TRENDS IN SHORTLEAF PINE TREE IMPROVEMENT

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ABSTRACT

Tree improvement programs of shortleaf pine (*Pinus echinata* Mill.) have developed over the past 25 years to the point that virtually all demand for planting stock is met with genetically improved trees. About 22,600 acres of improved stock are planted each year. Although shortleaf has the largest geographic range of any southern pine, it is not being promoted in reforestation programs as much as alternate species, presumably because of slower growth. The largest shortleaf reforestation and tree improvement programs are on the National Forests with the bulk of the program in Arkansas on the Ouachita and Ozark National Forests. Within a few years National Forests will have second generation orchards established.

Growth gains of 10%-15% are predicted from first generation unrogued orchards. Roguing will add another 5% and second generation gains will more than double those of the first generation.

With the advent of progressively faster growing trees from advanced generation breeding, and/or biotechnology, it is predicted that shortleaf will gain greater favor among landowners since it already has other traits equal to or better than alternative species.

INTRODUCTION

In order to present accurate, up-to-date information on shortleaf tree improvement, a questionnaire was sent to all organizations listed in the 1981 Directory of Seed Orchards (USDA 1982) with shortleaf pine seed orchards. The questionnaire was mailed during January 1986, and all replies were received by March 1, 1986. Follow-up phone calls were made when additional information or clarification was needed. The information in this paper is based on the results of the questionnaire, follow-up contacts, and the author's 15 years experience with the U. S. Forest Service in the National Forest Tree Improvement program.

Genetic tree improvement of shortleaf pine for reforestation programs began during the years 1959-1967 for thirteen organizations: 9 state, 2 federal, and 2 private industry (USDA-1981).

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Three of the states, Ohio, Alabama, and Virginia have dropped the program for lack of demand for shortleaf planting stock. Of the remaining programs, only 4 (Arkansas, North Carolina, Oklahoma, and the U.S. Forest Service) are collecting seed and growing seedlings for operational planting. Kentucky is growing improved seedlings from purchased seed. Tennessee Divison of Forestry plans to begin producing improved stock in 1987. Missouri has begun a cooperative program with the U. S. Forest Service which will provide the State's landowners with improved seedlings in a few years. The remaining programs have no firm plans for growing improved shortleaf planting stock. About 22,600 acres are planted with shortleaf improved stock each year, about 18,500 acres of which is on National Forests.

Figure 1 - Organizations with shortleaf pine seed orchards as of March 1, 1986.

ORGANIZATION	ACRES OF ORCHARD	DATE ESTABLISHED	PRODUCING SEED	M TREES YEARLY SEEDLING PRODUCTION	YEARLY ACREAGE PLANTED
American Can. Co.	7	1963	Yes	0	0
Arkansas, State of	10	1967	Yes	300	430
Georgia, State of	2	1962	Yes	0	0
International Paper	18	1959	Yes	0	0
Kentucky, State of	6	1965	No	2,000	3,000
N. C., State of	7	1963	Yes	200	285
Oklahoma, State of	27	1967	Yes	250	357
Tenn., State of	4	1967	Yes	0	0
Tenn. Valley Auth.	6	1967	Yes	0	0
U.S. Forest Service	580	1963	Yes	13,875	18,500
	667			16,625	22,572

INDUSTRY PROGRAMS

International Paper Company (IPC) made selections in South Arkansas and grafted a 30-clone, 18-acre orchard at Springhill, Louisiana in 1959 (Figure 1). The orchard has been producing seed for many years. IPC has not used much of the seed in the past but now have plans for producing about three million seedlings each year for sale to Arkansas landowners starting in 1987. They are progeny testing the clones with open-pollinated seed. Several of the tests are 5 years old or older. They have no plans for second generation breeding.

American Can Company established a 7-acre orchard at Myrtlewood, Alabama in 1963. The orchard has been producing seed since the mid-1970's but only small amounts have been collected since they have no plans for using it. They have four open-pollinated tests and one controlled-cross test. They also do not have plans for second generation breeding.

STATE PROGRAMS

Presently five state forestry organizations have orchards producing commercial quantities of improved seed. One is producing improved seedlings from purchased seed. Two more will be producing improved seedlings within the next few years.

The Arkansas Forestry Commission has a 10-acre shortleaf orchard and is currently producing about 300,000 seedlings per year for outplanting in Arkansas. They plan to increase production to about 2 million seedlings per year. Progeny testing is being done by controlled crosses and plans are to develop a second generation orchard.

