# TWELFTH ANNUAL REPORT

N. C. State-Industry
Cooperative Tree Improvement
and Hardwood Research Programs

School of Forest Resources
North Carolina State University
Raleigh

May, 1968

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GENERAL -- COMBINED PROGRAMS

The forest industry in the Southeast is experiencing an "explosion" of mergers, expansions and new mills. To meet the wood raw material needs for new and existing mills, revolutionary practices on forest regenerations, management and harvesting are being initiated. All the activities relate to the need for maximum production of reasonably priced desirable wood on each acre. Maximum production was the theme used in the 1967 Tree Improvement Annual Report, and because of the trends it will be used again in 1968 for both Cooperative Programs. The need for increased production on each acre is not limited to the southeastern United States. For example, Will[1/] from New Zealand recently stated, "Few plants, on an annual basis, use more than 5% of the energy available to them, so that it is not unreasonable to expect further increases in production. With increasing world demand for forest products, foresters too are seeking ways to increase yields. Tree breeding and selection programmes are under way in a number of countries."

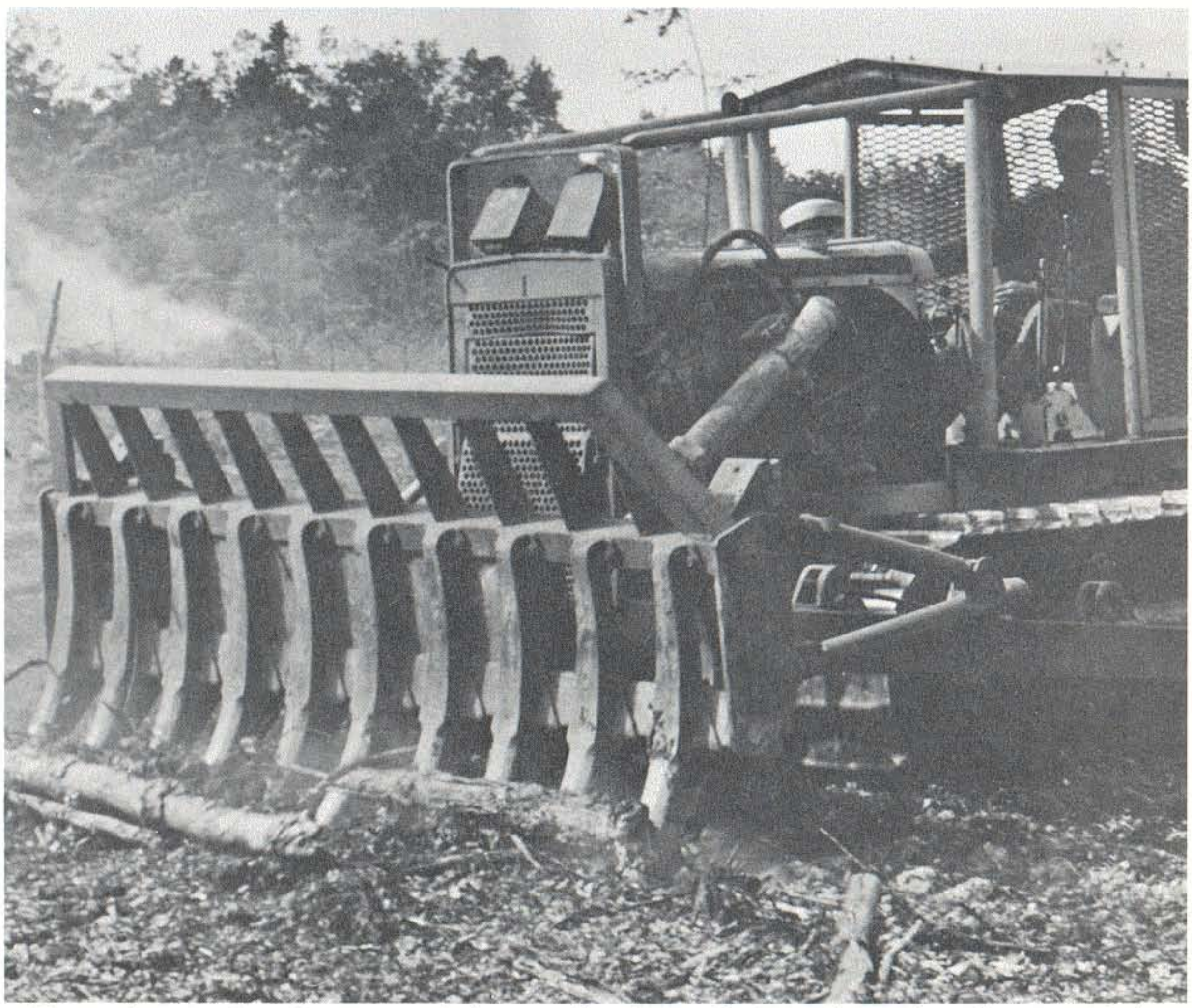
Throughout the Southeast increased forest productivity per acre is needed for both hardwoods and pines. Assurance of a sufficient and economically profitable supply of pines is of critical importance. Availability

1/ Will, G. M. 1966. Root growth and dry-matter production in a high-producing stand of *Pinus radiata*. New Zealand Forestry Research Notes No. 44, pp. 1-15.

of pine is becoming restricted in some areas; recent surveys, such as those in Virginia and Maryland, show pine being harvested at a much faster rate than it is being grown. A similar inequality of growth and drain in pine and hardwood is clearly evident in several other places within the operating territory of the cooperatives, although up-to-date survey figures are not available. For hardwoods, an inequality of economically available, desirable wood is one of the most critical problems in several parts of the South, while in other areas an excess of hardwoods causes difficulty in forest management and wood procurement programs. Therefore, major objectives of both the pine and hardwood cooperative programs are to increase yields at reasonable cost. Methods used to achieve this objective may differ but they all depend on growing the right species or strain of tree on the right site, optimum site preparation and cultural practices, mechanization and use of the raw material based on an understanding of its variability.

For efficiency and convenience, an annual report combining the activities of the Tree Improvement and Hardwood Cooperative Programs has been prepared. The combined report enables an emphasis on the need for maximum production on all forest land and to show how the two programs can help to do this. The merger of the pine and hardwood programs has brought about considerable efficiency, and all members of the staff work on both programs as the need arises. However, since field activities are usually handled as discrete pine or hardwood studies, this annual report will have sections devoted each to the pine and hardwood programs.

The Cooperative Tree Improvement Program has 21 industrial members and 3 state members operating in 13 southeastern states. There was one addition during the past year when Masonite Corporation joined in January, 1968. The Cooperative Hardwood Research Program has 13 industrial members, which



Many thousands of acres of forest land are being cleared and converted to farmland each year. Much of this area will never again be available for timber crops. Many different kinds of equipment are used to do this expensive job. Shown is a root rake in operation.

are primarily pulp and paper producers, although plywood and other products constitute a significant amount of production for several of them.

# THE COOPERATIVE TREE IMPROVEMENT PROGRAM -- PINE

## General

Last year we emphasized the need to increase yields by: (1) producing faster growing, better formed trees on good sites; (2) producing strains or species that will grow an economic timber crop on marginal sites; and (3) producing resistant strains to grow where disease is especially bad. Gains and improvements to accomplish these objectives by using orchard seed will be stressed in this report. Such gains are not theoretical or relegated to the future; for example, last year enough seed were obtained from seed orchards to plant about 12,000,000 trees, and this year enough have been harvested to plant about 24,000,000 trees.

The activity and progress in the Tree Improvement Program is so rapid as to be almost frightening; the results from many years of work and planning are now coming to fruition. The spirit of cooperation and participation among members of the Cooperative has produced early results and mutual benefits beyond our most optimistic expectations. Because of the extensive activities in the Cooperative, so many results are now becoming available that it is difficult to cover them even briefly in this annual report without leaving out significant achievements.

When writing the annual report there is the tendency to stress the application phases and to pass over basic or more fundamental studies done as part of the Cooperative. A portion of this Twelfth Annual Report will deal with the rather extensive basic activities, which will in the long run determine the progress gained in the applied phases.

Although it is never possible to separate clearly an application from a research program, as the years go by more and more of the findings of earlier studies are being used operationally. Such things as seed orchard

Seed orchard establishment is still a major activity of the Cooperative. Shown above is the white pine seed orchard being established for the Virginia Division of Forestry. Below is a rather unique combined seedling seed orchard and grafted seed orchard of Hiwassee Land Company in Georgia. It is a combination of grafted trees and control-pollinated seedlings from selected parents.

management, wood qualities of trees of different kinds grown under different conditions, use of disease-resistant stocks, and planting of strains or species for better production of desirable wood on marginal sites have become a part of operational activities. Despite the emphasis on use, many studies are in progress that can be classified as research which is necessary for continued improvement in the applied activities. Much of the research is done by graduate students, but an increasing part of the load is undertaken directly by cooperating organizations. This is a healthy trend and has significantly speeded up accomplishments of the Cooperative.

The greatest single research effort is expended on the Heritability Study, a joint undertaking by International Paper Company (Southlands Experiment Forest), the Cooperative Tree Improvement Program, and the National Institute of Health. Last year's report had several pages devoted to this large, intensive program.

## The Applied Program

### Yields, Volume and Weight of Dry Wood

Last year, results were presented showing volume and weight yields from the first 7.5-year-old open-pollinated progeny test plantation that was thinned. During the past year, two more plantations were thinned, and combined results from all are shown in Table 2. Each plantation was on a different site and grown at different spacings, so comparisons between plantations are not very meaningful. Of great importance, however, are the gross differences in volume growth, specific gravity and dry wood weight yields in progenies from different mother trees. Of importance, also, are the average yields of over two cords per acre per year (at 7.5 years) at an age when the stands are just beginning good volume growth. Also of interest is the variability in specific gravity from family to family, its effects on dry weight yield, and the obvious fact that the fastest growing families may have either high or low wood specific gravity.

