A PROVENANCE TEST OF VIRGINIA PINE TO EXAMINE ITS POTENTIAL FOR USE IN OKLAHOMA

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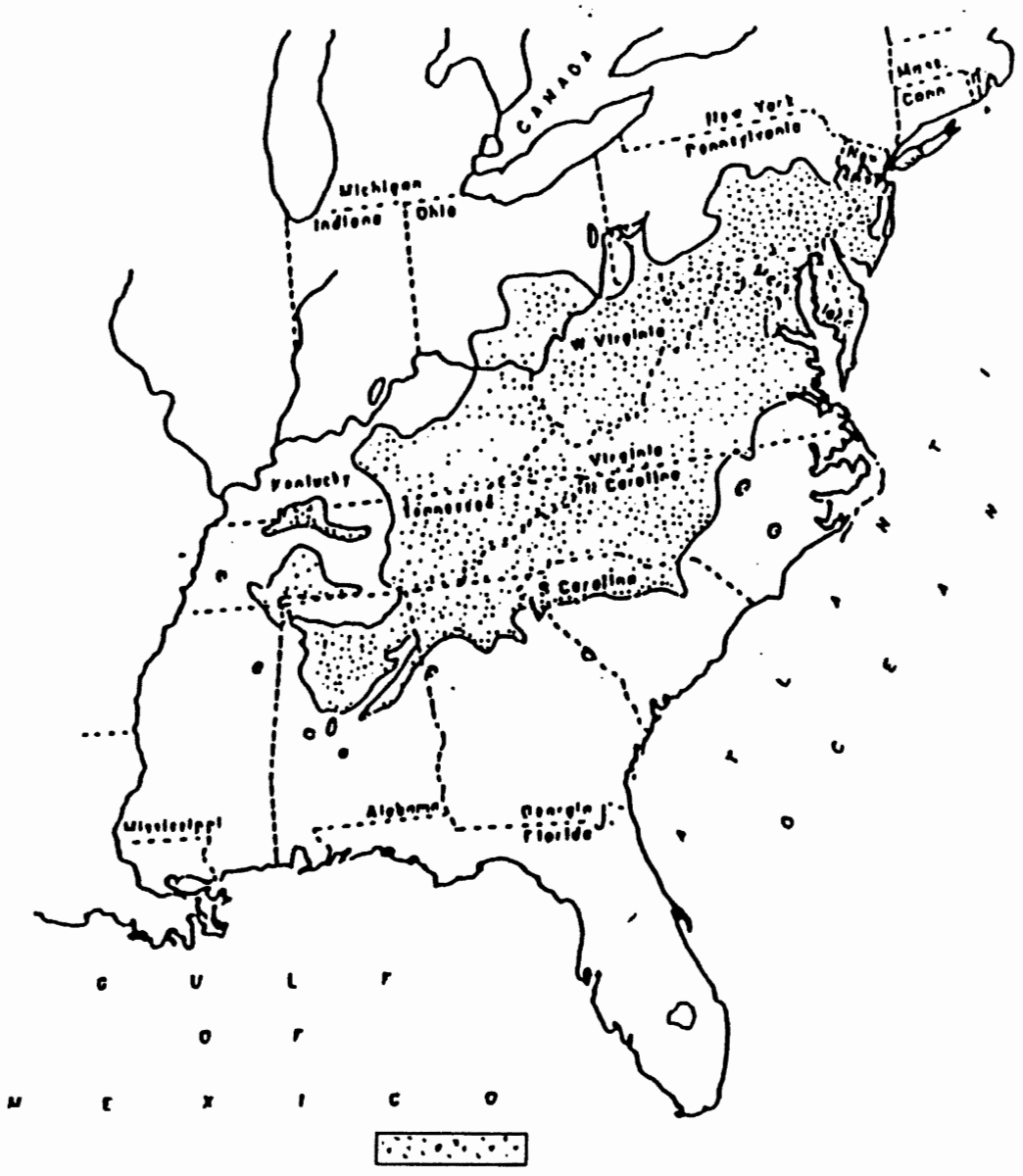
CHAPTER I

INTRODUCTION

Virginia pine (*Pinus virginiana* Mill.) is naturally distributed over much of sixteen eastern states of the United States. Its distribution extends from central Pennsylvania and New Jersey southward to mid Alabama (Box and Foil, 1973), and along the east coast from New York to Virginia (Figure 1).

Within its natural range Virginia pine occurs at elevations from 30 to 762 meters in areas with annual precipitation ranging from 89 to 140 centimeters (Williston and Balmer 1980), but its best growth is below 518 meters (Kellison and Zobel 1974). It grows best on north and east facing slopes but it is also often found on ridge tops and on south and west facing slopes (Slocum and Miller 1953). Virginia pine usually occurs on soils made up of crystalline rock, sand and shales (Fowells 1965), and can not tolerate poor drainage (Fenton and Bond 1964).

Virginia pine is a small tree usually reaching 9 to 12 meters in height. It is not a good lumber species and is generally used for paper pulp. Recently Virginia pine has been accepted among tree farmers as well as buyers in Southern states as a good quality Christmas tree.



Pinus virginiana

Figure 1. The natural range of Virginia pine (Critchfield and Little 1966)

Virginia pine is a prolific seed producer. It generally starts cone production around 5 years of age and produces large seed crops at 1 to 4 year intervals. The prolific seed production habit of Virginia pine makes its breeding faster and easier than most other pines. Most importantly, Virginia pine shows considerable tree to tree and source to source variation in growth and survival (Thor 1979). This variation is useful in selection of sources and families for a tree improvement program. In this study, 123 open pollinated families from 39 stands of Virginia pine from over most of its natural range were planted at different locations in central and eastern Oklahoma for Christmas tree production testing and progeny testing to identify the best surviving and fastest growing sources of Virginia pine for use in Oklahoma.

CHAPTER II

LITERATURE REVIEW

Virginia pine has not been given much attention for genetic improvement in the past because it was considered a relatively unimportant species in the lumber and pulp and paper industries. In recent years Virginia pine has gained in popularity as a pulp and paper fiber source, and as perhaps the best Christmas tree species in the Southern United States. This change in attitude toward Virginia pine is due to its fine fiber which is desirable to the pulp and paper industry, and to its fast juvenile growth, profuse branching habit, and positive shearing response, which are the most desired characters for Christmas trees. The use of Virginia pine for Christmas trees and as a pulp wood source provides justification for its introduction into Oklahoma for testing for its multipurpose uses.

Virginia Pine as a Christmas Tree

Bell and White (1966) have identified six important factors for the selection of a species for use for Christmas trees, (i) salability and consumer preference, (ii) distance from market and shipping qualities, (iii) adaptability to site, (iv) genetically proven seed sources for stock, (v)

resistance to diseases and insects, and (vi) growth rate or length of rotation. Virginia pine posses many of these qualities and thus, Virginia pine is one of the best species for Christmas tree production in the southeast United States. The Southern Cooperative Technical Committee (1982) has reported that among the thirteen species grown for Christmas trees in the southern states, Virginia pine is in the top four with a short rotation of 4-6 years. Virginia pine is gaining in popularity as a Christmas tree due to its high survival rate, rapid juvenile growth, positive response to shearing and relatively good growth on poor soils where other species may not survive (Bellanger and Bramlett 1975). Brown (1979) reported that Virginia pine has been accepted as a Christmas tree from Georgia to Texas. McKinley (1985) agrees that Virginia pine is widely accepted as a Christmas tree across the south due to its natural appearance and its ability to grow on wide variety of soils.

After 15 years of study Hu and Burns (1978) found that Virginia pine produced the best Christmas trees among the species tested for Christmas tree production in Louisiana. Their market study of 1976 and 1977 found that 90 percent of the Christmas trees sold were Virginia pine. The results of a survey by Hu & Main (1976) revealed that 93 percent of Louisiana consumers are willing to buy Virginia pine Christmas trees again. Murray (1983) reported an increasing trend of growing Virginia pine for Christmas trees in

Georgia, from about .1 million trees in 1976 to about 2.3 million trees in 1983.

Virginia Pine Seed Source Variation

Identifying and utilizing variation among provenances of a species can be a significant first step in the improvement of that species. Variation in growth, form, survival and other characteristics from provenance to provenance, stand to stand and tree to tree is the basis for genetic improvement through selection of the desired trees. There is considerable data reported on variation within many forest tree species, but there is relatively little data on Virginia pine source and family variation.

Genys (1966) reported that Virginia pine sources from Alabama, Tennessee, South Carolina and Virginia performed poorly on poor sites in northeastern Pennsylvania. He also reported that sources from high elevations grew best near their natural range; and that an Alabama source was below average in growth and survival compared to local sources in Maryland and Tennessee plantings. In a study of 21 seed sources planted in Michigan, Maryland and Tennessee, Genys et al (1974) reported high mortality, 42 to 45 percent, in the sources from Alabama and Mississippi. Greater variation among families than among sources was found in sources from Kentucky and Tennessee when grown in Tennessee (Thor 1979). Werlick et al (1985) reported significant differences in height growth among seed sources of Virginia pine in an

Alabama study.

A few studies have been conducted to examine the performance of Virginia pine sources outside their natural range. Zobel et al (1956) found good survival and growth of Virginia pine sources when planted on droughty sites in western Louisiana and in east Texas. In a study by Chandler, (1985) good growth of Virginia pine on acidic soils in east Texas proved Virginia pine a major species for Christmas tree production on acidic soils. Osterhaus and Lantz (1978) have recommended Virginia pine for Oklahoma due to its good survival and growth on shallow soils. It has also been successfully adapted in Korea (Han and Lee 1988).

Virginia pine sources have shown significant variation in growth and survival, and good performance outside their natural range in previous studies. It was thus logical to examine survival and growth of Virginia pine sources for Oklahoma for Christmas tree production and other uses.

CHAPTER III

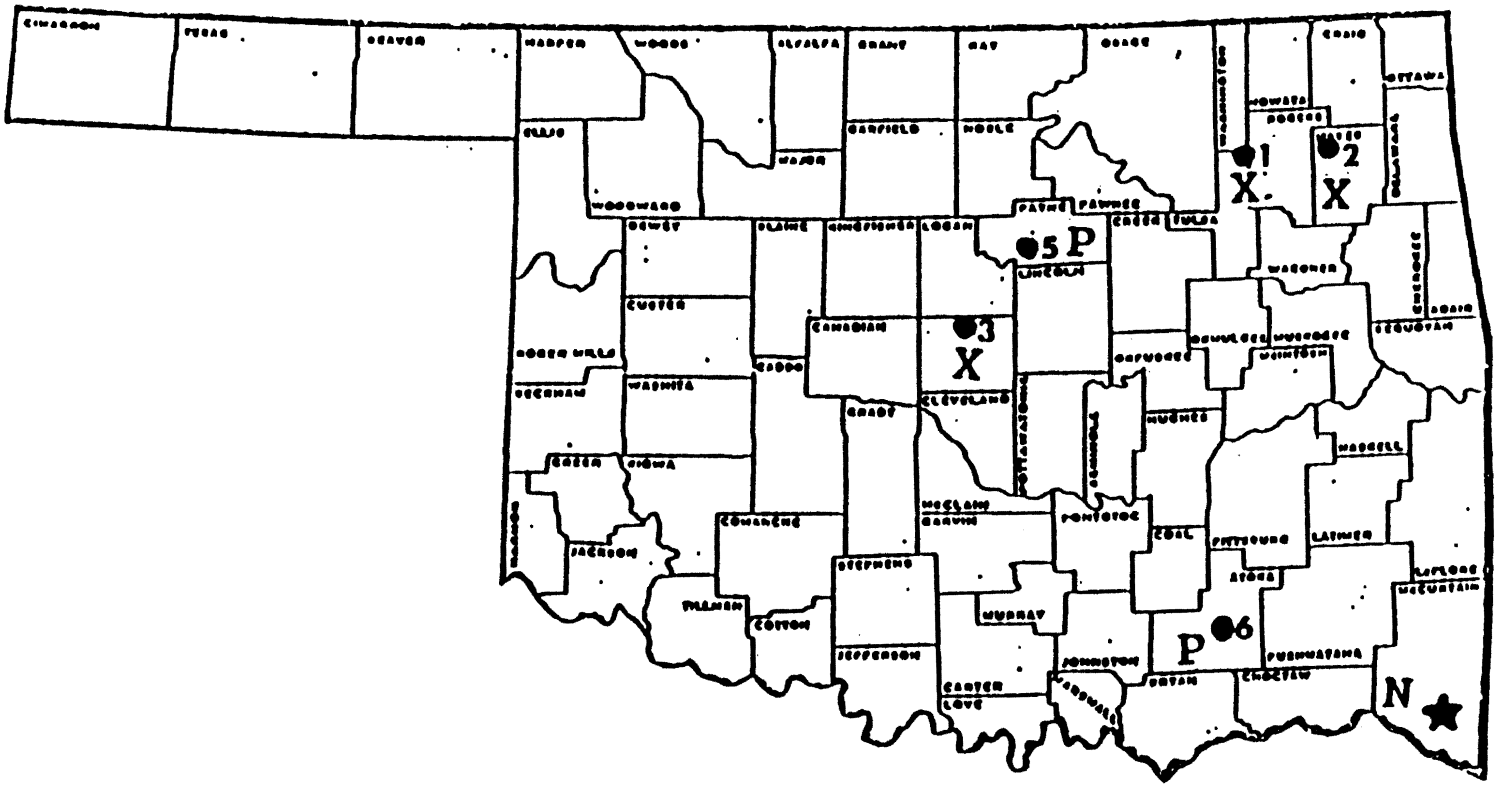
MATERIALS AND METHODS

Seed Collection

Seed collection was initiated in 1983. Cones from randomly selected trees were requested from state foresters and seed stands managers across the natural range of Virginia pine. The cones shipped represented 39 stands with 1 to 9 trees per stand, constituting a total of 123 open pollinated families of Virginia pine. This collection sampled much of the natural range of Virginia pine (Table XXV). After extraction, cleaning, and stratification, seed were sown in replicated nursery beds in the Oklahoma State University Forestry nursery at Idabel in the spring of 1984.