The Georgia Forestry Commission has a 2-acre shortleaf orchard composed of 61 clones obtained from the TVA program. Commercial seed production began in 1973. Open-pollinated progenies from 20 families were planted in 1982. Georgia has no plans for either producing improved shortleaf seedlings or second generation breeding.

The Kentucky Division of Forestry has a 6-acre orchard which was established in 1965 at Gilbertsville. It is not producing commercial quantities of seed; however, about 2 million improved shortleaf seedlings per year are produced from seed purchased from the U. S. Forest Service. They are not progeny testing the orchard and have no plans for second generation breeding.

In 1983, the Missouri Department of Conservation started a cooperative program with the U. S. Forest Service which will provide Missouri with first and second generation improved seed. The Department has already located some additional woods selections both on National Forest and State lands for testing and eventual use in seed orchards.

The North Carolina Division of Forest Resources has a 7-acre shortleaf seed orchard with 20 clones in Morganton. It was established in 1963 and has been producing commercial quantities of seed since 1977. The Division has produced about 200,000 superior shortleaf seedlings per year. Open-pollinated progeny tests were established in 1982 at two sites, one in the Piedmont and one in the Mountain province. Progeny test measurements are scheduled at ages 4, 8, and 12 years.

The Department of Forestry, Oklahoma State University, established 17 acres of shortleaf orchard at Idabel in 1967. The seed is used by the Division of Forestry to grow about 250,000 seedlings per year for Oklahoma landowners. Progeny testing is being done with open-pollinated seed. No plans have been made for second generation orchards.

The Tennessee Division of Forestry has a 4-acre shortleaf seed orchard at Pickett State Forest and has recently assumed management of TVA's 6-acre orchard at Norris. The first production of improved shortleaf seedlings is planned for 1987. There are no firm plans for progeny testing and second generation breeding of shortleaf because other species work has a higher priority.

FEDERAL PROGRAMS

Tennessee Valley Authority

The Tennessee Valley Authority (TVA) established a 6-acre shortleaf orchard in 1967 near Norris. TVA has decided not to continue tree improvement and has turned over management of the orchard to the Tennessee Division of Forestry. The Tennessee Division of Forestry plans production of improved seedlings from this orchard's seeds beginning in 1987.

National Forest Program

The largest shortleaf tree improvement program by far is for the National Forests. This is because the U. S. Forest Service opted to reforest with shortleaf instead of loblolly in many parts of the natural range of shortleaf. National Forest land, where shortleaf pine is the preferred management type, includes 2.8 million acres in 14 states extending from Virginia west to Texas and Oklahoma and north to Missouri and Illinois. Shortleaf management type on National Forests is exceeded only by the white oak red-oak-hickory type which has about 3.5 million acres. By contrast, the loblolly management type has about 2 million acres on the National Forests.

That shortleaf pine is the preferred management type over such a diverse geographic area is not surprising when one considers that it has the most widespread distribution of any southern pine and occurs naturally in 22 states and on a wide variety of soil and site conditions (Fowells 1965) (Lawson and Kitchens 1983).

However, to get a better picture of where National Forest managers intend to grow shortleaf pine, one must consider other factors besides geographic range. The bulk of the shortleaf pine acreage is located in mountainous areas of Arkansas, Missouri, and the Appalachians. In the Piedmont and Coastal Plain, loblolly is generally chosen over shortleaf. One exception to this general rule is demonstrated on the National Forests in Texas where more loblolly is planted than shortleaf but due to excellent shortleaf development about 1,000 acres are regenerated to shortleaf each year.

An area where the decision to reforest with shortleaf is most questioned is in the Ouachita and Ozark mountains of Arkansas. Since many private landowners and timber industries in this area choose loblolly, the question is often asked, "Why reforest with shortleaf when loblolly is a faster-growing species?" There are basically four reasons:

1) The National Forest timber objective is to grow quality sawtimber. Because of this and other multiple-use objectives, the National Forests are on long rotations (60 to 80 years). No doubt, loblolly will outproduce shortleaf on most sites on short rotations, but existing yield data suggests that shortleaf yields on long rotations will match that of loblolly.

Since shortleaf has other excellent lumber qualities (straightness, small limbs and branch angles), it suits the National Forest timber objective for quality sawtimber quite well.

