SEVENTH ANNUAL REPORT

N. C. STATE - INDUSTRY

COOPERATIVE TREE IMPROVEMENT PROGRAM

School of Forestry

North Carolina State College

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INTRODUCTION

We wish that each of you could spend a week with us as we visit and do the various jobs associated with the Cooperative Tree Improvement Program. The fun, enthusiasm and satisfaction of watching it grow and develop is hard to describe to those who have not been closely associated with it. Growth of this program can be illustrated by comparing it to a young couple with their first child - the period of waiting, anticipation and development to see what has been produced; the first signs of growth when, in the eyes of the parents, every movement is a success; the first smile and sign of recognition when there is assurance that development is normal; the first achievement such as a hesitant word, when pride by the parents at this early accomplishment may be out of proportion to the actual achievement; the first few hesitant steps, when a real sense of accomplishment is felt and a real idea of future potentials can be visualized.

The N. C. State-Industry Cooperative Tree Improvement Program is in this "toddling stage," and we are proud of it and pleased with its progress. We can now see and measure considerable accomplishment, not merely speculate on what might be done. Our objectives are clearer. However, each success is tempered with the knowledge that as with the young child, here, too, we will witness many hesitant steps, stubbed toes and skinned knees. But from each bump we learn something new and thus are in a better position to proceed more efficiently.

Each year a general theme is chosen for the Annual Report; the theme for this, the Seventh Annual Report, will be to indicate progress in the mass production of improved seed, one of the major activities of the program.

PRODUCING IMPROVED SEED

One major objective of the Cooperative Tree Improvement Program is to produce seed of known origin and improved quality on a commercial scale. There may be several ways that this objective might be achieved but we have settled on the method consisting of selecting outstanding tree phenotypes, bringing them together into a vegetative seed orchard for cross pollination, testing them for genetic superiority and retaining those that produce the best progeny. This method can be compared to a "dam-sire" approach in which good parents are chosen by performance of their progeny; these good parents are then used to mass produce progeny of proven superiority. The reasoning used in this particular seed orchard approach is discussed in an article to appear in a forthcoming issue of Silvae Genetica.

Tree Selection: The major species emphasized in the N. C. State-Industry Tree Improvement Program is loblolly pine (Pinus taeda); the effort expended on this species is evident from Fig. 1 and Table 1. Selections of loblolly have been made in nearly every state in the Southeast; where appropriate, this species has been subdivided into North Coastal Plain, South Coastal Plain, Piedmont, Northern Piedmont, and deep peat sources. Some of these divisions, such as North and South Coastal Plain, are arbitrary but have been done to help synchronize flowering in the seed orchards and to ascertain that errors in selecting for growth, frost resistance, and adaptability are not made due to latitude of origin. The division between Coastal Plain and Piedmont sources is based on biological factors, and if this division is not recognized large errors may be incurred. The deep peat source is most interesting and may have very high potential for excessively wet sites. This loblolly grows with pond pine on deep peat soils that vary from five feet to more than twelve feet in depth. Surprisingly, growth rate and form of the selected trees on deep peat are excellent and they appear to be windfirm against hurricanes, although regular loblolly and slash pine often tend to fall over.

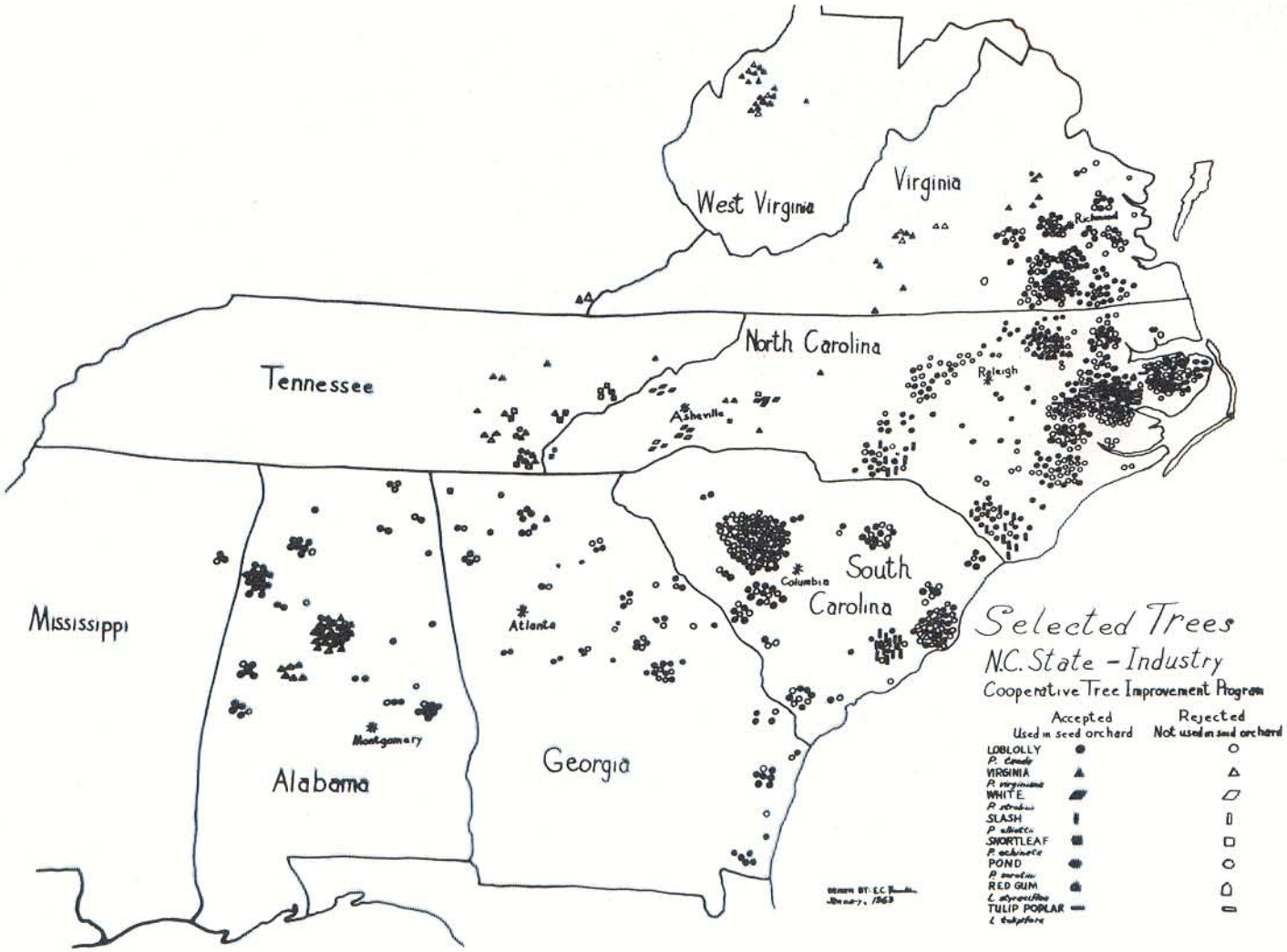

Fig. 1. Trees selected in the N. C. State-Industry Cooperative Tree Improvement Program to Feb. 1, 1963 are indicated by species. Eight species are shown but, in addition, five trees have since been selected in pitch pine (Pinus rigida). Also, preliminary selections have been made in Fraser fir but are not indicated on the map. Many of the rejected trees have had undesired wood qualities.

Considerable emphasis is being placed also on several other species of pine. One of the most important of these is Virginia pine (P. virginiana), a hardy species growing on the poorer sites and under the rigorous climates in the northern portion of the Southern Pine Region. Selections in this species have been made in seven states; all emphasis has been on Piedmont and mountain Virginia pine, with no selections having been made in the Coastal Plain. The recent increased interest in Virginia pine, usually considered a poor "scrub" species, is mainly due to: (1) the preference for its wood by certain industries making newsprint or high quality papers; and (2) the recognition that on millions of acres in portions of the Piedmont and mountainous areas this species can produce more cubic volume of desired wood on short rotations than can other pines. In the search for superior Virginia pine extending from West Virginia and Virginia to central Alabama, many fine stands have been located by the industries. The growth and form of selected Virginia pine has been striking and almost unbelievably good, as illustrated in Fig. 2.

