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PROCEEDINGS

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TREE IMPROVEMENT AND FERTILIZATION - PROGRAM OBJECTIVES

Thomas C. Nelson, Deputy Chief, NFS ^{1/}

I appreciate the opportunity to be here with you for this meeting. Hopefully, in this brief time, and with these few opening remarks, I can impress upon you the depth and seriousness of the Chief's and my interest generally in the practice of intensive silviculture on National Forest lands, and particularly in expanded and aggressive tree improvement and fertilization programs in all Regions.

You probably do not need to be reminded--but I will anyway--that one of the major purposes for which the National Forests were established is to furnish a continuous supply of timber for the use of the American people. There is not, and need not be, conflict between this objective and other environmental protection and natural resource management objectives, although I admit, we sometimes have difficulty articulating, if not recognizing, that intensive timber management can be synonymous with the perpetuation of high quality forest environments. Some of you had the privilege, recently, of seeing how this is accomplished in one European country, Germany. We expect you to draw from that experience and share with others here at home the silvicultural practices and achievements and the failures you observed there, which can benefit us here in managing the resources of the National Forests.

^{1/} Remarks at Servicewide Silviculture Conference, Sacramento, California, October 21, 1974.

Although, subject to the usual and sometimes seemingly regular fluctuations in demand and price, trees and timber are needed more today than ever before. Substantial increases in future demands for timber products are expected and prospective supplies are expected to fall substantially short of these demands. The contributions that the National Forests can and must make to supplying these demands are dependent on the area of commercial forest land managed for timber production, the capacity of those lands to produce timber, the constraints of other uses on those lands, and the intensity of the management or cultural practices on those lands.

Right here, lest some of you misunderstand, I want to make perfectly clear--to use a well worn phrase--that management of our timber producing lands under certain environmental or non-timber constraints calls for more precise, more intensive culture, not less precise or less intensive culture.

I don't intend to harangue you with a bunch of facts and figures about future timber demands, expected losses of commercial forest land wholly, or in part, to non-timber uses, or potential timber yields under one array or the other of available alternatives. You know the story! You are aware, or should be, of the urgency with which we must view the intensity of our management practices. Yet, I feel it necessary to call to your attention again, the fact that after over 70 years of management, the commercial timberlands of the National Forests are producing an average of only 30 cubic feet per acre per year or about 40 percent of what could be expected from fully stocked natural stands.

There are large, technical possibilities for increasing the timber productivity of the National Forests, even though economic factors and competition from non-timber uses of forest land set limits on attainable increases. We talked about these in a broad and general way at the Timber Management Conference on Intensive Forestry at San Francisco last February. Now, we want to zero in on two specific opportunities for increasing timber production--both the volume and the quality of our wood outputs..

One of the reasons that tree improvement and fertilization are the focal points of this meeting is that we have not moved aggressively enough, and fast enough in developing and implementing these programs. Another reason is that optimum production of timber (trees) to supply wood and other demands can be achieved only through the integrated use of all the cultural practices available to us and not through separate or individual use of a cultural treatment apart from others appropriate for the same species, stand, or conditions.

The state-of-the-art in both tree improvement and fertilization is way ahead of us. We have a lot of catching up to do in both areas to bring our silvicultural programs to the level where we can begin to realize the benefits of the knowledge and the experience already available to us. What we need now is a concerted effort in each Region to develop and implement programs in both activities which are both optimistic and aggressive. I expect no less, and the Chief expects no less. My personal goal is for the Forest Service to become the leader of intensive silviculture in 10 years.

So that you may have some idea of the importance and the urgency we attach to the role of tree improvement and fertilization in intensifying management of National Forest timber resources here are some objectives which reflect current Forest Service policy:

1. Tree Improvement. The overall National Forest System's objective is to regenerate with genetically improved stock within 2 rotations all stands of the major timber species on the commercial forest land available for timber production. Achievement of such an objective will, of course, be tempered necessarily by (1) the proven or demonstrated heritability in a given species of one or more desirable characteristics, for example, growth, form, disease resistance, seed production, etc., (2) by non-timber constraints on the management of a given area that may preclude the cultural practices essential to conversion to improved stock; (3) by priorities of conversion as may be determined by relative site capabilities and species importance or range; and (4) by the time and the people and financial resources required to mount such a program and produce the improved seed and planting stock required.

However, this objective is not enough. We need a more precise short-term objective covering the next 5 to 10 years. This objective should cover technological transfer and cost effectiveness as well as interim targets.

2. Fertilization. The overall National Forest System policy and objective is to fertilize those stands where soil and water conditions, physiological characteristics of the species, stand conditions, etc., combine to produce a positive growth response to nutrient additions. Again, the achievement of such an objective will be tempered by other environmental considerations, growth increase and cost relationships,

fertilizer availability, soil surveys and classifications, and other factors, such as sustained levels of funding.

Demonstrated growth response to fertilization in the Southeast and the Northwest particularly, justify an overall National Forest System target of at least 30,000 acres annually by FY 1979.

I really think these are minimum, but challenging, goals. Tree improvement benefits go far beyond just timber production to meet wood demands. We probably have just touched the tip of the potential for increased wood yields from fertilization and an opportunity in point is on our so-called poorer sites. Anyway you want to cut it though, what I have set out for you here is a big job, and one that will require the commitment of all of you here and the people at home in each Region down to the District Ranger and his people.

Our reforestation and timber stand improvement program has not been aggressive enough in light of Congress's attitude on these activities. Congress has directed us to eliminate the backlog of work in reforestation and stand improvement. I am not worried about money. In fact too much money may be a problem until we can gear up to spend the money wisely.

We have been talking about these programs here as National Forest System programs and indeed they are just that. But the impacts (demands and results) of these activities will reach far beyond just the National Forests. Furthermore, their success will depend on a keen sense of mutual responsibility and close cooperation between NFS, Research, and S&PF people. Recognition of that fact is borne out by the presence here of representatives of all three branches and that is as it should be.

The climate is right, the urgency is great. Furthermore, Congress has indicated it intends to sustain increased financial support of intensive management practices. We expect you to move out smartly in both tree improvement and fertilization activities. We will help you, but we also will hold each unit responsible for meeting its share of these programs. Now, let's get down to work here on the nitty-gritty aspects of these matters.

AN OVERVIEW OF TREE IMPROVEMENT¹

by William J. Libby, Professor of Forestry,
University of California

Historical

Patrick Matthew

In 1831 Patrick Matthew wrote in his *Naval Timber and Arboriculture*:

"There is a law universal in Nature tending to render every reproductive being the best possible suited to its condition. . . , From the unremitting operation of this law acting in concert with the tendency which the progeny have to take the more particular qualities of the parents . . . ; but in timber trees . . . the large varieties . . . are cut down . . . and weakly varieties . . . have been continually selected as reproductive stock . . . , nurserymen should attest the variety of their timber plants, sowing no seeds but those gathered from the largest, most healthy . . . abstaining from the seed of the prematurely productive . . ."

Charles Darwin later wrote:

"I freely acknowledge that Mr. Matthew has anticipated by many years the explanation which I have offered of the origin of species . . ."
"Thus, foresters were given a considerable lead on the rest of the biological world in understanding natural selection, dysgenic selection, and evaluation. These principles were rarely accepted in practice, ignored by most, and few experiments have since been performed with forest trees to demonstrate natural selection operating in native stands.²"

The Danish and Swedish Period (Larsen)

- Tree shows comparing good and bad characteristics
- Provenance tests
- Beginning of seed orchards (Swedish)

The Southeastern U.S.-New Zealand period (Around 1950)

- Better program in New Zealand than Australia principally because of central authority
- Single purpose seed orchard - high selection intensity

¹Prepared from notes taken at Servicewide Silvicultural Conference, Sacramento, California, October 21, 1974.

²Taken from "Forest Genetics and Forest-Tree Breeding" by W. J. Libby, R. F. Stretter, and F. W. Seitz. Reprinted from *Annual Review of Genetics*, Vol. 3, 1969.

- Problems: (1) graft incompatibility
(2) seed production poor on good sites
(3) harvesting cones
(4) pollen contamination
(5) progeny testing

The Wright School (Michigan State)

- Dual-purpose seed orchards - selection on site
--Problems: (1) conflicting purposes
(2) seed production
(3) pollen contamination

Early Neolithic Reforestation Program

- Collecting seed from wrong source on poor local trees
--Buying seed from unknown sources
--Seed production areas: good idea - never really caught on
--Cured ills by collecting seed from only outstanding trees in good years

Present and New Ideas

First Generation Selection

- Widespread selection: only one tree per stand maintained family
structure (except for red pine) avoiding in-breeding

Second Generation Selection

- Broader genetic base: with a closed program must start out with
a larger population (100-200 clones)
--Progeny testing abandoned (except special cases)
--Progeny testing very hard to justify on a cost basis
--Very little marginal increase
--Larry Davis' paper covers this
--Instead design a crossing study for second generation selection
--Dealing with about 10,000 trees

Computer Selection

Instead of first or second generation orchard use a computer to evaluate results and add best clones each year and eliminate poorest.

Vegetative Propagation

- Europe (W. Germany, Norway) and New Zealand
--Tissue culture

Future Ideas

Alternative to single-purpose seed orchard: select trees, cross-pollinate, and then propagate through cuttings from young trees

Final Point

Gene conservation - very important.

A Summary
Overview of Genetic Research That is Pertinent to NFS
Stanley Krugman, Timber Management Research^{1/}

The Chief and Deputy Chief Nelson are committed to an expanding national tree improvement program, but a similar commitment is often lacking at the field level. The problem appears to be most often with line officers rather than with the tree improvement program staffs.

We are doing a professional job with the timber sales program, but are still having serious problems with planting and growing trees. Research somehow has failed to communicate adequately with management. The best available information is still not being applied to our common problems.

Most Regions are not doing the best job that they are capable of doing. Region 8 has a good program, but some of the other Regions are still trying to reinvent the wheel rather than using the available research information.

There are numerous tree improvement program strategies available such as a progressive strategy now being applied in Region 6. But now that we plan to expand our programs each Region may want to consider additional approaches. To have a successful expanded program we must have a continued commitment to funding and a renewed commitment between NFS and Research. We need new ways to do business and we must be willing to accept some risks. Research concepts are there and so are the staffs to assist in their application. Different approaches may be needed by each Region. Many of the strategies mentioned by Bill Libby will not be needed by us to get started. These can be fitted in at a later date once tree selection has been done.

What about Regional commitment? What are the problems?

A. Programs need to have a biological basis, not an administrative basis. All too often the classical administrative set-ups we employ hinder new programs.

B. Coordination with research needs to be improved. We have allowed too great a separation between research and management at the field level.

^{1/} Prepared from notes taken at Servicewide Silvicultural Conference, Sacramento, California, October 21, 1974

C. Research in forest tree genetics is mature. It is no longer a pioneering science. We need to apply what we know.

D. Research is hungry. Research needs to demonstrate that it can apply the science it has developed.

E. Regeneration practices need to be improved. A total package concept needs to be developed from the nursery to the field.