Planting

One year old seedlings of Virginia pine were outplanted near (i) Collinsville, Rogers County (ii) Foyil, Mayes County and (iii) Oklahoma City, Oklahoma county, on Christmas tree growers' land for testing for Christmas trees potential in Oklahoma (Figure 2). The planting at each location was a randomized complete block design with four tree family- row plots at 1.5 X 1.8 meters (5 X 6 feet) spacing and 2 blocks per location. Box (1971) has reported



X = Christmas tree plantations

P = Progeny testing plantations

N = Nursery site

Figure 2. Map of Oklahoma showing plantation sites

that spacing of 1.5 X 1.5 meters (5 X 5 feet) or 1.8 X 1.8 meters (6 X 6 feet) is good for Christmas tree planting.

Plantings were also established at an Atoka and a Payne county site for progeny testing. These plantings were randomized complete block designs with 4 tree family-row plots and six blocks at each location. However, spacing for the progeny test was 2.4 X 2.4 meters (8 X 8 feet), larger than that of the Christmas tree plantings because these trees will be grown for a longer time period to identify the best sources for Oklahoma for uses other than Christmas trees. These tests will also allow quick access to the seed of the selected sources for further breeding. One block has been lost due to fire at the Atoka county plantation and five blocks were included in this study.

Test plantations on growers locations were given cultural treatments such as mowing, irrigation, herbicide and insecticide application and shearing for shaping into Christmas trees. No treatment beyond mowing was given to the plantations established for progeny testing.

Data Collection

Height of surviving trees was measured at age one through age five after each growing season for both the Christmas tree plantations and the progeny test plantations. In addition height data were collected at age seven for the progeny test plantations. A record of the trees sold as Christmas trees to age five was also maintained.

Data Analysis

Height and survival data of Virginia pine at age five for Christmas tree plantations and at age five and seven for progeny test plantations were analyzed separately.

All statistical analyses were performed using the General Linear Model Procedure (SAS Institute 1985). The analyses of variance were performed on a family plot mean basis.

Comparison of height and survival among stand and family means were made using the Least Significant Difference method of multiple range testing (Steel and Torrie 1980).

For comparison among families for survival and growth, separate analyses were conducted excluding stands from the model. The calculation of F values was based on a random model (Table I and II).

selection of the best ten stands and best fifteen families was based on both survival and height. This ranking was accomplished as follows. All stands and families having survival and height exceeding the across locations plantation means were given a number starting at one, according to their rank in LSD table for both survival and for height. The given numbers for a specific stand or family both for survival and height at a specific age were

TABLE I

ANALYSIS OF VARIANCE MODEL FOR VIRGINIA PINE ACROSS LOCATIONS AND BY LOCATION INCLUDING THE STAND COMPONENT

a. Across locations

Source	Df	Expected mean squares
Locations	2	$V^2_e + K_1V^2_{lf(s)} + K_2V^2_{f(s)} + K_3V^2_s + K_4V^2_{b(l)} + K_5V^2_l$
Blocks (locations)	3	$V^2_e + K_1V^2_{lf(s)} + K_2V^2_{f(s)} + K_3V^2_s + K_4V^2_{b(l)}$
Stands	38	$V^2_e + K_1V^2_{lf(s)} + K_2V^2_{f(s)} + K_3V^2_s$
Families (stands)	84	$V^2_e + K_1V^2_{lf(s)} + K_2V^2_{f(s)}$
Location X family(stand)	118	$V^2_e + K_1V^2_{lf(s)}$
Error	1027	V^2_e

b. By location

Source	Df	Expected mean squares
Blocks	1	$V^2_e + K_2V^2_{f(s)} + K_3V^2_s + K_4V^2_b$
Stands	38	$V^2_e + K_2V^2_{f(s)} + K_3V^2_s$
Families (stands)	84	$V^2_e + K_2V^2_{f(s)}$
Error	565	V^2_e

Where $K_1 - K_5$ = constants

V^2_e = pooled variance

$V^2_{lf(s)}$ = location X family within stand variance component

$V^2_{f(s)}$ = families within stand variance component

V^2_s = stand variance component

$V^2_{b(l)}$ = blocks within location variance component

V^2_b = blocks variance component

V^2_l = location variation component

TABLE II

ANALYSIS OF VARIANCE MODEL FOR VIRGINIA PINE ACROSS LOCATIONS AND BY LOCATION EXCLUDING THE STAND COMPONENT

a. Across locations

Source	df	Expected mean squares
Location	2	$V^2_e + K_1V^2_{lf} + K_2V^2_f + K_3V^2_{b(l)} + K_4V^2_l$
Blocks (locations)	1	$V^2_e + K_1V^2_{lf} + K_2V^2_f + K_3V^2_{b(l)}$
Families	122	$V^2_e + K_1V^2_{lf} + K_2V^2_f$
Location X family	118	$V^2_e + K_1V^2_{lf}$
Error	1027	V^2_e

b. By location

Source	df	Expected mean squares
Blocks	1	$V^2_e + K_2V^2_f + K_3V^2_b$
Families	122	$V^2_e + K_2V^2_f$
Error	604	V^2_e

Where K_1 to K_4 = constants

V^2_e = pooled variance

V^2_{lf} = location X family variance component

V^2_f = family variance component

$V^2_{b(l)}$ = blocks within location variance component

V^2_b = blocks variance component

V^2_l = location variance component

added together for a combine rank. The stand or family with the lowest sum was ranked at top for height and survival combined, and thus the stand or family with the highest score was ranked at bottom.

CHAPTER IV

RESULTS AND DISCUSSION

Growers

Survival

Survival of Virginia pine in the growers test plantations at age five ranged from 75.0 percent in Oklahoma county to 13.7 percent in Rogers county, with an across location average of 52.0 percent (Table III). Flooding in the Rogers county plantation after the second growing season was the cause of poor survival in that planting. Significant positive correlations (r_p = 0.97 at *a* (alpha) = 0.0001) in the survival of Virginia pine stands and (r_p = 0.98 at *a* = 0.0001) families between age 3 and age 5 was found (Table XXVII and XXVIII), which suggest the stability of Virginia pine survival after initial establishment. A significant difference in survival among stands and among families in stands as well as among families was found, but there was no significant genotype X environment interaction (Table XXXV a and XXXVI a). This non significant interaction indicates that survival of families of Virginia pine is essentially similar at different locations in Oklahoma. However, analyses based on individual location

TABLE III

PERCENT SURVIVAL, MEAN HEIGHT AND CHRISTMAS TREE PRODUCTION AT AGE FIVE ON GROWERS SITES

Test	Location	Survival percent*	Height cm	Christmas trees sold as percent of total trees	
				Planted	Surviving
All	Across Location	52.0	185.8	6.3	12.2
1.	Rogers County	13.7	201.0	0.0	0.0
2.	Mayes County	67.2	176.7	18.4	27.4
3	Oklahoma County	75.0	190.5	1.0	1.6

* Survival including the trees sold as Christmas trees.

showed no significant difference in survival among stands, families in stand, or among families, except among stands at the Rogers county site and among families at Mayes county site (Table XXXV b, c, d and XXXVI b, c, d). These non significant results were probably due to the large number of treatments assigned to only two blocks per location.

Percent survival of Virginia pine by stand at age five across locations varied from 72.2 for a New Jersey stand (NJ4) to 22.2 for another New Jersey stand (NJ3) (Table IV). With the exception of one stand from New Jersey (NJ4) all stands from New Jersey and Ohio had poor survival. There was a negative correlation (r_p = -0.32103 at a = 0.1176) between percent survival of stands and latitude, suggesting poor survival of northern sources (Table XXVI). Jenys (1966) reported poor survival of the northern sources in southern tests.

Percent survival by family varied from 79.2 for a Tennessee family (TN5-1) and a South Carolina family (SC4-4) to 12.5 for a Kentucky family KY4-2 (Table V). With the exception of stand NJ4, all of the best sixteen families had better survival than all stands, suggesting selection of the best families rather than stands to improve survival of Virginia pine in Oklahoma. All the best surviving families, with exception of one New Jersey family (NJ4-1), were from stands from Tennessee, North Carolina, South Carolina, Georgia, Kentucky and Virginia. Nine of the best sixteen families were from Tennessee and North Carolina (Table V).

TABLE IV

COMPARISON OF VIRGINIA PINE SURVIVAL BY STAND AT AGE FIVE ON GROWERS SITES USING THE LEAST SIGNIFICANT DIFFERENCE METHOD AT 0.05 ALPHA

	Percent survival at age five				
Stand No.*	Across location**		Rogers county	Mayes county	Oklahoma county
NJ4	72.2	a	50.0	66.7	100.0
TN7	69.4	ab	25.0	95.8	87.5
SC4	69.2	ab	32.5	87.5	87.5
TN3	66.0	abc	37.5	87.5	78.1
NC2	63.2	abcd	18.7	70.8	100.0
NC4	62.5	abcde	22.5	77.5	87.5
KY5	62.5	abcde	43.7	62.5	81.2
NC5	62.5	abcde	06.3	93.7	87.5
NC7	61.8	abcde	33.3	80.0	75.0
NC8	58.3	abcde	50.0	62.5	62.5
VA2	58.3	abcde	37.5	50.0	87.5
WV2	58.3	abcde	00.0	87.5	87.5
KY3	56.2	abcdef	28.1	62.5	78.1
TN5	55.6	abcdef	20.8	65.3	80.6
KY2	54.6	abcdefg	17.9	67.5	67.5
WV1	54.2	abcdefg	25.0	62.5	75.0
TN1	54.2	abcdefg	00.0	62.5	100.0
SC2	52.8	abcdefg	00.0	70.8	87.5
VA3	52.3	abcdefg	13.9	63.9	79.2
AL1	52.1	abcdefg	06.2	68.8	81.2
SC3	52.1	abcdefg	25.0	50.0	81.2
NJ5	51.6	abcdefg	00.0	80.0	70.8
OH4	51.5	abcdefg	12.5	90.0	58.3
GA3	50.0	bcdefg	00.0	68.7	81.2
KY1	50.0	bcdefg	00.0	81.2	68.7
GA1	48.9	bcdefg	06.2	59.8	81.2
VA1	46.8	cdefg	00.0	75.0	65.3
GA2	45.4	cdefgh	00.0	37.5	100.0
AL2	45.8	cdefgh	12.5	55.0	70.0
OH3	44.4	cdefgh	00.0	58.3	75.0
KY4	44.2	defgh	05.0	60.0	67.5
SC1	44.2	defgh	02.5	55.0	75.0
OH2	42.0	defghi	00.0	68.7	66.7
TN2	41.0	efghi	08.3	75.0	56.2
NC6	41.0	efghi	00.0	62.5	60.4
OH1	36.1	fghi	04.2	62.5	41.7

TABLE IV (Continued)

Stand No.	Percent survival at age five			
	Across locations	Rogers county	Mayes county	Oklahoma county
NC1	33.3 ghi	00.0	31.2	68.7
NJ2	25.0 hi	00.0	31.2	43.7
NJ3	22.2 i	16.7	00.0	50.0

* First two letters of stand number denote state and the third digit represents stand in state.

