep silt loam, was clear-cut during the winter before planting.

At the Jones Island site, six replications of 86 four-tree family plots (square) were planted at 3- by 3-m spacing. The design is a composite family block type, with families grouped by source elevation *(Table 1)* to avoid accentuating possible elevation-related growth differences through competition. The seven altitudinal groups are arranged in randomized complete blocks. One replication of the Jones Island planting was planted in a wet area, resulting in high mortality; this replication was dropped from the analysis.

Table 2. — Mean height of black cherry altitudinal provenance groups at high- and low-elevation plantings in the southern Appalachians.

Planting Site					
Jones Island, 275 m			Tellico, 1130 m		
Source Group	Mean Ht, cm		Source Group	Mean Ht, cm	
		Initial Height[1]			
G	109	a	G	105	a
E	107	a	E	103	a
D	102	a,b	F	81	a,b
C	98	a,b	C	79	a,b
F	98	a,b	B	78	a,b
B	87	b	D	75	a,b
A	86	b	A	61	b
		Fifth-year Height[1]			
G	357		G	308	a
A	350		F	300	a
C	342		E	277	a,b
B	333		D	233	b,c
D	331		B	225	b,c
E	289		A	213	c
F	279		C	195	c

1. Means with different letter postscripts differ significantly at the 0.05 level of probability.

Three replications of 67 families were planted at the high-elevation Tellico site following the design used at Jones Island. Competing vegetation in both tests was reduced during the plantings' first 3 years by mowing, hoeing, and herbicide treatment.

Results

Survival

The 5-year survival was high and about the same for all source groups at the Jones Island site *(Table 1)*. At the high-elevation Tellico site, survival of plants from low-elevation sources was substantially lower than that of high-elevation material.

Height

Total height was measured to the nearest centimeter after planting in the spring of 1971 and after the 1975 growing season. At planting, seedlings from high-elevation parents were significantly (0.05 level of probability) taller than low-elevation material in both tests *(Table 2)* as a consequence of differences established in the nursery (BARNETT and FARMER, 1972a).

After 5 years' growth on the Jones Island site, no significant differences were evident among the source groups *(Table 3)*, but individual family means ranged from 209 to 477 cm, and variance due to families within sources was statistically significant. Due to ranking shifts between years one and five, high-elevation groups ranked lowest in height after five growing seasons. An exception to this pattern was the high-elevation group G, which remained the top-ranking group in the planting. Low-elevation group A, which had significantly smaller plants at year one, was second-ranking at five years. An analysis of variance revealed significant source differences in the five-year height increment, with groups A and G performing best.

At the Tellico site, on the other hand, all low-elevation groups had mean heights which were significantly smaller than heights of high-elevation groups *(Table 2)*. Family means at this planting location ranged significantly from 80 to 386 cm.

A combined analysis of Jones Island and Tellico data from the 67 families common to both plantings indicated that both planting location x source and planting location x families/source interactions were significant at the 0.01 level of probability. As illustrated by the data in *Table 2*, these interactions result mainly from the previously noted poor performance of low-elevation trees at the high-elevation planting site.

Variance components (*Table 3*) were computed for 5-year height using the model and procedures for an experiment with unequal numbers of families within sources (SNEDECOR and COCHRAN 1972). Variance within plots was computed from data in every tenth plot because mortality resulted in some inequality in number of plants per plot. The harmonic mean of plant number per plot was used to convert variance to the appropriate scale for comparison with other mean squares. These analyses further indicated that a substantially greater expression of genetic variation occurred in the high-elevation planting (i.e., 44 percent of total variance) than at Jones Island, where only 18 percent of the total variance was associated with source groups and families within groups.

Budbreak

In the spring of 1972, after the first year of plantation growth, date of budbreak was recorded for trees in four replications of the Jones Island planting and in all replications at Tellico. Test sites were visited at least twice weekly during the flushing period in early April; trees were recorded as having flushed when at least one growing bud was a least 1 cm long. For analytical purposes, data were recorded as number of days from March 25 to budbreak date. Separate analyses of variance for each test were performed with plot means as units of analysis; variance within plots was estimated from data in every tenth plot.

Budbreak took place in the low-elevation plantation first (*Table 4*); in this planting, families from low-elevation sources completed flushing about 10 days before high-elevation trees. At the high-elevation site, however, average difference between low- and high-elevation material was less than seven days. While differences among sources and families within sources were both significant, families accounted for less variance than source groups as the following tabulation indicates:

Source of Variation	Variance Components Expressed As Percent of Total Variance in Budbreak	
	Jones Island	Tellico
Source Groups	70	70
Families/Groups	12	14
Replications x Groups	3	0
Replications x Families/Groups	8	5
Within Plot	8	11

Flowering

In 1973, flowering was noted in a few low-elevation families. Formal observation of flowering trees was subsequently made at full bloom in Tellico and Jones Island plantations in 1974 and 1976. Percent of trees flowering was computed for each plot, and family means were based on these values. As is apparent from data in *Table 4*, elevational provenance was the main source of variation in flowering, with only trees from sources below 700 m exhibiting any flowering during the tests' first six years. Further, trees from 460 to 730 m in Anderson County

Table 3. — Analyses of variance in five-year height of black cherry in high- and low-elevation plantings.

