Planting south of origin increases flowering in shortleaf (Pinus echinata Mill.) and virginia pines (P. virginiana Mill.)

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Abstract

Male and female strobili production of shortleaf and Virginia pine clones of Tennessee - North Carolina origin were evaluated in a North Carolina seed orchard and in a south Mississippi clone bank. Performance of shortleaf clones of Arkansas - Oklahoma origin were similarly examined in an Arkansas seed orchard and in the south Mississippi clone bank. In both cases, more than twice as many female strobili were produced in the southern location than in the seed orchards located near the origin of the clones, even though the clone bank was not managed for seed production. Establishing shortleaf and Virginia pine seed orchards south of their origin may be a practical method for increasing yields.

Key words: Flowering, cone production, seed orchards, genotype × environment interaction, *Pinus virginiana, Pinus echinata.*

Zusammenfassung

Es wurde die Produktion männlicher und weiblicher Blüten bei Klonen von *Pinus echinata* MILL. und *Pinus virginiana* MILL. aus Tennessee- und Nord-Carolina-Vorkommen sowohl in einer Samenplantage in Nord-Carolina als auch in einer Klonbank in Mississippi untersucht. Ebenso wurden Pinus echinata-Klone aus Arkansas und Oklahoma sowohl in einer Samenplantage in Arkansas als auch in einer Klonbank in Mississippi geprüft. In beiden Fällen wurden auf den südlicheren Standorten zweimal so viel männliche Blüten hervorgebracht als auf den Samenplantagen, die jeweils in der Nähe der Ursprungsorte lagen, obwohl die Klonbank nicht zur Samenproduktion angelegt worden war. So kann die Anlage von Samenplantagen mit *Pinus echinata* und *Pinus virginiana* auf Standorten, die südlicher gelegen sind als die natürlichen Vorkommen, eine praktikable Methode zur Erhöhung der Samenproduktion sein.

Introduction

Intensive research into flowering and seed production in conifers has been conducted because of the need for seeds for regeneration and tree improvement programs. Some research results on fertilization, crown release, competition control, subsoiling, and irrigation (reviews by PURITCH 1972 and JACKSON and SWEET 1972) have already been incorporated into programs for managing seed orchards.

Temperature and insolation are positively linked to flowering experimentally (GIERTYCH and KROLIKOWSKI 1978) as well as in studies of natural year-to-year variation (FOBER 1976, DAUBENMIRE 1960, SARVAS 1962). However, the only practical way to increase the temperature in a production seed orchard is to move the orchard to a warmer climate.

A survey of loblolly pine seed orchards reveals a trend for southern orchards to produce more than northern orchards (SCHMIDTLING 1978). Moving trees south of their natural range appears to enhance flowering and seed production, as has been found in slash pine (*Pinus elliottii* ENGELM.) (GANSEL 1973). Establishing seed orchards south of their original source is recommended practice in northern European countries (SARVAS 1970), and there seems to be a general consensus that this procedure is desirable (WERNER 1975). In a preliminary report based on a single year's observation of shortleaf pine (*Pinus echinata* MILL.), grafted ramets flowered better when planted in a southern location (SCHMIDTLING 1977). The present study extends the previous report to include 3 years of flowering data, along with a similar study on Virginia pine (*P. virginiana* MILL.).

Materials and Methods

This report includes the results of two shortleaf pine experiments and one Virginia pine experiment. Each experiment consists of ramets from several clones planted in a clone bank in south Mississippi and a seed orchard located in either central Arkansas or western North Carolina (*Fig. 1*). The clone bank plantings were established using surplus grafts from the orchards. The clone bank ramets are identical in age, rootstock, grafting technique, scion condition, early handling, and planting year to ramets in the orchards where they originated.

The North Carolina shortleaf study consisted of 18 clones originating from western North Carolina and eastern Tennessee (*Fig. 1*). The ramets were 8 years old when the study was initiated in 1976. The Arkansas shortleaf study consisted of 9-year-old ramets of 31 clones originating from north-central Arkansas. The Virginia pine study consisted of 8-year-old ramets from 16 clones originating from eastern Tennessee.