** Percents followed by the same letter are not significantly different from each other.

TABLE V

THE BEST AND WORST SIXTEEN FAMILIES OF VIRGINIA PINE BASED ON SURVIVAL AT AGE FIVE ON GROWERS SITES COMPARED BY THE LEAST SIGNIFICANT DIFFERENCE METHOD AT 0.05 ALPHA

Family No.*	Percent survival at age five				
	Across locations**		Rogers county	Mayes county	Oklahoma county
Best sixteen families					
TN5-1	79.2	a	37.5	100.0	100.0
SC4-4	79.2	a	50.0	100.0	87.5
KY3-3	75.0	ab	50.0	75.0	100.0
KY2-2	75.0	ab	50.0	75.0	100.0
TN7-2	75.0	ab	25.0	100.0	100.0
NC7-1	75.0	ab	50.0	87.5	87.5
SC4-5	75.0	ab	50.0	87.5	87.5
NC4-4	75.0	ab	50.0	87.5	87.5
NJ4-1	72.2	ab	50.0	66.6	100.0
TN3-4	70.8	abc	37.5	75.0	100.0
VA3-2	70.8	abc	37.5	75.0	100.0
TN3-2	70.8	abc	50.0	87.5	75.0
VA3-5	70.8	abc	50.0	75.0	87.5
NC2-2	70.8	abc	37.5	75.0	100.0
TN7-1	70.8	abc	50.0	87.5	75.0
NC7-3	70.8	abc	50.0	75.0	87.5
Worst sixteen families					
OH2-5	33.3	defghi	00.0	00.0	100.0
OH3-3	33.3	efghi	00.0	37.5	62.5
KY2-1	30.0	efghi	00.0	62.5	12.5
VA3-8	29.2	efghi	00.0	25.0	62.5
NC1-1	29.2	efghi	00.0	37.5	50.0
SC1-5	29.2	efghi	00.0	50.0	62.5
NJ2-1	29.2	efghi	00.0	25.0	62.5
TN2-1	25.0	fghi	00.0	50.0	25.0
AL2-4	25.0	fghi	00.0	37.5	37.5
OH2-1	25.0	fghi	00.0	50.0	25.0
VA3-4	25.0	fghi	00.0	37.5	37.5
TN2-5	25 0	fghi	25.0	----	----
NJ3-1	22.2	ghi	16.6	00.0	50.0

TABLE V (Continued)

Family No.	Percent survival at age five			
	Across locations	Rogers county	Mayes county	Oklahoma county
NJ2-2	20.8 hi	00.0	37.5	25.0
OH1-2	20.8 hi	12.5	25.0	25.0
KY4-2	12.5 i	00.0	00.0	37.5

* First two letters of family number denote state, third digit represents stand and fourth family within stand.

** Percents followed by the same letter are not significantly different from each other.

Height

Age five across location mean height was 186.0 cm., ranging from 201.0 cm. in Rogers county to 176.7 cm. in Mayes county (Table III). There were significant positive correlations between heights at age 1 and 5 based on both stand and family means (for both r^p = .67 at a = 0.0001), suggesting that the best stands and families at age 1 were also generally the best at age 5 (Table XXIX and XXX).

There were significant differences in height among stands, families in stands, and among families, in the across location analyses (Table XXXVII a and XXXVIII a). However, analyses based on individual location were less informative. No degrees of freedom were left for the error term for the Rogers county plantation due to high mortality, 82.3 percent by age five (Table XXXVII b and XXXIII b). Significant differences in height among stands for the Mayes county plantation and among families in stands for the Oklahoma county plantation were found at age five (Table XXXVII c, d). Families in the Oklahoma county plantation were also significantly different in height (Table XXXIII d).

Stands with the fastest growing trees were from Tennessee, North Carolina and Virginia, and one stand from Alabama. Trees from all stands from Ohio, West Virginia and New Jersey showed average or poor growth at age five (Table VI). A significant negative correlation (r_p = -0.76 at a = 0.0001) between latitude and average stand height also

TABLE VI

COMPARISON OF VIRGINIA PINE HEIGHT BY STAND AT AGE FIVE ON GROWERS SITES USING THE LEAST SIGNIFICANT DIFFERENCE METHOD AT 0.05 ALPHA

	Mean tree height (cm) by stand at age five				
Stand No.*	Across locations**		Rogers county	Mayes county	Oklahoma county
TN3	221.7	a	219.4	223.7	221.2
TN7	212.1	ab	219.5	202.2	216.1
TN2	204.8	abc	178.5	197.1	221 3
VA3	203.3	abcd	213.5	199.4	204.7
NC7	199.7	abcde	206.5	195.7	200.9
AL1	198.6	abcde	188.0	195.2	204.6
TN5	195.8	abcdef	208.1	188.6	196.3
NC4	195.5	bcdef	206.7	177.3	203.7
NC2	194.2	bcdefg	173.6	197.7	196.7
NC6	193.5	bcdefg	-----	213.2	167.0
KY3	191.0	bcdefgh	209.7	170.6	204.4
NC5	190.2	bcdefghi	162.0	198.0	189.5
KY1	189.3	bcdefghi	-----	178.2	198.9
VA2	186.9	cdefghi	177.6	160.5	217.9
SC4	186.8	cdefghi	209.0	173.1	191.5
GA2	186.1	cdefghi	-----	202.5	177.8
NJ4	185.8	cdefghi	185.0	150.0	204.1
NC1	183.0	cdefghi	-----	172.3	193.6
GA3	181.4	cdefghi	-----	152.3	203.2
SC1	181.3	cdefghi	227.0	159.8	191.7
KY2	180.1	defghi	180.6	171.4	188.6
VA1	180.0	defghi	-----	178.3	181.3
KY4	180.0	defghi	179.5	169.9	187.7
GA1	178.6	efghi	189.5	173.4	181.8
SC2	178.5	efghi	------	160.6	196.1
KY5	178.4	efghi	201.0	154.3	185.5
NC8	178.1	efghi	198.7	171.8	173.8
AL2	177.4	efghi	188.3	173.9	173.3
OH1	177.2	fghi	203.0	161.6	182.5
SC3	173.2	fghij	196.0	158.3	179.1
WV2	171.2	ghij	-----	179.0	163.4
OH2	170.7	ghij	-----	154.8	186.5
WV1	169.4	hij	197.7	154.0	167.9
NJ5	169.1	hij	-----	155.1	180.7
OH4	168.2	hij	212.3	163.9	164.5
OH3	167.0	hij	-----	156.5	174.0

TABLE VI (Continued)

Stand No.	Mean tree height (cm) by stand at age five			
	Across locations	Rogers county	Mayes county	Oklahoma county
TN1	167.0 ij	-----	143.5	178.6
NJ3	150.8 jk	173.0	-----	139.7
NJ2	141.6 k	-----	159.3	129.7

* First two letters of stand number denote state and the third digit represents stand in state.

** Means followed by the same letter are not significantly different from each other.

suggests the poor growth of northern sources of Virginia pine.

The families with the tallest trees were in the stands with the greatest mean heights which were stands from Tennessee, North Carolina, Virginia and Alabama (Table VII). The majority of the families with poor average growth rate were from northern stands from Ohio, New Jersey and West Virginia.

Mean height at age five by families varied from 232 cm (7.5 feet) to 129 cm (4.2 feet). Except for the poorest growing fourteen families (Table VII), all families were in the range of 165 cm (5.5 feet) to 218 cm (7 feet) in height at age five, which is the most suitable size for Christmas trees for household use (Schoenike 1983). On the basis of average height by family at age five 87 percent of the families appear suitable for Christmas trees production. But selection of the fastest growing families among these would be the best approach because this would result in salable Christmas trees by age three or four.

Christmas Tree Production

On a choose and cut basis, 6.3 percent of the original or 12.2 percent of the surviving trees on the growers plantations were sold as Christmas tree by age five. The trees sold as Christmas trees were mainly from the Mayes county plantation (which was the best managed), with a negligible number sold (1.0 % of original planted trees and

TABLE VII

THE BEST AND WORST FIFTEEN FAMILIES OF VIRGINIA PINE BASED ON HEIGHT AT AGE FIVE ON GROWERS SITES COMPARED BY THE LEAST SIGNIFICANT DIFFERENCE METHOD AT 0.05 ALPHA

Family No.*	Mean tree height (cm) by family at age five				
	Across locations**		Rogers county	Mayes county	Oklahoma county
The best fifteen families					
TN3-4	231.9	a	221.3	228.0	241.1
TN3-3	229.4	ab	220.0	236.2	227.2
NC6-1	221.7	abc	-----	236.3	192.3
AL2-4	219.3	abcd	-----	230.0	208.6
NC4-4	219.1	abcd	200.0	266.5	224.9
TN3-5	218.5	abcd	220.2	-----	216.7
VA3-3	218.0	abcd	-----	200.5	235.3
TN7-2	217.7	abcd	198.5	195.0	250.0
TN7-1	215.7	abcd	240.5	201.5	210.5
VA3-1	214.7	abcd	-----	195.3	224.4
TN2-2	214.3	abcd	-----	197.6	230.9
VA3-2	209.5	abcd	210.0	198.1	220.5
TN5-1	209.3	abcd	228.3	215.8	193.2
VA3-4	207.7	abcd	-----	195.0	214.0
VA3-9	207.6	abcd	-----	221.0	194.1
The worst fifteen families					
NJ5-2	165.0	m....y	-----	163.3	165.8
KY2-1	161.0	n....y	-----	171.0	141.0
SC3-1	160.0	n....y	196.0	176.0	134.1
VA1-2	159.8	n....y	-----	164.5	155.0
KY4-2	158.0	o....y	-----	-----	158.0
GA1-4	157.6	p....y	-----	177.3	137.9
KY2-4	155.5	r....y	-----	145.5	165.5
NJ2-2	151.3	r....y	-----	126.6	176.0
OH3-1	151.0	s....y	-----	136.6	165.4
NJ3-1	150.9	tuvwxy	173.0	-----	139.7
WV1-2	145.2	uvwxy	188.5	137.0	131.8
NJ2-1	135.1	vwxy	-----	192.0	106.6
OH1-1	133.2	wxy	-----	119.0	147.3
OH4-2	132.0	xy	-----	132.7	131.1
OH2-1	128.8	y	-----	117.0	152.0

* First two letters of family number denote state, third digit represents stand and fourth family within stand.

** Means followed by the same letter are not significantly different from each other.

1.6 % of the surviving trees) from the Oklahoma county plantation. A total of 18.4 percent of original trees planted or 27.4 percent of the surviving trees from the Mayes county plantation had been sold as Christmas trees by age five (Table III). This shows that with proper management trees at age five are marketable as Christmas trees.

Stands contributing salable Christmas trees were from West Virginia, Virginia, New Jersey, Ohio, North Carolina, Tennessee and Georgia. However stands from North Carolina and Tennessee produced the most trees sold (Table VIII), 38.8 percent of the total Christmas trees sold.

Based on percent of trees planted, three families, NC4-1, NC4-4, and NC7-1, two from the same stand produced the most Christmas trees, followed by family GA3-2 from a Georgia stand (Table IX). The rest of the trees sold were from families from all stands, but a majority of them were from the stands from Tennessee. Two families, TN2-1 and OH1-1, have the highest percentage of trees sold, 50 and 44 percent respectively, of surviving trees, but TN2-1 had very poor survival (25 %) (Table V) and below average growth. OH1-1 had a very poor growth rate, in the bottom 2 percent of the families for height (Table VII) with below average survival, 37.5 percent.

The Best Stands and Families on Growers Sites

Some stands and families were among the best in

TABLE VIII

PERCENT OF VIRGININA PINE TREES SOLD AS CHRISTMAS TREES BY AGE FIVE BASED ON ORIGIN

Stand No.*	Percent Christmas tree sold of: Total trees planted	Surviving trees
WV2	16.7	28.0
TN1	16.7	30.1
NJ4	16.7	23.5
NC4	15.8	25.3
TN2	12.5	23.4
OH1	12.5	34.6
NC7	11.8	19.0
TN7	11.1	16.0
GA3	10.4	20.8
VA1	9.3	20.6
VA2	6.9	12.4
NC2	6.9	13.1
TN3	6.8	10.3
TN5	6.5	12.5
KY1	6.2	13.0
NC5	6.2	10.0
AL2	5.8	12.8
KY4	5.8	13.2
SC2	5.5	10.5
KY3	5.3	9.3
SC4	5.0	7.2
NC3	4.2	10.0
GA2	4.2	9.1
NC8	4.2	7.1
NC1	4.2	12.5
KY5	4.2	6.7
OH3	4.2	9.8
SC1	4.2	9.4
NJ2	4.2	9.5
KY2	3.2	6.8
GA1	3.1	6.5
OH2	2.8	6.5
AL1	2.1	4.0
SC3	2.1	4.0
NJ5	1.6	3.0
WV1	1.4	2.5
OH4	0.0	0.0
NJ3	0.0	0.0

* First two letters of stand number denote state and third digit represents number of stand in state.