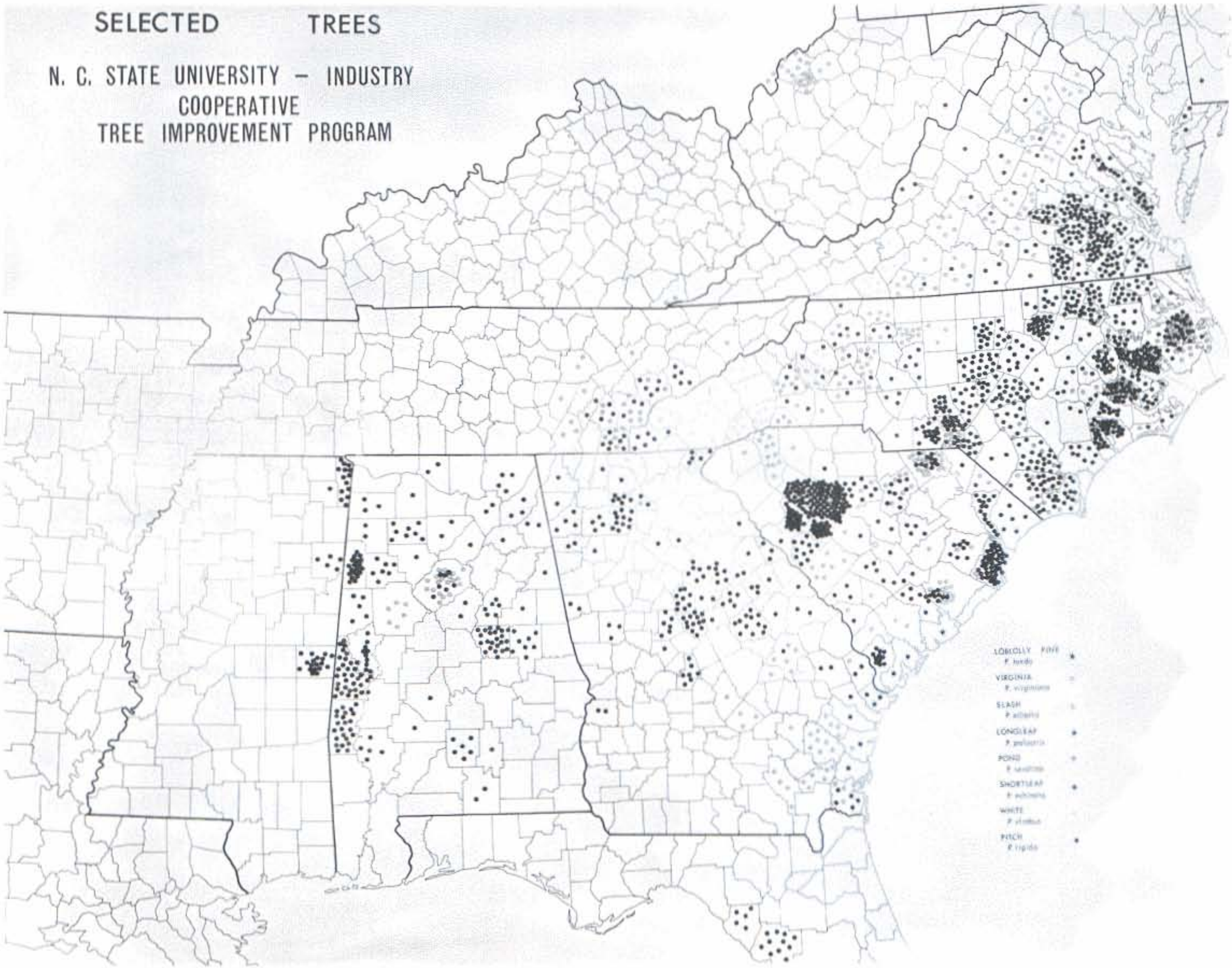
Table 2. Yields[1/] in cords per acre per year and tons per acre per year of 7.5-year-old open-pollinated loblolly pine. Parent trees are in commercial seed orchards.

| | Cords/ Ac./Yr. | Tons/Ac./Yr. (dry wood) | Av. Tree Diam. (b. h.) | Sp.Gr. (tot.bole) | Trees/ Acre |
|---|---|---|---|---|---|
| | Coastal South Carolina -- 15 Families[2/] | | | | |
| Best 2 Fam. | 2.74 | 2.56 | 4.5 | .38 | 548 |
| Poorest 2 Fam. | 1.97 | 1.79 | 4.2 | .37 | 589 |
| Av. - 15 Fam. | 2.36 | 2.22 | 4.3 | .38 | 598 |
| | Coastal South Carolina -- 16 Families | | | | |
| Best 2 Fam. | 2.42 | 2.32 | 3.9 | .38 | 831 |
| Poorest 2 Fam. | 1.83 | 1.79 | 3.4 | .39 | 827 |
| Av. - 16 Fam. | 2.13 | 2.04 | 3.7 | .39 | 807 |
| | Piedmont South Carolina -- 6 Families | | | | |
| Best 2 Fam. | 1.84 | 1.77 | 3.9 | .38 | 821 |
| Poorest 2 Fam. | 1.63 | 1.54 | 3.6 | .38 | 817 |
| Av. - 6 Fam. | 1.72 | 1.64 | 3.8 | .38 | 827 |

1/ Data from progeny tests of West Virginia Pulp and Paper Company, International Paper Company, and U. S. Plywood-Champion Papers, Inc.

2/ A family refers to trees from the same parent.

One of the most interesting phenomenon observed in the seed orchards is the clone in Albemarle Paper Company's orchard that is completely susceptible to Dioryctria sp. Every ramet is affected whether sprayed or not. Other clones in the orchard are not infected with Dioryctria.




There are now over 2,000 pine trees selected for use in cooperators' seed orchards. Their location and distribution over the Southeast is illustrated. Selections are established in over 70 seed orchards.

In an earlier annual report we summarized growth of the control-pollinated progenies from two companies at the end of the first year in the field but cautioned that such first-year results have only limited significance. We now have measured 1224 families from three species analyzed, using the computer program developed by Jim Roberds. A summary of these is shown in Table 3. Note the superiority in height of the 20% best families over the commercial checks. This amount of gain for so many families under all conditions of growth is gratifying, even if based on only two-year-old trees. Note also, however, that the poorest 20% of the families is no better than the commercial checks, indicating that some of the select trees may not be good enough to leave in the seed orchard.

Table 3. Height in feet of control-pollinated progenies compared to commercial checks after one year's growth in the field

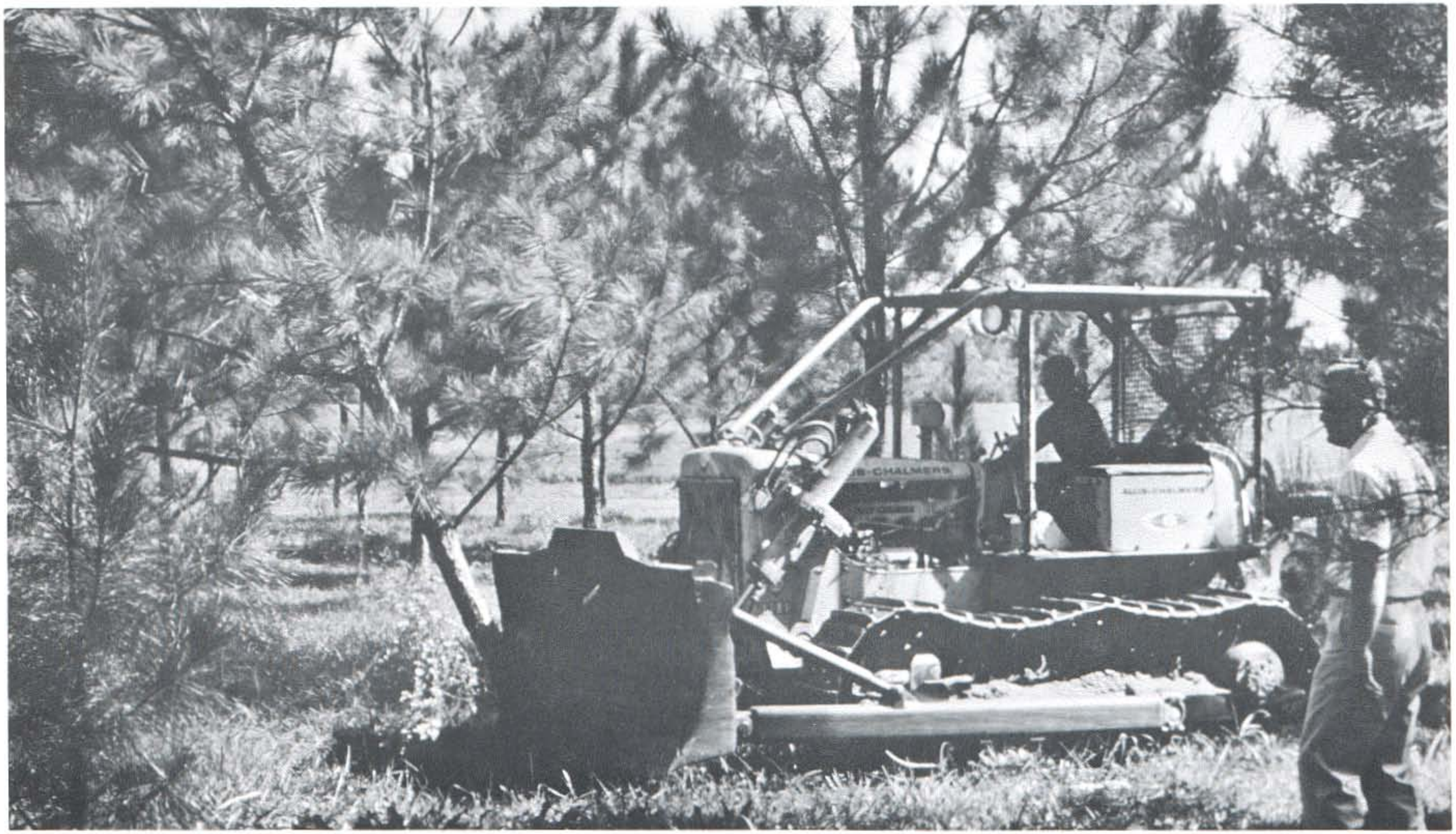
| | Number Families 1/ | Best 2/ 20% | Poorest 20% 2/ | Av./All Families | Commercial Check |
|---|---|---|---|---|---|
| Coastal Plain Loblolly | 843 | 1.65 | 1.28 | 1.43 | 1.31 |
| Piedmont Loblolly | 278 | 1.40 | 1.10 | 1.25 | 1.19 |
| Pond Pine | 69 | 1.19 | 0.94 | 1.05 | 0.88 |
| Virginia Pine | 341 | 1.37 | 1.16 | 1.25 | 0.95 |

1/ A family is represented by 6 replications of 10 trees each for three years, for a total of 180 trees of each family.