The three experimental locations differ in a number of ways. Climate varies considerably because the two seed orchards are 400 to 500 km north of the clone bank (*Table 1*). The orchards are also at higher elevations. The soils also vary but site quality is comparable. The clone bank is relatively flat, and the soils are well-drained McLaurin fine sandy loams. The orchards are quite hilly, but ramets

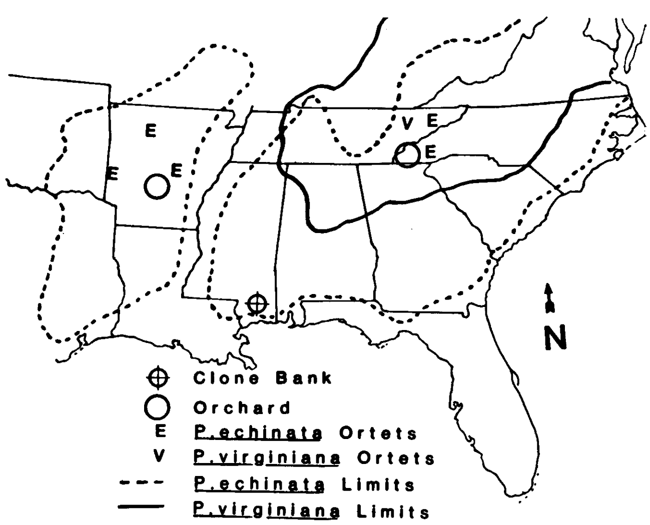

Figure 1. — Map of southeastern United States showing location of clone bank, seed orchards, and sources of the experimental clones. Botanical ranges of shortleaf (*P. echinata* MILL.) and Virginia (*P. virginiana* MILL.) pines adapted from CRITCHFIELD and LITTLE (1966).

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Table 1. — Geographic and climatic data for the experimental locations (from Little 1971 and Visher 1954).

Location	Latitude	Elevation	Growing season	Annual precipitation	Average temperature		
					Annual	Winter	Summer
	°N	m	days	mm		C°	
Mississippi Clone Bank	30.7	60	250	1520	20	12	29
Arkansas Orchard	34.6	300	205	1320	17	5	26
North Carolina Orchard	35.1	600	175	1500	13	3	21

on steep slopes or in poorly-drained areas were not used. The sample ramets in the North Carolina orchard are predominately on well-drained Hayesville fine sandy loams. Ramets in the Arkansas orchard are on Goldston shaley silt loams or Herndon gravelly silt loams, also well-drained. Site indices are similar for the orchards; 18 to 22 m at age 50 for shortleaf pine. Site index for the clone bank in 20—23 m for longleaf pine *(P. palustris* Mill.) which is a faster growing species. Spacing is 4.6 × 7.6 m in the clone bank; it is 4.6 × 9.1 m in the orchards. The orchards have been fertilized and pesticides applied to control insects. The clone bank was orignally for gene conservation and it has not been managed for seed production except for yearly mowing.

Ramets in the clone bank were arranged randomly with the constraint that ramets of the same clone would not be located adjacent to each other. Ramets in the orchards were systematically arranged, with each row offset by 5 clones from the previous row, so that ramets of the same clone were no closer than 25 m to each other. Sample