Source of Variation	Jones Island			Tellico			Expected Mean Square
	df	Mean Square	Variance[1] Component	df	Mean Square	Variance[1] Component	
Replications	4	89,219		2	13,360		
Source Groups (S)	6	52,377	6	6	54,698*	25	$\sigma^2/K + \sigma^2_{f(g)r} + r\sigma^2_{f(g)} + f\sigma^2_{rg} + rf\sigma^2$
R X S	24	23,901*	21	12	7,968*	11	$\sigma^2/K + \sigma^2_{f(g)r} + f\sigma^2_{rg}$
Families/Source Groups (F)	79	10,138*	12	60	6,495*	19	$\sigma^2/K + \sigma^2_{f(g)r} + r\sigma^2_{f(g)}$
R X F/S	305	5,248*	43	117	2,883*	23	$\sigma^2/K + \sigma^2_{f(g)r}$
Within Plot		1,551	18		1,418	22	σ^2/K ‡

1. Expressed as percentage of total variance less variance for replication.
* Statistically significant at the 0.05 level of probability.
‡ K = harmonic mean of plants per plot.

Table 4. — Budbreak and flowering characteristics of black cherry altitudinal provenance groups in high- and low-elevation plantings.

Source Group	Number of Days from March 25 to Budbreak Date		Percent of Trees Flowering			
			Jones Island		Tellico	
	Jones Island	Tellico	1974	1976	1974	1976
A Anderson Co., 275-425m	13	21	45	37	13	49
B Monroe Co., 275-425m	12	21	51	51	24	62
C Anderson Co., 460-730m	23	26	3	<1	0	1
D Monroe Co., 460-730m	12	21	23	21	11	30
E Anderson Co., 760-1160m	23	27	3	0	0	3
F Monroe Co., 760-1035m	21	24	0	0	0	6
G Monroe Co., 1065-1370m	22	25	0	0	0	<1

(Group C) did not flower much during this period. This group also performed more like a high-elevation group with respect to survival and budbreak. Within the low-elevation subpopulation (Groups A, B, and D, for which arc sine transformations of flowering percent were analyzed), the source groups had significantly different percentages of trees flowering, and family means within these groups ranged significantly from 3 to 82 percent in 1976.

Discussion

The major finding of the study to date is that black cherry from a range of altitudinal provenances in the southern Appalachians has survived and grown well for five years at a low-elevation site. Differences in size among source groups are significant at five years mainly due to wide variation among open-pollinated families within groups. The greater height of high-elevation material established in the nursery year has been mostly eliminated in the first five years of the Jones Island field test. Furthermore, with the exception of Group G (high elevation, Tellico) the trend at this low-elevation site presently appears to be toward better performance of low-elevation material, and this may be accentuated with time.

While estimates of genetic gain may be premature because of this shifting relationship, it is nevertheless of interest to examine genetic variance in height growth of this young cherry population in relation to reports for other southern and Appalachian hardwoods. Using only genetic variance associated with families within groups, the following heritability estimate is made under the assumption that all members of open-pollinated families are half siblings. (This assumption is probably not completely valid in an insect pollinated species such as black cherry.)

$$h^2 = \frac{4\sigma^2_F}{\sigma^2_F + \sigma^2_{RF} + \sigma^2_W} = \frac{4(978)}{978 + 3{,}696 + 1{,}552} = .63$$

If genetic variance associated with both altitudinal provenance and families within groups is used, the following heritability is obtained for the Jones Island population:

$$h^2 = \frac{4(\sigma^2_F + \sigma^2_G)}{\sigma^2_F + \sigma^2_G + \sigma^2_{RF} + \sigma^2_{RG} + \sigma^2_W} = \frac{4(978 + 467)}{978 + 467 + 1{,}833 + 3{,}696 + 1{,}552} = .68$$

This heritability value is higher than most estimates based on open-pollinated tests with other hardwoods such as sycamore (WEBB et al., 1973), sweetgum (MOHN and SCHMIDT, 1973; FERGUSON and COOPER, 1977), black walnut (BEINEKE and MASTERS, 1973), and northern red oak (GALL and TAFT, 1973). Individual tree selection (see FALCONER, 1960, page 235 for details) to include the top 10 percent of the population and the higher heritibility (.68) estimates a genetic gain of 43 percent over test mean height:

$$\text{Individual selection} = ih^2\sigma^2_P = (1.76)\ (.68)\ (119) = 142 \text{ cm}$$

$$142 : 327 = .43$$

Therefore, though selection would be premature at this stage of the test, there appears to be a basis for substantial gains if this degree of variation persists as trees mature.

In contrast to selection in the low-elevation plantation, at the Tellico site early selection must first eliminate low-elevation groups not suited to this high-elevation site. This can be done on the basis of results to date. Apparently, only Groups E, F, and G are adapted to this elevation, and further selection should therefore be concentrated within them. At five years, however, height differences among the 34 families in these groups were nonsignificant given the level of replication in the Tellico planting.

Genetic variation in time of budbreak suggests that cherry from low-elevation sources has a shorter chilling requirement than high-elevation material. This conclusion is further supported by seed germination data (FARMER and BARNETT, 1972a). This difference in phenology may be partly responsible for the poor performance of low-elevation material at the Tellico site since early budbreak there would frequently subject growing plants to frost. In general, however, growing black cherry is not very susceptible to spring cold as the 5-year survival of 65 to 72 percent for low-elevation material at Tellico suggests.

Flowering data support the hypothesis that there is a major genetic difference between cherry at high elevations in the southern Appalachians and the surrounding low-elevation population since there is a sharp difference in flowering characteristics of the two sets of groups (i.e., A, B, D vs C, E, F, G). FARMER and BARNETT (1972b) have previously reported the extreme sexual precocity of low-elevation trees.

Conclusions

This early information on growth and other characteristics of material from altitudinal provenances suggests that orchards providing material for high-elevation plantings should probably consist of only high-elevation selections. They should also be physically located at a high-elevation site to avoid contamination with low-elevation germ plasm. While it is too early to make recommendations for low-elevation seed orchards and plantings, some high-elevation families are growing well at the Jones Island site and show promise of retaining the excellent form characteristic of cherry growing at high elevations in the southern Appalachians.

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