2/ Averages for approximately the best and poorest 20% of the families

This year the fourth-year measurements were taken of the control-pollinated crosses in the two oldest plantations for two companies. Both plantations were growing on wet sites and each had been damaged by tipmoth. Even then, differences between families developed, both for the fertilized and unfertilized parts of the plantation. Results are most encouraging. For both the fertilized and unfertilized tests the seed orchard material was always superior to seed production area checks. The best 10 per cent of the families were 15 to 30 per cent superior in height growth.

At Georgetown, South Carolina (see Table 4) the crosses from the seed orchard had approximately 7 per cent fusiform rust infection, while the commercial check and seed production area seedlings were infected twice as badly. One clone, 7-56, has been fondly labeled the "All American Tree." Its progeny have better growth, less disease infection and better form than those from the other clones. It combines many good properties in its progeny despite the qualities of the other parent involved. The performance of this good clone is shown in relation to the other families in Table 4.



As grafted trees begin to compete and crowns close, it is necessary to thin the orchards. Even when thinning is based on progeny test information, seed production and compatibility records, thinning is a "traumatic" experience. Shown is the very effective method of thinning used in the Kimberly-Clark orchard.

Table 4. Progeny test results -- International Paper Company Main test and supplementary fertilizer test, Height growth in feet

| Kind of Test | Crosses[1/] with 7-56 | Av./All Crosses | Comm.Check +[2/] Coastal S.P.A. | Piedmont[2/] S.P.A. | 7-51 x 7-51 (self) |
|---|---|---|---|---|---|
| Main progeny (3 reps.) (4-yr-old) | 7.9 | 7.3 | 6.9 | --- | --- |
| Supp. progeny (Good site) (4-yr-old) | 10.2 | 9.4 | 8.0 | --- | 6.2 |
| Fertilizer None (2-yr-old) | 5.8 | 5.4 | 5.1 | 3.0 | 5.3 |
| Fertilizer 5 oz/tree (2-yr-old) | 6.9 | 6.4 | 5.6 | 5.7 | 5.6 |
| Fertilizer 12 oz/tree (2-yr-old) | 6.9 | 6.0 | 5.4 | 3.5 | 4.4 |

1/ Sometimes referred to as the "All American Tree"

2/ S. P. A. is seed production area seed.

Results on the North Carolina Coastal Plain (Weyerhaeuser Company) are shown in Table 5. One area responded to fertilizer application while the other did not. The best 10 per cent of the crosses were much better than the commercial checks, both on the supplementary test areas with the best sites and on the poorer site main test areas.

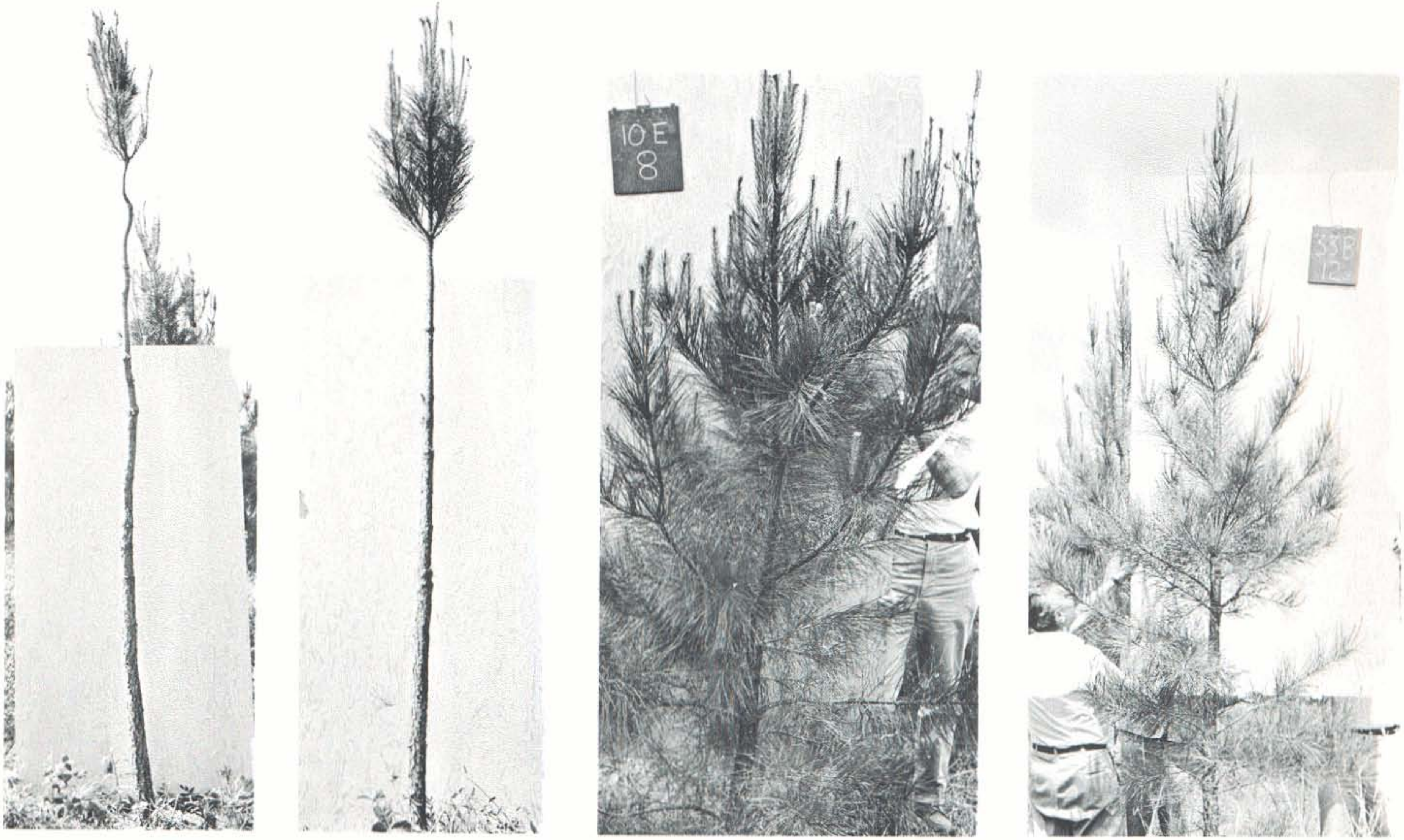
Table 5. Four-year-old progeny tests, fertilized and unfertilized, on wet sites (Weyerhaeuser Company). Trees fertilized at years one and three.

| Test | Best 10% of Crosses | Average All Crosses | Commercial Check | Seed Production Area 1/ |
|---|---|---|---|---|
| North Coastal (Main) | | | | |
| Fertilized | 7.0 | 6.1 | 5.3 | 6.3 |
| Unfertilized | 6.7 | 6.0 | 5.9 | 4.8 |
| Average | 6.8 | 6.1 | 5.6 | 5.5 |
| North Coastal (Supplementary) | | | | |
| Unfertilized | 9.4 | 8.8 | 8.3 | 9.4 |
| South Coastal (Main) | | | | |
| Fertilized | 7.1 | 6.5 | 5.9 | 5.2 |
| Unfertilized | 5.6 | 4.6 | 4.1 | 4.7 |
| Average | 6.2 | 5.6 | 5.0 | 4.9 |
| South Coastal (Supplementary) | | | | |
| Unfertilized | 10.4 | 9.7 | 9.3 | 9.2 |

1/ Seed production area from the Coastal Plain of North Carolina, the area where the progeny tests are made

Disease Resistance

Resistance to fusiform rust is outstanding. One study completed by Bro Kinloch (for Ph.D. Degree) showed some families very resistant and others nearly completely susceptible. Most striking, the resistant families maintained resistance in several quite different environments, and the susceptible families remained susceptible wherever grown. A somewhat unexpected, but most pleasing, result was his finding that seedlings of crosses from diseased x diseased parents produced 20 to 30 per cent more infection in their progenies than disease free x disease free crosses. Although very high narrow sense heritabilities were found




Over 325 acres of progeny tests have been established, consisting of nearly 3,000 separate lots. A system of progeny measurement has been developed that is simple and practical. Illustrated are Type 1 (best) and Type 6 (poorest) for crown and bole straightness measurements. A subjective rating system of this kind has proven successful.

(around 0.85), it was not expected that selection of gall-free parents would produce great gain because of the inability to detect the disease on large trees and because many diseased limbs will have been shed. Kinloch's results show that good gains will be obtained by selection through progeny testing and also that rejection of infected trees as parents in seed orchards has indeed paid off and meaningful resistance has resulted.

A major activity of the Cooperative is to utilize any disease resistance found. We know better plantations will be obtained by selection for resistance within species, by use of more resistant species such as shortleaf pine, and by hybridization (such as the loblolly x shortleaf hybrid). Resistant families can apparently be located quite successfully by means of progeny testing, even from parents from areas where the disease is not serious. For example, progeny from Weyerhaeuser's trees in the Coastal Plain of North Carolina, where fusiform rust is much less severe than farther south, showed differences in infection from 30 to 80 per cent after artificial inoculation in the greenhouse (see Table 6).