Less intensive selection effort has been directed toward seven other tree species. One of the most interesting of these is pond pine (P. serotina), a species commonly thought to be restricted to wet sites. This restriction is by no means always true; for present purposes, pond pine sources have been divided into "mineral soil or shallow peat" types and "deap peat" types (where the layer of peat exceeds four feet in depth). Slash pine (P. elliottii) has received some attention, with selections being made in the extreme northern end of the species range and from plantations in the Sand Hills Area of the Carolinas. There have been a few superior shortleaf pine (P. echinata) chosen in Tennessee, Alabama and North Carolina; interest in this species seems to be increasing and in the future it may well play a more important role than it has in the past. Last year a number of white pine (P. strobus) were graded for the N. C. Forest Service, and preliminary plans have been completed for selections in Fraser fir (Abies

Fig. 2. Superior trees have been selected in nine tree species. The two species on which the bulk of effort has been expended are illustrated by left, a loblolly pine graded for Weyerhaeuser and, right, a Virginia pine graded for the West Virginia Pulp & Paper Company. Photos of selected trees are difficult to obtain because they are always chosen in well-stocked, dense stands.

fraseri). Even four trees of pitch pine (P. rigida) have been selected. However, the trees are for use in the hybridization program with Union Bag-Camp Paper Corporation and West Virginia Pulp and Paper Company and are not for use in a seed orchard in the usual way.

The Cooperative Program has concentrated on the pines, but during the past three years two species of hardwood have received considerable study. About 40 yellow poplar (Liriodendron tulipifera) and 30 sweetgum (Liquidambar styraciflua) have been graded in the Coastal Plain for the Weyerhaeuser Company. Some exceptionally fine trees have been found.

The tree selection phase of the entire program has progressed very well. Although the grading system in use is very exacting, most companies have organized their selection programs in such an efficient manner that more than half of the graded trees are found to be acceptable now as to growth, form, and volume. The system in use is rigorous because it involves checking and comparing the select tree against the five best "crop" trees in the general area. The object of the grader is to find, if at all possible, five check trees of the same age on similar sites that can make the graded tree appear only average. Sometimes the checks used for the frame of reference are at a considerable distance from the graded tree. Thus, the select tree must clearly surpass the best five reference crop trees, which results in the select tree's being vastly superior to the average trees in the stand. This grading system was developed with a minimum of genetic and economic information concerning the nine characteristics forming the basic criteria. We are now obtaining more and more information on inheritance patterns, but, surprisingly, only a few changes have been required over the original system. In a few more years we will have accumulated sufficient knowledge and data to develop a mathematically determined selection index, making possible a much more precise determination of the worth of a superior tree selected as a parent for any seed orchard.

Table 1. Selected Trees in the Industry-N. C. State Tree Improvement Program[1/]

State	Species	Selected Trees	Trees Established in the Seed Orchards	Trees Rejected[2/] or not yet Established
Alabama	Loblolly Pine	65	50	15
	Virginia Pine	25	22	3
Georgia	Loblolly Pine	85	59	26
	Virginia Pine	1	1	0
	Shortleaf Pine	1	0	1
	White Pine	1	0	1
Kentucky	Virginia Pine	2	1	1
Mississippi	Loblolly Pine	3	2	1
North Carolina	Loblolly Pine	293	154	139
	Virginia Pine	14	10	4
	White Pine	25	17	8
	Slash Pine	19	14	5
	Shortleaf Pine	10	7	3
	Pond Pine	36	26	10
	Red Gum	22	18	4
	Tulip Poplar	34	18	16
South Carolina	Loblolly Pine	213	118	95
	Virginia Pine	1	1	0
	Slash	12	11	1
Tennessee	Loblolly Pine	3	2	1
	Virginia Pine	16	14	2
	Shortleaf Pine	11	6	5
Virginia	Loblolly Pine	140	84	56
	Virginia Pine	27	22	5
	Pitch Pine	1	1	0
West Virginia	Virginia Pine	18	15	3
	Pitch Pine	4	0	4
	Total	1082	673	409

1/ The locations of trees selected before Feb. 1, 1963 are shown on the map, Fig. 1. Table 1 includes trees selected up to April 1, 1963.

2/ Usually rejected for wood quality or poor grade. Only those trees are graded that, in the judgment of the grader, stand a good chance of being accepted. Many trees are rejected later for inferior wood qualities (specific gravity, tracheid length in some instances), the desired qualities depending on the product objectives and wood requirements of the company.

Seed Orchard Establishment: Each organization in the Cooperative Program has its own seed orchard or orchards. There have been established already 23 orchards at different locations, comprising 40 separate units if each species in a given location is counted as one, or 56 separate units if species, wood qualities, geographic races, or any combination of these is used for distinguishing a separate orchard. Locations of the various orchards are indicated in Fig. 3.

The size and extent of the seed orchards are presented in Table 2, which lists data based upon established orchards or upon those already initiated and scheduled for completion within the next two years. In general, orchard establishment has proceeded well. Many different methods have been employed by the different organizations, but the standard procedure is the "dry side-graft" used either in field grafting or in nursery bed grafting. Steps in development of a field grafted orchard are shown in Fig. 4.

Flowering in Seed Orchards: Flowering in all the pine orchards has started earlier and has been much heavier than anticipated. It is a thrilling sight to see an orchard in which most clones are flowering, with larger grafts frequently bearing a hundred or more flowers. Sporadic flowering occurs in two-year orchards, and in most instances has become quite heavy in the fourth year. Six-year orchards are producing enough seed to qualify for commercial production on a modest scale. Generally, both male and female flowers have been plentiful in the older orchards, and the size of both the male and the female flower crops in loblolly, pond, shortleaf and Virginia pine has been gratifying, with the crop being very early and profuse, particularly in the latter three species.

In the spring of 1963 flowering was generally heavy, but there have been a few disappointments despite the fact that almost all orchards are receiving intensive care. Slash pine has not reacted well or produced many flowers. All three orchards (two in North Carolina and one in South Carolina), composed of clones of slash pine from the extreme northern end of the species range, have failed to flower early

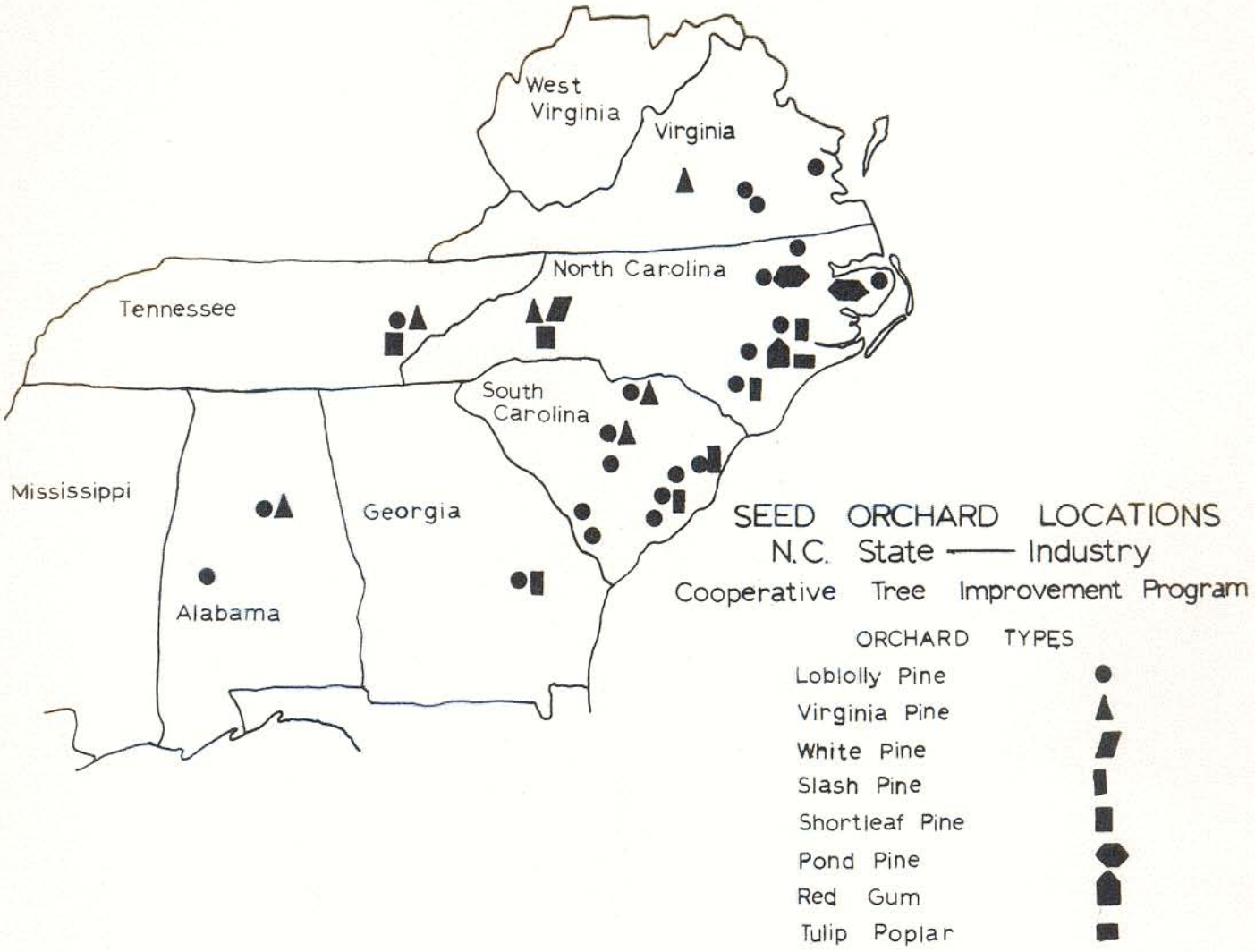

Fig. 3. Seed orchards are indicated in 23 separate locations. They include 40 orchards when separated by species alone, and actually constitute 56 separate orchards, based on location, species, wood qualities and physiographic source of the clones.