2) On many sites, especially in Arkansas, loblolly has been planted a considerable distance north of its native range by landowners. While experience shows this to increase volume production, the possibility exists for catastrophic events (especially snow and ice damage) to cause losses. This may prove to be best for short rotations, it may not be best for long ones. In other words, the decisions in favor of loblolly for short rotations and shortleaf for long rotations may both be correct.

3) The third reason is diversity. National Forest managers are charged by law to maintain diversity. By growing shortleaf within much of its range, this requirement is being fulfilled. A conscious decision has been made to put loblolly on some former shortleaf sites west and north of the present loblolly range. In Arkansas, this is generally on more mesic pine sites and lower elevation sites. However, the proportion of acres planned for this is relatively small.

4) A fourth reason is that we can breed shortleaf to grow faster and produce more quality volume. Shortleaf already has excellent wood qualities. First generation breeding is producing a high degree of straightness. Therefore, given high-wood quality and straightness at the end of the first generation, subsequent breeding can concentrate on growth and thus make larger gains in growth than could be made if several traits had to be factored into the selection index.

A breeding program for improving shortleaf for National Forests began in 1959 when Tom Swofford, the first Regional Geneticist for the Southern Region, Region 8 (R8), finalized plans for selection and grading. The Eastern Region, Region 9 (R9) started a program in the late 1960's for reforestation in Missouri and Illinois. Since R8 already had an orchard established in Arkansas, R9 established their orchard adjacent to it and used the same personnel for management. The R9 program was developed along the same lines as R8's with some exceptions, such as orchard design. The R8 and R9 programs had 12 geographic sources with 50 mother-tree selections per source. The geographic sources were divided along state boundaries except for Arkansas and Oklahoma which had three geographic sources (two for Ouachita National Forest and one for Ozark National Forest), and R9 which planned one geographic source to be used for Missouri and Illinois.

The very best trees were sought among 2.8 million acres of shortleaf pine as candidate parent trees for first generation orchards. After a candidate was found, it had to pass several screenings before it was finally accepted. Faster growth, pruning ability, straightness, disease resistance, and specific gravity were the traits sought in the superior tree selections. Then the selections were grafted onto potted rootstock and outplanted into clonal seed orchards at 15' X 30' spacing. Five orchard locations were established during the years 1963-1970.

Figure 2 - Shortleaf Pine National Forest Seed Orchards

ORCH. NAME AND LOCATION	REGION	ACRES	YEAR ESTABLISHED	CLONES	GEOGRAPHIC SOURCES
Ouachita Mt. Ida, AR	8	313	1963	147	Arkansas & Oklahoma
	9	85	1968	50	Missouri
Erambert Brooklyn, MS	8	11	1963	59	Mississippi
Stuart Pollock, LA	8	47	1964	100	Louisiana & Texas
Beech Creek Murphy, NC	8	99	1966	117	Tennessee, N. Carolina, Kentucky, & Virginia
Francis Marion Moncks Corner, SC	8	25	1970	50	Georgia

Early graft incompatibility was so great for about 10% of selected trees that they had to be discarded and new selections made. Some apparent graft incompatibilty showed up in later years but the number of clones affected was insignificant.

Once grafts were outplanted, orchard managers worked hard establishing ground cover and growing trees to seed production status. Orchards were fertilized early after establishment to promote grass and tree growth based on the recommendation of Dr. Jack May (for results see May 1977). Later, the fertilization regime was done to promote flower and cone development (Schmidtling 1975). Schmidtling also showed that irrigation would greatly increase seed production. However, due to the large size of orchards and the costs estimated for irrigation systems, irrigation has not been used.

Seed production in collectible quantities began at about age 10 in the shortleaf orchards. The largest crop collected was in 1983 when 8,653 pounds of seed were collected from four orchards. Even this is small in comparison to the 12,000 pounds predicted to be available for the 1986 collection on the Ouachita orchard alone.

The orchards have been thinned two or three times as the trees have grown larger. Thinnings were done based on spacing, appearance of the ramet, ortet characteristics, and seed and cone production. Since progeny test results were not available, no clone was completely removed. Now that some limited progeny test results are available, future thinning will be actual roguings where the poor performer will be removed. This will increase the overall average gain of the orchard seed collected subsequent to roguing.

The two greatest problems in orchard management thus far have been controlling cone and seed losses due to insects and collecting cones and/or seeds.