Table 6. Fusiform rust infection of some control-pollinated loblolly pine progenies from Weyerhaeuser's Coastal Plain Seed Orchard

| Cross | % Bole Infection | Cross | % Bole Infection |
|---|---|---|---|
| 8-53 x 8-76 | 31.3 | 8-33 x 8-35 | 56.3 |
| 8-7 x 8-21 | 31.8 | 8-21 x 8-33 | 57.5 |
| 8-7 x 8-46 | 36.7 | 8-29 x 8-51 | 59.1 |
| 8-33 x 8-67 | 40.2 | 8-4 (open-poll.) | 59.3 |
| 8-7 x 8-141 | 43.9 | 8-31 x 8-76 | 61.8 |
| 8-21 x 8-46 | 49.4 | 8-68 x 8-78 | 80.0 |
| 8-7 x 8-5 | 46.3 | | |

Progeny tests have yielded results better than anyone could have hoped. Shown are two-year-old loblolly pine in progeny tests of Union Camp Corporation in southern Georgia. To the left a 10-tree row plot of standard commercial seedlings is shown, and next to it, to the right, is a row of control-pollinated trees. This kind of growth at two years of age is good, and the superiority of the seed orchard selections is outstanding.

The height of two-year-old progeny test loblolly seedlings is shown by Marvin Zoerb (Union Camp). Growth on this wet, site-prepared and bedded area is very good.

Response to Fertilizers

Under most conditions, southern pines have responded well to fertilization but the economic importance of this is not always clear. In last year's annual report we noted the 10-year gain in volume of one cord per acre per year reported by Posey following heavy fertilization of 16-year-old loblolly pine. We do not have other data on fertilizer response of trees of this age but response to younger trees is obvious. In progeny tests we normally do not fertilize until the beginning of the second growing season in the field. Improved growth has been good -- for example, unfertilized control-pollinated pond pine progeny tests planted on deep peat averaged 2.30 feet in height at the end of the second year while fertilized trees averaged 3.35 feet (Table 7).

We have reported before that some families react differently to fertilizer than do others. A good example of this is shown in Table 7 for West Virginia Pulp and Paper Company's pond pine planting. The tallest family in the unfertilized plots dropped to the fourth position in the fertilized plot and the tallest family in the fertilized plot ranked number 11 in the unfertilized plot. Looked at differently (see the last two columns, Table 7), the slowest growing trees in the unfertilized plots responded the most the year after fertilization although there were exceptions. Such reversal in ranking of growth caused by fertilization is of considerable interest because the responsive families must be favored when fertilizers are used on a commercial scale in forest management.

Similar shifts in position were seen in the progeny from both the Weyerhaeuser Company and International Paper Company. Very little genotype x environment interaction is found for site differences usually found on a company's land, but very strong interaction is sometimes evident when fertilizers are used.

Table 7. Height of pond pine, two years in the field, one year following fertilization 1/

| | Unfertilized | | Fertilized | | Response to Fertilizer | |
|---|---|---|---|---|---|---|
| Cross | Ht. in Ft. | Ranking | Ht. in Ft. | Ranking | Response in Ft. 2/ | Ranking |
| 550 x 534 | 3.2 | 1 | 3.7 | 4,5 & 6 | 0.3 | 16 & 17 |
| 546 x 518 | 3.1 | 2 | 3.9 | 2 | 0.5 | 13 & 14 |
| 521 x 546 | 3.0 | 3 | 3.4 | 7 & 8 | 0.6 | 11 & 12 |
| 538 x 523 | 2.9 | 4 | 3.7 | 4,5 & 6 | 0.5 | 13 & 14 |
| 546 x 534 | 2.7 | 5 | 3.3 | 9 | 0.8 | 8 & 9 |
| 546 x 523 | 2.6 | 6 | 3.1 | 11 & 12 | 0.6 | 11 & 12 |
| 534 x 523 | 2.5 | 7 | 2.7 | 17 | 0.4 | 15 |
| 550 x 546 | 2.4 | 8,9 &10 | 3.2 | 10 | 0.8 | 8 & 9 |
| 522 x 534 | 2.4 | 8,9 &10 | 3.7 | 4,5 & 6 | 1.0 | 6 & 7 |
| 540 x 534 | 2.4 | 8,9 & 10 | 3.1 | 11 & 12 | 0.3 | 16 & 17 |
| 526 x 546 | 2.2 | 11 | 4.0 | 1 | 1.4 | 4 & 5 |
| 522 x 523 | 2.1 | 12 | 2.9 | 15 & 16 | 0.7 | 10 |
| 533 x 523 | 1.9 | 13 | 2.9 | 15 & 16 | 1.0 | 6 & 7 |
| Seed Orch. Mix | 1.8 | 14 | 3.8 | 3 | 1.5 | 2 & 3 |
| 526 x 534 | 1.6 | 15 | 3.4 | 7 & 8 | 1.7 | 1 |
| 521 x 534 | 1.5 | 16 & 17 | 3.0 | 13 & 14 | 1.5 | 2 & 3 |
| 526 x 523 | 1.5 | 16 & 17 | 3.0 | 13 & 14 | 1.4 | 4 & 5 |
| Average | 2.3 | | 3.4 | | | |

1/ Data provided by Henry Barbour, West Virginia Pulp and Paper Company Plantation on deep peat soil

2/ 1967 fertilized growth -- 1967 unfertilized growth

Shown is an eight-year-old progeny test, following thinning, on the lands of West Virginia Pulp and Paper Company. Growth has been better than 2.5 cords/acre/year at 7.5 years. Progeny tests thinned for U. S. Plywood-Champion and International Paper Company have shown good results and are summarized in the text.

Wood Properties

Wood properties such as specific gravity and tracheid length have proven to be strongly inherited. Note the variations in family specific gravities shown in Table 2. It is possible to have high gravity families that are fast growing, but it is easy to obtain low gravity families when fast growth is obtained by intensive management and fertilization. Thus, wood of very young, fast grown, fertilized pine, has many characteristics somewhat similar to hardwoods, and studies are under way to see if it can be used as a supplement to hardwoods where this kind of fiber is needed.

A whole series of studies are under way by members of the Cooperative to determine dry wood weight yields both within and between trees. As a result, local yield tables have been constructed to show tons of dry wood per acre. This information is useful for evaluating topwood and young thinnings, to determine the value of a given log for sawtimber or for pulpwood and to determine the species that should be used on a given site.

A comprehensive report on wood moisture content of southern pines was made at the TAPPI Forest Biology Committee and has been published as Technical Report No. 37. The data for this report were supplied by five companies and combined with information from other studies of the Cooperative. Information on moisture content variation among species, within trees and between geographic areas is necessary to set procurement policies. The relationship of moisture content at breast height to total tree values was remarkably good, enabling large studies to be made by limited sampling at the breast height position.

One rather detailed study on knots and knot volume was published as Technical Report No. 36, based on data from postdoctoral student Kay von

Wedel of Germany and graduate student Dr. Tony Shelbourne of New Zealand. Tree-to-tree differences were large, with knot volume varying from 0.7 to 1.4 per cent, and knot and associated compression wood varying from 6.3 to 11.5 per cent of the volume of wood in the tree (see Table 8).

Tree Selection and Seed Orchards

Selection of superior trees for inclusion in seed orchards continues to be a major activity. During the past year, 157 trees were graded to increase the total number of trees accepted for use in the Tree Improvement Program to 2047. The majority of those graded were loblolly, Virginia and longleaf pines, but selections were also made of slash, shortleaf, pond, white and pitch pines.

The distribution of the trees graded during the past year keeps the interest of this phase of the work at a high pitch. For example, within a matter of days we had the opportunity to observe variation in loblolly pine from its most northern extremity, the Eastern Shore area of Delaware, Maryland and Virginia, to its most southern extremity along the Gulf Coast in south-central Florida to south-central Mississippi. Loblolly pine is quite diverse from these different areas. For example, the beautiful stands of the Eastern Shore were characterized by wood specific gravities that approach the minimum found anywhere in the loblolly pine range, while the Florida loblolly, growing with an admixture of cabbage palm, southern sugar maple, basswood and a host of other hardwood species on a broken marl layer, has a wood specific gravity that exceeds that from any other part of the loblolly range. The Mississippi source is featured by two distinctive forms of loblolly, one of which we refer to as a green form and the other as gray. Here loblolly continues to be highly "promiscuous."

Table 8. Branch and knot characteristics of 11-year-old loblolly pines

| Tree No. | Stand Characteristics | | Tree Characteristics | | | Branch and Knot Characteristics | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Basal Area sq.ft./ acre | Number Trees/ acre | Ht. Ft. | DBH | Cu.Vol. Inside bark | Br. Diam. in. | Br. No. tot. | Br. Angle deg. | Knot Vol. %/tot. | Comp.[1/] Wood vol.% | Knot + Comp. vol. % | Ratio Knot to Comp.Wood |
| 2 | 140 | 335 | 56 | 8.3 | 8.75 | 0.66 | 157 | 57 | 0.7 | 6.9 | 7.6 | 1:8 |
| 7 | 140 | 400 | 55 | 8.3 | 7.24 | 0.74 | 129 | 57 | 1.1 | 6.3 | 7.4 | 1:7 |
| 8 | 110 | 392 | 54 | 10.2 | 11.49 | 0.83 | 153 | 54 | 1.1 | 6.1 | 7.2 | 1:6 |
| 3 | 110 | 231 | 55 | 8.0 | 7.72 | 0.85 | 106 | 52 | 0.9 | 6.8 | 7.7 | 1:8 |
| 1 | 110 | 212 | 52 | 11.2 | 13.32 | 0.86 | 133 | 45 | 1.2 | 8.5 | 9.7 | 1:7 |
| 5 | 120 | 330 | 59 | 11.2 | 15.11 | 0.90 | 140 | 69 | 0.8 | 5.5 | 6.3 | 1:8 |
| 4 | 170 | 472 | 59 | 7.9 | 7.83 | 0.93 | 111 | 50 | 1.4 | 10.1 | 11.5 | 1:7 |
| 6 | 90 | 319 | 54 | 11.2 | 13.11 | 0.99 | 119 | 56 | 1.2 | 7.0 | 8.2 | 1:6 |
| Average | 125 | 336 | 55.3 | 9.5 | 10.57 | 0.85 | 131 | 55 | 1.1 | 7.1 | 8.2 | 1:7 |

1/ Compression wood associated with knots only, and does not include the considerable amounts of compression wood in the bole between whorls

Seedlings from seed orchards have demonstrated exceptional growth and form in commercial plantings as well as in progeny tests. Shown is the division between a three-year-old plantation of seed orchard material (left) and commercial planting stock (right). The seed orchard seedlings averaged 2.6 feet superiority in height and have much better form than the commercial source seedlings.