Fig. 4. Steps in establishing a seed orchard by field grafting are illustrated. The top shows stock planted in the orchard of West Virginia Pulp and Paper Company, ready for grafting. The next photo illustrates field grafting in the orchard of the Kimberly-Clark Corporation in Alabama, where in this case a polyethylene cover is used under a kraft bag. The lower photograph shows the same orchard two years after grafting.

Table 2. Seed Orchards in the Industry-N. C. State Tree Improvement Program[1/]

Species	State Where Established	Acres of Seed Orchard[2/]		Number of Grafts		Number of Clones	
Loblolly Pine (Coastal Plain)	Alabama	15		3,000		20	
	Georgia	21		3,250		34	
	North Carolina	176		22,400		171	
	South Carolina	73		10,750		59	
	Virginia	28		1,400		21	
Total			313		40,800		305
Loblolly Pine (Piedmont and Mountain)	Alabama	30		6,000		21	
	North Carolina	100		12,600		206	
	South Carolina	35		6,000		101	
	Tennessee	22		4,400		44	
	Virginia	28		1,500		23	
Total			215		30,500		395
Virginia Pine	Alabama	20		4,000		22	
	North Carolina	6		1,200		15	
	South Carolina	3		600		15	
	Virginia	2		400		19	
	Tennessee	12		2,400		25	
Total			43		8,600		96
Slash Pine	North Carolina	30		4,000		35	
	South Carolina	10		500		12	
Total			40		4,500		47
Shortleaf Pine	Alabama	15		3,000		15	
	North Carolina	5		1,200		15	
	Tennessee	3		600		15	
Total			23		4,800		45
Pond Pine	North Carolina		7		1,400		31
White Pine	North Carolina		20		4,000		30
Yellow Poplar	North Carolina		10		800		18
Sweetgum	North Carolina		8		600		18
Grand Total			679		96,400		985

1/ Already established or to be completed by June, 1964.

2/ Most are established at a spacing of 15' x 15' or 15' x 30', although several orchards are 30' x 30' or 20' x 20'.

or consistently. Likewise, one older loblolly orchard situated on an excellent site in Tennessee has been slow, although the 1963 female flower crop is much better than in previous years. An intensive trial has been initiated in an effort to increase flowering by pruning and fertilizing. Even in orchards where flowering is generally good certain clones have "stubbornly" refused to flower. Earliness and heaviness of flowering certainly are clonal in nature (Fig. 5).

Progeny Testing Superior Trees: Progeny testing has been of two kinds. Early in the establishment of some of the orchards, open-pollinated progeny were obtained from the select trees and from the five best trees (checks) in the stand. The objective here was to determine if the open-pollinated progeny from the select trees were as good in growth and better in form and wood qualities than the progeny from the five best trees against which they were being compared. After three to five years, growth rates have been quite similar, with height growth of progeny from the select tree being superior to that of the five "checks" more often than expected. Sometimes the difference between the select trees and commercial checks has been spectacular, the superiority of the select tree progeny over the commercial checks being particularly striking. In this report no data on the observed differences are given but will be worked up as soon as enough measurements are obtained from five-year-old progeny. Approximately 100 acres of open-pollinated progeny tests have been planted in 11 locations by 11 companies, using a simple block design with four replications of 25-tree plots. Growth of open-pollinated progeny is illustrated in Fig. 6, a planting on lands of the West Virginia Pulp & Paper Company.

This spring the first control-pollinated progeny tests have been sown into nursery beds; one company is seeding 50 crosses, another, 16 crosses. Planting this first year is a mere trickle but next year will see many more, and two years from now there will be a veritable flood of seed because this spring's heavy flower crop enabled the making of many crosses. With the clones now selected,

Fig. 5. Nearly all orchards have flowered more profusely and earlier than expected. The top photo shows a single branch tip of loblolly pine with five flowers in the orchard of Chesapeake Corporation. The middle photo shows a young orchard of loblolly pine in South Carolina (Champion Papers, Inc.) flowering very heavily. The bottom picture shows "yearling" and nearly mature cones as well as mature cones on a heavy flowering clone of loblolly pine in the orchard of the International Paper Company, Georgetown, S. C.

Fig. 6. Selections in the seed orchard are checked for genetic value by open- and control-pollinated progeny tests. The plantation in the background is a fast-growing four-year-old progeny test of open-pollinated loblolly pine on lands of the West Virginia Pulp and Paper Company.

present plans call for over 1000 acres of control-pollinated tests to be planted within the next five years to determine the genetic worth of the clones in the seed orchards (Fig. 7).

The control-pollinated tests are so designed (by use of a 4-tester system) that an estimation of the general combining ability of all the clones in each orchard will be obtained plus an estimate of specific combining ability for 50 to 100 crosses in each seed orchard. The progeny tests will be established on lands typical for the individual companies. A standard design has been worked out in such a way that supplementary tests can be added with no difficulty. For example, Weyerhaeuser Company is going to duplicate plantings on mineral soil and organic soil; the mineral soil tests will be made both by seedling plantations and by direct seeding. The International Paper Company is making duplicate plantings in South Carolina and Georgia, while Champion Papers, Inc. plans to make duplicate plantings on the same site, one under current site preparation conditions, the other under management practices much more intensive than currently being used. Several companies are considering having supplementary progeny tests to assess reaction to fertilizers.

It is our hope that we can report results as encouraging as those in the 1962 Queensland, Australia, Annual Report, where it is stated: "A number of intensive assessments of progenies of trees (of slash pine) chosen as superior phenotypes were conducted. The best crosses have given 30% more volume than routine stock at age 10 years from planting and also show a substantial superiority in stem straightness."

Graft Incompatibility: Certain clones are incompatible; i. e., from one to four years following grafting a swelling, locally called a saddle swelling, appears above the graft union, and the grafted plant subsequently dies within a few months or a year (Fig. 8). Usually the death of the graft is preceded by death of the

Fig. 7. Progeny testing is a most important part of the Tree Improvement Program. It is expensive and time-consuming, requiring access to nursery facilities. The bed of seedlings illustrated is for progeny testing. These seedlings are produced by the Riegel Paper Corporation and by the Hiwassee Land Company (Bowaters Southern Paper Corporation) for other members of the cooperative program. It is such fine cooperation among members of the Tree Improvement Program that makes possible the large operation and success of the Tree Improvement Program.

Fig. 8. Graft incompatibility has been a source of difficulty and frustration in the vegetative seed orchards. This saddle overgrowth is on a four-year-old graft of the Kimberly-Clark Corporation. The tree died a few months later. About 10% of the 985 clones used in the Cooperative Program show some degree of incompatibility, from 10% to 100%.

root, which appear to be starved for nutrients. In loblolly pine, on the average, about one of every ten clones shows this incompatibility. The ratio appears higher in slash pine and lower in both Virginia pine and pond pine. Incompatibility is strictly clonal, some clones being 100% incompatible, others only 10%, while fortunately most clones exhibit no incompatibility whatsoever. We do not know its cause or its cure, although several things have been tried to overcome it. Special pruning has prolonged the life of some incompatible trees. Grafting on other species for rootstock, especially to pond or slash pine, has been tried and early indications seem hopeful; however, these interspecies grafts (oldest three years) have not been growing long enough to provide a critical assessment of their value. A number of companies have tried combining scion material and rootstock that were obtained from the same tree, hoping that this relationship between stock and scion might help overcome the incompatibility. As with the interspecific grafts, these trials have not been in progress long enough to provide a reliable measure of the effectiveness of this approach. Incompatibility is one of the most severe and aggravating problems in seed orchard management, especially when it appears that the best trees exhibit the highest degree of incompatibility, an observation that, as yet, is unproved (or lacks a factual basis).

