Thirty-five Years Later:
An Overview of Tree Improvement in the Southeastern United States[1]

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Abstract. Tree improvement efforts over the past three decades have resulted in important gains in tree growth rate, quality, and rust resistance. Recent estimates indicate that volume gains for loblolly pine (*Pinus taede* L.) at 25 years of age are as much as 12 percent. Estimated after tax returns of the tree improvement investment are approximately 17 to 19 percent.

Orchard yields south wide were approximately 126 tons of seed in 1987. Some 10.25 tons of second generation seed were harvested by members of the North Carolina State Cooperative Tree Improvement Program in the past year.

Many challenges and opportunities for tree improvement loom on the horizon. Expanded use of family harvest systems, vegetative propagation, and supplemental mass pollination can significantly enhance gains from tree breeding and improvement efforts.

Introduction -- The Background

During the 1950's applied tree improvement began to develop in several countries around the world. It was at this same time that forest industry in the United States became interested in developing tree improvement programs to enhance their increasingly large forest regeneration activity.

The essential goal of tree improvement is to enhance forest productivity through the use of genetics and breeding. It is important to view tree improvement within the overall frame work of other silvicultural practices; e.g., site preparation, competition control and, very importantly, nursery management. Through the combination of these silvicultural components that the maximum progress can be made toward enhancing forest productivity.

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Early gain predictions from tree improvement were relatively modest. However, early published analyses of the economics of tree improvement in the South (Davis, 1967; Bergman, 1968; Porterfield, 1974) indicated increased volume yields of 2.5 to 4 percent were sufficient to justify the expense of a tree improvement program.

Today, tree improvement has become an integral part of forest regeneration practices, including seed and seedling sales, throughout the southeastern United States. A combination of research and experience has overcome many hurdles and resulted in gains from tree improvement far in excess of original expectations.

The Current Situation

In 1985, Talbert et al. reported that tree improvement continued to be an attractive investment opportunity. Their analyses estimated that cubic foot volume gains from first generation loblolly pine (*Pinus* taeda L.) seed orchards were approximately 12 percent. Final crop gains in harvest value were estimated to be as high as 32 percent with after tax rates of return to the tree improvement investment of 17 to 19 percent!

All economic analyses done to date directly link the profitability of tree improvement investments to seed production levels. In fact, economists have concluded that forest tree seed orchards are sound investments only when they are fully productive (Porterfield, 1974). Much has been learned regarding the development and management of seed orchards in the southeastern United States. Abundant seed crops are reliably produced only when judicious selection of orchard sites is coupled with proper management practices such as fertilization and insect control.

Currently in the southeastern U. S. there are approximately 9750 acres of first and second generation seed orchards. In 1987, these orchards produced approximately 251,350 pounds of seed. [1] The annual seed orchard yields in the N. C. State Cooperative Tree Improvement Program continue to trend upward (Figure 1). These increasing yields across the region have resulted in

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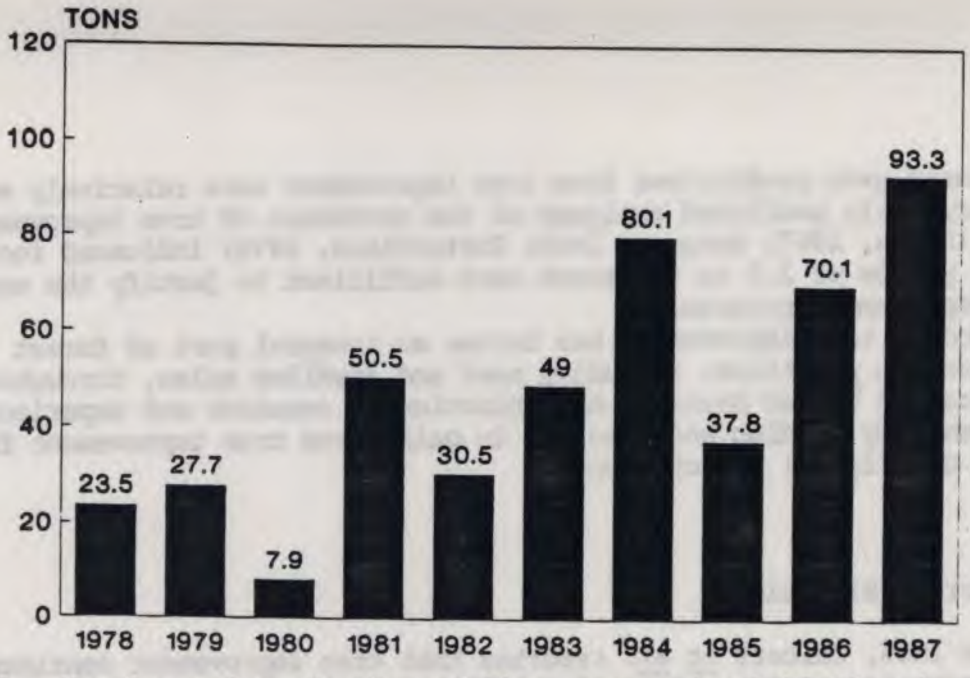