Form and growth of trees from the orchard is illustrated for trees from the plantation illustrated above, on the lands of Kimberly-Clark Corporation in Alabama.

Several species hybrid types were recognized, and more than one was thought to be a loblolly-spruce pine hybrid although we are told that the two species are in different taxonomic groups and cannot be expected to cross.

Seed orchard establishment is also progressing at an accelerated rate. A recent survey revealed that 1299 acres of seed orchard have been established at 37 locations and that an additional 850 acres are in the process of being established (Table 9).

Table 9. Area of pine seed orchard already established and total acres planned, by species, in the Cooperative Program 1/

| Species | Established (Acres) | Total Planned (Acres) |
|---|---|---|
| Loblolly | 1021 | 1682 |
| Slash | 95 | 203 |
| Virginia | 51 | 77 |
| White | 53 | 63 |
| Longleaf | 34 | 46 |
| Pond | 28 | 34 |
| Shortleaf | 17 | 22 |
| Pitch | 0 | 5 |
| Spruce | 0 | 1 |
| Fraser fir | 0 | 4 |
| Total | 1299 | 2137 |

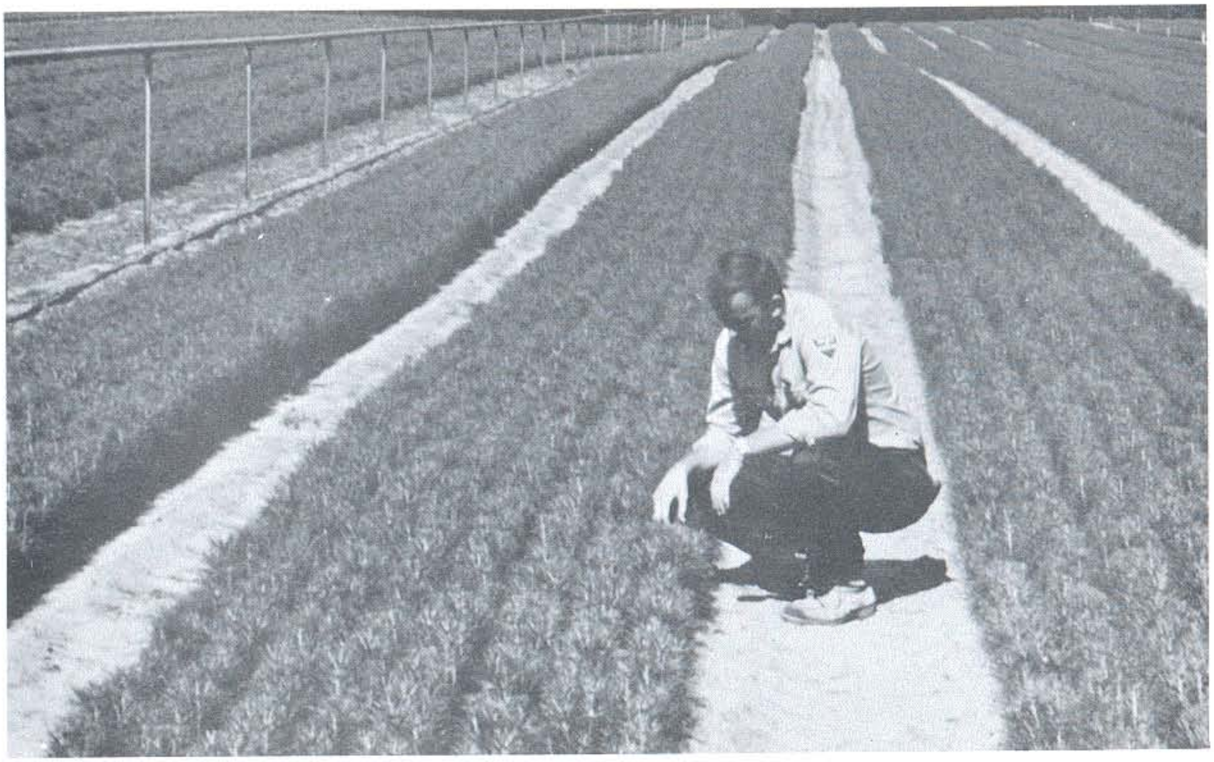
1/ Based on a spacing of 15 x 30'

Table 10. Cone and seed yields, pounds of seed per bushel and number of plants expected by species from seed orchards in the Cooperative (1967 cone crop)

| Species | Cones (Bu.) | Seed (Lbs.) | Seed (Lbs./Bu.) | Number of Plants Expected from Seed |
|---|---|---|---|---|
| Loblolly | 1648 | 2081.1 | 1.26 | 22,000,000 |
| Slash | 85 | 62.0 | 0.73 | 457,500 |
| Virginia | 59 | 34.0 | 0.60 | 1,000,000 |
| White | 0.5 | 0.25 | 0.50 | 4,500 |
| Shortleaf | 2 | 1.0 | 0.50 | 30,000 |
| Pond | 1 | 0.5 | 0.50 | 15,000 |

Many of the earlier established orchards have attained an age at which they are producing seed in commercial quantities. Enough seed was produced in 1966 to regenerate 20,000 acres during the winter of 1967-68 and it is estimated that 40,000 to 50,000 acres will be regenerated from seed obtained from seed orchards in 1967, to be outplanted in 1968-69 (see Table 10). These yields are sufficient to supply nearly all the planting needs of some of the cooperators, with the earlier established orchards. The bulk of the seed being obtained is from loblolly pine.

Unfortunately we do not expect a proportionate increase in seed yields in 1968 because of the hard freeze that damaged the loblolly flower crop to the north of South Carolina on March 24-25, 1967. The freeze followed an eight-day period of mild weather during which time the pine flowers were attaining full development. Following the freeze, Orion Peevy (Weyerhaeuser) described the situation well by noting that their loblolly pollen had taken on the consistency of dried sawdust. When



Progeny testing and commercial planting of seedlings from the seed orchards is well advanced. In 1968, approximately 20,000,000 seedlings will be produced from seed orchard seed. Shown (above) are seedlings from seed orchards for commercial planting grown in the Virginia Division of Forestry nursery for Chesapeake Corporation. Below are control-pollinated progeny in the Continental Can Company nursery used as part of the 1967 progeny tests.

pollen is damaged, cones can develop normally but most seeds will develop as "pops."

Because of the wide distribution of the seed orchards throughout the South it is expected that some major catastrophe will occur, but so far we have been extremely fortunate. As an example, an unbelievable accumulation of sleet, ice and snow pelleted the Coastal Plain and Piedmont of North and South Carolina in mid-January but, for some unknown reason, most orchards located in that area escaped with only minor breakage and none were severely damaged. Such good luck cannot continue indefinitely.

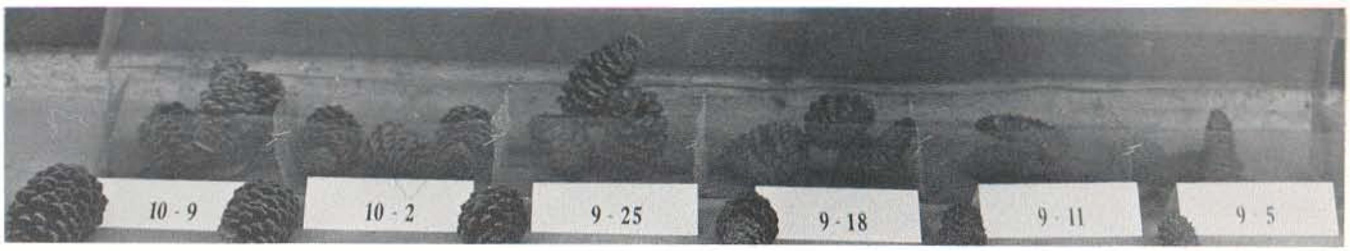
Cone and Seed Harvest

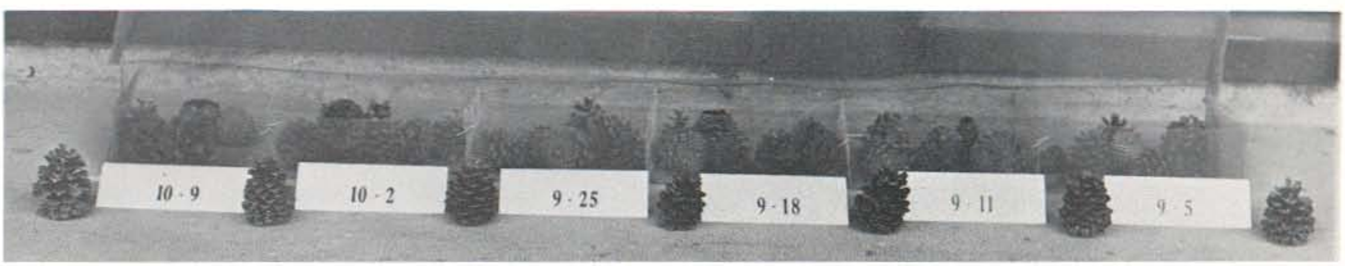
Considerable time and effort are being expended to develop methods of harvesting cones and seeds from seed orchards. The Seed Harvest Committee has been very active during the past two years. They have been responsible for the establishment of various trials that have proven to be acceptable as an interim approach, and they have presented the problem of cone harvesting to equipment dealers over much of the United States. No definitive results are available at this time but there is optimistic speculation that the problem can be solved by vacuum sweepers collecting the seed from the seed orchard following shaking of the seed from the open cones.