Disease: When grading, all diseased trees are rejected and are never knowingly used as superior trees. Over-all, disease on the grafts has been a very minor problem; for example, out of the approximately 100,000 grafts made, only a few (less than 10) clones have shown Cronartium fusiforme in the graft, and in each instance not more than one or two ramets of these clones have been infected. But fusiform rust must be listed as one of the most severe problems because of the high infection of the rootstocks on which the grafts have been made (Fig. 9). In some orchards over 25% of the rootstocks have turned up with stem cankers, even though the seedlings used for understock were carefully selected as being visibly disease-free.

Fig. 9. The grafts have been essentially disease-free, but great loss has occurred from diseased rootstocks. Out of nearly 100,000 grafts, less than a dozen have had Cronartium fusiforme on the graft itself, but some orchards have had heavy infection on the rootstock on which the graft was made, as illustrated by this photograph in the orchard on Union Bag-Camp Paper Corporation. Some ingenious methods have been used to arrest the growth or to excise the canker, and some have proved quite successful.

Where deep planting of field grafts occurred, development of cankers was concealed; and in many instances where a four- or five-year-old graft died, excavation revealed a large canker below ground level. This delayed discovery is very frustrating.

A number of ingenious methods have been tried to control or arrest the development of stem cankers of Cronartium fusiforme on infected rootstocks, and some of these methods have been quite successful. In many instances simply excising the diseased area has resulted in saving the graft, permitting the tree to grow normally and the wound to heal over. Many hundreds of grafts have been saved in this manner.

Fomes annosus infection is a real and constant danger in the seed orchards. So far, it has been found in two trees in each of two orchards, and intensive control measures have been applied (Fig. 10). Prevalence and fear of annosus root rot in our southern pine has necessitated revision of earlier methods of seed orchard management. For example, all surplus seedlings or dead trees are now pulled out instead of being cut off. Any pruning now done is treated with a saturated solution of borax, currently the best known preventative of Fomes annosus infection. Much research is being initiated on this disease, so new and improved control methods should be forthcoming.

Seed Orchard Management: The many different management practices in use are too numerous to cite here. It is sufficient to say that each organization has developed very effective methods peculiar to its own needs. The requirements for mowers, spray outfits, climbing equipment and the like, have produced a whole series of ingenious designs, suitable and successful, as one would expect from a large number of practical-minded, mechanically-inclined foresters. This phase of the seed orchard problem has depended on the ingenuity and inventiveness of the men in charge, with very satisfying (and sometimes startling) results (see Figs. 11 and 12). Spraying and spray schedules continue to be a major problem and surely one of the most costly of seed orchard management operations. Systemics have been tried extensively, but as yet they have not proven highly successful.

Fig. 10. When one works intensively with a species, many troubles are encountered that formerly were not recognized as being important. Fomes annosus infection in the seed orchard has been one of these. Such infection has occurred only in two orchards, entrance of the pathogen being obtained by means of stumps of small trees left near the graft. Illustrated is one of the two Fomes infected trees found in the Hiwassee Land Company orchard. Early removal and vigorous control measures such as treatment of the infected area with methyl bromide makes it appear that control has been achieved.

Fig. 11. Each organization has solved in its own way the problem of getting control-pollination done in the orchard. Everything from ladders to platforms on wheels to the mechanized equipment shown has been used. The top picture with the ladder on the front-end loading tractor is used by West Virginia Pulp and Paper Company, while the bottom one has been adapted for use on a bombardier by the Weyerhaeuser Company. The inset is a cheap, easily movable ladder used by the women control-pollinating for the Chesapeake Corporation.

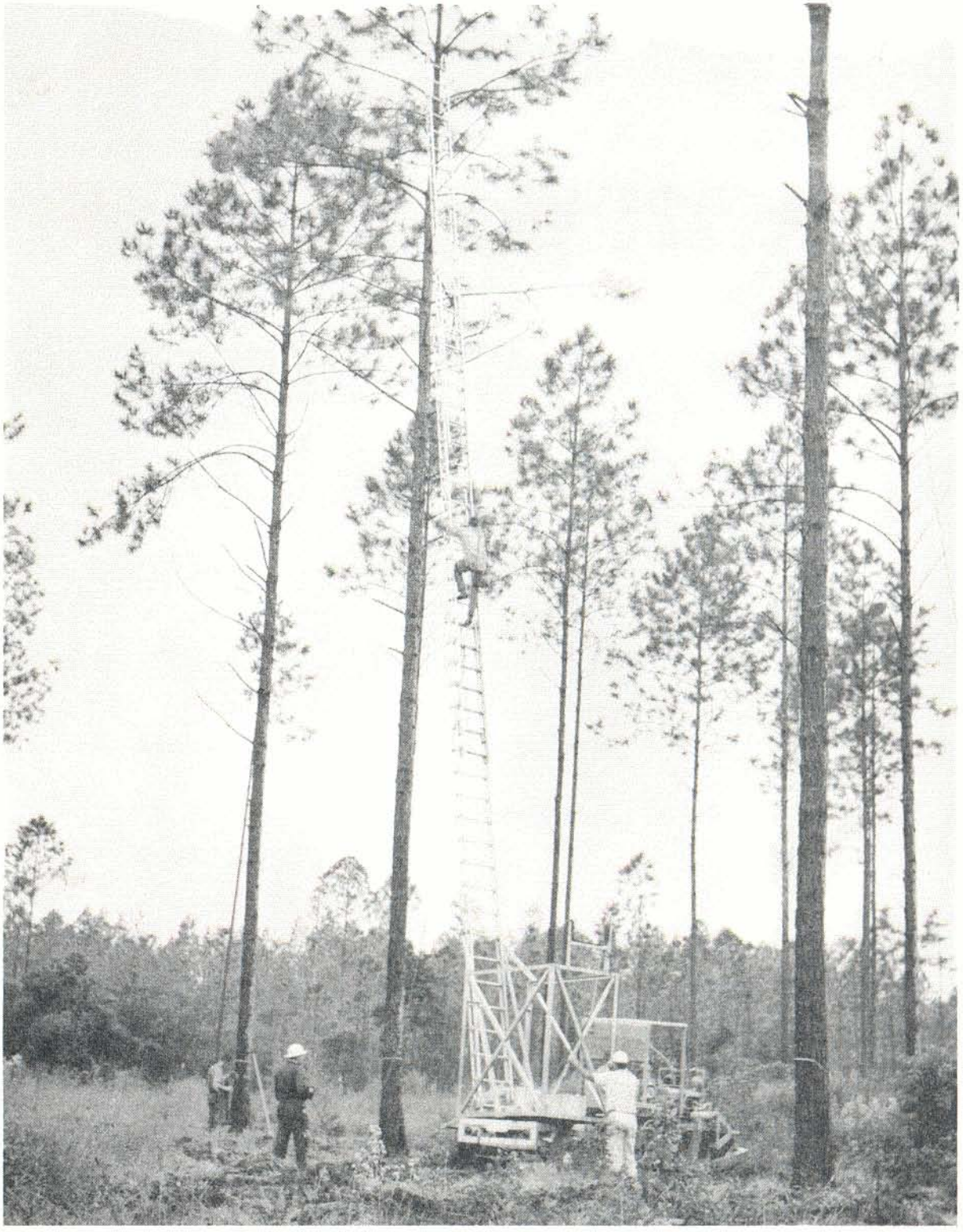

Fig. 12. A trailer-mounted ladder to climb large trees, such as those in a seed production area, was developed at Southland Experiment Forest of the International Paper Company. This ladder was used to make the bulk of the crosses necessary in the large pine heritability project.

Physical Damage to Seed Orchards: Of the many hazards to seed orchards, among the most serious are violent winds, ice and snow. Hurricanes have struck several orchards but, fortunately, in field-grafted trees the damage has been minor. Ice has caused more trouble, especially during the past two years. Several orchards were literally flattened this year; initially, the worst-appearing was the Albemarle Paper Company orchard at Tillery, North Carolina, but it has made remarkable recovery and is now flowering heavily. In the Chesapeake orchard near West Point, Virginia records have been kept of ice damage by clones, revealing some very striking results; certain clones have been damaged by ice every year, while others show no signs of injury. Similar clonal resistance to ice was obvious in the West Virginia orchard and the International orchard, both near Georgetown, South Carolina. Damage was particularly heavy in both orchards and many cones were lost (Fig. 13). However, in a year's time recovery has been phenomenal, considering the battered appearance of the orchard shortly after the storm. This destructive agency is one that we don't know yet how to control. Most discouraging in some respects, perhaps, the worst damage so far has occurred in orchards assumed far enough south to escape ice, but unusual storms have occurred and really caused havoc.