F. Where and when to fertilize needs to be better established before we go into a major program. But fertilization should be part of a tree improvement program.

G. Economics point the way for increasing our tree improvement program on selected areas.

All of these factors must be fitted together in an integrated and coordinated program for each Region. Tree improvement is not an isolated program from other management practices.

Questions and Comments

Q=Questions

C=Comments

R=Response

C. Objection to the reference of biological vs. administrative programs.

R. Biological programs would cover the natural range of a timber species such as loblolly pine or ponderosa pine. Administrative program covers administrative Region such as Region 8 or a ranger district. We are interested in the tree and not some artificial boundary.

Q. By integrated and coordinated program did you mean Federal, and State and Private program?

R. No. Our first effort should be on the National Forest, then on other lands. We need to first establish our own objectives and programs before we make a commitment on other lands. All too often our lands differ from other owners and the so-called cooperative program distorts our effort.

C. In Region 1 because of a lack of Forest Service commitment, we have been getting funding from other sources in a cooperative effort.

R. We should not be dependent on outside funding. We should have internal commitment so we will have a stable program over the long run.

Q. What is a stable program?

R. Region 8 is an example. The Region has an objective and a line and funding commitment which it has followed successfully for a number of years.

C. Cooperative programs are a necessary approach from a financial standpoint in scattered ownership.

Q. What steps are necessary for the coordinated approach?

R. (1) Research should be involved in the development stages in a real sense. Why not use the best information available.

(2) Careful development of plans with related management areas.

(3) Continual communication in planning stage to arrive at priorities for both research and administration.

C. First, we must define the problem and next lay out what research must do, given funding.

C. We need a true working team not just a reference service.

C. The gap between Research and NFS is artificial--we have not exploited the working relationship. National Forest Service is not always sure how Research can help.

C. Avoid formal barriers--keep contacts informal. When a field problem exists, Research must step in and help.

C. We need more effort on the D side of R&D.

Q. Where should expertise be? RO or Forest?

R. Both levels should have a certain level of expertise. But it has worked out better to have the leadership and expertise at the RO. When a program is developed expertise can be shifted to the field.

C. The man-in-the-job concept is needed.

C. Agree 100%, but we have a hard row to hoe because of the difficulty to manage. The first step in grade stacking into which we have made some inroads. Need to show we have a career ladder. CSC now developing a "bench-mark" approach.

C. We need commitment of the Supervisor and the Ranger.

C. Also, forestry aid. Keep all people abreast of current state-of-the-art .

G. E. Howe
10/21/74

Region 1 Presentation at 1974 National
Silvicultural Workshop

I. Introduction

- A. Thank you
- B. Comments on seed zones - in use for 11 years
- C. Sequence of presentation
 - 1. Will show slide tape
 - 2. Will elaborate briefly
 - 3. Will open for discussion

II. Slide-tape.

III. Elaboration

- A. Produces genetically improved seedlings 2 ways.
 - 1. On-the-ground forester selects phenotypically superior parents on all CFL cut over in natural regeneration harvest cuts.
 - 2. Selection and breeding projects will produce genetically improved seedlings for our planting needs on PC 1 and 2 lands.
 - a. Does include some acres in 2020 which are naturally regenerated in 1974.
 - b. Rationale for not including PC 3 and 4 lands was economic rather than biological.

B. WO Direction. Produce genetically improved material for all CFL cutover in regeneration harvest cuts. The ways we see we can respond to this direction are:

- 1. Identify and educate our foresters to recognize highly heritable traits so that their plus-tree selection in natural regen. harvest cuts can be more efficient.

2. Enlarge our selection and breeding program to produce improved seedlings for planting needs for all CFL.
3. Expand our planting program.
 - a. By interplanting among natural seedlings. By underplanting under seed trees or shelterwood. Both assume ability to identify planted seedlings at first thinning.
 - b. Increase, where other constraints permit, "clearcut and plant" acreages.

C. Problems in organization and commitment. Solving these.

D. Conclusion.

1. Greatest obstacle to our responding to WO appears to be competition with natural regeneration and improved planted trees.
2. Anxious to intensify--need WO advice in solving (1)
3. Hope that we can participate actively in establishing national policy

IV. Open for discussion.

NATIONAL SILVICULTURE CONFERENCE

REGION 2 - TREE IMPROVEMENT ^{1/}

(a) Rationale for program -

- Better survival
- Faster growth rate
- Insect and disease resistance

(b) Goals of program -

"Produce and utilize genetically improved seed and seedlings for reforestation that will yield more and better timber and other products that will be less susceptible to damage by diseases, insects, and other pests, and in other ways be better, more vigorous and more responsive to management."

(c) Level of program development -

- Establishing seed zones, first priority; cone collection presently limited by (1) elevational range of 500 feet, and (2) within a 100-mile radius of the area to be reforested.
- Interim Tree Improvement Plan prepared by Committee (C.D. McAninch, TM; Rich Cunningham, S&P; Bill Ellis, White River NF; and Richard Gredfenius, S&P) This is being reviewed by TM now.
- New comprehensive tree improvement plan to be written by July 1, 1975.
- Tree improvement handbook written by July 1, 1976.

(d) Program organization

Regional tree improvement plan

Funding

Technical responsibility will be retained in RO

1/ Presented by Rich Cunningham for C. D. McAninch

(e) Problems

- Selling the Region on the importance of tree improvement
- Staffing at the Regional and Forest level to do the job.
- Handicapped by a slow growth potential and climate

October 17, 1974

Southwestern Region Tree Improvement Program¹

Having recently initiated a tree improvement program, the Region is in an excellent position to capitalize on the experiences of other Regions and the recent results of Research into the genetics of forest trees.

Seed Zones

Region 3, like most of the other Forest Service Regions, is anticipating a greatly expanded reforestation program to catch up on the backlog of acres in need of planting plus maintain current reforestation acres.

Most or about 80% of this reforestation effort will be done with ponderosa pine. Based on our current seed inventory and projected reforestation needs, R-3 has sufficient seed of ponderosa pine to carry the program into FY 78.

It is physically impossible to develop genetically improved seed prior to the exhaustion of the current seed inventory. But it should be possible to obtain some reliable data on seed sources in the Region. This data will at least provide for the production of planting stock that is generally suitable for the programmed reforestation sites. Longer term trials will more precisely define ecotypes especially suitable for planting within specific areas.

Following the establishment of ponderosa pine seed source trials, similar trials will be established with Douglas-fir, Englemann spruce and other Southwestern timber species.

¹Presented by Jack Pitcher, Regional Geneticist, R-3.

Seed Production Areas

Region 3 will not establish a program of seed production areas at the present time. Instead, it will rely upon the designation of specific collection areas within seed zones. These will be broad areas, essentially unmanaged for cone production.

Until the Region establishes species ecotype boundaries based upon provenance trials, development of SPA's seems premature.

Investment in SPA development and management in Southwestern pine types offers doubtful opportunity for genetic improvement of tree seed beyond that which could be achieved by general collections within specified zones.

The Region anticipates considerable difficulty in the collection of cones from standing trees in areas which might be developed for seed production and prefers to rely on supervised collections from designated areas.

Seed Orchard Development

The traditional program of superior tree selection and the development of clonal or half-sib seedling seed orchards is one way to achieve improved forest trees. Superior tree selection demands phenotype comparisons under essentially uniform environments. These conditions generally do not exist in natural stands. For this reason, progeny of selected phenotypes are tested under plantation conditions. Selection, cloning and progeny testing are expensive long term procedures.

On the other hand, family selection methods can be equally effective when initiating a program based on untested trees from wild stands. In considering the alternatives, the Region has opted for this family selection seedling seed orchard approach. The Region feels that significant genetic improvement can be anticipated under this approach at a ~~much~~ lower investment cost. Family selections will be evaluated in the plantations to be established from the current seed zone tests. This approach will further provide the advantage of using families from within defined population groups and thus avoid the necessity to further test the progeny for adaptation to specific subregions.

If desirable, superior phenotypes can be selected within the best families for the development of clonal seed orchards in the next phase of the tree improvement program.

Species Introductions

The Region will initiate a program of testing exotic tree species under local conditions. Seeds of several provenances of pinus halepensis, pinus brutia, and pinus elderrica, all pines from the semi-arid Mediterranean region, will be made available to the Region as part of a FAO/IUFRO sponsored international provenance trial. The objective for Region 3 will be to evaluate these species for timber production within the extensive transition zone between ponderosa pine and the pinyon-juniper types. Pinus halepensis appears to offer some very real promise as a timber tree for drier sites based upon isolated examples in the Region. Further evaluation of this species group is warranted.

The Region is also investigating the use of pinus contorta on a very limited scale for recapturing some of the high elevation reforestation sites. This work is being conducted in close cooperation with the Rocky Mountain Forest and Range Experiment Station. Aspen clones might also be developed for this same purpose but the Region lacks adequate facilities to carry on this work.

V. Developments:

Region 3 is the only Forest Service Region without nursery facilities. Neither Arizona nor New Mexico operate state nurseries. There is a small private nursery under development at Sedona, Arizona. No other facilities exist.

To implement the Regional tree improvement program the Region needs to develop nursery facilities and greenhouse space.

We definitely need to give major consideration to some problems in seed orchard management. Cone and seed harvest techniques must be improved and mechanized. In the arid Southwest, we must consider the advantages of supplemental irrigation. We also need to consider how we will protect the developing cones and seeds from insect damage in the light of recent restrictions limiting insecticide use

Summary of the R-3 Tree Improvement Program

1. The Region has established provisional tree seed collection zones for the Southwest. Currently we are sampling all seed zones to provide a basis for modifying zone boundaries and later on for the exchange of seed between zones.
2. The Region will designate seed collection areas to provide seed for reforestation programs based on the results of seed zone sampling. Seed production areas may be developed in the future within these collection areas but this will be lower priority work.
3. Seedling seed orchards will be developed from family selections in several locations in the Region. Within the best families, superior phenotypes may be selected for the establishment of clonal orchards during advanced stages of the development program.
4. Some species introductions will be evaluated for special purpose areas.
5. The Region needs to develop nursery and greenhouse facilities to implement the tree improvement program.

REGION 4 TREE IMPROVEMENT PROGRAMS

PRESENTED BY BOB PATEE, REGIONAL GENETICIST, R-4

A. Rationale - What we have:

1. Started 1960
 2. Cooperative program PP, SW Idaho
Forest Service, three Forests and INT
University of Idaho, Dr. Chi Wu Wang
BLM
State of Idaho
So. Idaho Timber Association, Bosie Cascade and several
smaller cooperators
 3. Low Level selection when seed available (wind pollinated) 1962
 4. Seedling progeny test seed orchards (4)
 5. Replications by cooperators
 6. Use early progeny test results to select mother trees to be
used as initial seed source
 7. Rogue seed orchards to top 20 to 30 percent as seed producers
 8. Controlled crosses of best for further improvement
- Same general program being initiated for LP, DF, and ES

B. Goals

Immediate objective is to provide improved seed for regeneration of Forest stands - careful selection of seed sources. 1974 much from individual selected trees.