One study of this type has been undertaken by a number of cooperators under the lead of John Kundt of N. C. State. Cones were collected at weekly intervals, starting five weeks prior to the time of normal cone maturity, and attempts were made to mature them by various treatments.

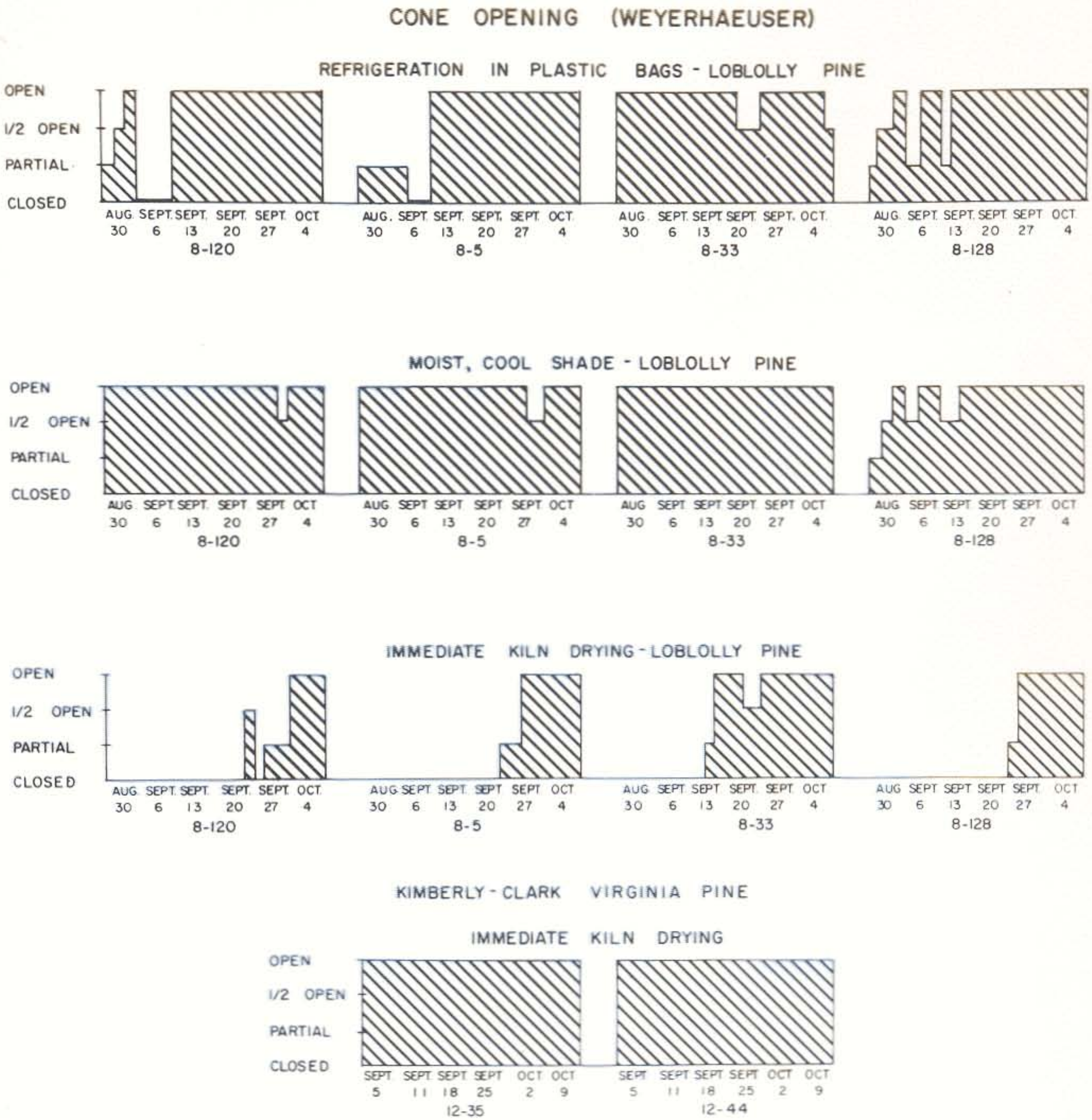
Results of cone opening indicate that the cool, moist treatment was most effective of the ten treatments tested. Response was similar for loblolly, Virginia and shortleaf pine (see graph), but Virginia pine cones


For a number of years Albemarle Paper Company has been developing a pine arboretum. It is now well established and contains over 60 species, many of which are flowering. Crosses between a number of species have been made by Ray Brown.




A concentrated effort is being made to improve cone and seed harvest methods or to lengthen the time for cone collection and seed extraction. Illustrated are loblolly cones collected at weekly intervals prior to normal opening. When kiln dried, the early collections case-hardened (top); when collected and stored under moist conditions (bottom), all cones opened normally. Tests are under way with a number of cooperators to determine the quality of seed from early collections (see graph on following page).




Cone opening of loblolly pine is shown graphically, by clone, for three treatments. Also shown is Virginia pine, which opens without treatment even after early collection.

regularly mature and open without a postharvesting treatment, even when collected five or six weeks early. The encouraging aspect of this study is that it may be possible to lengthen the cone harvesting season several weeks beyond the normal season. Tests are now under way to determine quality of seed from the cones that were harvested early.

Outplanting of control-pollinated seedlings for progeny testing continues at an accelerated pace. These tests, necessary for each orchard, require that specific crosses be made between each established clone and four or five male testers. Each cross is outplanted in test plantations for each of three different years. The first control-pollinated tests were made during the 1963-64 planting season; acreage planted through the 1966-67 planting season totaled 197 acres, made up of 1796 individual crosses for the main and supplemental tests. During 1967-68, 1147 more crosses were outplanted on 131 acres, for 40 per cent of the total crosses (2943) and acres planted (328). The crosses to be planted should continue at the present rate for the next couple of years and then will become less as entire orchards are completed. Establishment of new orchards continues to add to the testing load, but required crosses are nearing completion for several orchards and two are essentially completed.

## The Research Program

### Variation Studies

When the Cooperative started in 1956 a major objective was to find out "just what do we have to work with?" This meant studies of variation within trees, among trees, among sites, among geographic areas and between species. Considerable effort is still being expended on such activities; for example,

The effect of fertilizer is sometimes dramatic. Shown are two-year-old pond pine (West Virginia Pulp and Paper Company) growing on deep peat. The tall trees above were fertilized; the short ones below were not. (See text for results.)

Studies with both pine and hardwoods can have their value negated by many things. Shown are what is left of pine seedlings in a study of West Virginia Pulp and Paper Company after the deer had finished. Nearly every tree was reduced to a stub.

Marcelino Quijada (graduate student from Venezuela) recently completed a comprehensive study on wood (moisture, gravity, resin content) of longleaf pine growing on wet and dry sites at six locations within North Carolina. Some results of his study are summarized in Table 11.

Because of the extensive variation studies, we have attained considerable knowledge about the species on which we work. In addition to the numerous studies on loblolly and on longleaf pine, research is currently under way on variability of Virginia pine, pond pine, slash pine, and pitch pine.