TABLE IX

TOP TWENTY FIVE FAMILIES OF VIRGINIA PINE BASED ON CHRISTMAS TREES PRODUCTION BY AGE FIVE

Family No.*	Percent sold as Christmas trees of	
	Total trees planted	Surviving trees
NC4-4	29.2	38.9
NC4-1	25.0	37.6
NC7-1	20.8	27.8
GA3-2	20.8	35.7
TN1-6	16.7	30.8
OH1-1	16.7	44.4
KY4-4	16.7	30.8
TN7-3	16.7	25.0
SC1-4	16.7	26.7
NJ4-1	16.7	23.5
TN2-2	16.7	26.7
VA3-7	16.7	30.7
KY1-5	16.7	28.6
TN3-3	16.7	25.0
TN7-1	16.7	23.5
WV2-3	16.7	28.5
VA1-1	16.7	36.4
OH1-4	12.5	25.0
NC4-3	12.5	21.4
NC4-5	12.5	20.0
TN2-1	12.5	50.0
TN5-5	11.1	25.0
VA1-4	11.1	21.4
KY2-1	10.0	20.6

* First two letters of family number denote state, third digit represents stand and fourth family within stand.

survival, but among the poorest or below average in growth rate, or *vice versa*. Therefore, ranking of the best stands and families was carried out by considering survival and height together. Those stands and families having the best or above average survival as well as growth were ranked as the best performing stands and families. Three stands from Tennessee, TN3, TN5 and TN7; three from North Carolina, NC2, NC4 and NC5; and one each from Alabama, AL1, Kentucky KY3 and Virginia VA3 were among the top ten stands considering both survival and growth together (Table X). These stands also contributed to Christmas trees sales. The best performing stands (except for NC2 whose exact origin is unknown) from North Carolina and Tennessee are from the same general geographic region, that is, along the border of eastern Tennessee and western North Carolina. Sources of Virginia pine from Tennessee and North Carolina have previously been reported to perform well outside their natural range (Zobel 1956, Han *et al* 1987). The results of this study agree with previous studies, and Virginia pine sources from western Tennessee and eastern North Carolina are recommended for further breeding of Virginia pine in Oklahoma.

The best 12 families in overall performance both in survival and growth were from the best stands except family GA3-2 from Georgia (Table XI). Although one Alabama stand (AL1) and one Kentucky stand (KY3) were among the top ten stands, no families from these stands showed up in the best

TABLE X
TOP TEN STANDS OF VIRGINIA PINE AT AGE FIVE
BASED ON BOTH HEIGHT AND SURVIVAL
ON GROWERS SITES IN OKLAHOMA

Stands No.*	Mean height (cm)	Percent survival	Christmas trees sold as percent of total trees planted
TN3	221.7	65.9	06.8
TN7	212.1	69.4	11.1
NC7	199.7	61.8	11.7
VA3	203.3	52.3	06.9
AL1	198.6	52.3	02.1
NC2	194.2	63.2	06.9
NC4	195.5	62.5	15.8
NC5	190.2	65.5	06.8
TN5	195.8	55.6	06.5
KY3	191.1	62.5	05.2

* First two letters of stand number denote state and the third digit represents stand in state.

TABLE XI

TOP TEN FAMILIES OF VIRGINIA PINE AT AGE FIVE
BASED ON BOTH HEIGHT AND SURVIVAL
ON GROWERS SITES IN OKLAHOMA

Family No.*	Mean height (cm)	Percent survival	Chistmas trees sold as percent of total trees planted
TN3-4	231.9	70.8	8.3
NC4-1	219.1	66.7	25.0
TN7-1	215.7	70.8	16.7
TN3-3	229.7	66.7	16.7
VA3-2	209.5	70.8	00.0
VA3-9	207 6	62.5	8.3
TN3-2	205.1	70.8	00.0
GA3-2	205.1	58.3	20.8
NC4-4	204.9	75.0	29.0
NC7-3	204.5	70.8	08.3
NC7-1	207.1	70.8	20.0
TN7-3	198.0	62.5	16.7

* First two letters of family number denote state, third digit represents stand and fourth family within stand.

12 families. One family, (AL2-4) from a northern Alabama stand was among the top 5 percent of families in height growth (Table VII) but it was among the bottom 5 percent in survival (Table V). Osterhaus and Lantz (1978) have reported 88 percent survival and good height growth of Virginia pine at age two from northern Alabama in a species trial in Oklahoma. They tested Virginia pine sources only from northern Alabama in comparison with other species on shallow soils in Oklahoma, thus the studies are not comparable.

Five Tennessee families, three from stand TN3 (TN3-2, TN3-3 and TN3-4) and two from stand TN7 (TN7-1, TN7-2); four North Carolina families, two each from stand NC4 (NC4-1, NC4-4) and NC7 (NC7-1, NC7-3); two Virginia families from stand VA3 (VA3-2, VA3-9); and one Georgia family from stand GA3 (GA3-2) were among the top 12 families both in growth and survival at all test plantations on growers sites (Table XI). Seven of these families NC4-1, NC4-4, NC7-1, NC7-3, TN3-3, TN3-4, TN7-1, had survival above 67 percent and height above two meters at age five and contributed in Christmas tree sales. These seven families should be included in a seed orchard for Christmas tree seedling production and for further breeding.

Nongrowers

Survival

At the end of fifth growing season mean survival across locations was 74.6 percent, with 77.8 percent survival in Atoka county and 72.1 percent survival in Payne county. There was no significant difference in Virginia pine survival between the two locations or in survival at age 5 and 7 (Table XII). Positive significant correlations (r_p = 0.61 at a = 0.0001) based on stand survival and (r_p = 0.78 at a =0.0001) based on family survival between ages 1 and 7 suggests the same stands and families with high survival at age one maintain high survival to age seven (Table XXXI and XXXII).

Virginia pine stands, families in stand and families were significantly different in survival at both age five and seven in the across locations analyses (Tables IXL - XLIII a). There was no significant genotype X location interaction, thus no significant change in ranking by survival across locations. Analyses based on individual locations showed a significant difference in survival among families, families in stand, and stands for the Atoka county planting but there was no significant difference in survival among stands for the Payne county plantation (Tables IXL b, c - XLIII b, c)

Virginia pine survival by stand varied from 87.3 percent (OH2) to 48.5 percent (TN5) at age five (Table XIII)

TABLE XII

VIRGINIA PINE SURVIVAL AND MEAN HEIGHT AT AGE FIVE AND SEVEN ON NONGROWERS SITES IN OKLAHOMA

		Percent survival at age		Height(cm) at age	
Test	County	5	7	5	7
Across locations		74.6	74.2	173.0	241.0
5	Payne	72.1	71.6	167.3	234.0
6	Atoka	78.0	77.4	179.3	249.2

TABLE XIII

COMPARISON OF VIRGINIA PINE SURVIVAL BY STAND AT AGE FIVE ON NONGROWERS SITES USING THE LEAST SIGNIFICANT DIFFERENCE METHOD AT 0.05 ALPHA

Stand No.*	Percent survival at age five			
	Across locations**		Payne county	Atoka county
OH2	87.3	a	84.2	91.0
GA2	86.4	a	79.2	95.0
OH3	86.2	a	85.9	86.6
NC5	84.1	a	81.2	87.5
VA2	84.1	a	83.5	85.0
SC2	84.1	a	87.5	80.0
NJ5	83.0	a	81.2	85.0
NC7	82.8	a	80.5	85.7
GA1	82.4	a	79.2	86.2
TN1	81.8	a	83.3	80.0
NC8	81.8	a	83.3	80.0
KY5	79.5	a	83.3	75.0
NC1	79.5	a	75.0	85.0
SC4	79.5	a	85.0	73.0
OH4	79.4	a	80.8	77.6
WA2	79.2	a	79.2	--.-
SC3	78.4	ab	75.0	82.5
VA1	78.0	ab	76.4	80.0
VA3	77.5	ab	72.7	83.3
TN7	77.3	ab	70.8	85.0
SC1	76.3	ab	79.2	73.0
GA3	75.0	ab	70.8	80.0
OH1	73.3	abc	70.3	77.0
NC6	72.7	abc	64.6	82.5
NJ4	72.7	abc	58.3	90.0
NC4	72.3	abc	62.6	84.0
AL1	71.6	abc	60.4	85.0
NJ2	71.6	abc	64.6	80.0
KY2	71.3	abc	69.2	74.0
KY3	71.0	abcd	68.7	72.5
KY4	69.1	abcd	70.0	68.0
KY1	68.3	abcd	61.6	76.3
TN2	68.2	abcd	64.6	72.5
AL2	67.3	abcd	60.8	75.0
NC2	65.5	abcd	63.2	68.3
TN3	65.3	abcd	63.5	67.5
WV1	57.0	bcd	51.8	63.3

TABLE XIII (Continued)

Stand No.	Percent survival at age five		
	Across location	Payne county	Atoka county
NJ3	52.3 cd	41.6	65.0
TN5	48.5 d	52.8	43.3

* First two letters of stand number denote state and the third digit represents stand in state.

** Percents followed by the same letter are not significantly different from each other.

and 87.3 percent (OH2) to 47.7 percent (NJ3) at age seven (Table XIV). There were no significant differences between percent survival by stand at age five and seven (Table XIII, XIV).

At age five all the stands of Virginia pine exceeded 65 percent survival except for three, one each from West Virginia, New Jersey and Tennessee, (WV1, NJ3 and TN5 respectively) (Table XIII). One additional stand from North Carolina (NC2) was below 65 percent survival at age seven (Table XIV). All stands from Ohio showed high survival, exceeding 70 percent, and two (OH2 and OH3) were among the top three stands with 87.3 and 84.9 percent survival at age seven (Table XIV). Except for stands from Kentucky and West Virginia, at least one stand each from the rest of the states exceeded 80 percent in survival at age seven. There is no distinction between northern and southern sources in survival. A non significant correlation, approximating zero, (r_p = 0.045 at a = 0.8292) between Virginia pine survival and latitude also suggests that survival is not related to latitude.

Virginia pine survival on a family basis varied from 100 percent (GA3-1) to 36.4 percent (TN5-3) at age seven (Table XVI). Nine out of 123 families; three from Ohio (OH2-1, OH2-3, OH4-2), two from Georgia (GA1-3, GA3-2), two from South Carolina (SC1-1, SC2-3) and one each from Virginia (VA1-4) and New Jersey (NJ5-3) were the best surviving families at age seven with 90 percent or higher

TABLE XIV

COMPARISON OF VIRGINIA PINE SURVIVAL BY STAND AT AGE SEVEN ON NONGROWERS SITES USING THE LEAST SIGNIFICANT DIFFERENCE METHOD AT 0.05 ALPHA

Stand No.*	Percent survival at age seven			
	Across locations**		Payne county	Atoka county
OH2	87.3	a	84.2	91.00
GA2	86.4	ab	79.2	95.00
OH3	84.9	ab	84.8	85.00
VA2	84.1	ab	83.3	85.00
SC2	83.3	ab	87.5	78.33
NC5	83.0	ab	79.2	87.50
NJ5	83.0	ab	81.2	85.00
GA1	82.4	ab	79.2	86.25
NC7	82.0	ab	79.2	85.71
TN1	81.8	ab	83.3	80.00
KY5	79.5	abc	83.3	75.00
SC4	79.5	abc	85.0	73.00
WV2	79.2	abc	79.2	-----
OH4	78.9	abc	80.0	77.67
NC1	78.4	abc	72.9	85.00
SC3	77.3	abc	72.9	82.50
VA1	77.3	abc	76.4	78.33
TN7	77.3	abc	70.8	85.00
VA3	77.3	abc	72.7	82.78
SC1	76.3	abc	79.2	73.00
GA3	75.0	abc	70.8	80.00
OH1	73.3	abc	70.3	77.00
NC6	72.7	abc	64.6	82.50
NJ4	72.7	abc	58.3	90.00
NC4	71.8	abc	61.7	84.00
AL1	71.6	abc	60.4	85.00
KY2	71.4	abc	69.2	74.00
KY3	70.4	abcd	68.7	72.50
NJ2	70.4	abcd	62.5	80.00
KY1	68.3	abcde	61.6	76.33
KY4	67.3	abcde	66.7	68.00
AL2	66.8	abcde	60.0	75.00
TN2	65.9	abcde	64.6	67.50
TN3	65.3	abcde	63.5	67.50
NC2	64.4	bcde	63.2	65.83

TABLE XIV (Continued)

Stand No.	Percent survival at age seven		
	Across locations	Payne county	Atoka county
WV1	57.8 cde	53.2	63.33
TN5	48.5 de	52.8	43.33
NJ3	47.7 e	37.5	60.00

* First two letters of stand number denote state and the third digit represents stand in state.