Specific needs:

PP 2,000 acres plant - 600 pounds seed per year
DF 5,000 acres plant - 400 pounds seed per year
LP 5,000 acres plant - 300 pounds seed per year
ES 3,000 acres plant - 40 pounds seed per year

Second objective. Provide improved seed from tested seed sources, seed orchard mother trees, and eventually from seed orchards--10 to 20 percent improvement. Need progeny test to prove gain.

Third objective. Crosses of seed orchard trees for further improvement.

C. Level of Development

Region has seed zones based upon National Forest and sub-divided by 500 foot elevation, major climatic differences, and soil types. It has been in effect 5 years.

Region has 100 acres of seed production areas for 3 species established in the early 1960's. No new areas are being established as they are too costly to establish and maintain.

Sixty acres of PP seedling progeny test seed orchards existing--10 years old from seed. 30a FS, 30a coop, 271 original mother trees from 37 stands representing all elevations and seed zones in SW Idaho. Recently enlarged with 330 recent mother tree selections from 37 stands. 60,000 trees--1 year old in nursery--to be out planted in 5 progeny test seed orchards in 1976. LP mother tree selections and seed collection are underway. They should be sown in nursery by 1976--all F.S.

Our seedling progeny test seed orchards are strictly progeny tests so far. We expect precocious individual PP to begin seed production in immediate future. Seed was collected from mother trees this year. Expect reasonable amounts from orchards within 5 to 10 years and substantially all PP planting by 1980 will be from tested sources. We could have forced seed orchard production by irrigation and fertilization, but we have considered natural testing more important to date.

Seed orchards and progeny tests are an opportunity to have individual records kept on thousands of trees from different sources planted on replicated sites. Much can be learned about genetic characteristics, but also about importance of provenance, planting effects, and general physiology.

It is amazing to walk through seed orchards and be able to identify family similarities. The good trees have maintained dominance or vigor of height, diameter and survival percentages from nursery through the first ten years. In contrast, poor trees have less growth and survival when grown on the same sites. We have 40 replications to prove this. (measured at nursery 1966, 1968, 1971, and 1974).

D. Organization

PP is cooperative; all others will be Forest Service.

RO - Branch of Silviculture - planning, training, and analysis.

Forests - Forest with Nursery - assistant nurseryman in charge

of tree improvement with help from District personnel.

other Forests - silviculturist with District technicians -

small loose organization.

E. Problems

1. Cooperators - little financing - small land base or need

2. Drift of funds - Less in Tree Improvement.

3. Changing personnel - move as soon as capable. Tree

improvement is not the principal job for anyone.

Usually transfer man to new area and field for promotions.

Environmental factors in intermountain country are as difficult as any in country, but we are getting 80 to 90 percent survival in planting. Quality important.. Growth is acceptable - expect 4 to 6 rings per inch average with management. Can add substantially to the national wood pile.

California Region Tree Improvement Report ^{1/}

for

Service-wide Silviculture Conference

Rationale for Program

Let us first deal with the question of why California needs a tree improvement program. Most people would agree that California has some of the most beautiful and productive forests in the world. This alone is an excellent reason for learning the best ways of not only maintaining this natural wealth but also developing it to the fullest potential for man's use!

Although the trend has changed, forest management in California has traditionally been harvesting big, old-growth timber. Extraction and timber sale have been the major activities. Very little emphasis has been on aggressive silviculture aimed at optimizing growth and maintaining ecological balance.

The practice of high grading with reliance on natural regeneration has been all too common. This leaves the poorest quality trees to pass their genes on to form the next forest. During the short two years I have worked in California, I have observed dysgenic forestry in even-aged second growth stands of white fir. The "biggest and best" trees were cut leaving poorer genotypes to provide reproduction. Two reasons why this cutting practice was used is: 1) the field foresters were wrongly assuming that the stands were unevenaged due to the very wide distribution of diameter classes in these dense stands; and

1/ Presented by Jay Kitzmiller, Regional Geneticist, R-5

2) local markets are generally poor for small material. Planting might have avoided the dysgenics except that survival of planted white fir has been terrible.

California is blessed with a wide diversity of environmental and plant populations. Our very important Mixed Conifer Type is comprised of both tolerant and intolerant species. The type of cutting used has a strong direct effect on species composition. Heavy cutting of high value pines and Douglas-fir has favored regeneration of the tolerant incense-cedar and true firs which are often less productive and of lower quality. I recently visited an area marked for timber sale on a very high site for Douglas-fir. The "overstory" was scattered, magnificent old growth Doug-fir and the "understory" was very low-quality but merchantible white fir timber. All the Doug-fir was marked for removal which would completely convert the stand to the white fir. Since this was obviously a very high Doug-fir site, the stand should have been marked to augment Doug-fir regeneration. It is poor economics and, in a sense, is also dysgenic selection in matching species to site.

We have some genetic-related problems with planting as well. Natural reseeding is very erratic and we have alot of unstocked land from wildfires, so there is much planting to be done. We are unable to successfully regenerate our high elevation True Fir Type. So, we have been converting true fir sites to Jeffrey and ponderosa pines which may again be poor matching of species to site. In addition, much planting has been with unknown seed source of a very narrow genetic base until

very recently. Now we have the state divided into small seed zones, and elevations are usually closely matched. Finally, and perhaps the best rationale for tree improvement is that as forest management intensifies, it is essential that the best genetic stock be used so that the full potential of improved cultural practices can be reached.

These are some of the reasons why I think we need to manage the genetic resources in this Region.

Goals of Program

Our overall objective is to increase productivity of National Forest lands. Specific goals will vary with the productive potential of the land and thus with the level of intensive management that is economical.

On our high quality sites the goal is mass production of genetically improved seed as quickly and economically as possible. Highest priority will be given to Douglas-fir on northern California Forests and to ponderosa pine in the central Sierras. The prime traits for improvement in these species are volume growth and adaptation to a broad range of environments. Selection will be highly aggressive for genotypes that show consistency in superior performance throughout a relatively broad breeding zone.

Sugar pine will be included but will receive lower priority because of its lesser abundance, and its disease and regeneration problems. For sugar pine our goal is two-fold: (1) develop strains that are resistant to white pine blister rust in areas of high rust hazard especially on northern Forests; and (2) improve high and stable growth in the Sierras where the rust hazard is relatively lower.

Although close cooperation is needed with our PSW research in all our projects, it is particularly important with the sugar pine rust resistance program.

It should be emphasized that although we are plagued with silvicultural problems of a less genetical nature that must be solved first, the intensive program of selection and breeding must be started now and be our major effort so that in 10-15 years this genetically improved seed will be in mass production.

This intensive effort must be composed of two important parts: (1) the production orchard for commercial plantings; and (2) the research or breeding orchard which consists of the broad gene pool used for recurrent selection. The research or breeding orchard is necessary to reduce inbreeding, maintain broad genetic variation, and permit continual upgrading production orchards.

Now, on our average and lower quality sites, our goal is to apply silviculture that will maintain a broad diversity of locally adapted genotypes without going into a specific selection and breeding program for these areas. For example, in a natural regeneration cutting we would leave the better phenotypes as seed-trees; or, if planting is done, we would use stock of known local origin developed from seed that was collected from a specified number of good, unrelated trees. Additionally, each tree would contribute approximately equal amounts of seed to make up the seedlot. Furthermore, more than one species could be planted in mixture if appropriate for the site. These plantations will also serve as populations for further selection and breeding.

The appropriate position of true firs in the overall program is presently an open question.

Level of Program Development

From its initiation in 1957 the Program has spanned five major efforts: (1) hybridization of pines; (2) seed production areas; (3) sugar pine blister rust resistance; (4) plus-tree selection and orchard establishment; and (5) seed-tree selection.

The hybrid project involves the knobcone x Monterey and the (Jeffrey x Coulter) x Jeffrey hybrids. The knobcone x Monterey hybrid has been planted rather widely at low elevation, dry and infertile sites. Over 50,000 seedlings are produced annually by the Placerville Nursery.

The (Jeffrey x Coulter) x Jeffrey was started to improve insect resistance in Jeffrey, but infusion of Coulter genes has resulted in lower frost resistance and poor form compared to pure Jeffrey. This hybrid backcross is being used in test plantations in dry southern California. Production of both these hybrids is the responsibility of the nursery. There is a strong need to evaluate both these hybrids in comparative species test.

The Seed Production Area Project has not been successful. Although some 300 acres were established 10 years ago only a few are well-maintained. It was initiated as an interim approach until seed orchards or plus-trees began producing.

The Sugar Pine Rust Resistance Project involves selection of rust free trees, grafting into clone banks, and testing progeny for resistance.

About 350 trees have been selected, 60 have been progeny tested and 6 have been found to have "dominant resistance", one complete and 5 at 50% level of resistance. This project has been the most successful part of our breeding effort but must be greatly expanded for production planting to become a reality. With resistance controlled primarily by a single dominant gene an expanded base of resistant genotypes could be obtained cheaply and easily by testing open-pollinated families, and rapid results can be obtained with artificial inoculation in rust nurseries.

Concerning the Plus-Tree Selection - Seed Orchard Project, some 200 - 300 trees have been intensively selected using the comparison tree method of the following species: Ponderosa, Jeffrey, and Sugar Pines, and Douglas-fir.

We have seed orchards of Ponderosa pine and Douglas-fir each in three locations however most are failures due to several reasons: poor graft survival, massive outside pollen contamination, poor flowering, and poor orchard design. As Ib Thulin recently put it, "a rather dismal picture indeed."

We have one successful ponderosa orchard zone at Forest Hill composed of 100 clones which are beginning to flower at age 4. We have one successful Douglas-fir orchard at Badger Hill which is about 6 years old but we are still losing some grafts to incompatibility. Both of these orchards are mass selection clonal orchards with no progeny testing and they were planted at final spacing. Certainly much faith has been put in initial phenotypic selection.

About two years ago a major change occurred in the California Region with adoption of the Seed Tree Method. This method involves the selection of good seed-trees which are accessible and easy to climb. A minimum of 30 trees per elevation and seedzone will be selected and marked for protection. This is an excellent interim method of obtaining seed for our regular planting program in which the exact seed source is known and better control over the genetic base is achieved.

At the time seed is collected a portion is separated out for genetics work. The seedtrees then will be evaluated for their inclusion into the plus-tree orchard and progeny testing program.