Table 11. Variation in wood of longleaf pine in North Carolina 1/

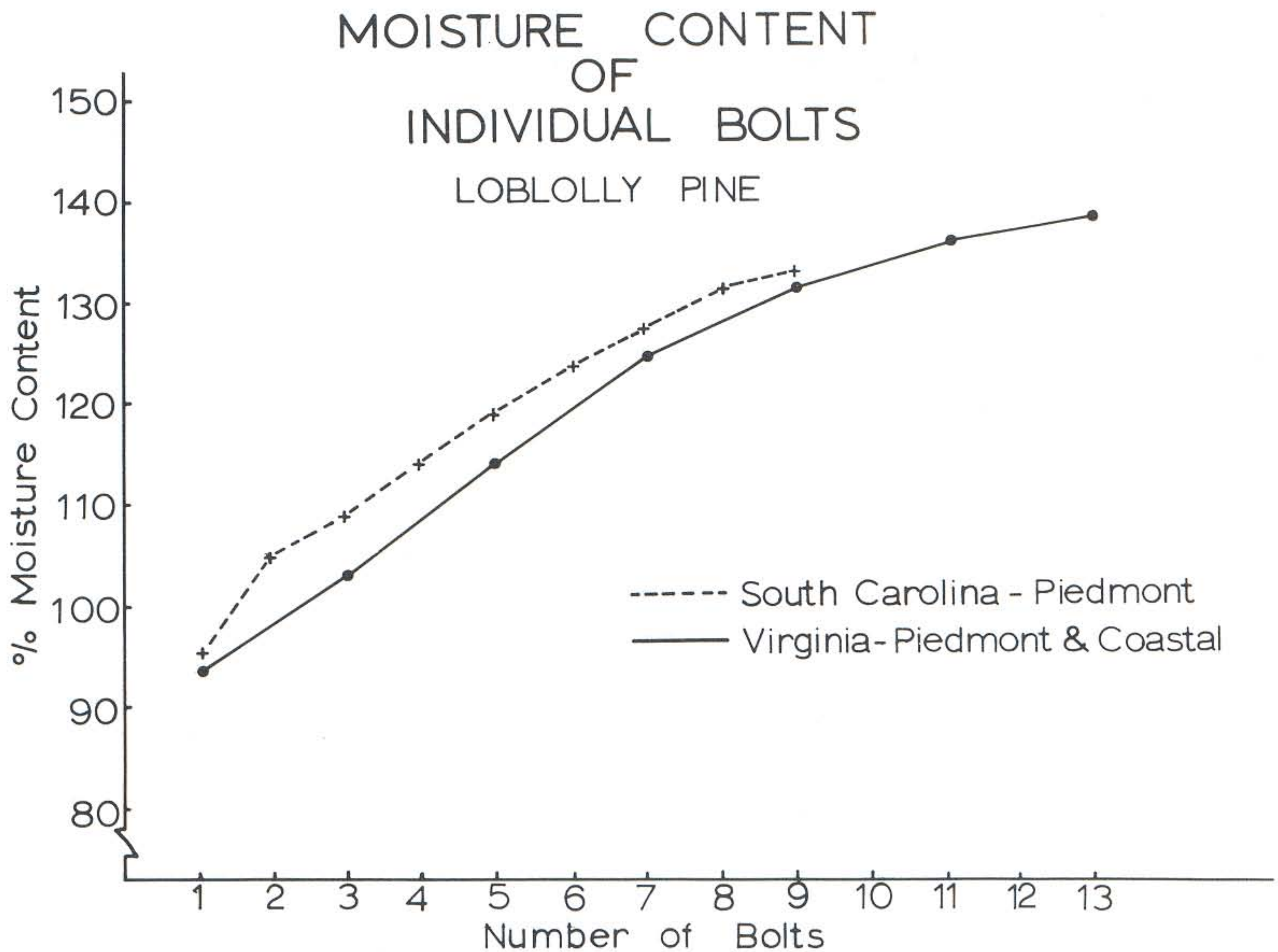
| Kind of Sample | Specific Gravity Unext. 4/ | Specific Gravity Ext. 3/ | Moisture Content 2/ | Resin Content 2/ | Number of Trees |
|---|---|---|---|---|---|
| | | | % | % | |
| Juvenile Wood: | | | | | |
| Breast Ht. - Cores | .560 | .480 | -- | 16.7 | 300 |
| Tot. Tree - Wedges | .480 | .455 | 87.2 | 6.6 | 80 |
| Mature Wood: | | | | | |
| Breast Ht. - Cores | .567 | .548 | -- | 3.5 | 300 |
| Tot. Tree - Wedges | .519 | .505 | 96.3 | 2.9 | 80 |
| Total Tree: 4/ | | | | | |
| Breast Ht. - Cores | .563 | .525 | -- | 6.1 | 300 |
| Tot. Tree - Wedges | .511 | .494 | 93.7 | 3.4 | 80 |

1/ Data from a study by Marcelino Quijada, graduate student, N. C. State University. Trees sampled were from lands of cooperators in the Tree Improvement Program.

2/ Per cent moisture based on dry wood weight

3/ Resins extracted with alcohol-benzene

4/ Weighted by the per cent of volume that is juvenile and mature wood




A great deal of information about wood has been obtained from studies by members of the Cooperative. Five companies made available information on moisture content, which was published as Technical Report No. 37. Shown is moisture content by bolt from base to top of tree for loblolly pine from two areas.

Genetic Studies

Efforts to determine inheritance patterns are so numerous we can mention only a few. Roy Stonecypher and Bruce Zobel are preparing a "Monograph" of the results from the Heritability Study, which will summarize the studies of growth rate, bole form, crown characteristics, wood qualities, disease resistance and root properties.

Additional genetic studies are under way, such as those by John Kundt (diallel crossing of Virginia pine), genotype-x-environment interaction by Jim Barker, and drought and cold resistance by Marcelino Quijada. Special mention should be made of the recently completed studies by Sam Land of differences among sources and trees to salt tolerance. It appears that some trees can stand considerably more salt (or they die less rapidly with the same amount of salt) than others. Because of the practical value this project has for plantations near the coast, Land will follow this up for his Ph.D. research.

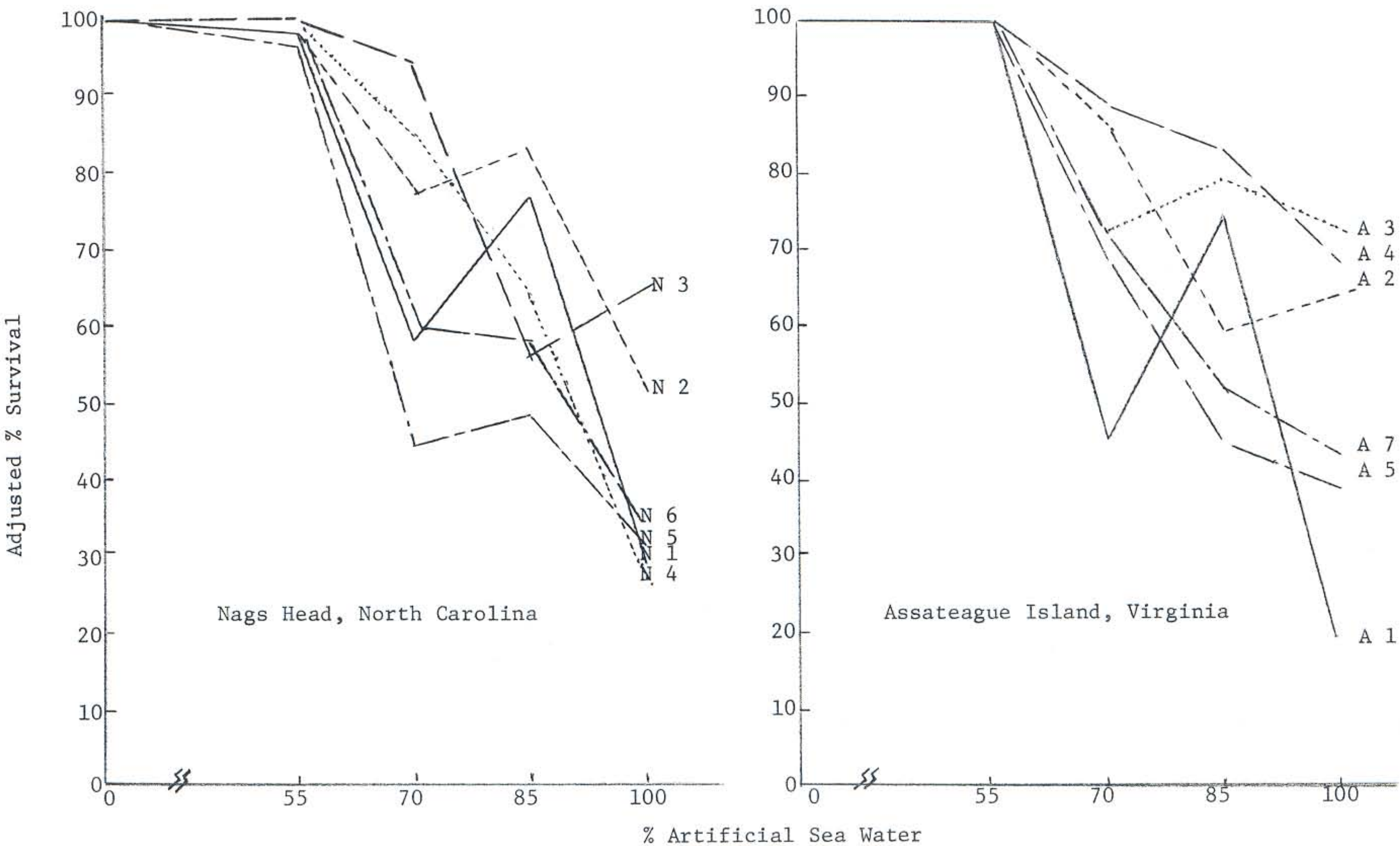
Dr. O. R. Byrne from the National University in Australia is spending a year at N. C. State doing postdoctoral research to develop use of electrophoretic methods on pines. Hopefully this will enable "fingerprinting" trees and permit more efficient and accurate population studies, hybridization studies, disease resistance studies, etc. We are anticipating this use of isoenzyme analyses on a wide scale to help "mark" the trees in which we have interest. Most interesting results are being obtained by Axel Bergman from Sweden on cone production by clones. He finds the environmental control of cone production to be considerable but age of clone and the potential of the clone for cone production to be very large. One clone was a heavy seed producer when fertilized, while another one had a relatively reduced cone production after fertilization.

The bulk of our activities revolve around improving plant breeding methods useful for forest trees; for example, Jim Roberds' thesis deals with the theory and development of more efficient progeny testing methods. We are greatly helped in this effort by Gene Namkoong, a member of the U. S. Forest Service stationed at Raleigh, who works closely with Jim and a number of the graduate students.

Several conferences and exchanges of ideas have been held during the past year. For example, Bill Libby from California and Peter Burrows from Africa met with us at Bainbridge for one week to discuss policies and methods to be used for second-generation seed orchards. As a result, our general policies for improved orchards have been determined and included as part of a chapter in the "Tree Improvement Handbook." First activities on second-generation orchards will start next year when the progeny tests have attained sufficient age.

One major effort to provide a broad base of genetic material is Ron Woessner's wide-cross loblolly pine study. With the help of a number of members of the Cooperative, Ron was able to make crosses among select trees from Texas to Virginia. These wide crosses have in turn been planted on lands of the cooperators in ten different areas throughout the South. From these, future selections will be made for trees with outstanding characteristics of growth, wood, adaptability or disease resistance to be used in the second-generation seed orchards.

Ultimately, all activities in the Tree Improvement Program will make the plant breeding activities more efficient. The progeny tests are beginning to yield information; the best source to date is the Heritability Study. We shall soon be able to determine the value of open-pollinated




Considerable individual tree variation is encountered in resistance to flooding by salt water. Shown are survivals of progeny from six different mother trees from two areas after being flooded with different concentrations of sea water for four days. Survivals are 2-1/2 months after flooding. (From thesis by Sam Land) versus control-pollinated progeny tests, to construct a selection index, and to reduce the time and effort and money associated with a seed orchard program.