** Percents followed by the same letter are not significantly different from each other.

TABLE XV

THE BEST AND WORST SIXTEEN FAMILIES OF VIRGINIA PINE BASED ON SURVIVAL AT AGE FIVE ON NONGROWERS SITES COMPARED BY THE LEAST SIGNIFICANT DIFFERENCE METHOD AT 0.05 ALPHA

Family No.*	Percent survival at age five		
	Across loactions**	Payne county	Atoka county
The best sixteen families			
GA1-3	100.0 a	100.0	100.0
OH2-3	97.7 ab	95.8	100.0
SC2-3	95.4 abc	95.8	95.0
OH2-1	95.4 abc	95.8	95.0
GA3-2	93.2 abcd	95.8	90.0
VA1-4	93.2 abcd	100.0	85.0
NJ5-3	93.2 abcd	91.7	95.0
SC1-1	90.9 a..e	87.5	95.0
OH4-2	90.9 a..e	95.8	85.0
OH3-1	88.6 a..f	83.3	95.0
VA3-9	88.6 a..f	83.3	95.0
OH4-4	88.6 a..f	83.3	95.0
NC7-1	88.6 a..f	79.2	100.0
OH3-5	88.6 a..f	87.5	90.0
SC2-4	88.6 a..f	95.8	80.0
GA1-1	88.6 a..f	91.7	85.0
The worst sixteen families			
NJ2-2	59.1 j..r	54.2	65.0
OH1-5	59.1 j..r	50.0	70.0
GA3-5	56.8 k..s	45.8	70.0
AL1-3	58.8 k..s	41.7	75.0
KY3-2	56.8 k..s	45.8	70.0
NC2-1	56.1 k..s	47.2	66.7
TN3-4	54.5 l..s	50.0	60.0
KY1-2	53.6 m..s	52.5	55.0
NJ3-1	52.2 m..s	41.7	65.0
OH4-1	52.2 m..s	51.4	53.3
KY4-5	50.0 n..s	37.5	65.0
TN5-5	47.7 o..s	50.0	45.0
NC4-1	43.2 pqrs	20.8	70.0

TABLE XV (Continued)

Family No.	Percent survival at age five		
	Across locations	Payne county	Atoka county
WV1-4	41.7 qrs	22.2	65.0
AL2-4	38.6 rs	33.3	45.0
TN5-3	36.4 s	54.2	15.0

* First two letters of family number denote state, third digit represents stand and fourth family within stand.

** Percent followed by the same letter are not significantly different from each other.

TABLE XVI

THE BEST AND WORST SIXTEEN FAMILIES OF VIRGINIA PINE BASED ON SURVIVAL AT AGE SEVEN ON NONGROWERS SITES COMPARED BY THE LEAST SIGNIFICANT DIFFERENCE METHOD AT 0.05 ALPHA

Family No.*	Percent survival at age seven		
	Across locations**	Payne county	Atoka county
The best sixteen families			
GA1-3	100.0 a	100.0	100.0
OH2-3	97.7 ab	95.8	100.0
OH2-1	95.4 abc	95.8	95.0
SC2-3	93.2 abcd	95.8	90.0
GA3-2	93.2 abcd	95.8	90.0
VA1-4	93.2 abcd	100.0	85.0
NJ5-3	93.2 abcd	91.7	95.0
SC1-1	90.9 a..e	87.5	95.0
OH4-2	90.9 a..e	95.8	85.0
VA3-9	88.6 a..f	83.3	95.0
OH4-4	88.6 a..f	83.3	95.0
OH3-5	88.6 a..f	87.5	90.0
SC2-4	88.6 a..f	95.8	80.0
GA1-1	88.6 a..f	91.7	85.0
NC7-1	86.3 a..g	75.0	100.0
NC1-2	86.3 a..g	79.2	95.0
The worst sixteen families			
GA3-5	56.8 k..s	45.8	70.0
NJ2-2	56.8 k..s	50.0	65.0
AL1-1	56.8 k..s	41.7	75.0
KY3-2	56.8 k..s	45.8	70.0
NC2-1	56.0 k..s	47.2	66.6
OH1-5	56.0 k..s	44.4	70.0
TN3-4	54.5 l..s	50.0	60.0
KY1-2	53.0 m..s	52.5	55.0
OH4-1	52.2 m..s	51.4	53.3
KY4-5	50.0 n..s	37.5	65.0
TN5-5	47.7 o..s	50.0	45.0
NJ3-1	47.7 o..s	37.5	60.0
NC4-1	43.2 pqrs	20.8	70.0

TABLE XVI

Family No.	Percent survival at age seven		
	Across locations	Payne county	Atoka county
WV1-4	41.7 qrs	22.2	65.0
AL2-4	38.6 rs	33.3	45.0
TN5-3	36.4 s	54.2	15.0

* First two letters of family number denote state, third digit represents stand and fourth family within stand.

** Percent followed by the same letter are not significantly different from each other.

psurvival. At age seven the six poorest families, with survival below 50 percent included two from Tennessee (TN5-3, TN5-5) and one each from North Carolina (NC4-1), New Jersey (NJ3-1), West Virginia (WV1-4) and Alabama (AL2-4). There was no significant difference in percent survival or ranking order of families between ages five and seven (Table XV and XVI). A significant positive correlation (r_p = 0.99457 at a =0.0001) in survival between age five and seven also suggests the stability of families in survival after age five (Table XXXII).

Height

Plantation mean height at age five was 179.3 cm in Atoka county, and 167.3 cm in Payne county, with an across plantations average of 172.0 cm. At age seven plantation mean height increased to 249.2 cm in Atoka county and 233.9 cm in Payne county with an across plantation average of 240.9 cm (Table XII).

Among Virginia pine stands, families in stands, and families, significant differences in height were found at age five as well as at age seven in the across location analyses. No significant genotype X environment interaction in height growth was found in either the age five or age seven analysis (Table XLIII to XLVI). Significant differences in height among stands and among families were also found in the analyses based on individual locations for both ages five and seven. There was no significant

difference in height among families in stands at the Atoka plantation in both analyses for ages five and seven. However, the value of alpha decreased from 0.45 at age five to 0.29 at age seven. This decrease suggests that significant differences may appear in later growth stages.

Trees from stands from Tennessee, North Carolina, Georgia and Virginia showed good growth in Oklahoma at age five. Mean height of trees by stand from these four states exceeded the across location mean height of 173.0 cm (Table XVII). The tallest trees were in a stand from Tennessee (TN1) followed by a stand from North Carolina (NC1), with mean heights of 191.6 cm and 190.1 cm, respectively, (Table XVII), both approximately 11 percent taller than plantation mean. At age seven, in addition to above mentioned four states, all stands from Alabama and South Carolina also exceeded the across locations mean height of 240.0 cm (Table XVIII). With exception of one stand each from New Jersey (NJ4) and Kentucky (KY5) trees from all stands from Kentucky, New Jersey, Ohio and West Virginia showed poor growth and were below the across location average height at age seven. A significant negative correlation ($r_p = -0.65$ at $a = 0.0006$) between Virginia pine mean height by stand and latitude suggests the poor growth of Virginia pine from northern sources (Table XXVI). No significant difference in the order of ranking of stands by height was found between ages five and seven (Table XV, XVI), although some minor changes occurred.

TABLE XVII

COMPARISON OF VIRGINIA PINE HEIGHT BY STAND AT AGE FIVE ON NONGROWERS SITES USING THE LEAST SIGNIFICANT DIFFERENCE METHOD AT 0.05 ALPHA

Stands No.*	Mean tree height (cm) by stand at age five		
	Across locations**	Payne county	Akota county
TN1	191.6 a	199.1	182.7
NC1	190.1 ab	180.3	200.8
AL1	187.9 ab	175.4	199.0
TN5	186.8 abc	181.9	194.4
GA3	186.4 abc	179.5	192.6
NC4	186.3 abc	181.6	191.4
TN7	186.0 abc	180.0	193.1
VA2	184.9 abcd	179.4	191.6
TN3	184.5 abcde	173.6	198.5
NC7	183.6 abcde	174.5	195.3
KY5	183.5 abcde	172.8	196.2
NJ4	182.3 abcdef	169.7	194.8
GA1	181.0 abcdef	166.8	197.3
NC2	179.2 abcdef	177.0	182.0
SC2	179.2 abcdef	174.6	184.7
VA1	178.0 abcdefg	176.1	180.0
GA2	177.7 abcdefg	179.5	175.6
OH3	176.1 abcdefgh	171.3	183.4
NC6	176.1 abcdefgh	161.8	193.2
VA3	175.5 abcdefgh	172.7	178.8
SC1	175.5 abcdefgh	170.6	181.7
SC3	175.1 abcdefgh	174.3	176.2
TN2	173.6 abcdefgh	169.7	178.8
NC5	173.1 bcdefgh	171.0	175.6
NC8	173.1 bcdefgh	168.8	178.2
SC4	172.8 bcdefgh	168.4	178.0
KY2	172.2 bcdefgh	169.2	175.5
KY4	169.2 cdefgh	157.2	183.7
AL2	167.7 defgh	160.7	175.7
NJ5	167.6 defgh	161.4	175.1
KY1	167.4 defgh	157.8	179.4
OH4	166.7 efgh	161.1	173.6
KY3	165.2 fgh	160.7	170.1
OH2	159.2 ghi	159.9	160.0
OH1	158.3 hi	153.5	163.5
WV2	144.7 ij	144.4	-----

TABLE XVII (Continued)

Stand No.	Mean tree height (cm) by stand at age five		
	Across locations	Payne county	Atoka county
NJ2	133.0 j	133.3	132.8
NJ3	132.2 j	125.0	137.9
WV1	131.8 j	133.5	130.3

* First two letters of stand number denote state and the third digit represents stand in state.

** Means followed by the same letter are not significantly different from each other.

TABLE XVIII

COMPARISON OF VIRGINIA PINE HEIGHT BY STAND AT AGE SEVEN ON NONGROWERS SITES USING THE LEAST SIGNIFICANT DIFFERENCE METHOD AT 0.05 ALPHA

Stands No.*	Mean tree height (cm) by stand at age seven		
	Across locations**	Payne county	Atoka county
TN1	268.8 a	279.4	256.2
TN5	267.0 ab	261.3	276.0
NC1	263.7 abc	253.4	275.0
NC4	261.0 abcd	257.2	265.2
VA1	259.4 a..e	256.4	262.8
TN7	258.5 a..e	248.7	270.3
NJ4	258.5 a..e	236.3	280.6
GA3	258.1 a..f	249.4	265.8
AL5	258.0 a..f	234.7	279.0
NC7	257.8 a..f	247.0	271.0
KY5	256.3 a..g	249.0	264.9
NC2	255.9 a..h	251.3	261.5
VA2	255.3 a..h	248.9	262.9
TN3	253.9 a..h	240.4	270.2
SC2	250.3 a..h	250.4	250.2
GA1	249.4 a..h	231.8	269.7
TN2	248.3 a..h	240.9	258.0
SC3	246.0 a..h	245.0	247.1
SC1	245.4 a..h	240.7	251.2
GA2	244.5 a..i	245.6	243.1
NC8	244.3 a..i	244.7	243.8
NC5	244.0 a..i	242.4	245.9
NC6	243.8 a..i	219.9	272.7
VA3	243.5 b..i	236.8	251.3
SC4	243.2 b..j	238.4	248.8
AL2	241.1 c..j	234.6	248.0
KY4	240.4 c..j	227.2	256.3
KY2	236.9 d..j	230.2	244.8
KY3	234.9 e..j	233.0	237.1
OH3	233.2 f..j	227.3	242.3
OH4	231.9 ghij	221.5	244.9
KY1	231.6 ghij	219.7	246.4
NJ5	231.0 hij	223.3	240.1
OH1	219.9 ij	213.3	227.1
OH2	218.3 j	216.5	220.4
WV2	184.5 k	184.5	-----

TABLE XVIII (Continued)

Stand No.	Mean tree height (cm) by stand at age seven		
	Across locations	Payne county	Atoka county
NJ3	183.2 k	172.5	194.1
WV1	182.1 k	183.4	180.9
NJ2	173.8 k	180.6	167.1

* First two letters of stand number denote state and the third digit represents stand in state.

** Means followed by the same letter are not significantly different from each other.

Generally, families with the best average height were from the stands with the best average height. Three families from North Carolina, NC1-2, NC4-5 and NC4-3, were the tallest at age seven, followed by the five families from Tennessee, three from Virginia and one family each from Georgia, Kentucky and South Carolina, constituting the best fifteen families in height (Table XX). At age five two other families from Georgia and one family from Alabama were among the best fifteen families in height (Table XIX) and these were out performed by the families from Virginia and South Carolina by age seven. At age seven all of the slowest growing fifteen families were from northern sources, including Ohio, New Jersey and West Virginia. At age five one family each from Kentucky and Alabama was also among the poorest performing fifteen families (Table XIX). With few exceptions all families from Alabama, Kentucky, Georgia and South Carolina were between the best and the poorest families at age seven, and families from these sources are those showing the transition from best to average or from poorest to average from age five to seven. Families from the northern sources of Ohio, West Virginia and New Jersey were consistently the poorest in height growth and families from North Carolina and Tennessee were consistently the best in growth ages five and seven. (Table XIX and XX).