Program Organization

Just briefly concerning the organization of our program: the Region is subdivided into a Northern Zone which includes the Northern Forests and a Central Zone which includes all the Sierra Forests and the Southern Forests. The Northern Zone Geneticist, John Alden, is administratively attached to the Klamath National Forest and has three technicians, one working at the Humboldt Nursery. The Central Zone Geneticist, Gaylord Parks, is administratively attached to the Eldorado National Forest and has one technician. The Zone Geneticists work closely with the Forests in all phases but mainly in tree selection and seed collection and processing. I work in the Silviculture Group at the Regional Office. The regional office is giving full support to the tree improvement effort

Problems

We have several major problems: the first two relating to straight silviculture -

- (1) very poor survival with true firs and sugar pine in plantations;
- (2) lack of species comparisons on various sites;
- (3) lack of knowledge concerning genetic variation among areas, stands, and trees;
- (4) difficulty in evaluating plus-tree candidates due to variable environmental conditions and inability to accurately assess site quality; thus we are forced to use a lower selection intensity with much reliance on progeny testing for gain;
- (5) we want to use open-pollinated progeny tests to determine breeding value but are unsure of the accuracy for the various species;
- (6) poor establishment of present orchards and the absence of progeny tests on orchard trees; in fact, my understanding is that we don't have seed collected from plus-trees as yet, although we have many family lots from seedtrees;
- (7) problems in grafting associated with growing rootstock at low elevation and collecting scionwood at higher elevation;
- (8) determine how broad a breeding zone can be without disrupting adaptation;
- (9) and finally one of the most important problems is that of establishing priorities of intensive work when dealing with such a wide diversity of species and environmental populations.

I hope this has given a reasonably clear general picture of the Region 5 Program. Since I am new in this position, I am not completely informed of many details. But if we have time I will try to answer some questions.

INTRODUCTION

Tree improvement programs in the Pacific Northwest Region are strongly oriented toward participation by Forest and Ranger District personnel. This participation is considered essential for rapid progress, high commitment to tree improvement by field units, and proper use of improved seed.

The Region covers a very complex land area (7). Forested zones range from coastal temperate to subalpine. Within these forested zones there is a great diversity in plant species, soil types, temperature, and moisture. Environmental considerations were paramount in the development of the Region's tree improvement plan. Due to the complexity of the area covered, this plan covers only the general approaches that the Pacific Northwest Region will use in tree improvement. Each Forest will have a detailed tree improvement plan based on the biological opportunities available on the Forest for tree improvement. The Forest plans are developed in four parts to provide program continuity. These parts are: 1, general overall Forest plan; 2, detailed technical procedures; 3, action plan; and 4, accomplishment record. The Forest plans are updated on a continual basis to keep them current with program progress and recent developments in tree improvement technology.

Tree improvement work which can best be done at centralized locations are carried out at such locations either on a Forest or a Regional basis. The Region has one centralized Regional project and at this time no others are planned. Forests in intensive breeding programs have centralized Forest crews. A considerable amount of field work is delegated to the Ranger District level. The Regional Geneticist provides technical direction for the tree improvement programs and training of personnel involved in tree improvement work.

Development of white pine blister rust resistant western white pine and sugar pine is assigned to the centralized Regional project (see appendix 5 for project plan, part 1). The Region has a cooperative agreement with the Bureau of Land Management for the development of rust resistant white pine. The evaluation of western white pine and sugar pine families for resistance to blister rust is done and western white pine seed orchards are located at the Region's Dorena Project. The Bureau of Land Management develops and maintains the sugar pine seed orchards for both agencies. Other work centralized at the Dorena Project is the extraction and storage of tree improvement seed lots. The project also serves as a training location for tree improvement workshops.

Certification of tree seed used for reforestation purposes to source and origin is Regional policy including seed harvested by Forest Service crews and extracted at Forest Service facilities.

The Region's commercial forest land will be assigned to one or more breeding zones. A breeding zone identifies an area within which a superior strain of a specific tree species will be developed for reforestation use in the zone. Zone boundaries are based on the best available environmental

¹Presented by Peter Thiesen, Regional Geneticist, R-6.

information and are to some extent arbitrary but they provide a land unit planning base for tree improvement. Generally, seed will not be used outside the seed zone and elevation band of origin until it is proven that it can be used safely. An exception would be the bulking of open pollinated seed in approximately equal amounts from each selected tree in a breeding zone for use throughout the breeding zone. It is recognized that some of the families may not perform satisfactorily if planted beyond the very local source area but we are dealing with a large number of families from locations relatively evenly scattered over the breeding zone and expect the poor families to be a minor segment in resulting stands and that they will be weeded out during cultural practices.

Eight stages are identified in the Region's program to increase wood fiber yield through genetics. These are:

1. Identification of tree seed to origin and source.
2. Stand manipulation to take advantage of best available plant material.
3. Seed collection areas.
4. Seed production areas.
5. Selected trees.
6. Provenance evaluation.
7. Intensive breeding.
8. Redefinition of breeding zone boundaries.

The Region will enter into cooperative tree improvement programs with other landowners where the opportunity exists.

STAGE 1

Stage 1, the identification of tree seed to origin and source, was fully implemented in 1972 when a policy decision was made to have all Region 6 seed acquisitions certified to the highest certification class for which the seed is eligible in accordance with the tree seed certification standards of the Northwest Tree Seed Certifiers' Association, Appendix 1, and to maintain certification of seed in Region 6 seed stores. The tree seed certification standards for Oregon and Washington are identical. Forest Service personnel were instrumental in the development of the certification standards and are active in keeping the standards current.

It has been Regional policy for a number of years to use tree seed only in the area of origin until it is demonstrated that trees produced from the seed will perform satisfactorily in other areas. The possibility of certifying not only tree seed but also seedlings produced in nurseries from certified seed is being studied. The certification of seedlings produced from certified seed is desirable since a significant number of seedlings for Region 6 are produced in other than Forest Service nurseries and even in Forest Service nurseries errors in seedling identification have been found.

Human error will not be eliminated through the certification program, but we do expect that the errors will be discovered and corrective action taken before the seed or seedlings are used.

The tree seed zones, Appendix 2, established by the Western Forest Tree Seed Council are used to identify seed and seedlings to origin. The Region further identifies seed and seedlings to the Forest and Ranger District on which the seed was collected and provides a further identification for more local conditions, Appendix 3. Our short-term planned tree seed inventory, Appendix 6, is based primarily on wild stand seed collections. The planned seed inventory for improved seed is shown in Appendix 4.

The identification of tree seed to origin and source is not expected to result in a genetic gain from general stand seed collections but it will prevent a wood fiber production loss if the seed is properly used. ~~Origin and source identification is essential~~ if the gains available through tree improvement are to be realized. Genetic gain or loss is the difference between the mean for a given trait in the improved population and that in the nonimproved population. For adaptability traits, extending the use of improved strains of forest trees to areas for which they are poorly adapted will cancel some, all, or result in a loss for these traits.

STAGE 2

Stage 2, stand manipulation to take advantage of the best available plant material for a given site and maintenance of desirable growth, is essential to capture the full potentials of tree improvement.

Knowledge from tree improvement research and of the plant material from tree improvement projects can be applied and used to man's advantage provided adequate planning is done and the people who are charged with implementing the plans are committed. The Ranger District silviculturist manipulates existing and future stands to achieve the defined management plan goals.

Some of the methods available to silviculturists to manipulate stands in a positive genetic manner are:

1. Selection of the best tree species for a given reforestation site.
2. Selection and use of seed of proper origin.
3. Wise use of improved seed. As genetic information becomes available for selected trees in intensive breeding programs, trees having high heritability for frost tolerance, animal damage resistance, drought avoidance, disease resistance, early juvenile growth rate, etc., will be identified. With this knowledge, the silviculturist will have the capability of tailoring a seed lot for a specific reforestation site to avoid or reduce potential problems.

4. For wood fiber production, concentrate growth on better than average trees in stocking level control operations. Local silvicultural guidelines will have to be developed for each improved strain coming from breeding programs since response of the improved strains to cultural practices are not expected to closely follow the response obtained from management of unimproved stands. Evaluation plantations will furnish some of the data for use in developing silvicultural guidelines for the improved strain.
5. Use a harvest or site preparation method that will leave the site in condition for prompt reforestation with the desired tree species.

STAGE 3

Stage 3, seed collection areas, is an interim step between wild stand seed collections and collections from seed production areas, selected trees, and seed orchards. In this method of tree improvement, better than average native stands or sites favorable for seed production are selected from which to harvest seed. A small increment of genetic gain is expected since seed will not be harvested from poor stands. Seed collection areas are usually phased into seed production areas as rapidly as possible.

STAGE 4

Stage 4, seed production areas, is considered as an interim tree improvement method in those tree improvement programs where intensive breeding is planned and as the goal in programs where recurrent selection only is planned; see Appendix 4 for breeding method per breeding zone.

Three types of seed production areas are recognized in the Region. These are natural stand, plantation, and planned seed production areas. Natural stand seed production areas are developed by roguing and thinning native natural stands. Plantation seed production areas are developed by roguing and thinning plantations of known origin. Planned seed production areas are developed by planting seedlings from well scattered selected native sources within a seed zone or breeding zone in a predetermined design to avoid inbreeding and managing the plantation for seed production. Current natural stand and plantation seed production areas, where applicable, will be converted to planned seed production areas by the introduction of new plant material. All trees in a planned seed production area are identified to origin and source to facilitate phasing into an intensive breeding program if it becomes desirable.

In the intensive breeding programs, an evaluation plantation, when properly designed, can be converted to seed production by roguing. The desirability of this action will be determined at a future date and will depend to a large extent on the progress of seed orchard development.

Seed production areas will be established only on sites favorable for seed production as verified by historical records. A number of areas have been identified where climatic conditions are such that potential seed crops are seldom destroyed by insects or climatic events and conversely, other areas have been identified where seed crops seldom mature due to climatic or insect damage.

STAGE 5

Stage 5, selected trees, is the tree improvement method in which well scattered native trees are selected within each breeding zone. Seed from the selected trees is harvested for reforestation use.

In the Region's intensive breeding programs, the genetic value of the selected trees is evaluated, reselection among the selected trees is done to increase genetic gain, and the selected trees provide a base for intensive breeding. See Appendix 4 for the number of selected trees planned per species per breeding zone. In the Region's low intensity programs (recurrent selection), the selected trees will not be evaluated. Their sole purpose is a source of reforestation seed until adequate seed is obtained from planned seed production areas.

STAGE 6

Stage 6, provenance evaluation, will be used to extend the range of native species. The only planned program is the identification of noble fir provenances that will perform satisfactorily north of the natural range of noble fir in the Washington Cascades.

STAGE 7

Stage 7, intensive breeding, is planned for the principal species in those breeding zones where most of the regeneration of denuded areas will be accomplished by planting. Seed will come from seed orchards. Seed orchards will be clonal, seedling, or clonal and seedling combined and will be developed from plant material of known genetic worth based on evaluation plantations within the breeding zone except where seedlings from single tree mating of selected trees are used. In the single tree mating approach, an orchard will be rogued on the basis of family performance in evaluation plantations prior to significant seed production in the orchard.

The evaluation plantations will preserve genetic material at four to six different locations in a breeding zone and provide material for selection and future intensive breeding. The plantations will be managed to the same intensity anticipated to be used as general practice in the future.