Because a seed orchard has many trees of the same age, it is an alluring home for insects--especially those which feed on cones and seeds. Safe and effective ways had to be developed to control these seed-destroying insects. Entomologists worked closely with orchard managers on pesticide formulation, application, and timing for effective control. With the help of several organizations, technology for the aerial application of insecticides was developed. Now an orchard can be treated in hours instead of the weeks required for ground-application methods. In addition, aerial applications place the insecticide in the top portion of the crown, where the cones are. This means less insecticide is necessary to do an effective job.

When trees started producing sufficient quantities of cones, picking them presented no real problem. However, when the crop increased to thousands of bushels, the job became formidable. Since this procedure must be done within 4 to 5 weeks (or the cones will open and seeds will fall out), many people are required to pick the cones. Also as the trees grow taller, the conventional ways of using ladders, truck beds, and tractor platforms become less effective. Since bucket trucks and other hydraulic lifts are so expensive, not enough of them can be purchased or rented to do the job.

With the cooperation of the Georgia Forestry Commission, a new system has been developed, called the Net Retrieval System. Netting is placed on the ground. The cones are allowed to ripen then the seeds fall on the net. Then a combine-type machine is used to roll the net and separate the seeds. The Net Retrieval System is now in operation on all or parts of five Forest Service orchards (Edwards and McConnell 1983, McConnell and Edwards 1985), and other organizations are considering using this system.

Results have been excellent on level topography on three of the orchards. The use of the Net Retrieval System has not worked well at the Ouachita Orchard due to hilly, rocky terrain and birds feasting on the seeds. Several noise devices have been used to deter the birds, but with only limited success. In order to shorten the time the seeds were on the nets, a helicopter was used to create a turbulence to remove the seeds from the opened cones. The helicopter worked well--in fact too well--it created so much turbulence that the seams in the netting came loose. Next year, additional tie-downs will be used to keep the netting in place.

Progeny Testing

Progeny testing is being done to measure gains, test worth of parents, and most importantly, as a source of selections for second generation orchards. In 1974, controlled crosses among orchard trees were started according to a plan that employed disconnected half-diallels. Individual matings were made to match desirable characteristics as indicated by the original mother-tree scoring sheets (McConnell 1983).

When the progeny testing plan was developed in 1974, it was decided that the 12 geographic sources for R8 could be combined into five. Due to low demand for shortleaf planting stock in Mississippi, it was decided not to carry that population past first generation breeding, so progeny testing in it has been suspended. Including Missouri, a total of about 1,315 individual crosses will have been made when the progeny-test plan is completed. Through the 1985 breeding season, about 75% of the crosses have been made.

When sufficient controlled-pollinated seed from 15 or more families is available, progeny tests are planted. To date, 123 tests have been established. Eighteen are five or more years old and have had 5-year measurements made.

Figure 3 - 2-year old shortleaf pine progeny test, Caddo Ranger District, Ouachita National Forest. Range pole is in one-foot graduations.

Early results have been quite surprising. Of course, early results must be used with a great degree of caution. Nevertheless, they indicate that large genetic gains are being realized.

<u>Gains</u>

Based on results of progeny tests and observations and measurements of operational plantings, conclusions of benefits and gains can be made. Since loblolly breeding has been going on longer than shortleaf, experienced gain figures for loblolly have been used to estimate those obtainable in shortleaf. Based on early results with shortleaf tests to date, using loblolly results seems reasonable.

Volume gains of 10%-15% from first generation seed in unrouged orchard has been predicted. Thus far on shortleaf progeny tests at 5 years, heights of all control-crossed families has averaged 7%-25% higher than commercial checks on seven tests thus far analyzed. At 5 years, no diameter measurements were taken and no volume measurements made. Measurements at 10 years will give more definitive results. However, for actual gain figures to be fully known, tests will have to be much older. Nevertheless, 10% to 15% volume gain seems to be a reasonable assumption.

One point often overlooked is that volume gains (faster growth) translates into much higher economic gains mainly due to shorter rotations. Trees that will grow 15% faster than woods-run trees will give economic gains of up to 25% or more. In fact, by shortening rotations, some acres that otherwise would lose money growing timber, can be made profitable. Combining faster growth with improvement in quality traits really multiplies gains.

Gain in straightness is apparent early. Straightness has a high heritability and phenotypic selection works well. Almost all families from the first round of selection are producing a high proportion of straight trees.