The Best Stands and Families on Nongrowers Sites

All stands from Ohio, a northern source, were among the

TABLE XIX

THE BEST AND WORST FIFTEEN FAMILIES OF VIRGINIA PINE BASED ON HEIGHT AT AGE FIVE ON NONGROWERS SITES COMPARED BY THE LEAST SIGNIFICANT DIFFERENCE METHOD AT 0.05 ALPHA

Family No.*	Mean height (cm) by family at age five: Across locations**	Payne county	Atoka county
The best fifteen families			
NC1-2	197.5 a	191.6	204.6
NC4-5	195.7 ab	181.8	212.4
NC4-3	194.3 abc	196.2	192.0
TN3-5	192.0 abcd	186.5	199.0
TN1-6	191.6 abcd	199.1	182.7
GA1-3	191.6 abcd	187.4	196.6
TN5-5	191.6 abcd	182.4	205.4
GA3-5	190.1 a..e	184.2	193.7
VA3-9	189.4 a..f	192.4	185.7
AL1-5	189.2 a..f	179.1	210.4
TN3-3	189.2 a..f	174.7	210.9
TN7-3	189.1 a..f	188.2	190.0
GA1-1	189.0 a..f	167.0	215.5
TN5-1	188.9 a..g	186.5	191.3
KY5-5	188.7 a..h	166.5	215.3
The worst fifteen families			
OH2-4	159.3 u	144.6	176.9
Al2-4	158.6 u	155.5	161.5
KY2-4	158.2 u	158.5	158.0
OH2-2	157.7 uv	161.7	153.0
NJ5-2	149.2 uv	149.2	-----
OH4-4	149.0 uv	137.0	163.6
OH1-3	148.4 uv	137.7	161.1
NJ2-1	146.0 uv	142.5	150.2
WV2-3	144.4 uv	144.4	-----
WV1-3	143.6 uv	140.0	147.9
WV1-2	135.2 vw	139.3	130.2
OH1-5	133.6 vw	126.7	139.1
NJ3-1	132.2 vw	125.0	137.9
NJ2-2	117.2 wx	119.5	115.3
WV1-4	108.0 x	96.2	112.7

* First two letters of family number denote state, third digit represents stand and fourth family within stand.

** Means followed by the same letter are not significantly different from each other.

TABLE XX

THE BEST AND WORST FIFTEEN FAMILIES OF VIRGINIA PINE BASED ON HEIGHT AT AGE SEVEN ON NONGROWERS SITES COMPARED THE LEAST SIGNIFICANT DIFFERENCE METHOD AT 0.05 ALPHA

Family No.*	Mean height (cm) by family at age seven: Across locations**	Payne county	Atoka county
The best fifteen families			
NC1-2	273.7 a	263.1	286.6
NC4-5	272.4 ab	253.7	294.8
NC4-3	272.1 abc	275.4	268.2
GA3-5	271.8 abcd	266.2	275.2
VA3-9	271.2 a..e	273.4	268.5
TN5-1	271.1 a..e	266.5	275.6
VA1-4	270.9 a..f	269.9	272.1
TN5-5	270.3 a..g	262.7	281.8
TN1-6	268.8 a..h	279.4	256.2
KY5-5	265.6 a..i	243.8	291.8
TN7-3	263.5 a..j	259.6	268.2
VA1-1	262.5 a..k	250.2	274.8
TN3-5	262.1 a..l	251.4	274.9
SC2-4	262.0 a..l	262.9	260.9
NC2-2	261.6 a..l	254.6	272.0
The worst fifteen families			
OH2-1	219.1 a	211.0	228.7
OH2-4	219.1 a	204.1	237.1
OH1-2	218.3 a	204.6	234.6
OH2-5	216.6 a	227.2	204.0
NJ5-2	216.2 a	216.2	-----
OH2-2	210.7 a	216.4	203.8
OH4-4	208.5 a	194.2	225.7
OH1-3	206.2 a	193.6	221.3
WV1-3	197.7 a	191.4	205.2
NJ2-1	193.3 a	195.5	190.6
OH1-5	190.7 ab	177.1	201.5
WV1-2	190.1 b	192.0	187.9
WV2-3	184.5 b	184.0	-----
NJ3-1	183.3 c	172.5	194.1
NJ2-2	150.1 d	158.2	143.0
WV1-4	145.0 e	133.0	149.5

* First two letters of family number denote state, third digit represents stand and fourth family within stand.

** Means followed by the same letter are not significantly different from each other.

best surviving, with 73 to 87 percent survival (Table XIV), and five families from Ohio were in the best fifteen families with survival exceeding 88 percent at age seven (Table XVI). However, all Ohio stands were among the bottom ten stands in height (Table XVIII) and most Ohio families were among the poorest growing fifteen families. No Ohio families were among the best growing families at age seven (Table XX). So, in spite of high survival, trees from Ohio stands and families should not be selected for any end product because growth is too important a factor. However, trees from these stands and families might be used for watershed or erosion control purposes where survival plays a more important role.

The stands and families from North Carolina, Virginia and Tennessee were almost all among the best stands and families in survival (with few exceptions exceeding 60 percent survival) and were excellent in height growth, having mean heights above the plantation average. Considering both height and survival at age seven, ten stands and fifteen families, all exceeding 75 percent in survival with mean heights greater than the across location plantation mean, were identified as the best in overall performance in Oklahoma (Table XXII, XXIV).

Two out of three Georgia stands, and two families (from the same parent stand) GA1-1, GA1-3, out of a total of seven, were among the best ten stands and the best fifteen families, respectively, at age seven based on both height

TABLE XXI

TOP TEN STANDS OF VIRGINIA PINE AT AGE FIVE BASED ON BOTH HEIGHT AND SURVIVAL ON NONGROWERS SITES IN OKLAHOMA.

Stands No.*	Mean height (cm)	Percent survival
TN1	191.6	81.8
NC1	190.0	79.5
NC7	183.6	82.4
GA1	181.0	82.4
GA3	186.0	75.0
TN7	186.0	77.0
KY5	183.5	79.5
VA3	175.5	77.5
VA2	184.9	84.1
AL1	187.9	71.6

* First two letters of stand number denote state and the third digit represents stand in state.

TABLE XXII

TOP TEN STANDS OF VIRGINIA PINE AT AGE SEVEN BASED ON BOTH HEIGHT AND SURVIVAL ON NONGROWERS SITES IN OKLAHOMA

Stand No.*	Mean height (cm)	Percent survival
TN1	268.8	81.8
VA2	255.3	84.1
NC1	263.7	78.4
NC7	257.8	82.0
KY5	256.3	79.5
VA1	259.4	77.3
TN7	258.5	77.3
GA1	249.4	82.4
GA3	258.0	75.0
NC5	244.0	83.0

* First two letters of stand number denote state and the third digit repreents stand in state.

TABLE XXIII

TOP FIFTEEN FAMILIES OF VIRGINIA PINE AT AGE FIVE BASED ON BOTH HEIGHT AND SURVIVAL ON NONGROWERS SITES IN OKLAHOMA

Family No.*	Mean height (cm)	percent survival
GA1-3	197.6	100.0
NC1-2	197.5	86.4
VA3-9	189.4	88.6
VA1-4	187.6	93.2
SC2-3	184.8	95.4
GA1-1	189.0	88.6
GA3-2	183.7	93.2
NC4-5	195.7	84.1
OH4-5	186.2	86.3
NC4-4	184.0	86.3
SC1-1	180.2	90.9
NJ5-3	179.4	93.1
NC7-1	181.4	88.6
NC7-2	185.9	85.0
VA2-3	184.9	84.0
TN1-6	191.6	81.8
TN7-2	182.0	79.5

* First two letters of family number denote state, third digit represents stand and fourth family within stand.

TABLE XXIV

TOP FIFTEEN FAMILIES OF VIRGINIA PINE AT AGE SEVEN BASED ON BOTH HEIGHT AND SURVIVAL ON NONGROWERS SITES IN OKLAHOMA

Family No.*	Mean Height (cm)	Percent survival
NC1-2	273.8	86.4
NC4-5	272.4	84.1
VA3-9	271.2	88.6
VA1-4	270.9	93.2
GA1-3	260.0	100.0
SC2-4	262.0	93.2
TN1-6	268.9	81.8
GA1-1	261.5	88.6
TN7-3	263.5	77.3
NC7-2	259.8	85.0
TN7-1	261.9	77.3
NC7-1	255.0	86.4
NC7-3	258.7	75.0
SC1-1	253.6	90.9
NC4-4	252.8	84.1

* First two letters of family number denote state, third digit represents stand and fourth family within stand.

and survival (Table XXII and XXIV). Family GA1-3 was the only one with 100 percent survival at age seven, it was also among the top 6 families in growth at age five (Table XIX) but at age seven it was not in the best fifteen families in height (Table XX). An explanation for this may be that the 100 survival of family GA1-3 would result in greater competition among trees within the plot with crown closure, reducing the growth of the family, while families with low survival have not yet experienced crown closure and continue to grow freely.

Six out of seventeen North Carolina families (NC1-2, NC4-4, NC4-5, NC7-1 NC7-2 and NC7-3) were excellent in height growth, with mean heights exceeding the plantation average, as well as exceeding 75 percent survival. These families were among the best fifteen at age seven (Table XXIV). Four of these families were also among the best fifteen families at age five (Table XXIII). Thirteen families from Virginia have been tested and only two of them (VA1-4 and VA3-9) ranked high in both height and survival. Three out of thirteen Tennessee families (TN1-6 TN7-1 and TN7-3) have shown good performance in both height and survival.

None of the four stands from South Carolina were among the top 10 stands at age five or seven, but two families (SC1-1 and SC2-3) did perform well in growth and survival. These two South Carolina families were above 90 percent in survival and were among top 20 percent in height. None of

the stands and families from Alabama, Ohio, New Jersey or West Virginia ranked among the top ten stands or the top fifteen families in overall performance at age seven, but one stand from Alabama (AL1) and one family each from Ohio (OH4-5) and New Jersey (NJ5-3) were in the top performing groups at age five (Table XXI and XXIII).

One stands from Kentucky (KY5) was among the top 10 stands at age five as well as seven, but non of 21 families from Kentucky were among top performing families at age five or seven.

The best performing sources and families are mostly from along the borders of western North Carolina and eastern Tennessee, lying between 35^{o} and $36^{o}15'$ latitude, almost parallel to central Oklahoma. The unknown best sources and families were from Georgia, South Carolina and Virginia. The extreme southern edge of the natural range of Virginia pine is northern South Carolina and northern Georgia, along the 35^{o} latitude, So these unknown sources and families, which showed good performance in Oklahoma, are within this 35^{o} to 36^{o} 15′ range. Seed collection of Virginia pine for planting in Oklahoma should be from northern Georgia and South Carolina, all of Tennessee and North Carolina and southern Virginia, between $34^{o}45'$ and $36^{o}30'$ latitude.

Growers vs Nongrowers

Stands and families of Virginia pine from Georgia, North Carolina, Virginia and Tennessee performed well in

both Christmas tree test plantations and progeny test plantations at age five. Stands and families from Ohio, New Jersey and South Carolina performed better in survival and height on nongrowers sites than growers sites. This was due perhaps to irrigation on growers sites because Virginia pine is intolerant to of wet soils. Only four stands, one each from Alabama (AL1), North Carolina (NC7), Tennessee (TN7) and Virginia (VA3) were among the best ten stands based on both height and survival, in both tests at age five (Table X and XXI). Two of these stands, NC7 and TN7 were also among the best ten stands at age seven on nongrowers sites

Two families from North Carolina (NC4-4 and NC7-1) and one family from Virginia (VA3-9) were among the best families on both progeny test and Christmas tree production test plantations, based on both survival and height, at age five (Table XI and XXIII). However, six of the best families, NC4-4, NC7-1, NC7-3, TN7-1 TN7-3 and VA3-9, were common in both test plantations, at age five on grower sites and at age seven on nongrower sites (Table XI and XXIV). These six families should be included in seed orchards for seedling production of Virginia pine in Oklahoma for any end product as well as a future breeding program.

Sources and families from North Carolina, eastern Tennessee, southern Virginia, northern Georgia and northern South Carolina were the best in overall performance both in survival and height in both test plantation types. Seed

collection of Virginia pine for planting in Oklahoma should be from these areas, and these sources and families should be included in local seed orchards and breeding programs.

CHAPTER V

SUMMARY AND CONCLUSION

Seed from 123 randomly selected trees from 39 random stands of Virginia pine, constituting 123 open pollinated families from its natural range, were included in this study to determine the best sources and families of Virginia pine for use in Oklahoma. One year old seedlings from the Oklahoma State University forestry nursery at Idabel were outplanted at different locations in central and eastern Oklahoma for both Christmas tree production testing and for progeny testing.