Activities dealing with seed orchard management and fertilization have progressed rapidly, thanks to the help of Chuck Davey and Waldy Maki. In his studies on the Albemarle Seed Orchard, Jimmy Gregory, working under the direction of Dr. Davey, found that the number of sound seeds obtained per tree increased 18% by irrigation, 68% by fertilization, and 100% by fertilization plus irrigation. Seed quality, cone size, seeds per cone, per cent full seed and per cent germination were affected very little by fertilization, irrigation or the combination of both. He reported that individual differences among clones were very important and some clones responded positively, some negatively and some not at all to fertilization, irrigation or the combination of fertilization and irrigation. In the Union Camp seed orchard nearby, with different soils, fertilizer and irrigation had very little effect on seeds or seed production.

Population Studies

We cannot be efficient without understanding the makeup of the stands with which we work. A number of studies are geared toward this objective, such as the Heritability Study and the recently completed project by Carlyle Franklin[1/] which was designed to determine the prevalence of self-pollination in natural loblolly pine stands and to see what this means to the plant breeder. He self- and control-crossed 132 trees and found abnormal trees in 25% of the progeny from selfed trees. Per cent filled seed was very low from selfed families (14.3%) compared to 74.2% for crossed families. He estimated 2% natural self-pollination in the upper crown and

1/ Now employed by the U. S. Forest Service at Lake City, Florida

26% in the lower crown of the parent trees. Franklin summarizes part of his results as follows: "The major effect of inbreeding in a seed orchard will be reduced seed yields. Effect of quality of outplanted seed orchard seedlings will be negligible."

## Membership in the Cooperative

One new organization (Masonite Corporation) became a member of the Cooperative during the past year. They are very active and have already selected many acres of seed production areas. The seed orchard site is already located, the land cleared and a number of candidate tree selections have been made. The company is going into a massive harvesting and regeneration program of 23,000 acres a year.

Current members of the Cooperative are listed below. There are 21 separate industrial units and 3 state units operating in 13 of the southeastern states. It really keeps us hopping but we have managed to keep up the necessary services. Because of the reorganization, Bruce Zobel and Bob Kellison are seen most frequently in the field but all five faculty members are working together to service the Cooperative.

COOPERATING ORGANIZATIONS

| Organization | Working Units and States |
|---|---|
| Albemarle Paper Manufacturing Company (Roanoke Rapids Division) | N. C., Va. |
| American Can Company (Southern Woodlands Division | Ala., Miss. |
| Catawba Timber Company (Bowaters Carolina) | S. C., N. C., Va., Ga. |
| Chesapeake Corporation of Virginia | Va., Md., Del. |
| Continental Can Company, Inc. | Savannah Div. - S. C., Ga.<br>Hopewell Div. - N. C., Va. |
| Georgia Kraft Company | Ga., Ala. |
| Georgia-Pacific Corporation | Va., N. C., S. C., Ga., Fla. |
| Hammermill Paper Company | Ala. |
| Hiwassee Land Company (Bowaters Southern) | Tenn., Ga., Ala., Miss., N. C. |
| International Paper Company | Coastal Plain - S. C., N. C.<br>Piedmont - S. C., N. C. |
| Kimberly-Clark Corporation (Coosa River Division) | Ala. |
| Masonite Corporation | Miss. |
| North Carolina Division of Forestry | N. C. |
| Riegel Paper Corporation | N. C., S. C. |
| South Carolina State Commission of Forestry | S. C. |
| Tennessee River Pulp and Paper Company | Tenn., Ala., Miss. |
| U. S. Plywood-Champion Papers, Inc. | S. C., N. C., Ala., Ga., Tenn. |
| Union Camp Corporation | Savannah Div. - Ga., S. C., Ala.<br>Franklin Div. - N. C., Va. |
| Virginia Division of Forestry | Va. |
| West Virginia Pulp and Paper Company | South - N. C., S. C.<br>North - Va., West Va., Ohio |
| Weyerhaeuser Company | N. C. Div. - N. C., Va.<br>Miss.-Ala. Operations - Miss., Ala. |

STUDENT ACTIVITIES

A number of students are aided by funds from the Cooperative, and several students completed their Ph.D. studies during the past year. In the light of a pending shortage of funds, student assistantships were reduced last year but have been restored; this was made possible by the increase in contributions voted by the Advisory Committee last year. We have had a veritable "flood" of student applications for the 1968-69 school year. Seven assistantships have been granted, five of which are to work with hardwoods. In addition, several other students and two post-doctorals are expected to join us during the next school year.

Many of our students are supported by other than the N. C. State Cooperative funds. For example, one has been aided for several years by a grant from the Insect and Disease Research Council administered through the Southern Pulpwood Conservation Association. This same organization handles funds for hardwood research and we have received monies to partially support two students from this source. An additional hardwood fellowship was contributed by Union Camp Corporation. These are in addition to special monies from the National Science Foundation and the National Institute of Health. As for most other things, the assistantships for students have increased throughout the University. In those several instances when outside grants fall below the increased university level we make up the difference from the Cooperative funds.

# PUBLICATIONS

The flow of information from the Cooperative Programs becomes steadily greater every year. Some of it is put out as "bona fide" publications, *i. e.*, in some recognized national or international journal. Much of it is put out in "secondary" journals or in media such as our technical report series. The latter are used in the interest of time and more complete information. The "bona fide" journals are swamped with papers, and it often is one to two years before publication is accomplished. We feel members of the Cooperative cannot wait this long for useful information. Also, in the journals, articles must be short with only one or two illustrations or tables. We feel the graphs and tables are what members of the Cooperative can use to best advantage so beneficial ones are included in the technical reports. A case in point is our summary article on wood moisture content (Technical Report No. 37). It was not acceptable for *Tappi* -- one reason given was that one table and graph were all that was necessary to show trends. But we felt members of the Cooperative would be interested in the trends in the Coastal Plain and in the Piedmont, in natural stands and in plantations, in young stands and in older stands. Therefore, the technical report included numerous tables and graphs.

Students often prefer to publish results of their research in standard journals. In this case we summarize their results and send it to members of the Cooperative in mimeographed form. Several student studies, completed two or more years ago, still have not been officially published, although Cooperative members had immediate access to the results.

Normally we list the past year's publications with annotations. For the sake of brevity in this already long annual report we will list references only. Copies of the papers listed have been sent to each member of the Cooperative Programs.

Franklin, E. C. 1968. Artificial self-pollination and natural inbreeding in Pinus taeda L. Ph.D. Thesis, School of Forest Resources, N. C. State University, Raleigh. pp. 1-131.

Gregory, J. D. 1968. The effects of fertilization and irrigation on the flowering and seed production of two loblolly pine (Pinus taeda L.) seed orchards. M. S. Thesis, School of Forest Resources, N. C. State University, Raleigh. pp. 1-86.

Johnson, J. W. and McElwee, R. L. 1967. Geographic variation in specific gravity and three fiber characteristics of sweetgum. Proc., 9th South. Conf. on Forest Tree Impr., Knoxville, Tenn. June. pp. 50-54.

Johnson, J. W. and McElwee, R. L. 1967. Larger sweetgum seedlings are more vigorous two years after planting. Tree Planters Notes 18(4):24-27.

Kinloch, B. 1967. Genetic variation in susceptibility to fusiform rust in control- and wind-pollinated progenies of loblolly pine. Ph.D. Thesis, School of Forest Resources, N. C. State University, Raleigh. pp. 1-49.

Land, S. B. 1967. Interspecific variation in sea-water tolerance of loblolly pine (Pinus taeda L.). M. S. Thesis, School of Forest Resources, N. C. State University, Raleigh. pp. 1-97.

Quijada Rosas, M. 1967. Variation and relationships of wood characteristics of longleaf pine in North Carolina. M. S. Thesis, School of Forest Resources, N. C. State University, Raleigh. pp. 1-91.

Roberds, J. H., Zobel, B. J. and Kellison, R. C. 1967. Progeny testing in the N. C. State University-Industry Tree Improvement Program. XIV IUFRO Kongress, Vol. III, pp. 387-394.

Saylor, L. C. and Koenig, R. L. 1967. The slash-x-sand pine hybrid. Sil. Gen., 16(4):134-138.

Shelbourne, C. J. A. and Ritchie, K. 1968. Holzforschung (In press)

Shelbourne, C. J. A. and Stonecypher, R. W. 1968. The inheritance of bole straightness in young loblolly pine. Sil. Gen. (In press)

Shelbourne, C. J. A., Zobel, B. J. and Stonecypher, R. W. 1968. The inheritance of compression wood and its genetic and phenotypic correlations with six other traits in five-year-old loblolly pine. (In press)

von Wedel, K. W., Zobel, B. J. and Shelbourne, C. J. A. 1967. Knotwood in loblolly pine. Tech. Rept. No. 36, School of Forest Resources, N. C. State University, Raleigh. pp. 1-45.

Zobel, B. J. 1967. Cooperative university and industry programs. Southern Forest Tree Improvement Conference, Knoxville, Tenn.

Zobel, B. J. 1967. Mexican Pines. FAO-IPB Technical Symposium on Exploration, Utilization and Conservation of Plant Gene Resources. FAO, Rome, Sept. pp. 1-13.

Zobel, B. J. and Kellison, R. C. 1967. Southern pulpwood supply outlook clouded. Pulp and Paper 41(27):28-31. (Summary by Al Wilson of all-day symposium)

Zobel, B. J. and Kellison, R. C. 1967. Seed orchard establishment and operations and their relationship to insect problems. 12th Ann. Southern Forest Insect Conference, Charlottesville, Va.

Zobel, B. J., Matthias, M., Roberds, J. and Kellison, R. 1967. Moisture content of southern pine trees. Proc., 4th For. Biol. Conf., TAPPI, Canada. pp. 11-35. Also Tech. Rept. No. 37, School of Forest Resources, N. C. State University. pp. 1-44.

Zobel, B., Stonecypher, R. W. and Browne, C. 1967. Inheritance of spiral grain in young loblolly pine. Forest Science (In press)