A very surprising result of the tree improvement program is the great improvement in survival of orchard stock. This was first noted in progeny tests where survival was typically 90% or better and in some tests approached 100%. This was mostly attributed to the fact that progeny test seedlings are handled and planted with greater care than operational plantations.

However, when plantation records for 5 years (1980-1984) were examined, more surprising results appeared. During the 5-year period, the Ouachita and Ozark National Forests planted 57,655 acres with shortleaf orchard seedlings and 11,695 acres with general forest area shortleaf. The orchard seedlings had a survival rate 22% greater than general forest area seedlings. How much of the increase is due to genetics and how much to that intangible "when-you-got-something-good-you-take-better-care-of-it" principle, no one knows. It certainly is plausible that orchard seedlings have better adaptability for a wider range of sites since the mother trees were selected over a wide range of habitats and gene combinations are produced that never could happen in the woods.

FUTURE

Due to rapid advances in genetics and biotechnology, it is hard to predict the exact path of the future of shortleaf tree improvement. One certainty is that additional gains will be made in breeding this marvelous species. I predict that when present and future gains are demonstrated with older tests, shortleaf pine will gain greater favor among landowners and be replanted on formerly occupied sites.

There are at least three possible routes of additional improvement. Combinations of these three are possible also.

Biotechnology/Genetic Engineering

Ledig and Sedaroff summarized the state-of-the-art of genetic engineering new improved trees as follows.

> Gene transfer, using recombinant DNA technology, can be used to engineer new, improved trees in a fraction of the time required by traditional breeding methods. Genetic engineering requires isolation of genes, their multiplication in bacteria, their transfer to tree cells, and regeneration of the transformed cells into new trees. Success has already been achieved in cloning conifer genes and in developing a transfer system, and several genes of potential value to forestry have been isolated from bacteria. The inability to regenerate to forestry conifers from transformed cells is the major remaining barrier to application of genetic engineering in tree improvement (Ledig and Sedaroff 1985).

The major remaining barrier is a huge one indeed and no one predicts it will be overcome soon. However, when it is overcome, tree breeders will make gains in an incredibly short time frame.

Interspecific Hybridization

The greater growth rates of loblolly and slash pines suggest potential for improving shortleaf growth by hybridizing. Shortleaf X loblolly and shortleaf X slash were made as early as 1933 and outplanted at several locations throughout the Southern United States. Generally, both hybrids grew faster at many locations than did shortleaf. Considerable recent work with loblolly and shortleaf has been reported by Kraus and LaFarge (Kraus and LaFarge 1977, LaFarge and Kraus 1980). Their goal is to develop rust-resistant strains of loblolly through hybridization, but it is not known how well these strains will perform in the northern parts of shortleaf's range. The possibility exists that through testing, some excellent strains could be developed for planting in places where shortleaf is the preferred species.

Conventional Breeding Techniques

Given current technology, the greatest additional gains in shortleaf tree improvement will probably be made through another cycle of selection and grafting clonal orchards. Several organizations have indicated plans to go into second generation programs. The U. S. Forest Service is closest in time to establishing second generation orchards.

The 12 first generation shortleaf pine geographical sources have been streamlined into six (five for R8, one for R9) second generation breeding populations (Wells and McConnell, 1983). The decision has been made not to carry the North Mississippi population to a second generation; therefore, there are five populations where second generation orchards are planned. The breeding populations have been prioritized for second generation orchard establishment based on timing of progeny tests and on how important a particular breeding population is to the total tree improvement program (Kitchens 1985).

Selections for second generation orchard parents will be made from first generation progeny tests. The best individual trees from the best families will be grafted into second generation orchards.

The shortleaf breeding population for Arkansas and Oklahoma has the highest priority. Orchard clearing is scheduled for 1988 with establishment shortly thereafter. Other populations will be 2 to 6 years behind. Of course, all plans are contingent on budgets which could delay plans for some time.

In order to keep the genetic base broad, new woods selections of superior phenotypes will be made. These selections will be cloned into breeding orchards for testing and use in advanced generation breeding (past second generation).

CLOSING

Shortleaf tree improvement has developed in the last quarter-century such that almost all demand for planting stock is met with genetically improved seed. Due to size of present orchards and their increasing production, future demand can be met even if there is a significant increase in demand. Second generation orchards should be producing even better stock before the beginning of the 21st century.

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