Height of surviving trees at ages one through five were recorded for all plantations. In addition, height at age seven was measured for progeny test plantations. Height and survival at age five for the Christmas tree plantations and at age five and seven for the progeny test plantation were analyzed.

On the basis of survival and height, four stands from North Carolina (NC2, NC4, NC5, NC7), three stands from Tennessee (TN3, TN5, TN7), and one stand each from Alabama AL1), Kentucky (KY3) and Virginia (VA3) were identified as good sources of seed for Christmas tree production in Oklahoma. Seven families were identified as good performers

for Christmas trees production with survival exceeding 70 percent and mean heights above two meters at age five. Included were three families from North Carolina (NC4-4, NC7-1, NC7-3), three from Tennessee (TN3-2, TN3-4, TN7-3) and one family from Virginia (VA3-2). Their good growth and survival under production conditions indicate that they responded well shearing. These families should be included in a production seed orchard for Virginia pine Christmas trees in Oklahoma.

The progeny test site analyses identified stands from North Carolina (NC1, NC5, NC7), Tennessee (TN1, TN7), Virginia (VA1, VA2), Kentucky (KY5) and Georgia (GA1, GA3) as good seed sources based on height and survival at age seven. Three stands, two from North Carolina (NC5, NC7) and one from Tennessee (TN7) were identified as good seed sources for use for Christmas trees as well as for other uses. Fifteen families, two Georgia (GA1-1, GA1-3), six North Carolina (NC1-2, NC4-4, NC4-5, NC7-1, NC7-2, NC7-3), two Virginia (VA1-4, VA3-9), three Tennessee (TN1-6, TN7-1, TN7-3), and two South Carolina (SC1-1, SC2-4), were identified as the best families, having 75 to 100 percent survival and mean height 2.5 meters to 2.7 meters at age seven. These families should be included in a seed orchard for breeding of Virginia pine for use in Oklahoma other than Christmas trees production.

Three North Carolina (NC4-4, NC7-1 and NC7-3), two Tennessee (TN7-1 and TN7-3), and one Virginia VA3-9) family

were consistent in good performance in the both Christmas tree plantations (Table XI) and progeny test plantations (Table XXIV). These families could be grown for any purpose.

All the best performing sources and families were from western North Carolina and eastern Tennessee lying between 35^{o} and 36^{o} latitude. The sources of Virginia pine from northern Georgia, South Carolina and southern Virginia, located near or between 35^{o} and 36^{o} latitude in addition to the Tennessee and North Carolina sources were among the best performing sources. For use in Oklahoma a strong emphasis should be placed on seed collection of Virginia pine from southeast Tennessee, southwest North Carolina, northwest South Carolina and northeast Georgia.

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APPENDIXES

APPENDIX A

ORIGIN OF VIRGINIA PINE STANDS AND FAMILIES

TABLE XXV

THE SOURCES AND FAMILIES OF VIRGINIA PINE TESTED IN OKLAHOMA

Stand #*	Trees**	Latitude	State	County	City
OH1	5	39°25′	OH	Unknown	Unknown***
OH2	5	38°58′	OH	Vinton	Orland
OH3	4	38°40′	OH	Unknown	Unknown
OH4	5	-----	OH	Unknown	Unknown
NJ2	2	40°30′	NJ	Middlsex	New Bruswick
NJ3	1	40°18′	NJ	Mercer	Titusville
NJ4	1	39°58′	NJ	Burlington	Pemberton
NJ5	3	39°58′	NJ	Burlington	New Lisbon
VA1	3	-----	Unknown Virginia/ Pennsylvania		
VA2	1	-----	Unknown Virginia/ Pennsylvania		
VA3	9	-----	VA	Unknown	Unknown
WV1	3	38°13′	WV	Pocahontas	Marllinton
WV2	1	38°13′	WV	Pocahontas	Marlinton
KY1	5	36°40′	KY	Bell	Frakes
KY2	5	38°08′	KY	Bath	Olympia
KY3	4	37°10′	KY	Christian	Dawson Springs
KY4	5	37°38′	KY	Breathitt	Noble
KY5	2	37°45	KY	Powell	Nada
TN1	1	-----	Unknown		
TN2	2	35°35′	TN	Monroe	Vonore
TN3	4	35°10′	TN	Polk	Benton
TN5	3	35°44′	TN	Polk	Walland
TN7	3	-----	TN	Monroe	Vonroe
NC1	2	35°33′	NC	Henderson	Enka
NC2	2	-----	NC	Unknown	Unknown
NC4	5	35°05′	NC	Cherokee	Murphy
NC5	2	35°45′	NC	Burke	Morganton
NC6	2	36°13′	NC	Durham	Rougemont
NC7	3	35°47′	NC	Iredell	Statesville
NC8	1	35°29′	NC	Catawba	Lincolnton
SC1	5	-----	SC	Unknown	Unknown
SC2	3	-----	SC	Unknown	Unknown
SC3	2	-----	SC	Unknown	Unknown
SC4	5	-----	SC	Unknown	Unknown
GA1	4	-----	GA	Unknown	Unknown
GA2	2	-----	GA	Unknown	Unknown
GA3	2	-----	GA	Unknown	Unknown

TABLE XXV (Continued)

Stand #	Trees	Latitude	State	County	City
AL1	2	33°15′	AL	Clay	Munford
AL2	5	34°30′	AL	Dekalb	Crossville

* First two letters of stand number denote state and the third digit represents stand in state.

** Number of trees sampled in stand.

*** The identification of these stands was by state only.

APPENDIX B

TABLES OF CORRELATION

TABLE XXVI

CORRELATION OF HEIGHT AND SURVIVAL OF VIRGINIA PINE AT AGE FIVE WITH LATITUDE

Variable	Latitude
Survival on growers sites	-0.32103 (0.1176)*
Height on grower sites	-0.75618 (0.0001)
Survival on nongrowers sites	0.04544 (0.8292)
Height on nongrowers sites	-0.65063 (0.0006)

* Values in brackets are the alpha for the correlation coefficients.

TABLE XXVII

CORRELATION COEFFICIENTS FOR SURVIVAL OF VIRGINIA PINE BY STAND FOR AGES ONE THROUGH FIVE ON GROWERS SITES

Survival at age	Survival at age 2	3	4	5
1	0.67743 (0.0001)*	0.49289 (0.0001)	0.48567 (0.0001)	0.48854 (0.0001)
2		0.81235 (0.0001)	0.79959 (0.0001)	0.80142 (0.0001)
3			0.98061 (0.0001)	0.97494 (0.0001)
4				0.99113 (0.0001)

* Values in brackets are the alpha for the correlation coefficients.

TABLE XXVIII

CORRELATION COEFFICIENTS FOR SURVIVAL OF VIRGINIA PINE BY FAMILY FOR AGES ONE THROUGH FIVE ON GROWERS SITES

Survival at age	Survival at age 2	3	4	5
1	0.70730 (0.0001)*	0.55269 (0.0001)	0.54798 (0.0001)	0.55006 (0.0001)
2		0.87696 (0.0001)	0.86737 (0.0001)	0.86788 (0.0001)
3			0.98493 (0.0001)	0.98437 (.0001)
4				0.99710 (0.0001)

* Values in brackets are the alpha for the correlation coefficients.

TABLE XXIX

CORRELATION COEFFICIENTS FOR HEIGHT OF VIRGINIA PINE BY STAND FOR AGES ONE THROUGH FIVE ON GROWERS SITES

Height at age	Height at age			
	2	3	4	5
1	0.73656 (0.0001)*	0.73587 (0.0001)	0.78796 (0.0001)	0.67093 (0.0001)
2		0.86502 (0.0001)	0.67664 (0.0001)	0.67536 (0.0001)
3			0.81664 (0.0001)	0.72876 (0.0001)
4				0.86321 (0.0001)

* Values in brackets are the alpha for the correlation coefficients.

TABLE XXX

CORRELATION COEFFICIENTS FOR HEIGHT OF VIRGINIA PINE BY FAMILY FOR AGES ONE THROUGH FIVE ON GROWERS SITES

Height at age	Height at age 2	3	4	5
1	0.75235 (0.0001)*	0.74517 (0.0001)	0.73854 (0.0001)	0.67476 (0.0001)
2		0.88381 (0.0001)	0.70727 (0.0001)	0.69737 (0.0001)
3			0.82729 (0.0001)	0.76475 (0.0001)
4				0.87918 (0.0001)

* Values in brackets are the alpha for the correlation coefficients.

TABLE XXXI

CORRELATION COEFFICIENTS FOR SURVIVAL OF VIRGINIA PINE BY STAND FOR AGES ONE THROUGH SEVEN FOR NONGROWERS SITES

	Survival at age				
Survival at age	2	3	4	5	7
1	0.93119 (0.0001)*	0.91598 (0.0001)	0.91399 (0.0001)	0.60652 (0.0001)	0.60625 (0.0001)
2		0.99204 (0.0001)	0.98835 (0.0001)	0.74820 (0.0001)	0.74745 (0.0001)
3			0.99707 (0.0001)	0.75858 (0.0001)	0.75899 (0.0001)
4				0.75865 (0.0001)	0.75879 (0.0001)
5					0.99455 (0.0001)

* Values in brackets are the alpha for the correlation coefficients.

TABLE XXXII

CORRELATION COEFFICIENTS FOR SURVIVAL OF VIRGINIA PINE BY FAMILY FOR AGES ONE THROUGH SEVEN FOR NONGROWERS SITES

	Survival at age				
Survival at age	2	3	4	5	7
1	0.96457 (0.0001)*	0.95169 (0.0001)	0.94939 (0.0001)	0.78323 (0.0001)	0.78015 (0.0001)
2		0.98906 (0.0001)	0.98500 (0.0001)	0.82919 (0.0001)	0.82433 (0.0001)
3			0.99588 (0.0001)	0.84010 (0.0001)	0.83569 (0.0001)
4				0.84396 (.0001)	0.83936 (.0001)
5					0.99457 (0.0001)

* Values in brackets are the alpha for the correlation coefficients.

TABLE XXXIII

CORRELATION COEFFICIENTS FOR HEIGHT OF VIRGINIA PINE BY STAND FOR AGES ONE THROUGH SEVEN FOR NONGROWERS SITES

Height at age	Height at age				
	2	3	4	5	7
1	0.83761 (0.0001)*	0.84928 (0.0001)	0.74305 (0.0001)	0.64645 (0.0001)	0.67889 (0.0001)
2		0.83923 (0.0001)	0.69632 (0.0001)	0.56580 (0.0001)	0.59490 (0.0001)
3			0.95214 (0.0001)	0.88636 (0.0001)	0.88467 (0.0001)
4				0.96584 (0.0001)	0.95411 (0.0001)
5					0.97529 (0.0001)

* Values in brackets are the alpha for the correlation coefficients.

TABLE XXXIV

CORRELATION COEFFICIENTS FOR HEIGHT OF VIRGINIA PINE BY FAMILY FOR AGES ONE THROUGH SEVEN FOR NONGROWERS SITES

	Height at age				
Height at age	2	3	4	5	7
1	0.82497 (0.0001)*	0.79348 (0.0001)	0.67561 (0.0001)	0.59256 (0.0001)	0.58120 (0.0001)
2		0.82806 (0.0001)	0.67927 (0.0001)	0.55386 (0.0001)	0.52093 (0.0001)
3			0.93420 (0.0001)	0.86103 (0.0001)	0.81781 (0.0001)
4				0.94757 (0.0001)	0.90373 (0.0001)
5					0.95346 (0.0001)

* Values in brackets are the alpha for the correlation coefficients.