Figure 1. Yearly seed production of first generation loblolly pine seed over the recent decade for the N. C. State Cooperative Tree Improvement Program.

many tons of genetically improved first generation seed being offered for sale. Despite the general seed surpluses for many organizations there is not a surplus of the very best genetically improved seed. Second generation seed orchards are increasingly productive and in the next four or five years will begin to replace first generation production given the evident upward seed production trend from these young orchards (Figure 2).

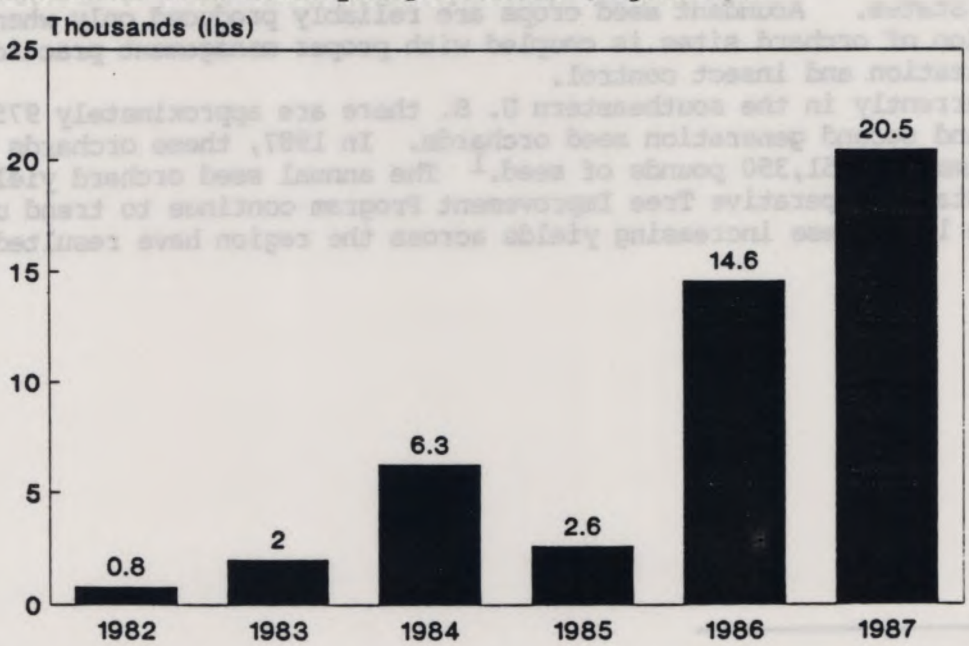


Figure 2. Yearly production of second generation loblolly pine seed for the N. C. State Cooperative Tree Improvement Program.

It is anticipated that the over production of seed currently extant in the Southeast will not be repeated by either the second or third cycle orchards. Future orchards will be much more tailored to the needs of each organization and anticipated trends in forest management. Additionally, because of progress in orchard site selection and orchard management, fewer acres of orchard will be required. The net result is that the seed surpluses so widely offered for sale in today's market may not be available in the future.

The development of a third cycle of seed orchards is anticipated to begin by the mid-1990's in the N. C. State Cooperative Tree Improvement Program. The breeding and testing of second generation selections and other material for use in these future orchards should be completed early in the 1990's thereby setting the stage for another cycle of selection and testing. It is anticipated that future breeding and testing efforts will be an ongoing process that periodically and regularly provides genetically improved material to the production seed orchard program. It is likely that future orchards will be developed incrementally as improved genetic material becomes available rather than the complete replacement of an orchard by the next cycle of improvement. As a result, orchards will not be recognizable as a discrete generation of improvement but instead will be a blending of progressively better material. This is commonly acknowledged as the "advancing front" concept of orchard development (Lowe and van Buijtenen 1981).