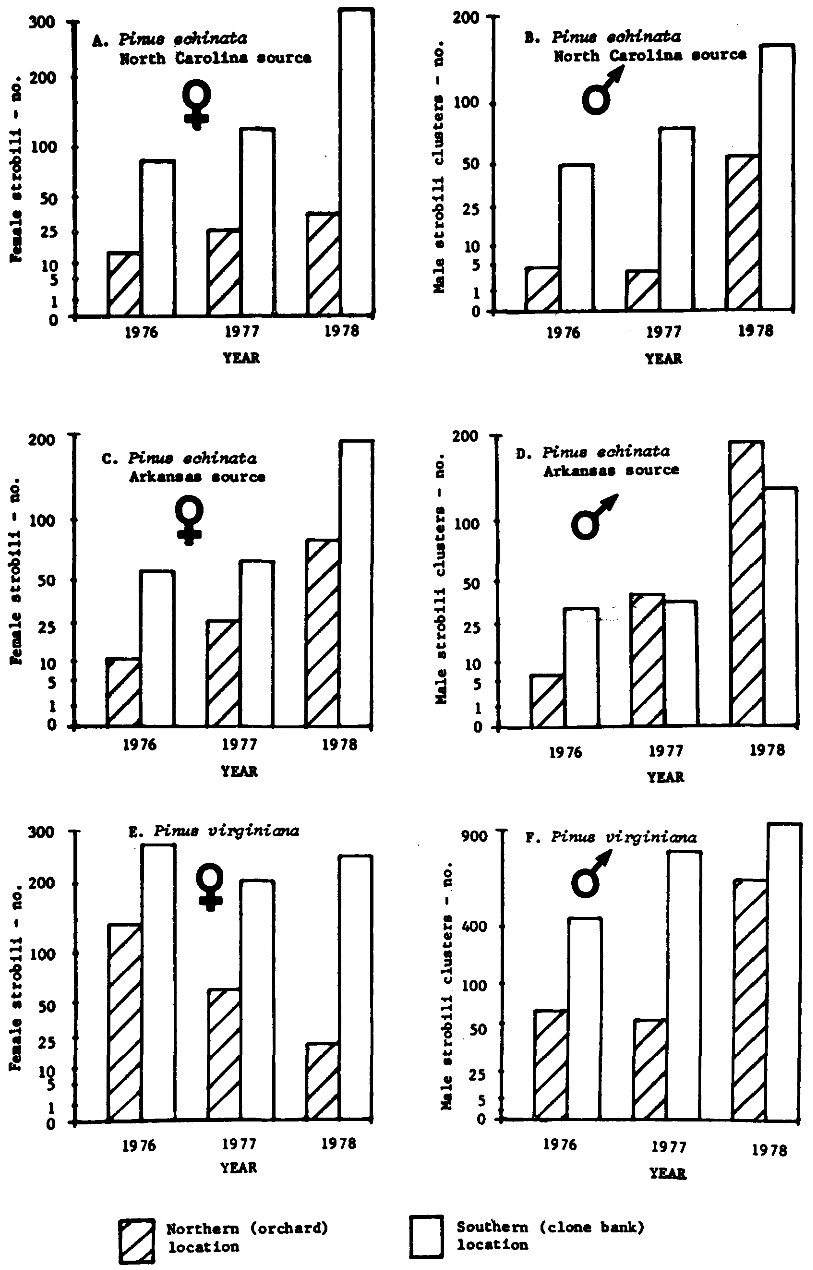

Figure 2. — Flowering of shortleaf *(P. echinata* Mill.) and Virginia *(P. virginiana* Mill.) pine clones in northern orchards compared to flowering of the same clones in a southern clone bank over a 3-year period. Vertical axes are square-root scale.

ramets were widely scattered throughout the orchards and clone bank.

For 3 years, starting in the spring of 1976, male strobili clusters and female strobili were counted on all ramets. Height and d.b.h. were measured on all trees the first year. A bulk sample of cones was collected from the clone bank and the seed orchards to obtain a measure of seed yield. Measurements were made on three ramets per clone in each location.

The orchard locations were compared with the clone bank location in each experiment. For all three experiments, the ananlysis of variance has the form:

Source	D.F.	Expected Mean Squares
Locations (L)	L-1	$\sigma^2_e + R\sigma^2_{LC} + CR\lambda^2_L$
Clone (C)	C-1	$\sigma^2_e + LR\sigma^2_C$
Clone × Location	(L-1) (C-1)	$\sigma^2_e + R\sigma^2_{LC}$
Ramet/Clone × Location (R)	$\sum$ (R-1)	σ^2_e

Variables analyzed include height, DBH (diameter at 1.5 m), male and female flowering each year as well as the 3-year average for male and female flowering. Clone and ramet are considered random effects; location is fixed. Significance tests were made at the 0.05 level of probability.