APPENDIX C

ANALYSIS OF VARIANCE FOR GROWERS SITES

TABLE XXXV

ANALYSIS OF VARIANCE FOR SURVIVAL OF VIRGINIA PINE AT AGE FIVE ON GROWERS SITES ACROSS LOCATIONS AND BY LOCATION INCLUDING STANDS

a. Across locations

Source	Df	M S	F	P > F
Locations	2	256621.64	26.13	0.0126
Blocks (Locations)	3	9819.52	5.76	0.0024
Stands	38	1704.42	1.61	0.0830
Families(stands)	79	1057.67	1.46	0.0155
Location X Families(std)	153	669.21	0.18	0.9273
Error	340	859.03		
Total	691	1671.83		

b. Rogers county

Source	Df	M S	F	P > F
Blocks	1	22667.87	21.30	0.0010
Stands	38	1064.09	1.81	0.0136
Families (stands)	78	587.14	0.68	0.9629
Error	114	858.66		
Total	231	897.97		

c. Mayes county

Source	Df	M S	F	P > F
Blocks	1	6790.67	5.07	0.0303
Stands	38	1340.69	1.26	0.1950
Families (stands)	76	1064.08	1.34	0.0815
Error	111	796.56		
Total	226	1006.64		

d. Oklahoma county

Source	Df	M S	F	P > F
Blocks	1	0.00	0.00	1.0000
Stands	38	865.02	1.02	0.4531
Families (stands)	78	844.50	0.92	0.6538
Error	115	919.69		
Total	232	883.32		

TABLE XXXVI

ANALYSIS OF VARIANCE FOR SURVIVAL OF VIRGINIA PINE AT AGE FIVE ON GROWERS SITES ACROSS LOCATIONS AND BY LOCATION EXCLUDING STANDS

a. Across locations

Source	Df	M S	F	P > F
Locations	2	256621.64	26.18	0.0126
Blocks (locations)	3	9819.52	7.65	0.0001
Families	117	1282.82	1.78	0.0001
Location X Family	229	721.98	0.84	0.9221
Error	340	859.03		
Total	691	1671.83		

b. Rogers county

Source	Df	M S	F	P > F
Blocks	1	22667.87	30.39	0.0001
Families	116	745.92	0.87	0.7744
Error	114	858.66		
Total	231	897.97		

c. Mayes county

Source	Df	M S	F	P > F
Blocks	1	6790.67	5.88	0.0169
Families	114	1155.61	1.45	0.0250
Error	111	796.55		
Total	226	1006.64		

d. Oklahoma county

Source	Df	M S	F	P > F
Replication	1	0.00	0.00	1.0000
Families	116	854.86	0.93	0.6525
Error	115	919.69		
Total	232	883.32		

TABLE XXXVII

ANALYSIS OF VARIANCE FOR HEIGHT OF VIRGINIA PINE AT AGE FIVE ON GROWERS SITES ACROSS LOCATIONS AND BY LOCATION INCLUDING STANDS

a. Across locations

Source	Df	M S	F	P > F
Locations	2	7353.65	4.65	0.1172
Blocks (locations)	3	1544.20	0.88	0.4590
stands	38	1750.61	1.87	0.0100
Families (stands)	79	936.80	1.35	0.0567
Location X families (stands)	156	693.20	0.96	0.6070
Error	178	723.54	----	-----
Total	456	974.07	----	-----

b. Rogers county

Source	Df	M S	F	P > F
Blocks	1	247.53	0.57	0.4583
Stands	25	436.25	1.56	0.1471
Families (stands)	22	279.30		
Error	0			
Total	48	348.95		

c. Mayes county

Source	Df	M S	F	P > F
Blocks	1	2486.97	1.64	0.2087
Stands	37	1519.00	1.85	0.0127
Families (stands)	73	821.01	1.04	0.4277
Error	75	787.03		
Total	186	980.69		

d. Oklahoma county

Source	Df	M S	F	P > F
Blocks	1	1898.09	1.38	0.2473
Stands	38	1374.88	1.30	0.1619
Families (stands)	78	1055.37	1.56	0.0176
Error	103	667.30		
Total	220	969.63		

TABLE XXXVIII

ANALYSIS OF VARIANCE FOR HEIGHT OF VIRGINIA PINE AT AGE FIVE ON GROWERS SITES ACROSS LOCATIONS AND BY LOCATION EXCLUDING STANDS

a. Across locations

Source	Df	M S	F	P > F
Locations	2	7353.65	4.76	0.1172
Blocks (locations)	3	1544.20	1.23	0.3016
Families	117	1254.21	1.81	0.0003
Location X family	156	963.19	0.96	0.6073
Error	178	723.54		
Total	456	974.07		

b. Rogers county

Source	Df	M S	F	P > F
Blocks	1	247.50	0.70	0.4086
Families	47	356.05		
Error	0	0.00		0.0000
Total	48	348.95		

c. Mayes county

Source	Df	M S	F	P > F
Blocks	1	2486.97	2.26	0.1356
Families	110	1100.04	1.40	0.0614
Error	75	787.03		
Total	186	890.70		

d. Oklahoma county

Source	Df	M S	F	P > F
Blocks	1	1898.09	1.55	0.2152
Families	116	1222.34	1.80	0.0012
Error	103	677.30		
Total	220	969.63		

APPENDIX D

ANALYSIS OF VARIANCE FOR NONGROWER SITES

TABLE IXL

ANALYSIS OF VARIANCE FOR SURVIVAL OF VIRGINIA PINE AT AGE FIVE ON NONGROWER SITES ACROSS LOCATIONS AND BY LOCATION INCLUDING STANDS

a. Across locations

Source	Df	M S	F	P > F
Locations	1	11110.94	1.33	0.2792
Blocks (locations)	9	8378.44	3.71	0.0021
Stands	38	2259.96	1.58	0.0417
Families (stands)	84	1427.36	1.92	0.0005
Location X family (stand)	118	742.91	1.19	0.0886
Error	1079	623.07		
Total	1329	797.36		

b. Payne county

Source	Df	M S	F	P > F
Blocks	5	14320.58	7.93	0.0001
Stands	38	1806.89	1.23	0.2148
Families (stands)	83	1468.11	2.16	0.0001
Error	604	679.03		
Total	730	921.57		

c. Atoka county

Source	Df	M S	F	P > F
Blocks	4	950.78	0.76	0.5606
Stands	37	1257.72	1.60	0.0395
Families (stands)	82	784.60	1.42	0.0138
Error	475	551.91		
Total	598	630.21		

TABLE XL

ANALYSIS OF VARIANCE FOR SURVIVAL OF VIRGINIA PINE AT AGE FIVE ON NONGROWER SITES ACROSS LOCATIONS AND BY LOCATION EXCLUDING STANDS

a. Across locations

Source	Df	M S	F	P > F
Locations	1	11110.93	1.33	0.2792
Blocks (locations)	9	8378.44	4.95	0.0001
Families	122	1693.43	2.28	0.0001
Location X Family	118	742.91	1.19	0.0886
Error	1079	623.07		
Total	1329	797.36		

b. Payne county

Source	Df	M S	F	P > F
Blocks	5	14320.58	9.10	0.0001
Families	121	1574.35	2.32	0.0001
Error	604	679.03		
Total	730	921.57		

c. Atoka county

Source	Df	M S	F	P > F
Blocks	4	950.78	1.02	0.3996
Families	119	931.62	1.69	0.0001
Error	475	551.91		
Total	598	630.21		

TABLE XLI

ANALYSIS OF VARIANCE FOR SURVIVAL OF VIRGINIA PINE AT AGE SEVEN ON NONGROWER SITES ACROSS LOCATIONS AND BY LOCATION INCLUDING STANDS

a. Across locations

Source	Df	M S	F	P > F
Locations	1	11593.30	1.36	0.2742
Blocks (locations)	9	8552.57	3.72	0.0020
Stands	38	2296.89	1.61	0.0363
Families (stands)	84	1426.35	1.91	0.0006
Location X Family (stand)	118	447.58	1.20	0.0836
Error	1079	624.39		
Total	1329	801.56		

b. Payne county

Source	Df	M S	F	P > F
Blocks	5	14678.00	8.05	0.0001
Stands	38	1823.44	1.25	0.2009
Families (stands)	83	1462.20	2.17	0.0001
Error	604	673.58		
Total	730	919.64		

c. Atoka county

Source	Df	M S	F	P > F
Blocks	4	895.77	0.69	0.6006
Stands	37	1289.96	1.64	0.0335
Families (stands)	82	788.74	1.40	0.0169
Error	475	561.84		
Total	598	640.31		

TABLE XLII

ANALYSIS OF VARIANCE FOR SURVIVAL OF VIRGINIA PINE AT AGE SEVEN ON NONGROWER SITES ACROSS LOCATIONS AND BY LOCATION EXCLUDING STANDS

a. Across locations

Source	Df	M S	F	P > F
Locations	1	11593.30	1.36	0.2792
Blocks (locations)	9	5852.57	5.02	0.0001
Families	122	1703.97	2.28	0.0001
Location X Family	118	747.58	1.20	0.0836
Error	1079	624.39		
Total	1329	801.56		

b. Payne county

Source	Df	M S	F	P > F
Blocks	5	14678.00	9.31	0.0001
Families	121	1576.28	2.34	0.0001
Error	604	673.58		
Total	730	919.64		

c. Atoka county

Source	Df	M S	F	P > F
Blocks	4	895.78	0.10	0.4387
Families	119	944.50	1.68	0.0001
Error	475	561.84		
Total	598	640.21		

TABLE XLIII

ANALYSIS OF VARIANCE FOR HEIGHT OF VIRGINIA PINE AT AGE FIVE ON NONGROWER SITES ACROSS LOCATIONS AND BY LOCATION INCLUDING STANDS

a. Across locations

Source	Df	M S	F	P > F
Locations	1	49357.46	3.24	0.1053
Blocks (locations)	9	15220.10	2.91	0.0101
Stands	38	5228.03	5.75	0.0001
Families (stands)	84	909.90	1.51	0.0197
Location X Family (stand)	118	602.99	1.14	0.1530
Error	1027	527.67		
Total	1277	831.55		

b. Payne county

Source	Df	M S	F	P > F
Blocks	5	22701.07	8.97	0.0001
Stands	38	2530.70	3.49	0.0001
Families (stands)	83	724.56	2.10	0.0001
Error	565	345.42		
Total	691	658.52		

c. Atoka county

Source	Df	M S	F	P > F
Blocks	4	5868.89	1.71	0.1696
Stands	37	3441.61	4.52	0.0001
Families (stands)	82	761.12	1.01	0.4515
Error	462	750.57		
Total	585	960.17		

TABLE XLIV

ANALYSIS OF VARIANCE FOR HEIGHT OF VIRGINIA PINE AT AGE FIVE ON NONGROWER SITES ACROSS LOCATIONS AND BY LOCATION EXCLUDING STANDS

a. Across locations

Source	Df	M S	F	P > F
Locations	1	49357.46	3.24	0.1053
Blocks (locations)	9	15220.10	6.94	0.0001
Families	122	2193.10	3.64	0.0001
Location X Family		602.99	1.14	0.1530
Error	1027	527.68		
Total	1277	831.55		

b. Payne county

Source	Df	M S	F	P > F
Blocks	5	22701.07	18.21	0.0001
Families	121	1246.95	3.61	0.0001
Error	565	345.42		
Total	691	658.52		

c. Atoka county

Source	Df	M S	F	P > F
Blocks	4	5868.89	3.65	0.0076
Families	119	1605.76	2.14	0.0001
Error	462	750.57		
Total	585	960.17		

TABLE XLV

ANALYSIS OF VARIANCE FOR HEIGHT OF VIRGINIA PINE AT AGE SEVEN ON NONGROWER SITES ACROSS LOCATIONS AND BY LOCATION INCLUDING STANDS

a. Across locations

Source	Df	M S	F	P > F
Locations	1	79045.97	4.24	0.0697
Blocks (locations)	9	18657.40	1.60	0.1513
Stands	38	11684.25	6.70	0.0001
Families (stands)	84	1742.86	1.67	0.0050
Location X family (stand)	118	1041.73	1.01	0.4501
Error	1024	1029.07		
Total	1274	1567.55		

b. Payne county

Source	Df	M S	F	P > F
Blocks	5	23682.14	3.94	0.0056
Stands	38	6004.08	4.97	0.0001
Families (stands)	83	1208.07	1.56	0.0002
Error	564	755.29		
Total	690			

c. Atoka county

Source	Df	M S	F	P > F
Blocks	4	12376.45	1.70	0.1704
Stands	37	7273.09	4.99	0.0001
Families (stands)	82	1456.38	1.09	0.2967
Error	460	1340.24		
Total	583	1810.89		

TABLE XLVI

ANALYSIS OF VARIANCE FOR HEIGHT OF VIRGINIA PINE AT AGE SEVEN ON NONGROWER SITES ACROSS LOCATIONS AND BY LOCATION EXCLUDING STANDS

a. Across locations

Source	Df	M S	F	P > F
Locations	1	79045.00	4.25	0.0697
Blocks (locations)	9	18657.40	3.97	0.0002
Families	122	4696.25	4.51	0.0001
Location X Family	118	1041.73	1.01	0.4501
Error	1024	1029.07		
Total	1274	1567.55		

b. Payne county

Source	Df	M S	F	P > F
Blocks	5	23682.14	9.01	0.0001
Families	121	2627.37	3.39	0.0001
Error	564	777.29		
Total	690	1256.89		

c. Atoka county

Source	Df	M S	F	P > F
Blocks	4	12376.45	3.77	0.0064
Families	119	3284.96	2.45	0.0001
Error	460	1340.24		
Total	583	1810.89		

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Biographical:

Personal Data: Born at sohawa sharif, Azad Kashmir, Pakistan, Feburary 02, 1960, the son of Khadim H. Shah and Hajira Bibi.

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