Seed Production Areas: Nearly every company in the Cooperative Program has established seed production areas, and several currently depend on them for the bulk of their seed. Practically everyone operating such areas reports good seed yields; the one exception is an area hit very hard by cone moths this year. Yields of as much as 1.25 to 1.75 lbs. of seed per bushel of cones are not rare, and seed of high viability have been secured. One major contribution of the seed production area is to provide a source of seed of known geographic source. Although the amount or extent of genetic improvement from such areas is largely unknown, a recent Journal of Forestry article on growth of progeny from a seed production area of West Virginia Pulp and Paper Company reports significant improvement in height

Fig. 13. Many hazards beset the seed orchards, not the least of which is ice. The orchard of Albemarle Paper Company was knocked "flat" by ice this year but has recovered and is bearing a heavy crop of flowers. The Chesapeake Corporation of Virginia has had its orchard hit for two consecutive years and reports damage as strictly clonal, extensive on some, none on others. The research orchard of the West Virginia Pulp & Paper Company was severely damaged last year, as was that of the nearby International Paper Company. Young grafts recovered, while older grafts (inset) were often severely damaged.

growth and, consequently, volume yields over commercial lots in a five-year plantation.

Costs and yields of seed from seed production areas have been published in the past; for example, those by L. T. Easley, West Virginia Pulp and Paper Company. In Georgia several companies have certified seed production areas. A report on this was published by Don Cole, Continental Can Company, in the February, 1962 Forest Farmer. Other companies have kept detailed records that should become available soon.

STUDIES UNDER WAY

The Sixth Annual Report summarized the many studies under way in the N. C. State-Industry Cooperative Tree Improvement Program; this listing will not be repeated here, but it seems relevant to briefly review several of the larger studies.

Heritability Project: This series of studies is the largest and most basic of those done in the Cooperative Program. They were made possible through a National Science Foundation grant, coupled with special and close cooperation of the International Paper Company and use of their Southland Experiment Forest. All crosses have now been completed, with nearly 260 parent trees being used. Approximately 50 acres of open-pollinated progeny are now nearly head high, and the first control crosses of male groups were outplanted this spring. Additional male groups were sown in the nursery bed this spring, and the last of the nearly 60 male groups will be planted next year, making a total of nearly 35 acres of control-pollinated progeny tests. Real differences are already evident in the seedbed (Fig. 14). In addition, special studies on root form, wood qualities and disease resistance have been established, requiring a tremendous expenditure of time by Dr. Cech at the Southland Experiment Forest, as well as by three technicians and three graduate students. Definitive results are already emerging; the first paper outlining results will be presented by Roy Stonecypher and Dr. Franklin Cech in November, 1963.

Fig. 14. The large heritability study, possible with funds from a National Science Grant and with full cooperation of the Southland Experiment Forest (International Paper Company), Bainbridge, Georgia, is nearly two years ahead of schedule. First published results will soon be available. Note the difference in appearance of progeny of different crosses in the nursery beds.

Hybridization Program: Two years ago a program of directed hybridization was started with Union Bag-Camp Paper Corporation to produce trees suitable for problem areas on company lands. A number of crosses have been made and the first seed will be harvested this fall. For example, in the spring of 1963, Union Bag-Camp reports having made 305 "successful" hybrid pollinations in their seed orchards, while another 105 were made on parent trees. On the parent trees in the field similar crosses were made last year by this company, and other crosses were made at Raleigh and in the seed orchard of the West Virginia Pulp and Paper Company. These crosses combine various combinations of slash pine, sand pine, pond pine, longleaf pine, Virginia pine and pitch pine. West Virginia Pulp and Paper Company has cooperated in this hybridization program, making crosses and selecting trees for crosses of special interest to them. Recently, McElwee graded a total of five pitch pine in the Virginia-West Virginia area to obtain pollen and flowers for crosses in this program, making this operation probably the first instance of grading of this species in the South. Other companies have indicated interest in the potentials of producing selected hybrids for specific problem areas or products.

Breeding Arboreta: Two breeding arboreta have been established, one by the Albemarle Paper Company in northern North Carolina at Tillery, and one by N. C. State near Raleigh. Dr. Hofmann with Albemarle and Dr. Saylor from N. C. State are cooperating on these arboreta and have obtained seed of many pine species, approximately 60 of which have already been established at Tillery. The exotics underwent the "acid test" the past cold winter. Seven or eight species froze, including several of the Mexican pines, but several species not expected to survive surprisingly came through the winter with minor injury or none at all. Dr. Saylor is using these arboreta as a "living herbarium" in which he studies the chromosomes on roots and then outplants the trees from which the roots were obtained in the arboretum. Dr. Hofmann reports that already pollen and female flowers are present in the

Tillery arboretum on at least P. thunbergii, P. densiflora, P. pungens, P. virginiana, P. banksiana, P. murrybanksiana and P. massoniana.

Core Wood - Spacing - Age Study: The International Paper Company at Georgetown, South Carolina is collecting wood samples at 4.5' above ground from stands of loblolly pine of different ages, spacings and site indices. In addition, enough trees are felled and completely sampled to obtain regression equations of breast height specific gravity to total tree values. Specific gravity of the first ten rings from the tree center and specific gravity of the remaining rings is determined. This study will enable a determination of wood qualities and wood weight yields of stands of various ages and spacings. Seed will be obtained from those trees found to have very high or very low specific gravities in the core wood (juvenile wood) near the center of the tree, to determine how strongly this character is inherited and whether it will be possible to produce a "strain" of trees with wood better than the usual core (juvenile) wood characteristics.

THE MEXICAN TRIP

Details of the Mexican pine seed collection trip will be covered in a forthcoming publication by the participants. The trip was made by Jim Hill (Bowaters), Don Cole (Continental Can), Ed Hinkle (Union Bag-Camp), Vernon Knight (Kimberly-Clark), Bud Saylor (N. C. State), and Bob McElwee (N. C. State). Champion Papers, Inc. and West Virginia Pulp and Paper Company contributed financial aid for the trip but did not send men. Over-all, the trip was very successful. The collection teams reported excellent cooperation from the Mexican foresters, obtaining seed from 17 pine species represented by 117 individual trees (Fig. 15).

In addition to seed and foliage specimens, wood specimens were obtained for each tree. Preliminary observations indicate wood quality to be extremely variable. Although final analyses of the wood will not be completed for some time, species

Fig. 15. Pinus montezumae is one of the fine species of pines in Mexico. Collections were made from this tree, 80 feet tall, 16.4 inches in diameter, growing at 8,000 feet elevation in Puebla, Mexico. Seed, foliage and wood specimens were obtained by the two collection teams from 117 trees representing 17 species.

averages of extractive-free wood for specific gravity are shown in Table 3. Each specific gravity represents an average of five or more trees. Individual tree variation within species was large; for example, one P. michoacana cornutu tree averaged 0.59 in specific gravity, while another in the same stand averaged only 0.42. Another point of special note is the difference of trees of the same species when grown in different areas. For example, five trees of P. montezumae in Puebla averaged 0.47 in specific gravity, while another stand of five trees of this same species in Michoacan averaged only 0.41. Wood within this one species would be quite different from the two areas. Differences among species were striking; for example, P. hartweggii averaged 0.36 while P. michoacana averaged 0.54. This difference in wood weight amounts to over 1600 lbs. per cord, green weight, assuming a 100% moisture content. The wood of the Mexican pines varies from soft, "cheesy" and brittle wood to hard, strong wood. The color differences are outstanding, and it is expected that other characteristics will also show marked variation.

RESEARCH AND GRADUATE STUDENT PROGRAM

Research continues on many phases dealing with tree improvement, mainly by studies of graduate students. The graduate program remains large but more turnover is taking place as an "all-age stand" of students develops, with a more normal distribution of old and new students. Currently, seven assistantships are made possible by industry and National Science funds. There are now approximately 15 Ph. D. students either working directly with the Tree Improvement Program or on programs closely related to it.

Four students completed, or nearly completed, their studies during the year and have been employed in tree improvement. One of these, Dr. Floyd Goggans, made an intensive study on the inheritance of tracheid characteristics of loblolly pine, publishing the results in Technical Report No. 14 of the N. C. S. Forestry School

Table 3 - Specific Gravity of Twelve Species of Mexican Pines, by Species and State. Each figure represents an average of five or more trees taken in a single stand.