Results and Discussion

In the experiments, female strobili were much more numerous at the Mississippi clone bank location than at

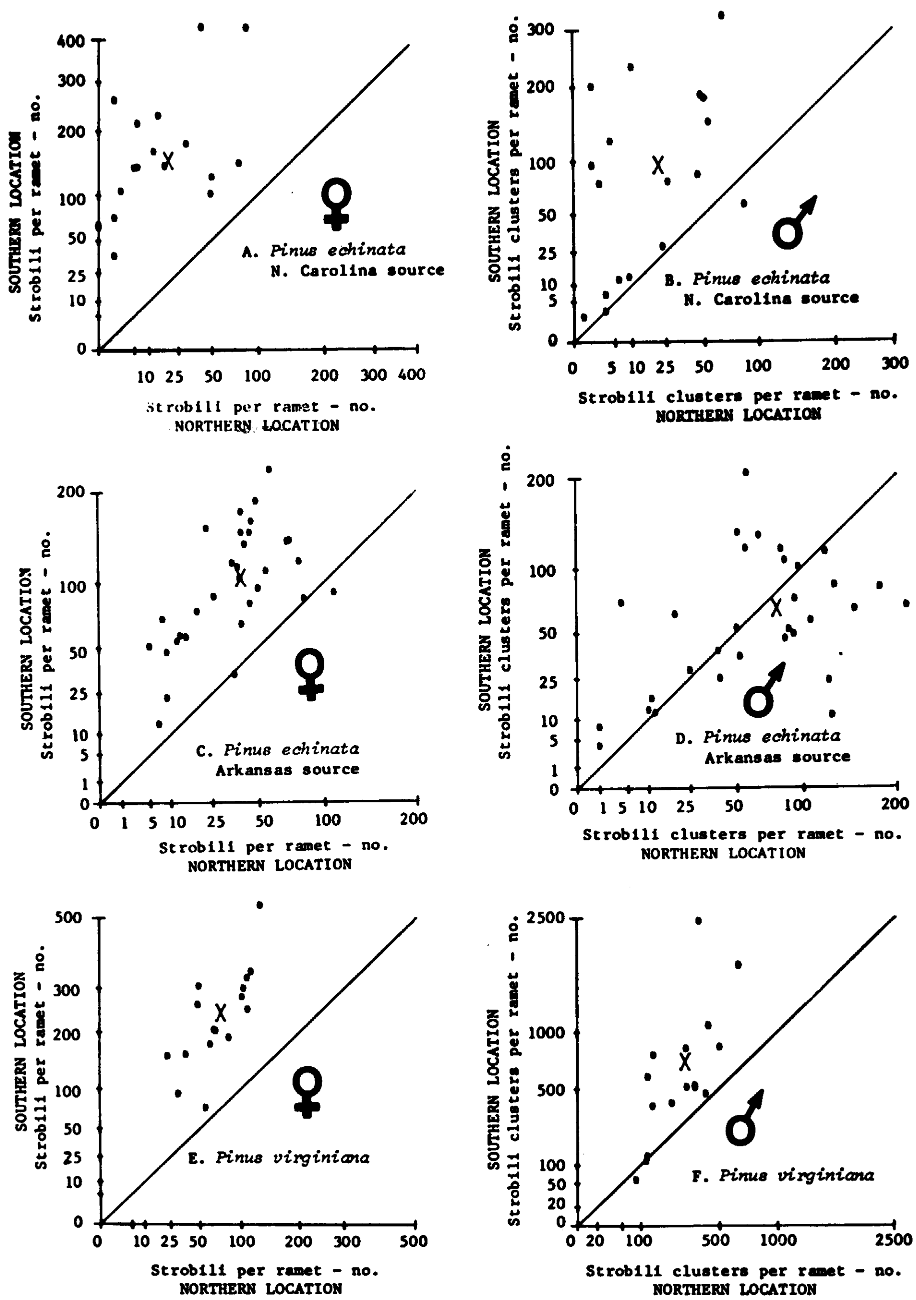

Figure 3. — Scatter diagram of flowering of individual clones in a southern location versus a northern location. Based on 3-year averages; 45° line indicates equal flowering at both locations, i.e., clones located above and to the left of the line flowered better at the southern location; those located below and to the right flowered better at the northern location. "X" indicates the mean. Axes are square-root scale.