Selective breeding will be carried out on a planned basis to provide plant material for second generation and more advanced seed orchards.

STAGE 8

Stage 8, redefinition of breeding zone boundaries will be accomplished by evaluating plant material outside the breeding zone of origin but within the natural range of the species to determine how far the improved plant material can be moved and still provide superior performance. The goal is to find plant material that can perform in a superior manner over a wide area in order to reduce the number of seed orchards and provide additional selection intensity for increasing genetic gain.

ESTIMATES OF GENETIC GAINS AVAILABLE

Orr-Ewing (15), Greathouse (10), Bingham and others (2), and Roche (19) have emphasized the gains available through the proper identification and use of tree seed. Through proper identification and use of tree seed, production and quality losses can be avoided; financial resources that would ordinarily be used to correct the most serious off-site problems would be available for other high priority work to increase productivity; and if seed is from selected trees or stands, a genetic gain in desirable traits is possible.

Orr-Ewing (15) has pointed out the problems involved in general unsupervised seed collections. Of special interest is the probability of the collections being made from the poorer trees in a stand because they are often heavy seed producers and easy to climb, or from plantations of unknown origin.

Proper identification and use of tree seed is a basic requirement in any tree improvement program. The efforts of tree improvement workers can be negated by poor seed identification procedures or improper use of an improved strain.

Planned seed production areas are the ultimate seed production unit in the Region's mass selection programs. The general guidelines for this type of area were discussed by Squillace (26). Evaluation of plant material in the seed production areas is not planned but identity to origin is maintained so that the plant material may be evaluated in the future. Trees, usually natural seedlings from approximately 200 sources of local origin widely scattered over a seed zone or breeding zone, will be planted in a planned seed production area. Advantages are:

1. Maintenance of heterozygous populations in plantations as a buffer against insect, disease and climatic losses (9, 13, 20, 29). This is considered to be an important consideration especially where reforestation seed needs are low. In this case, it is entirely possible, if not guarded against, to obtain sufficient seed for a number of years from a single collection representing one or two parents which may not do well over the seed use zone.

2. Secure a genetic gain by reducing vigor loss due to inbreeding. Sorensen (25) estimated that natural self-fertilization in Douglas-fir could result in a volume growth depression of 4.5 to 6 percent. He pointed out that mating of close relatives in natural stands may contribute to loss of vigor due to inbreeding. The mating of close relatives would essentially be eliminated in planned seed production areas since close relatives would not be planted in close proximity to one another. Screening of the trees in the area for selfing ability and using only trees that are self-sterile or nearly so for seed collection would add an additional increment of genetic gain. Total gain for Douglas-fir should approach Sorensen's estimate of 4.5 to 6 percent for volume growth based on random selection of parent trees. Phenotypic selection could result in an additional 10 to 13 percent gain.
3. Concentrates seed production in one unit.
4. Preserves plant material for the future (3, 13).

Silen (21) described a progressive tree improvement program for Douglas-fir based on the results of the Douglas-fir heredity study. Most of the Region's intensive tree improvement programs will essentially follow Silen's plan and modifications as they are developed by Silen's research group. Exceptions are resistance breeding. Silen pointed out that "within a race, best families from wind-pollinated parents outproduce poorest families in timber volume per acre at 50 years by ratios of 2:1 and sometimes over 3:1" and that "even from randomly selected parents within a race, the one best parent in four would have provided more than 10 percent increased volume over the average of unselected parents."

Silen (21) recommended that 300 parents be used and based this on a reselection intensity of 1:4. Burdon and Shelbourne (3) recommended that 200 or more parent trees be used to avoid loss of uncommon genes. The Region is using at least 200 parents per breeding zone and a selection system primarily for volume to identify the parent trees, recognizing that the greatest gains will be after reselection based on results from evaluation plantations.

The estimated volume gain from obtaining reforestation seed from the originally selected trees is 10 to 13 percent (14). Squillace and Silen (27), Silen (22), Walters et. al. (30), and Dorman (6) have reported taper to be highly heritable in conifers. Since the Region's tree selection system is strongly orientated toward the selection of rapidly growing trees having low taper, the estimated gain could be conservative.

In an unpublished paper given at the Tree Improvement Workshop, Eugene, Oregon, April 1966, Frank Sorensen, Pacific Northwest Forest and Range Experiment Station Geneticist, discussed potential growth increases through tree improvement in Douglas-fir based on the Douglas-fir heredity study. The parent trees for the study were randomly selected in 1912 and Sorensen's

comparisons are based on half-sib family performance at age 50 years. Reselection of the best families based on field performance resulted in the following estimates for volume gain at the Wind River Plantation.

Selection Intensity	Percent Gain by Source	
	Darrington	Palmer
1 in 11	63	58
2 in 11	42	41
5 in 11	23	23

Mature survival was very important in volume production by family. Wright (31) pointed out the deficiencies in the Douglas-fir heredity study, however, the study does provide information based on long-term field performance.

Snyder (23) reported the effect of selection intensity on potential gain for wind-pollinated families of longleaf pine after reselection based on family performance at age 8 years to be as follows:

Reselection Intensity	Percent Gain in Plot Volume at Age 15
1 in 10	43
1 in 4	15

Most of the gain was attributed to better survival of taller families not to differences in growth of the survivors.

The effect of increasing selection intensity on rate of gain is strikingly shown in the above examples and indicates the amount of gain to be expected upon reselection based on field performance. Both studies show the importance of survival within families on productivity per unit area.

For Douglas-fir, Campbell (5) estimated an 11 to 15 percent genetic gain per generation for stem volume and a 7 to 10 percent gain for diameter breast height of individual trees using a 1 in 100 selection intensity. Stonecypher (28) estimated that fiber yields per acre could be increased at least 10 percent in the first generation for loblolly pine. For slash pine, Nikles (14) listed gains for volume of 10.7 to 39.4 percent depending upon intensity of breeding method.

In summary, when considering gain in volume, the estimates vary widely but show that substantial gains are possible. Gains available by taking advantage of traits other than volume will also be identified in evaluation plantations or elsewhere. Desirable traits such as drought avoidance (11), rapid juvenile height growth which reduces severity of competition from brush (4, 14), resistance to animal damage (17, 18), etc., will not only get plantations off to a rapid start but will also reduce the need for the use of pesticides and release plantation maintenance funds for productivity increases elsewhere in the forest.

The productivity gains available through the development of white pine blister rust resistant western white pine and sugar pine are difficult to quantify. It is estimated that rust resistant strains of western white pine and sugar pine will increase productivity on suitable white pine lands on a Regional basis by more than 15 percent. Additional gain can be made by improving tree volume. Some commercial forest lands would be eliminated from the commercial forest land base if the white pines are not available for reforestation since other tree species will not produce merchantable products on these lands. Western white pine is also capable of good growth and survival on Poria weirii infested land.

It is desirable to develop resistance in Port-Orford-cedar to phytophthora root rot, in Sitka spruce to the Sitka spruce weevil, and in Pacific silver fir to balsam woolly aphid. Sufficient information is available to start resistance programs in Sitka spruce (8) and Pacific silver fir (16) but clues are lacking on how to approach resistance breeding in Port-Orford-cedar.

ESTIMATED COSTS

ITEM	
Tree selection	\$10-\$50/tree
Includes marking and records	
Seed collection and processing from selected tree for tree improvement purposes	\$25/tree
Single pair mating of selected trees in forest	\$100/cross
Evaluation plantations	
Establishment	\$16,000/breeding zone
Maintenance (lifetime)	\$20,000/breeding zone
Data collection and processing	\$15,000(?) /breeding zone
Seed orchards	
Site preparation	\$ 500/acre
Fencing	\$1000/5 acres
Seedling orchard	
Planting	\$ 150/acre
Grafted orchard	
Understock planting	\$ 120/acre
Scion collection	\$6-\$50/parent
Grafting (includes clone bark and incompatibility testing)	\$5/orchard tree
Maintenance	\$200/acre/year
Planned seed production area	
Establishment	\$850/acre
Maintenance	\$100/acre/year
Selective breeding based on performance	\$100/cross
Program administration, etc.	
Regional	\$60,000/year
Forest	Up to \$12,000/year

SILVICULTURAL CONSIDERATIONS

Nikles (14) stated that "the greatest returns from investment in attempts to improve quantity and quality of forest economic yield must come from an integrated programme employing genetic, environmental and managerial approaches." Larsen (12) pointed out that "manipulation of stand density is the most powerful method available to the silviculturist for regulating both total wood yield and wood quality" and discussed tree growth as if affects wood yield and wood quality. Bergman (1) also pointed out that the optimum increase in volume production and quality will come from a combination of forest tree breeding and silviculture.

The tree breeder can make better strains of trees available to the silviculturist but it is the silviculturist's job to use and manage them correctly in order to achieve maximum economic gains. At best, integrating tree breeding with silvicultural practices will be a complicated process and especially so for the intensive tree improvement programs.

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The R-8 Tree Improvement Programs
Talk presented by T. F. Swofford at
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October 22, 1974

Rationale for Program

The Region 8 tree improvement program is pre-dated by most of the major programs in the South. The States of Georgia and Texas and the Callaway Foundation in Georgia started their programs in 1954. In just a few years after 1954, many of the pulp companies had started their own programs and joined tree improvement cooperatives.

Three cooperatives now operate in the South - one by the University of Florida with 11 members, one by the North Carolina State University with 22 members, and one by the Texas Forest Service with 12 members. The tree improvement cooperatives were formed for the purposes of obtaining technical guidance, pooling of information, and exchange of tree selections. In addition to the 45 members of the cooperatives, 21 corporations, government agencies and individuals are engaged in tree improvement.

The Region 8 pine program was initiated in 1961 and the hardwood program in 1969. The rationale for the programs was the indication from research of the strong inheritance of many desired timber characteristics and the improvement demonstrated by the superior seed sources established by the early tree improvement programs. Faster growth, pruning ability, straightness, disease resistance, gum yield, and drouth resistance were some of the desired characteristics demonstrated as obtainable through selected seed source.

Goals of Programs

1. Abandonment of wild stand seed collection.

Wild stand collection is still necessary to fill present seed needs.

2. Interim use of seed production area seed until pine seed orchard production.
3. Conversion of all commercial forest stands to superior tree stands in one rotation. This applies to both pine and hardwood forests and will progress as rapidly as seed becomes available and hardwood conversion techniques are developed.
4. Selection and establishment of second generation pine orchards from progeny tested trees created by controlled breeding of first generation orchard trees.
5. Selection of a minimum of 30 superior hardwood trees in each geographic source and establishment of clone holding banks.
6. Development of techniques for successful artificial regeneration of hardwoods despite traditional slow initial height growth and overwhelming competition from sprouts of already established hardwood root systems.

Level of Program Development

1. Pine seed production areas are established on every forest in six of the seven species selected for the tree improvement program. 2800 acres of seed production areas were established. Use of SPA seed has varied from year to year depending upon the availability of SPA cones. Maximum use to date has been the use of SPA seed for 90% of pine nursery production in one year. The seed production areas are slowly being liquidated as better seed sources become available.