Species	State	Specific Gravity 1/ Rings 0-10	Rings 11-20	Rings 21-30	Rings 31-40	Ave. 2/
P. montezumae	Puebla	.39	.43	.47	.48	.44
"	Puebla	.44	.45	.47	.50	.47
"	Michoacan	.38	.40	.42	.45	.41
"	Mexico	.39	.44	.43	.44	.43
	Average	.40	.43	.45	.47	.44
P. patula	Tlaxcala	.39	.41	.45	.48	.43
"	Puebla	.39	.41	.47	.48	.44
	Average	.39	.41	.46	.48	.44
P. rudis	Tlaxcala	.34	.36	.39	.40	.37
P. hartweggii	Mexico	.34	.34	.37	.39	.36
P. pseudostrobus	Puebla	.39	.44	.47	.49	.45
"	Michoacan	.41	.47	.49	-	.46
	Average	.40	.46	.48	.49	.46
P. lawsoni	Michoacan	.49	.48	.49	.45	.48
"	Michoacan	.51	.53	.55	.55	.53
	Average	.50	.51	.52	.50	.51
P. oocarpa	Michoacan	.54	.52	.53	.51	.53
"	Michoacan	.44	.47	.46	.43	.45
	Average	.49	.50	.49	.48	.49
P. leiophylla	Durango, Jalisco, Michoacan	.36	.41	.44	.40	.40
"	Puebla	.38	.42	.44	.45	.42
	Average	.37	.42	.44	.43	.41
P. tenuifolia or pseudostrobus	Michoacan	.38	.44	.47	.50	.45
P. tenuifolia	Michoacan	.42	.42	.45	.45	.44
P. michoacana	Michoacan	.54	.56	.53	.52	.54
P. michoacana	Jalisco	.39	.43	.46	-	.42
var. cornutu	Michoacan	.43	.47	.53	.54	.49
"	Michoacan	.44	.47	.49	.45	.46
	Average	.42	.46	.49	.50	.47
P. teocote	Puebla	.44	.49	.50	.53	.49
"	Tlaxcala	.42	.46	.51	.53	.48
	Average	.43	.48	.51	.53	.49

1/ Specific gravity at 4.5 feet above ground, based on two large (11 mm.) increment cores per tree taken 180° from each other. Specific gravity is on extractive free wood.

2/ This average is a straight, non-weighted one, to be used as a guide only.

series. Floyd has continued his research in tree improvement upon his rejoining the Faculty at Auburn University. Mr. Charles Webb has nearly completed his Ph. D. thesis on variation of wood properties in sweet gum. Charlie has obtained some very interesting trends and relationships on specific gravity, tracheid characteristics, vessel characteristics and interlocked grain on trees he sampled from Florida to Virginia. He is now employed by the U. S. Forest Service at Macon, Georgia. Mr. Fred Taylor is in a similar situation, having worked on variation and interrelationships in wood of yellow poplar. Fred is now on the Faculty of the University of Missouri, and will complete his thesis soon. Mr. Thomas Conkle completed his Master of Science degree and has gone to California to work and to continue his studies. Tom's thesis on analysis of plot size and efficiency has been published as N. C. State Technical Report No. 17; his research results have been most helpful as a guide to designing our progeny tests.

In addition to the students mentioned above, seven others are far advanced in their research. Three of these have practically completed their investigations, which will contribute greatly to information necessary for an efficient tree improvement program. Mr. Gene Namkoong, a specialist in quantitative genetics has done his research for the Ph. D. degree on hybridization and introgression between loblolly and longleaf pine. His interesting results help elucidate the present position of P. sondereggeri (the hybrid between these species) and its possible future role in southern forestry. Gene is a staff member of the Institute of Forest Genetics in Gulfport, Mississippi, but is assigned to duty at N. C. State, working with both the Genetics and the Forestry Departments. All designs and analyses used in the heritability study have been developed or adapted to forest trees by Mr. Roy Stonecypher, another specialist in quantitative genetics. During the past year he has worked full time at N. C. State on the cooperative heritability project with the International Paper Company; next year he will be employed by International, a portion of his efforts to be expended on the heritability study.

Roy will wait for another year's growth on the progeny outplantings before completing his thesis, but the information already obtained has been of great value in developing tree grading methods and designing progeny outplantings. Mr. Dan Schmitt has completed his studies and nearly completed his Ph. D. thesis. He has made a very meticulous study of self-compatibility, flowering and seed development in sweetgum.

We especially enjoy scientists who come to N. C. State in the category of "post doctoral students." These men already have their degrees and are engaged in research; and although they come to study, they make significant contributions of value both to the students and staff. In 1961-62 Dr. Bill Libby took nine months' leave from his professorial duties at the University of California to study at N. C. State. Bill, another specialist in quantitative genetics, concentrated his studies in genetics and statistics in the Genetics Department, but he was most helpful and stimulating to the Faculty and students in forest genetics. He returned to California last summer, but not before producing a definite influence in our thinking. Dr. Rex Mirams is spending three months at N. C. State, working on wood properties of certain species of the Mexican pines. He will be associated with both the Tree Improvement Program and the Department of Wood Sciences and Technology. Dr. Harold Hocker, on leave from the University of New Hampshire, has spent two semesters with us and returns to his duties in June, 1963. Although his studies have been concentrated in the statistical field, his general interest covers the whole field of tree improvement.

In addition to the students who have nearly completed their degrees, ten other students are currently working with the program for advanced degrees. In September, four additional students will begin their studies. We were particularly fortunate to obtain a special travel grant of $2000 from the Rockefeller Foundation for Mr. Garth Nikles from Australia. Mr. Nikles is going to make a special study of

the slash pine complex and the pines of the Caribbean Region, and this travel grant will aid greatly in obtaining a complete coverage of this area.

The Cooperative Program gets additional help from students working with National Science grants. Two college teachers have been awarded ten-week grants to study and do research with the Tree Improvement Program during the 1963 summer. Three outstanding undergraduates have been awarded National Science Foundation Undergraduate Research Participation grants. Each of these students works on a research project of interest to tree improvement during his undergraduate studies. The three URP students are: (1) Sam Land, who has under way a project to determine if there is a differential in tolerance to salt water in various races of loblolly and pond pine; (2) Jimmy Hamrick, who has two research projects under way. He is working on a provenance analysis and is also engaged in a study of seed and cone characteristics of the Mexican pines, with the objective of developing a key to help in identification of Mexican species by these characteristics; and (3) Carlyle Franklin, who is now completing an analysis of a two-year study on individual progeny resistance to drought of newly-germinated seedlings of loblolly pine. Although Carlyle's efforts have mainly been concentrated on techniques, he has found much individual tree variation but little clear-cut "racial" differences.

The research contribution of students to the Tree Improvement Program is very substantial when the combined efforts of all are considered. A mass of research results is now becoming available, greatly aiding in the development of more precise, more efficient applied tree improvement programs.

In addition to the student research, continued research is done on wood qualities by the staff and Faculty of the Tree Improvement Program and with industry members of the Cooperative Program. For example, two studies were completed and reported during the year. One, made with the assistance of Weyerhaeuser field personnel, dealt with the variation of wood qualities of pond pine and a comparison of wood of this species and loblolly pine grown under similar conditions. A large

amount of variation was found in wood of pond pine, especially among individual trees. Differences between areas were present but could not be related to geographic location, site or depth of peat. Pond pine wood proved to be quite similar to that of loblolly pine, being a little lower in specific gravity and having a little shorter tracheid length.

Another, more basic study done in cooperation with the Continental Can Company, using grafts they were removing from their seed orchard, indicated the gross heritability of specific gravity and tracheid length to be quite high (see Fig. 16). Another finding was that the wood of grafts was essentially independent of that of the rootstock on which the graft was made. This outcome is illustrated graphically in Fig. 17.

FACULTY AND STAFF

Several important changes have been made, or will soon be made, in faculty and staff. Most important of these is the forthcoming "loss" of Bob McElwee, the liaison geneticist who has worked with the Tree Improvement Program from its inception, and whose efforts have been so largely responsible for its success. Bob is going to take over as head of the new Cooperative Hardwood Research Program sponsored by forest industries, for which his training and experience in the Cooperative Tree Improvement Program will be of real value. We hate to lose Bob, but are happy that he has this opportunity to head a program of great challenge and high significance.