the more northern orchards for the 3 years studied *(Fig. 2)*. Over a 3 year period, the Arkansas shortleaf ramets averaged 40 female strobili per tree compared with 105 strobili per tree annually in the clone bank *(Fig. 2 C)*. The North Carolina shortleaf ramets averaged only 19 female strobili per ramet at the orchard versus 149 strobili per ramet annually at the clone bank *(Fig. 2 A)*. The southern location was also much more favorable for Virginia pine flowering, as a average of 242 female strobili per tree were produced in the clone bank versus only 73 strobili per tree annually in the orchard *(Fig. 2 E)*.

The clone × location interactions were significant for female flowering in all 3 studies. There were large rank changes for clones across locations. In spite of this, nearly all clones flowered better at the southern location. Scatter diagrams of clonal means for female flowering showed that the North Carolina shortleaf clones had more female flowers at the southern location over the 3 years measured *(Fig. 3 A)*. Flowering of the Arkansas shortleaf clones was similar although 3 of the 31 clones had essentially the same number of female strobili at both locations *(Fig. 3 C)*. The Virginia pine clones also had more female strobili at the southern location *(Fig. 3 E)*.

Clone × environment interactions in female flowering seem to be common in southern pines. Strong clone × fertilizer interactions have been documented (Beers 1974) but these interactions are generally of the kind found in this study. That is, all of the clones produce more female flowers when fertilized but differ greatly in the magnitude of response (Schmidtling 1974). Similarly, most clones flower well in good years and poorly in bad years, but extensive change in ranking of clones occurs from year to year (Schmidtling 1983).

Generally, male strobili production was also greater at the southern location, but the differences were not as clear-cut. In 1976, male strobili were five times more abundant at the clone bank than at the orchards for the three experiments *(Fig. 2)*. In 1977 and 1978, however, there was no significant location difference in male flowering between the clone bank and the orchard for the Arkansas shortleaf *(Fig. 2 D)*. Both orchards were fertilized in May of 1976. Previous work has shown that fertilizers applied at this time would affect both male and female flowering in 1977 (Schmidtling 1983). The clone bank continued to be a superior location for the production of male strobili by the North Carolina shortleaf and Virginia pine in 1977 and 1978 *(Fig. 2 B, 2 F)*.

There was a strong location × clone interaction in male flowering for all 3 experiments. Nearly all the North Carolina shortleaf clones averaged more male strobili over the 3 years measured at the southern location than at the northern location *(Fig. 3 B)*. This is also true for the Virginia pine clones *(Fig. 3 F)*.

The occurrence of male strobili on the Arkansas shortleaf clones were about evenly divided between north and south locations *(Fig. 3 D)*. Differences in size may explain the discrepancy. Locational differences in d.b.h. were not significant, but the location × clone interaction was significant for shortleaf pine studies. Twelve of the 32 Arkansas clones, or 38 percent, were larger in d.b.h. at the northern location than at the southern location. Eleven of these 12 clones had more male strobili at the northern location than at the southern one.

Male strobilus production in *Pinus* is usually confined to the least vigorous branches in the lower part of the crown (Eggler 1961, Wareing 1957), and in southern pines catkins occur mainly on those branches that produced only one cycle of growth (Eggler 1961, Greenwood 1980). Small trees, whether seed grown or grafted ramets, have relatively few of these branches. Conversely, female strobili are generally formed in the upper part of the crown on shoots having 2 or more cycles of growth the previous year (Eggler 1961, Greenwood 1980). Thus, size may have a greater impact on male flowering than female flowering.

For Virginia pine, differences in size among locations were significant; the orchard ramets were considerably larger than the clone bank ramets. In 1976, the orchard ramets averaged 4.3 m in height and 8.1 cm in d.b.h. while the clone bank ramets averaged only 3.4 m in height and 5.8 cm in d.b.h. The clone bank is located on the southern edge of the natural shortleaf distribution but is more than 300 km southwest of the natural range of Virginia pine *(Fig. 1)*. This may account for the poorer growth of the Virginia pine at the clone bank relative to the shortleaf pine. This was not a deterrent for flowering as the Virginia pine produced larger flower crops on smaller trees in the southern location.