2. Thirty-eight species - geographic source combinations of pine seed sources were recognized. Fifty trees from each species geographic source were selected after meeting exacting standards of superiority when compared to the same species of trees of same age and growing on the same site. An additional 15% were selected because of anticipated grafting incompatibility making a total 2,500 selections. The selection program was completed in 1967. The species in which selections were made were shortleaf, longleaf, white, slash, Virginia, sand and loblolly. Approximately 50 selections were exchanges with private industry.

3. Five pine seed orchards totaling 1,044 acres have been established and are starting seed production. They are located in the following States:

Louisiana	202 acres
Arkansas	251 acres
Mississippi	302 acres
North Carolina	171 acres
South Carolina	118 acres

A total of 99,429 grafts are established in these orchards.

In addition to the above 5 seed orchards, a sand pine orchard of 45 acres is now being established in Florida. This orchard was originally located in Mississippi but was re-established in Florida due to orchard destruction by root rot and regular flower destruction by unseasonably cold weather.

A shortleaf orchard of Missouri source was also established in Arkansas for Region 9 under a cooperative agreement. Region 9 made the tree

selections, supplied the scions and understock and financed the orchard. Region 8 established and manages the 85 acres of orchard. Seed production is just beginning.

The seed and seedling production from the 5 completed R-8 orchards is as follows:

Year	Orchard					TOTAL	M SEEDLINGS
	KIS	OUA	MISS	NC	SC		
1969				1		1	16
1970	1/2	1	11	3		15 1/2	245
1971	21	1	26	33	15	96	1,463
1972	10	26	21	21	7	85	1,389
1973	235	3	76	20 1/2	51 1/2	386	3,541

4. In cooperation with the SE and Southern Forest Experiment Stations, a pine breeding plan was prepared for the controlled pollination of the superior trees now established in the seed orchards. This plan included the best combinations of geographic sources based on research developed since the original division of seed sources. Some sources were combined where no differences have been demonstrated and others were kept as single sources when distinct racial characteristics were proven. A disconnected partial diallel system was used to sample the population. Individual matings were made to match characteristics indicated by the original scoring sheets, insect and disease resistance tests and progeny performance. The seed produced by the controlled pollinations will be used to grow seedlings for test plantations. The geographic locations of the test plantations will further validate the seed source divisions.

From the plantations, selections will be made for second generation orchards. The controlled pollination seed will also be used for special tests to determine disease resistance such as fusiform in slash and loblolly, brown spot in longleaf and commandra rust in shortleaf and loblolly. Here is a condensed review of the controlled pollination program.

R8 Breeding Program

Species	Number of Breeding Populations	Number of Controlled Crosses	Number of Pollinations	Number of Plantations
Longleaf	4	975	29,250	14
Slash	1	540	16,200	4
Loblolly	5	1,005	30,150	24
Shortleaf	5	1,155	34,650	21
Virginia	1	150	4,500	5
White	1	225	6,750	4
Total	17	4,050	121,500	72

Controlled pollinations were started in the spring of 1973. Completion in 4 years after the start of work with a species - geographic source is expected.

5. Selections of hardwood superior trees are nearing the goal of 50 per species in each of the 5 geographic zones. The following tables give the status of hardwood tree selection as of September 1, 1974.

Status of Hardwood Superior Tree Selection
as of September 1, 1974

Zone	Forest	Species	Approved	Total for Zone	Total Needed
Kentucky	Daniel Boone	BO	40	40	30
		WO	37	37	30
		NRO	30	30	30
		CO	36	36	30
		YP	41	41	30
Arkansas	Ozark	BO	14		
	Quachita		11	25	30
	Ozark	WO	11		
	Quachita		21	32	30
	Ozark	NRO	13		
	Quachita		24	37	30
Northern Appalachian	George Wash- ington	BO	7		
	Jefferson		8	15	30
	GW	WO	4		
	Jefferson		2	6	30
	GW	NRO	15		
	Jefferson		10	25	30
	GW	CO	8		
	Jefferson		14	22	30
	GW	YP	22	(1 Monogahela)	
	Jefferson		6	29	30
Central Appalachian	Jefferson	BC	6	(11 Monogahela)	
	Jefferson			17	30
	Cherokee	BO	7		
	N. Carolina		5		
			1	13	30
	Jefferson	WO	3		
	Cherokee		8		
	N. Carolina			11	30

Zone	Forest	Species	Approved	Total for Zone	Total Needed
Southern Appalachian	Jefferson	NRO	13	31	30
	Cherokee		10		
	N. Carolina		8		
	Jefferson	CO	5	20	30
	Cherokee		12		
	N. Carolina		3		
	Jefferson	YP	3	21	30
	Cherokee		14		
	N. Carolina		4		
	Jefferson	BC	12	33	30
	Cherokee		16		
	N. Carolina		5		
	Francis Marion	BO	2	38	30
	Cherokee		18		
	Chatt-Oconee		8		
Southern Appalachian	N. Carolina		10	39	30
	Francis Marion	WO	1		
	Cherokee		18		
	Chatt-Oconee		12	33	30
	N. Carolina		8		
	Francis Marion	NRO	1	31	30
	Cherokee		5		
	Chatt		11		
	N. Carolina		16	42	30
	Francis Marion	CO	18		
	Cherokee		9		
	Chatt		4	34	30
	N. Carolina		15		
	Cherokee	BC	15		
	Chatt		4		
	N. Carolina		15		

6. Techniques for successfully incorporating superior hardwood stock in present hardwood stands are unknown. Pending development of these techniques, the superior tree selections will be preserved in clone holding banks at the Ouachita and Beech Creek Seed Orchards. Initially an effort was made to propagate the clones by rooting. However, after a three year effort, successful rooting techniques were developed only for black cherry and yellow poplar. The oaks remain an unsolved problem. Therefore, the oak clone holding banks are being established by grafting. This work is being pushed as rapidly as possible to prevent the destruction of the selected trees in the forest by trespass, inadvertent cutting, disease or insect attack, tornadoes and hurricanes.
7. Pending the development of artificial regeneration methods, test plantations of open pollinated progeny are being established. Evaluations of these progeny will be used to eliminate those selections that produce undesirable progeny.
8. Some method of economic justification is needed for the tremendous expenditures required by a massive and on-going tree improvement program. In 1971, an economic evaluation of the R-8 tree improvement pine program was made to determine the genetic volume gain, quality gain and rate of investment return. These calculations were made for each species in all recognized seed sources. The results are presented in the following tables.

Table 1 - Percentage Increase in Present Stand Volume Resulting
from Use of Superior Tree Stock

	Percentage Gain in Volume					
	<u>Shortleaf</u>	<u>Slash</u>	<u>Loblolly</u>	<u>Longleaf</u>	<u>White</u>	<u>Virginia</u>
<u>Alabama</u>		21	19			
<u>Mountain</u>				30		
<u>Coastal</u>				14		
<u>Chattahoochee-Oconee</u>	26		24		40	20
<u>Cherokee</u>	29				29	21
<u>Daniel Boone</u>	23					
<u>Florida</u>		22		15		
<u>Francis Marion & Sumter</u>				15		
<u>Piedmont</u>			22			
<u>Coastal</u>			26			
<u>George Washington</u>	27				33	21
<u>Jefferson</u>	26					18
<u>Kisatchie</u>	25	42	27	26		
<u>Mississippi</u>	25	29		23		
<u>North</u>			24			
<u>South</u>			17			
<u>North Carolina</u>	27		31	29	33	
<u>Ouachita</u>						
<u>East</u>	22					
<u>West</u>	25					
<u>Texas</u>	23		21	27		

The estimated gains in stumpage price resulting from increased tree quality are presented in Table 2. Greater total and merchantable heights, earlier and more complete pruning, and greater straightness of bole are the bases for estimating the superior tree increase in quality.

Table 2 - Quality Gain from Superior Trees

<u>Species</u>	<u>% Gain in Current Stumpage Price</u>
Shortleaf	20
Slash	15
Loblolly	20
Longleaf	15
Virginia	8
White	None

The financial return on the investment necessary for completion of the R-8 tree improvement program with genetically superior trees through the first sawtimber rotation was calculated. In any tree improvement program the items of cost and benefit occur at different times during the life of the project. To compare these items, all costs and benefits must be discounted or adjusted to a common point in time. One compound rate of interest will adjust all cost and benefit items to this point where costs equal benefits. The interest rate that accomplishes this is the financial return on the investment. These compound rates of return are presented in Table 3.

Table 3 - Percent of Financial Return from Tree Improvement Investment

Forest and Geographic Zone	Species					Average Pine Acre
	Shortleaf	Slash	Loblolly	Longleaf	White	
Alabama		17	16			15
Mountain				15		
Coastal				14		
Cherokee	14				13	14
Daniel Boone	15					15
Florida		19		14		16
Francis Marion & Sumter				14		19
Coastal			20			
Piedmont			18			
Chattahoochee-Oconee	16		19		17	17
George Washington	17				18	18
Jefferson	12				12	12
Kisatchie	19	22	20	16		19
Mississippi	19	20		17		19
North			20			
South			19			
North Carolina	15		17	12	15	15
Ozark	14					14
Ouachita						17
East	17					
West	18					
Texas	18		18	16		18
REGIONAL AVERAGE						16

9. Periodically the tree improvement program needs review to determine adequacy of present practices and future plans. The R-8 pine program was reviewed in 1973 for identification of problems and factors associated with final implementation. The review included seed supply, seed needs, adequacy of extraction facilities, nursery, capacity and financing. Hopefully, this report will be the basis for long range planning for full implementation of tree improvement and silvicultural programs. One example is a review of forest seed needs and orchard seed supply. The other items listed in the preceeding paragraph were analyzed in the same manner.

Changes Affecting Original Orchard Planning

Since the initial plans for the establishment of the seed orchards were prepared, many timber management practices have been changed. We are faced with plus and minus factors in making a current evaluation of forest seed needs and supply. This analysis was made with consideration given to all these factors.

Some of the conditions that changed seed needs are as follows:

A. In the mid-1960's, the R-8 standard spacing for planting was changed from 6' x 6' requiring 1,210 seedlings per acre for all species to 20' x 20' for white pine with 100 seedlings per acre, 6' x 12' for longleaf with 600 seedlings per acre, and 8' x 12' for other conifers with 450 seedlings per acre. These spacing changes reduced our seed needs for seedling production from 50 to 90% of the original estimate.

B. Acreage of pine management type obtained through prescription surveys is now more precise than the original guesses formerly used as a planning basis. Some planned species acreages were reduced drastically, thus altering seed needs.

G. Changes in management concepts reduced the acreage planned for exclusive timber production. Developing capabilities and public needs diverted some acreage to other uses. This, in turn, further reduced the seed needed for regeneration.

H. A major change in regeneration methods that increased seed needs was the expansion of direct seeding with a resulting decrease in planting. Greater quantities of seed are needed in direct seeding.