Although, normally, finding a replacement for a man of Bob McElwee's calibre would be most difficult, we have been very fortunate in obtaining the services of another Bob, also from West Virginia. Bob Kellison will take over the duties of liaison geneticist on July 1, 1963. He comes to the Cooperative Program well-prepared, having worked in the lumber industry, having been in charge of the School Forest at West Virginia University for some time, and having spent two years of

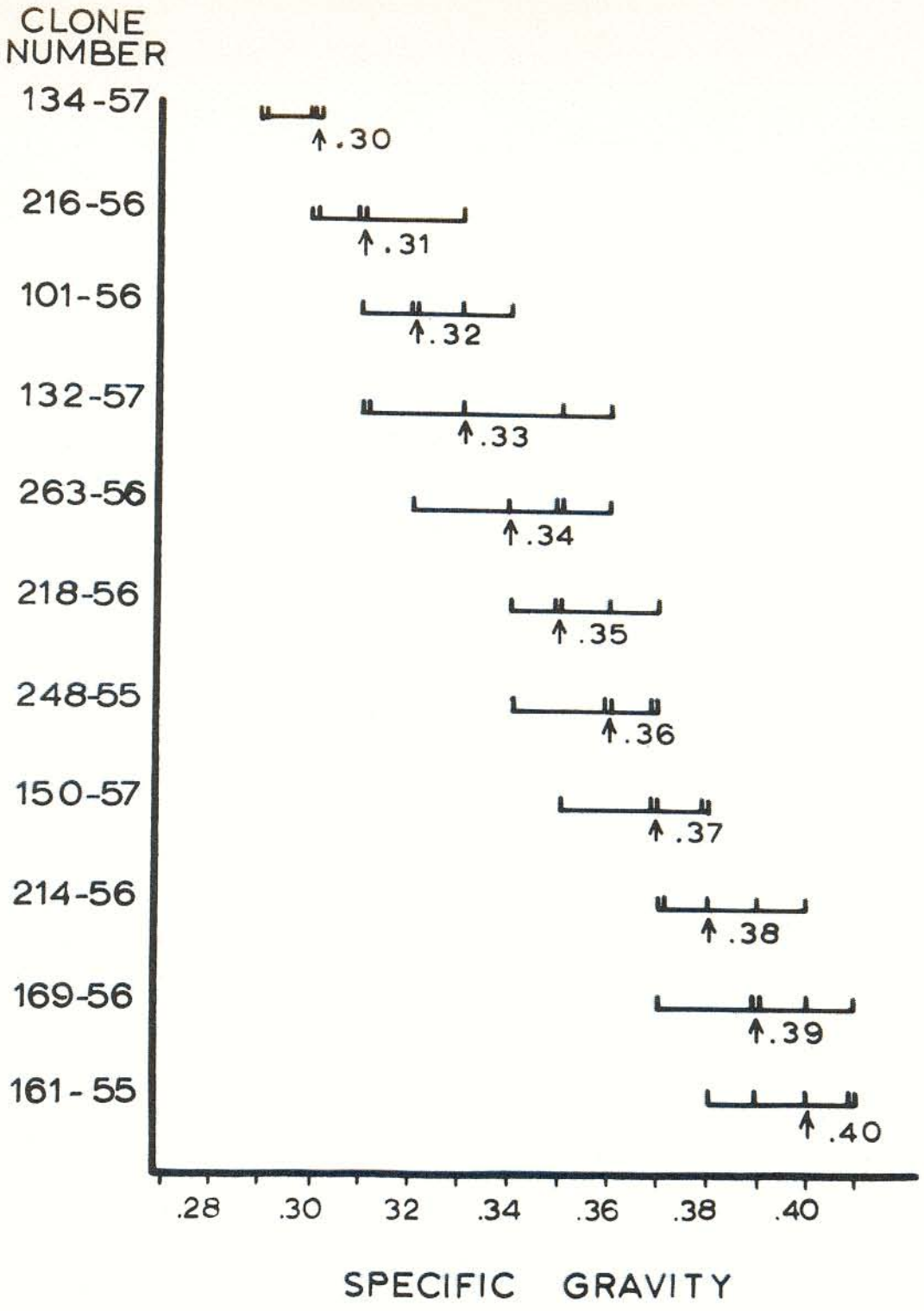

Fig. 16. Eleven slash pine grafted clones have been chosen and graphed to show the difference between clones and among ramets of the same clone. These grafts, five years old, had specific gravities from quite low to quite high, rather uniform within clones and independent of rootstock. This study, made with the cooperation and grafts of Continental Can Company, indicates the intensity of genetic control of specific gravity. The arrow and figure are the average for the five members (ramets) of the clone; each vertical line represents the value of a given ramet.

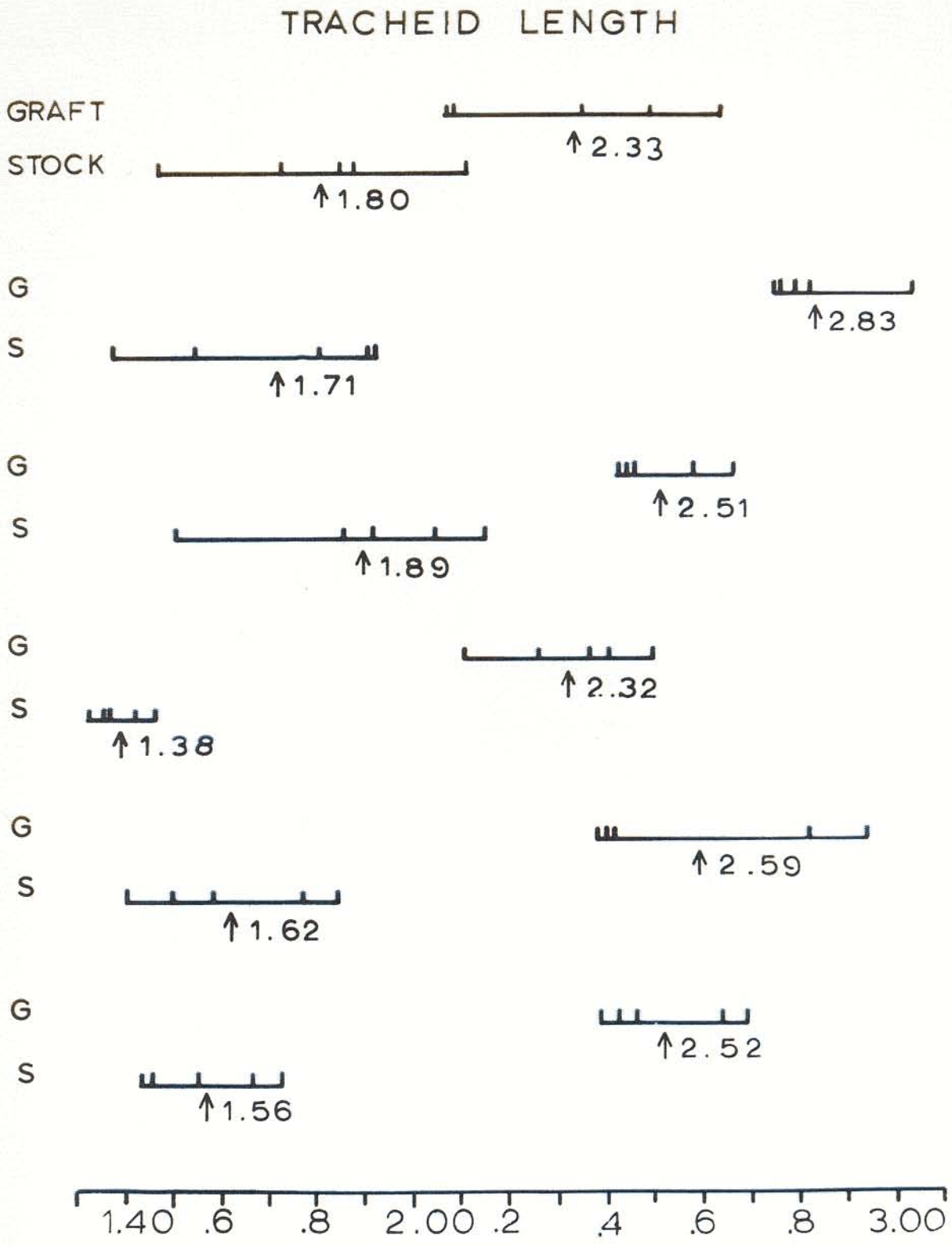

Fig. 17. In the study of slash pine clones with the Continental Can Company it was possible to demonstrate conclusively that both specific gravity and tracheid length are independent of the wood qualities of the stock plant to which they are grafted. Note that tracheid length of the graft is always more than that of the stock but may be relatively long or short in relation to other ramets of the same clone. The arrow indicates the average of five grafts or stocks, the vertical line values for each ramet or stock plant.

graduate study at N. C. State travelling extensively with us on the Tree Improvement Program. He has met many of the company personnel and is familiar with their programs. With this background and training, there should be a smooth shift between the two Bobs on July 1, and the Cooperative Tree Improvement Program should move along without a hitch.