Reproductive phenology appeared normal at the clone bank. The Arkansas and the North Carolina shortleaf sources flowered at about the same time as local sources. In a shortleaf provenance test located about a mile from the clone bank, seed yields were good in controlled crosses involving a wider sampling of the shortleaf range than reported here (Wells and Schmidtling 1983). The southern location appeared favorable for reproduction of the northern sources.

Seed yields from shortleaf cones collected at the clone bank averaged only 4.4 full seeds per cone, and 8.5 total seeds per cone. Those are poor yields but yields from the Arkansas orchard were no better, averaging 3.5 full seeds and 9.3 total seeds per cone. Similarly, the Virginia pine cones collected at the clone bank averaged 10.0 full seeds and 33.0 total seeds per cone, versus 11.6 sound seeds and 23.4 total seeds per cone from the North Carolina orchard. All of the lots of full seeds germinated at 80 to 90 percent after 60 days stratification. The seedlings from the clone bank grew as well as those from the orchard.

Conclusions and Recommendations

The differences among locations in latitude and elevation result in large differences in average temperature, but more important, there is a large difference in growing season *(Table 1)*. Greenwood (1978) feels that the critical factor determining flowering is the existence of a quiescent bud long enough during the growing season to allow differentiation of primordia. Thus, if the growing season can be lengthened without increasing vegetative growth, enhanced flowering could be expected. In this study, average female flowering of shortleaf clones was increased 263 percent by moving from central Arkansas where the frost-free season is 205 days to south Mississippi, where the frost-free season is 250 days. The difference in frost-free season between western North Carolina and south Mississippi is even greater, 175 days versus 250 days, respectively. The increase in flowering was also much greater, as average female flowering was increased 941 percent by moving clones from western North Carolina to south Mississippi. In both cases vegetative growth, as measured by height and d.b.h., was not significantly increased.

This study supports earlier suggestions that movement to a warmer climate will increase pine seed orchard productivity. An advantage of locating the Virginia pine far south of its natural range is that it provides a 300 km wide isolation zone from contamination of outside pollen. This would be a disadvantage the first few years, as no pollen would be available for the earliest female flower crops.

The same advantage would not accrue for shortleaf pines, since local pollen is available, and progeny resulting from seed produced the first few years might not adapt well in northern latitudes. One advantage in moving Scots pine (*P. sylvestris* L.) orchards southward in Finland is that the northern provenances are receptive earlier than local sources, providing isolation from local pollen (Chung 1981). Variation in reproductive phenology in shortleaf pine among provenances is too small to provide isolation, however (Schmidtling 1971).

There are several advantages to splitting orchards between two locations; one near the origin of the ortets, and the other some distance south, similar to the situation described in this experiment. In addition to increasing production over what would be expected from a single orchard near the origin, splitting would provide insurance against a catastrophic loss to weather, fire, or disease.

Another benefit has been realized in this situation, as pollen was provided from ramets in the clone bank for use in controlled pollination in the orchards for several years. The clone bank ramets flowered several weeks earlier than the orchard ramets for both species. Pollen was shed early enough in the clone bank to provide fresh pollen from the latest flowering clones. In addition, pollen was provided from clones that did not produce any pollen in the orchard.

It may be risky to move orchards as far south of the origin as was the Virginia pine in this study. The clone bank is 300 km southwest of the nearest native Virginia pine and 750 km southwest of the origin of the ortets. Indeed, eastern white pine (*P. strobus* L.) from the same location has grown very poorly in south Mississippi (Schmitt and Namkoong 1965). There has recently been a problem with pitch canker in the clone bank Virginia pine, and several ramets have died.

Nevertheless, there seems to be enough evidence to justify locating orchards south of the origin of the ortets by 100 km or more. This would generally be advantageous in the southeastern United States, since more suitable sites for orchards (i.e., flat, well-drained) would be available south and east toward the coast.

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