Future Trends and Opportunities

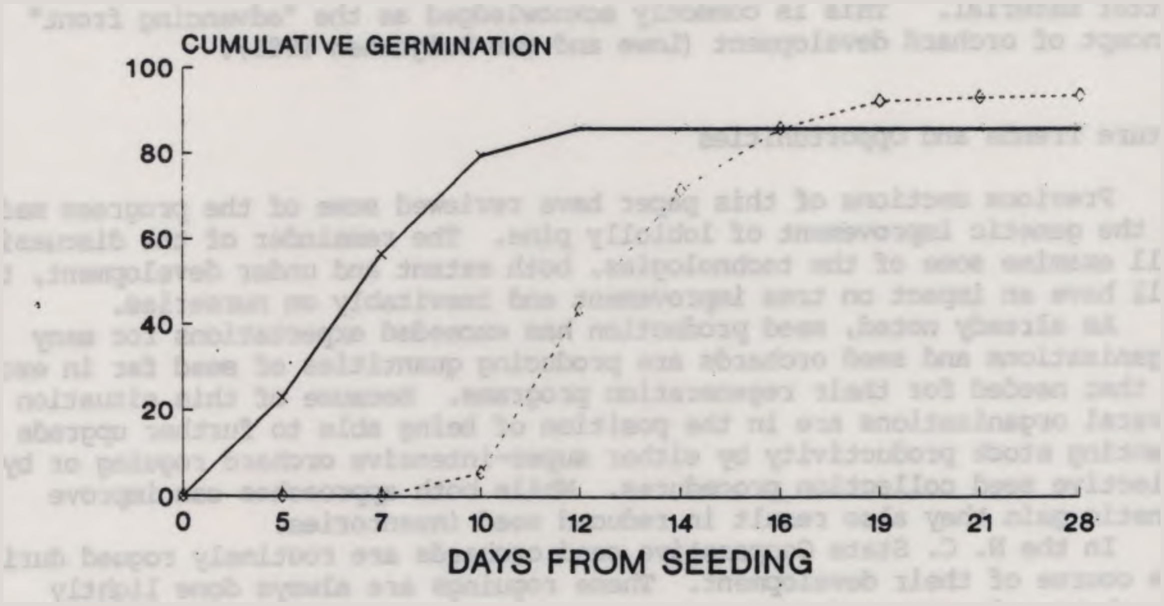
Previous sections of this paper have reviewed some of the progress made in the genetic improvement of loblolly pine. The remainder of the discussion will examine some of the technologies, both extant and under development, that will have an impact on tree improvement and inevitably on nurseries.

As already noted, seed production has exceeded expectations for many organizations and seed orchards are producing quantities of seed far in excess of that needed for their regeneration programs. Because of this situation several organizations are in the position of being able to further upgrade planting stock productivity by either super-intensive orchard roguing or by selective seed collection procedures. While both approaches can improve genetic gain they also result in reduced seed inventories.

In the N. C. State Cooperative seed orchards are routinely rogued during the course of their development. These roguings are always done lightly enough to maintain seed production. However, given the current large seed inventories several organizations are roguing first generation seed orchards to the best 8 or 10 clones without regard to the impact of low residual stocking levels on seed production. While there is less total seed, the resultant seed is from the best clones. A conventional roguing of an orchard will approximately double the gain over unrogued orchards (32 percent versus 18 percent) (Talbert et al. 1985). Intensive roguing will further improve gains. It should be pointed out, however, that super-intensive roguing is a matter of some discussion (Libby, 1981; Zobel, 1981; Talbert, 1982; Jett, 1986) and questions remain regarding the practice. Despite the questions the use of super-intensive roguing is anticipated to increase.

Altering seed collection procedures has been and will continue to be a widely accepted and practical strategy in the face of surplus seed. While seed supplies lagged behind seed needs, orchard managers harvested all available seed. With increased seed inventories, attention was turned toward stratifying orchard clones based on performance or end use and then harvesting and handling seed by groups of open-pollinated families. Today, while stratified collection is still practical more emphasis is being placed on harvesting seed by individual parent, sowing in the nursery by family and finally, and planting in the field by family.

An immediate benefit of handling seed by half-sib families has been increased seedling quality brought about by more uniform germination and more timely application of cultural practices compared to mixed open-pollinated seedlots. As can be seen in Figure 3, family 5-5 germinates much slower than family 1-82. By day 10 family 1-82 has essentially reached maximum germination while 5-5 has just begun to germinate.



5-5 —— 1-82

Figure 3. Germination rate for two open-pollinated loblolly pine family seedlots.