During the past year, four College Faculty members have been "officially" made a part of the School of Forestry through the medium of joint appointments. Although these Faculty members are not officially a part of the Tree Improvement Program, we have been working closely with some of them for several years and their help and advice has been of tremendous value to us. Dr. L. C. Saylor continues his close working relationship with the program and is handling cytological studies as well as phases of pollination and hybridization studies and related problems. He has a joint appointment with Genetics and Forestry, and we have two graduate students working with both groups. A similar joint appointment with Plant Pathology is held by Dr. Arthur Kelman. Art has been most helpful in guiding us in disease problems related to seed orchards; his shift to forest disease research comes at a most opportune time with the recognition of the danger of Fomes annosus in the seed orchards. Students interested in disease resistance work jointly with Dr. Kelman and us. Similar help and advice has been given on insect problems by Dr. Maurice Farrier from Entomology, while Dr. Davey, a new Faculty member in the Department of Soil Science, already has been most helpful in advising on forest soils problems encountered in the Tree Improvement Program.

We were naturally disappointed when Miss Ann Law, who had been performing secretarial duties for the Cooperative Program for several years, resigned to travel and work in Turkey and points East. We really miss her friendly smile, her most descriptive drawings (see Sixth Annual Report), and her quiet efficiency. But in seeking a replacement for her, our usual "luck" continued to hold. Mrs. Martha Holland decided to resume working after having taken time out to raise

her family, and we were fortunate to be the ones to hire her. Despite fears of a struggle at the shift of personnel, Mrs. Holland has picked up the job where Miss Law left off and the program has proceeded without a hitch. During the first week she really waded into the complexities of the job and is now thoroughly familiar with the Cooperative Program. Until one is aware of the vast amount of correspondence, the many manuscripts to be typed, the necessity to keep the office functioning during our long absences, the complex forms to be filled out and kept current, it is impossible to assess the tremendous contribution that Mrs. Holland has already made to the Program.

Fig. 18. A new, though minor, activity of the Cooperative Tree Improvement Program is the improvement of Fraser fir for Christmas trees. The tree pictured here has very fine shape and color and has been selected in the program of the North Carolina Forest Service as one of the trees to be used in a Fraser fir seed production area.

Fig. 19. Seed orchard management requires many talents and skills. One management practice, beautifully illustrated by the photograph of a Scotch pine seed orchard at Ekebo, Sweden, is to trim or round off the trees to produce rounded or "apple tree form" of the grafts. Efficiency of this practice in the very vigorous southern pines is doubtful and is not being used in the commercial seed orchards. It should be successful on the hardwoods.

PUBLICATIONS

The Sixth Annual Report listed all publications made in the Tree Improvement Program to July 1, 1962. Since that time several others have been added:

1. Cech, F. C., Barber, J. C. & Zobel, B. J. 1962. Comments on "Who wants tree seed certification, and why?" Journal of Forestry 60(3): 208-210.

2. Conkle, M. T. 1963. The determination of experimental plot size and shape in loblolly and slash pines. Tech. Rept. No. 17. School of For., N. C. State College, pp. 1-51.

3. Goggans, J. F. 1962. The correlation, variation and inheritance of wood properties in loblolly pine (Pinus taeda L.) Tech. Rept. No. 14. School of For., N. C. State College, pp. 1-135.

4. Hamrick, J. L. 1963. Environmental and genetic control of bark thickness in loblolly pine. Mimeographed Student Report. pp. 1-17.

5. Kinloch, B. B. 1963. Observations on the effects of fusiform rust on specific gravity and fiber length in the wood of loblolly pine. Mimeographed Student Rept. pp. 1-9.

6. McElwee, R. L. 1962. Clonal seed orchards. Northeastern For. Tree Imp. Meet. August. (In press).

7. McElwee, R. L. & Zobel, B. J. 1963. Variation in wood properties of pond pine. Forest Genetics Workshop, SAF, Macon, Ga. (In press).

8. Taft, K. A. 1962. The effect of controlled pollination and honeybees on seed quality of yellow poplar (Liriodendron tulipifera L.) as assessed by X-ray photography. Tech. Rept. No. 13, School of For., N. C. State College, pp. 1-21.

9. Zobel, B. J. 1962. Impact of forest genetics on plantation management. Am. Pulpwood Association, Gulfport, Miss.

10. Zobel, B. J. 1962. Wood quality improvement through better trees. LSU Tenth Ann. For. Symposium. pp. 35-40.

11. Zobel, B. J. & Haught, E. A. 1962. Effect of bole straightness on compression wood of loblolly pine. Tech. Rept. No. 15, School of For., N. C. State College, pp. 1-5.

12. Zobel, B. J. Breeding for wood properties in forest trees. 1963. World Consul. of For. Genetics, Stockholm, pp. 1-25.

13. Zobel, B. J. 1963. Improved wood qualities through use of seed from selected parents and the effect of different environmental and growth conditions. Presented at the symposium on wood quality, N. C. State College, Nov. 1962. pp. 1-10 (In press).

14. Zobel, B. J., Cole, D. E. & Stonecypher, R. W. 1963. Inheritance of wood qualities in clones of slash pine. For. Gen. Workshop, SAF, Macon, Ga. (In press).

PARTICIPATING ORGANIZATIONS

All the companies that started the Cooperative Program in 1956 are still actively participating, although there has been considerable renaming and shuffling due to mergers. Several companies joined the program in later years; during the past year three new organizations have become participants. As indicated on the last page of this Annual Report, there are now 16 cooperators, several of whom have more than one active division taking part in the program.

The newest industrial participant is Marathon Southern Corporation, Butler, Alabama. They joined the Cooperative Program on Jan. 1, 1963 and have become immediately active in tree improvement operations. Their seed orchard site has been located and is planted and prepared for grafting next year. They are selecting trees and already have had a number of trees graded for them. A couple of their loblolly and shortleaf rate among the finest that we have in the program.

The Cooperative Tree Improvement Program has always been supported by members of the forest industries. This year for the first time there has been a departure from this practice but a logical and very helpful departure. Several state organizations have felt their responsibility for producing seed of improved strains of forest trees in state nurseries. Most trees thus produced will ultimately be bought and processed by the forest industries, either directly or indirectly through small, independent land owners. Better trees, produced more efficiently by such independent owners, will thus directly benefit the forest industries in the state. In addition, membership in the Cooperative Tree Improvement Program will directly benefit the state organizations through better liaison, exchange of selected trees, and improvement of operations possible through association with other organizations that have already had considerable experience in tree improvement.

Two such state organizations joined the Cooperative Program in 1963. On January 1 the North Carolina Forest Service became an active participant, as did

the South Carolina State Commission of Forestry on April 1. Both organizations immediately started work in tree improvement, having already selected a number of trees and already having initiated extensive grafting operations. The bulk of the effort is concentrated on species already of so much importance in the Cooperative Program - i.e., loblolly, slash, shortleaf and Virginia pines. In addition, over 20 trees of white pine have been selected in North Carolina for a proposed 20-acre seed orchard. Requiring only minor effort, but being completely different, some preliminary activities have been undertaken to obtain a superior source of seed in Fraser fir for Christmas trees in North Carolina.

Although two state organizations have joined the Cooperative Program, its objectives and method of operation remain exactly the same as when all members were industrial organizations - in fact, the official name of the Cooperative Program will continue to be the N. C. State-Industry Cooperative Tree Improvement Program. Even a proposed name change for N. C. State College will not alter the name of the Cooperative Program.

COOPERATING ORGANIZATIONS

Organization	Working Units and States
Albemarle Paper Mfg. Co. (Roanoke Rapids Div.)	N. C., Va.
Catawba Timber Co. (Bowaters Carolina)	S. C., N. C.
Champion Papers, Inc.	S. C., N. C.
Chesapeake Corp. of Virginia	Va., Md., Del.
Continental Can Co.	Savannah Div. - S. C., Ga. Hopewell Div. - N. C., Va.
Georgia Kraft Co.	Ga., Ala.
Hiwassee Land Co. (Bowaters Southern)	Tenn., Ga., Ala., Miss.
International Paper Co.	Coastal Plain - S. C., N. C. Piedmont - S. C., N. C.
Kimberly-Clark Corp. (Coosa River Div.)	Ala.
Marathon Southern Corp.	Ala.
North Carolina Forest Service	N. C.
Riegel Paper Corp.	N. C., S. C.
South Carolina Forestry Commission	S. C.
Union Bag-Camp Paper Corp.	Savannah Div. - Ga., S. C. Franklin Div. - N. C., Va.
West Virginia Pulp & Paper Co.	South - N. C., S. C. North - Va., West Va., Ohio
Weyerhaeuser Co. (North Carolina Div.)	N. C., Va.