I. The potential seed supply anticipated in the original orchard planning will not be collected. Improved cone and seed collection techniques for all species were expected to develop prior to orchard seed production. Improvement has been made only for slash and longleaf. With the limited manpower and methods now available, realistic planning must be based upon the fact that only a part of each cone crop will be harvested in the two

10. Several studies have been initiated to determine the requirements for fast initial growth of oak. Some are our own administrative studies involving root pruning, stem pruning and fertilization in the nursery. One study is in cooperation with the Tennessee Valley Authority in the production of physiologically superior nursery stock for fast initial height growth. Another study already started is a cooperative effort with the Southeastern Forest Experiment Station concerned with different types of mycorrhizal growth on hardwood seedlings.

Program Organization

Until recent years, the programs were headed by a tree improvement forester in the Regional Office and four in the field assigned to a National Forest Supervisor but given zone responsibility for several forests. At the present time, the organization is being modified with a Regional Tree Improvement Forester in the RO and two zone tree improvement foresters with each assigned approximately one-half of the Region. In addition, each silviculturist on the Forests is concerned directly with tree improvement activities. A majority of the District Rangers and many aides and technicians are involved on an intermittent basis. Each orchard is managed by a technician with one or more assistants.

Problems

Insect Control

Cone Collection techniques

Hardwood artificial regeneration

Pollinations for pine and hardwoods

Hardwood vegetative propagation

Site-species relationships-what species where

Pine and hardwood juvenile - mature relationship

Pollen management

Scion-understock incompatibility

Establishment and management of seedling seed orchards

Lack of seed production increase despite increased

Orchard age in white pine

Silviculture Conference

1. Goal - Provide the best possible seed sources to Nurseries and National Forests that will produce fast growing, high quality, pest resistant forest trees.

Educate Forest personnel in tree improvement and genetics.

Develop seed sources for wildlife plantings

2. RATIONAL-

A. Program began in early 60's.

B. Program based on

1. Acres CFL/timber type (exhibit A)
2. Amount of genetic variation within species
3. Regeneration possibilities
4. Work being performed by others

C. Species priority (exhibit B)

1. 8 conifers
- 2 14 hardwoods

3. PROGRAM DEVELOPMENT -

A. Established seed zones (exhibit C)

1. Rudolph - Lake States
2. Limstrom - Central States

B. Established Seed Production Areas

1. Table 1.

C. Seed

1. Lake States

a. All seed comes from known areas.

b. Most seed comes from selected stands, S&A's, and individual trees.

D. Forest Tree Improvement Diagrams

E. Number of selections

1. Table 2

2. Over 3,000 made to date

F. Seed orchards - table 3

G. Progeny tests - table 4

H. Seed in storage - table 5

I. Breeding scheme

J. White Pine Program and trees included in program

4. ORGANIZATION

A. Three specialists

1. One in RO

2 One in Warren, Pa. (Allegheny)

B. One trained technician on each Forest -- usually on a District
or at a Nursery

C. Need an additional specialist to cover Missouri, Illinois,
Indiana, and Ohio

5. PROBLEMS -

A. Budget system

1. Budget should be computed with no side boards--how much is really
needed to do the quality job.

2. Genetics is a Cinderella Program - - we will get money anyway.

3. This year we had to eliminate superior tree selection due to
lack of funds.

4. 036 was still subsidized by 033 and 034 to carry out on-going
seed orchard and testing work.

B. Workload

1. Regional genetical needs to spend more time on genetics work. Presently working in 033, 035, and 036.
2. Need one additional Project Geneticist to cover Central State Forests.
3. GS 7-9 Tree Improvement Forester positions should be established on selected Forests.
4. Develop technician positions on each Forest.
5. Develop better career ladder for professionals--especially the Project Geneticists

C. Research

1. Research needs to be more responsive to our needs.
2. Perform more applied research in addition to their basic research
 - a. Flowering and controlled pollination
 - b. A sexual propagation
 - c. Use of exotic species
 - d. How to plant hardwoods

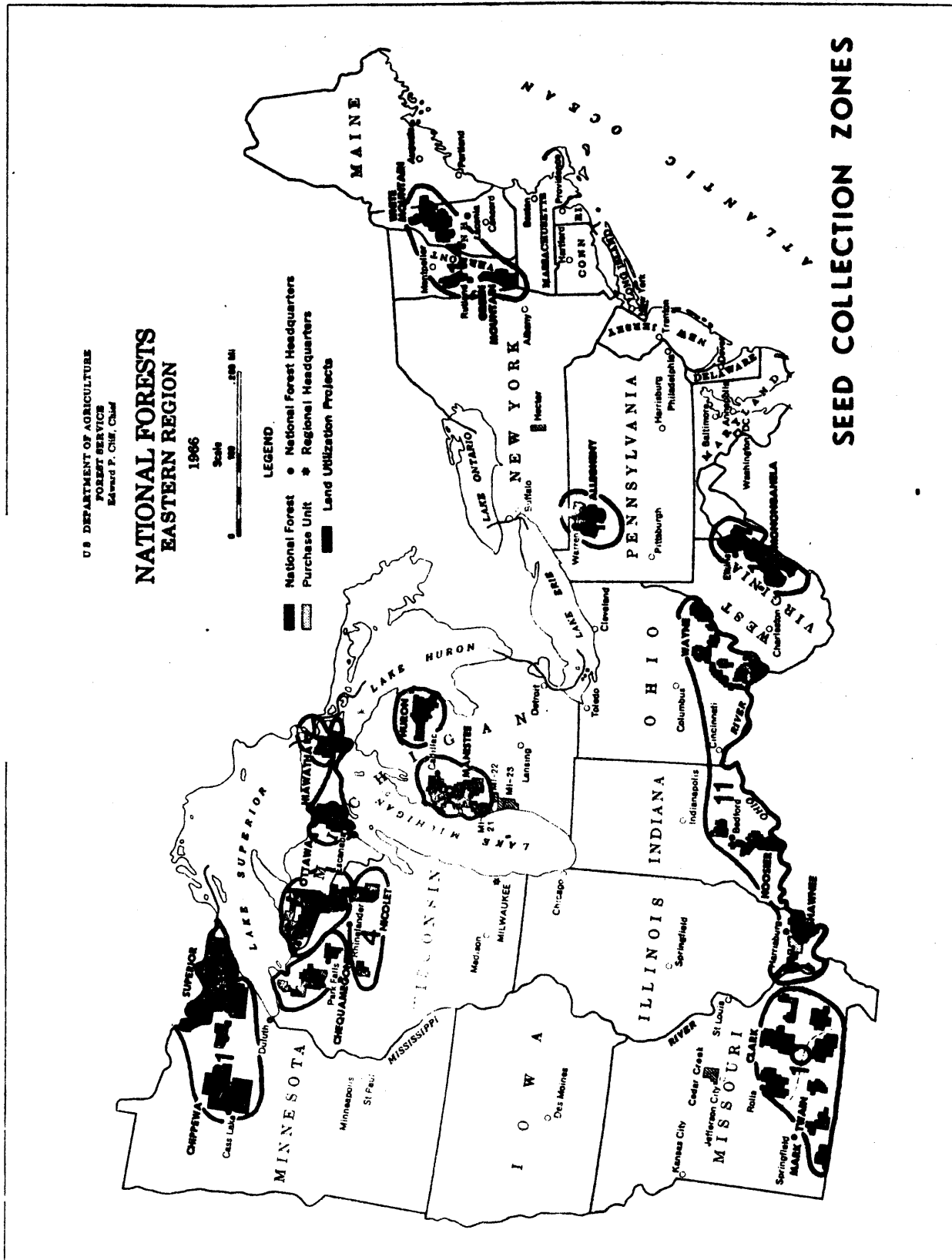
EXHIBIT A

REGION 9 -- TIMBER TYPES

Timber Type	Acres CFL	REGION WIDE RANKING					-- Acres/Type		Central Forests
		Region	Lake States	New Eng.	Alleg. Mtn's				
Northern Hardwoods	2,347,200	1	2	1	1				7
Aspen Birch	1,755,000	2	1	4	6				-
Oak-Hickory	1,652,000	3	8	-	2				1
Spruce-Fir	638,300	4	6	3	4				-
Jack Pine	592,000	5	3	-	-				-
White-Red Pine	545,700	6	4	5	7				-
Swamp Conifers	518,800	7	5	-	-				-
Brush and Open	356,200	8	7	-	8				4
Spruce-Hardwood	270,100	9	-	2	-				-
Southern Pine	232,800	10	-	-	3				2
Oak-Pine	172,700	11	-	-	-				3
Lowland Hardwoods	141,200	12	9	-	-				8
Post-Blackjack Oak	34,300	13	-	-	-				5
Red Cedar	27,700	14	-	-	-				6
TOTAL	9,284,000		8	5	7				7

FTI PROGRAM - Species Priority

<u>Species</u>	<u>Lake States</u>	<u>Central States</u>	<u>Eastern States</u>
White Pine	1		
Red Pine	6		
Jack Pine	4		
Shortleaf Pine		3	
White Spruce	2		
Black Spruce	5		
Balsam Fir			9
Larch	14		
Yellow Birch	4		4
Paper Birch	8		7
Black Cherry	9		1
Black Walnut		1	2
Yellow Poplar		2	3
Basswood	12		
Aspen	3		
Cottonwood		4	
White Ash		7	5
Sugar Maple	10		10
Red Maple	13		6
Red Oak	11		8
White Oak		5	
Black Oak		6	

SEED HANDBOOK

SEED HANDBOOK

CHAPTER 110 - CONE AND SEED COLLECTION

111 - SEED COLLECTION ZONES. The Region is divided into fourteen general seed collection and dispersion zone limits.

Dispersion zone limits for tree seed from developed seed orchards will be established on the basis of progeny test performance. Until such zone limits are defined, the present seed collection zones will be used.

Exhibit 1 shows the boundaries of the Tree Seed Collection Zones. These zones follow the climatic zones proposed by Rudolf^{1/} and Linstrom^{2/}.