When included in a mixed lot, it is doubtful that many of the 1-5 seedlings would actually make it to the field. The net result of family harvest is to extract additional gain from tree improvement programs thereby further enhancing profitability.

While significant gains can be made by harvesting and utilizing half-sib families in regeneration programs, additional gains in growth, form and rust resistance are possible by using full sib families. An example of one such family is shown in Table 1. The use of open-pollinated seed from clone 7-56 or 10-10 would result in good field performance. However, the specific combination of 7-56 x 10-10 results in progeny that performs exceptionally well and would significantly boost realized gain. It has been estimated that the use of some specific crosses would result in estimated height gains of 25 percent or more over the commercial checks (Weir et al., 1982). Although not yet widely employed, mass production of specific crosses is apparently now feasible on an operational scale utilizing supplemental mass pollination techniques (Bridgwater et al., 1987).

Table 1 The performance levels[1] of families 7-56 x 10-10, 7-56(OP) and 10-10(0P).

Family	Height	Form	Fusiform Rust Resistance
7-56 x 10-10	85	75	63
7-56 (OP)	73	68	70
10-10 (OP)	68	56	37

[1] Performance level is a standardized score for family performance. The range of values is from 0 (poorest) to 100 (best). A performance level of 50 indicates average performance.

Looming on the horizon are other techniques that will allow multiplication of genetically improved plant material. Vegetative propagation methods of rooted cuttings and tissue culture are constantly being refined and it should only be a matter of time when one or both of these techniques becomes operational. The major advantage of using clonal material for reforestation are: (1) all of the genetic potential is utilized thereby yielding greater gains, and (2) the increased uniformity among propagules enhances many aspects of forest management, harvesting and utilization.

Although the rooting of loblolly and slash (P. elliotti Engelm.) pine is quite feasible from juvenile cuttings (van Buijtenen et al., 1975; Greenwood, 1981) difficulties are encountered rooting older material. Unfortunately, the rooting success (McAlpine and Jackson, 1959) and subsequent growth rate

(Foster et al. 1986) of loblolly pine decreases with increasing age of the material being rooted. This is an important problem since the optimum genetic selection age is at a time when consistent rootability is rapidly declining.

The use of young untested but rootable trees in loblolly pine significantly lessens the potential for genetic gain. The large genetic gain potential hinges on propagation of older trees which have demonstrated their genetic value (McKeand and Weir, 1984). Work with other species offers the hope that juvenility can be maintained or that maturation can be slowed (Libby et al., 1972; Franclet, 1979). If systems are developed to effectively deal with aging problems, and if efficient production systems can be developed, rooted cuttings for reforestation may prove feasible.

Tissue culture of conifers has proven to **be** difficult compared with many other species. However, methodology has progressed to the point that plantlets can now be produced from several species and production of loblolly pine plantlets fram seed embryos is more or less routine (Amerson et al. 1988). Despite these advances the operational use of tissue culture plantlets is still in the future and the use of embryos as the starting material has the same limitations as starting with young trees in a rooted cutting program.

The key to the operational use of tissue culture is the development of a cost effective production system. The southeastern U. S. probably has the lowest bare root seedling costs in the world. Although tissue culture and other vegetative propagation procedures offer more genetic gain, the per plant costs are currently very high. If plant costs (the most optimistic estimates are 10-15 cents per plant) were not a concern, existing methods of tissue culture would be actively utilized. In the house plant industry, with a high value per plant, tissue culture is an operational reality.

A tremendously exciting aspect of tissue culture and related cell suspension work is the incorporation of new technologies. Laboratory screening for disease resistance appears increasingly feasible (Frampton, 1986; Gray and Amerson, 1983) and, the rapidly expanding field of biotechnology will eventually have a significant impact on operational forestry. DNA transfer, herbicide resistance, and creation of interspecific hybrids are all possibilities that will ultimately depend upon tissue and cell culture technology for their practical realization.

Summary

The early years of tree improvement in the southeastern United States were directed at learning to establish and manage seed orchards, and to develop methodologies that permitted the basic programs to move forward. Today, as evidenced by the abundance of genetically improved seed, we know how to do many of the things required to insure the productivity of applied tree improvement programs. However, increasing economic pressure demand that we learn to do things more efficiently and that we develop cost effective technologies that are and will yield even more genetic gain. These additional gains will help bolster an industry facing some dramatic changes and challenges in the years ahead. However, the necessary gains will only be obtained by continued research and the aggressive application of research results.

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