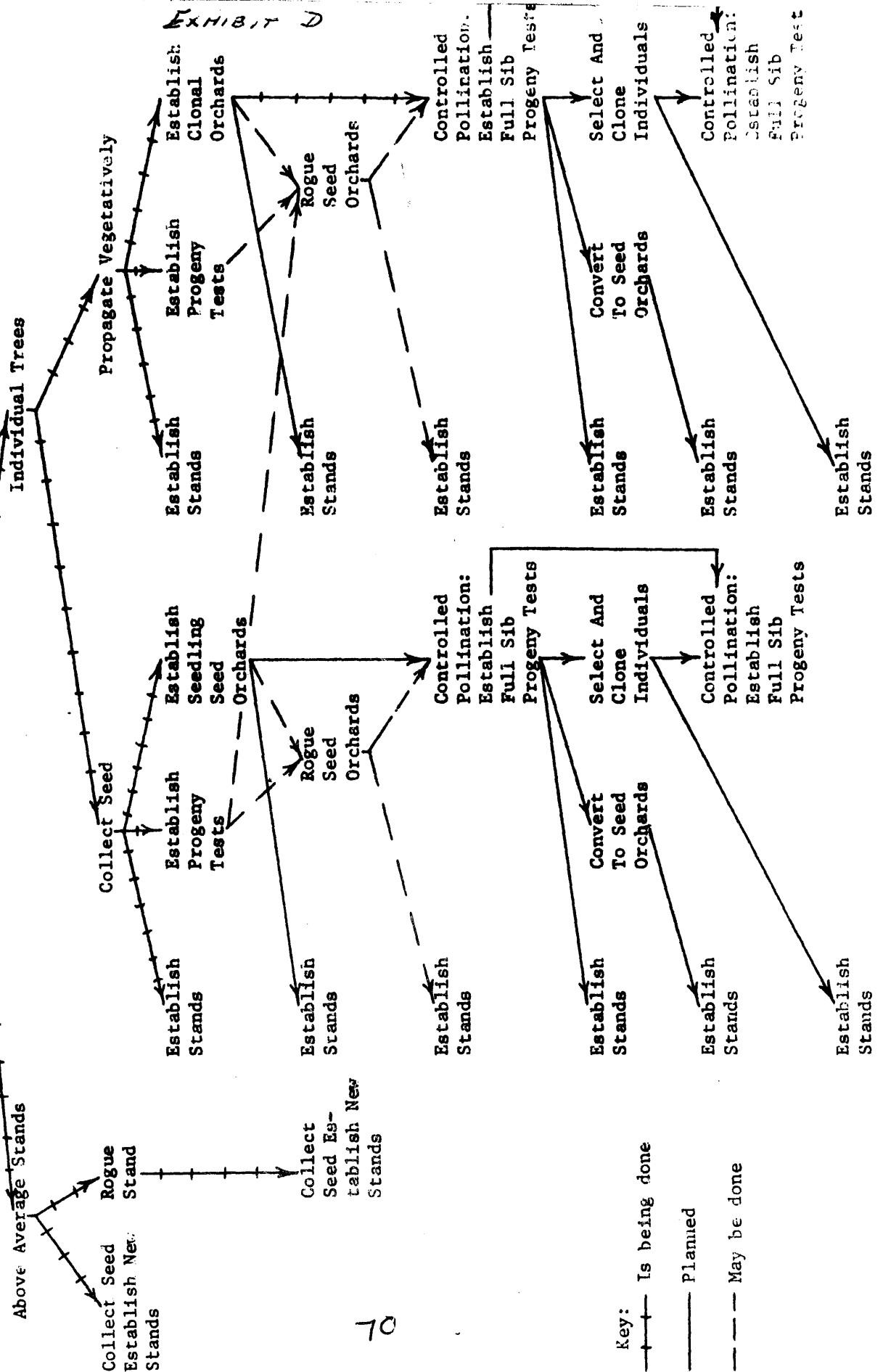
<u>Zone</u>	<u>Forest</u>	<u>Districts</u>
01	Chippewa Superior	All Aurora LaCroix Virginia
02	Superior	All others
03	Chequamegon	All except Medford
04	Chequamegon Nicolet	Medford Lakewood
05	Nicolet Ottawa	All except Lakewood All
06	Hiawatha	All except Soo
07	Hiawatha	Soo
08	Manistee	All
09	Huron	All
10	Clark Mark Twain	All All
11	Shawnee Hoosier Wayne	All All All
12	Monongahela	All
13	Allegheny	All
14	Green Mountain White Mountain	All All

^{1/} Rudolf, Paul O. A Basis for Forest Tree Seed Collection Zones in the Lake States. Proc. Minn. Acad. Sci. Vol. 24, pp21-28, 1956.

^{2/} Linstrom, G. A. Interim Forest Tree Improvement Guides for the Central States. USFS Res. Paper CS-12, 1965.

R-9 FOREST TREE IMPROVEMENT DIAGRAM

SELECTION



Key: —+— Is being done
 — Planned
 - - - May be done

STATISTICS FOR R-9 FOREST TREE IMPROVEMENT PROGRAM

The following tables summarize the forest tree improvement work being conducted by the U.S. Forest Service, Region 9^{1/}

TABLE 1. SEED PRODUCTION AREAS

<u>SPECIES</u>	<u>NUMBER OF AREAS</u>	<u>TOTAL AREAS</u>
White Spruce	6	244
Red Spruce	2	136
Norway Spruce	1	33
Red Pine	11	677
Eastern White Pine	3	23
Shortleaf Pine	5	283
Loblolly Pine	1	12
Black Walnut	<u>1</u>	<u>4</u>
	30	1,412

TABLE 2. SUPERIOR TREE SELECTION

<u>SPECIES</u>	<u>NUMBER OF SELECTIONS</u>	<u>SPECIES</u>	<u>NUMBER OF SELECTIONS</u>
White Spruce	184	Black Cherry	183
Black Spruce	151	Yellow Poplar	132
Eastern White Pine	825	Black Walnut	210
Red Pine	86	Yellow Birch	209
Jack Pine	434	White Ash	17
Shortleaf Pine	65	Red Maple	22
Balsam Fir	13	Paper Birch	103
Misc. Conifers	<u>40</u>	Sugar Maple	93
	1,798	Basswood	56
		Red Oak	63
		White Oak	17
		Misc. Hardwoods	<u>7</u>
			1,112

Total Selections = 2,910

11,000 00672 3000

12,411 10/21/74

^{1/} Prepared by Richard G. Miller, Regional Geneticist, July 18, 1974

TABLE 3. SEED ORCHARDS

SPECIES	LOCATION	ORCHARD NUMBER	NUMBER CLONES	NUMBER GRAFTS	TOTAL ACRES	% ESTABLISHED	YEARS ESTABLISH
Eastern White Pine ^{1/}	Wis.	1	806	4,005	40	86	1969
Eastern White Pine	Wis.	3	36	865	10	95	1969
White Spruce	Wis.	4	50	2,001	21	52	1969
White Spruce	Wis.	6	50	2,003	21	59	1969
White Spruce ^{2/}	Wis.	14	20	1,401	14	30	1973
White Spruce ^{2/}	Wis.	16	40	473	5	68	1973
Black Spruce	Wis.	8	50	2,003	21	82	1971
Black Spruce	Wis.	10	50	1,842	20	42	1973
Red Pine ^{2/}	Wis.	12	85	450	5	88	1971
Shorleaf	Ark.		50 ^{4/}	7,875	85	80	1969
Black Cherry	Penn.	100, 102 & 104	115 ^{4/}		5	100	1969, 70 & 7
Black Cherry	W. Va.	103, 105	115 ^{4/}		5	100	1969, 70 & 7
Yellow Birch	Vermont	618	42 ^{4/}		4	100	1973,
Yellow Birch	N. Hamp.	621	42 ^{4/}		4	100	1973,
Black Walnut	Ill.	633	52 ^{4/}		10	100	1973
Tulip Poplar	Ill.	100	15 ^{4/}		1	10	1973
Black Walnut	Ind.	635 & 640	56 ^{4/}		10	100	1974

^{1/}Clonal breeding arboretum - Blister-rust resistant Eastern White Pine Program

^{2/}Established in cooperation with the Institute of Forest Genetics, Rhinelander, Wisconsin

^{3/}Established in cooperation with Region 8

^{4/}Number of families in seedling seed orchards

TABLE 4. PROGENY TESTS

SPECIES	LOCATION	NUMBER OF FAMILIES	TOTAL ACRES	NUMBER REPS. PER TEST	YEAR ESTABLISHED
Eastern White Pine	Michigan	20	4 (1) ^{1/}	15 ^{2/}	1967
White Spruce ^{3/}	Michigan	2 sources	15 (1)	Alternate rows	1968
Black Cherry	Wisconsin	163	5 (1)	4	1971
Black Cherry	Pennsylvania	115	15 (9)	4	1969, 70 & 71
Black Cherry	West Virginia	115	14 (8)	4	1969, 70 & 71
Yellow Birch	New Hampshire	42	7 (2)	8	1973, 74
Yellow Birch	Vermont	42	7 (2)	8	1973, 74
Yellow Birch	Pennsylvania	40	4 (1)	8	1973, 74
Yellow Birch	West Virginia	38	4 (1)	8	1973, 74
Yellow Poplar	West Virginia	60	3 (2)	5	1973, 74
Yellow Poplar	Indiana	105	4 (3)	3	1973, 74
Yellow Poplar	Ohio	98	5 (2)	3	1973, 74
Yellow Poplar ^{4/}	Illinois	83	3 (2)	2	1973, 74
Hybrid Aspen	Wisconsin	8	27 (1)	10	1974

1/() = number of test sites within State.

2/Only six blocks have all 20 families.

3/Established in cooperation with the Institute of Forest Genetics, Rhinelander, Wisconsin

4/Established in cooperation with the Institute of Paper Chemistry, Appleton, Wisconsin and the Institute of Forest Genetics, Rhinelander, Wisconsin.

TABLE 5. NUMBER OF INDIVIDUAL TREE SEED LOTS

USED - NO SEED IN STORAGE

White Spruce	1
Jack Pine	9
White Pine	28 (19 controlled pollinated)
Black Walnut	122
Yellow Poplar	111
Yellow Birch	18
Black Cherry	<u>11</u>
Total	300

SEED IN STORAGE

White Spruce	168 (23 controlled pollinated)
Black Spruce	99
Jack Pine	259
White Pine	714 (329 controlled pollinated)
Black Walnut	7
Yellow Birch	151
Paper	25
Black Cherry	<u>103</u>
Total	1,526

Total seed lots included in program 1826.

Region 9 - FTI Computer System
Richard G. Miller, Regional Geneticist

I. Introduction

- A. Our situation 3 years ago.
- B. Data wasn't lost - just couldn't find it.

II. Development of System

A. Must have following attributes

1. Flexibility

- a) Progeny tests
- b) Seed Orchards
- c) Other planting (inoculation)

2. Help in work planning

- a) Accurate updated records
- b) Historical Records

3. Help with field work

- a) Where is work required
- b) Summaries to help interpret what's happening in field

B. Programs have been developed

- 1. Written in Fortran IV
- 2. Run on UNIVAC 1108 - Fort Collins

C. Handout

- 1. Brief description of each program
- 2. Copy of processing request form
- 3. Copy of data sheet

D. Improvements are still being made

E. Review outputs for 30 minutes - then discussion

III. Description of Programs

A. Superior tree Register

1. A listing of all trees included in program
Softwood report form
Hardwood report form
2. Trees are sorted on NF (State), species, acc. no.
3. Two tapes required
4. New selection can be added
5. Data for existing selection can be added or deleted
6. Sample printout (exhibit 1)

B. Status Report

1. Shows how each tree has been used in program
Softwood report form
Status codes
2. Status Report (exhibit 2)
3. Trees sorted by N.F. (State), species, acc. no.
4. Updated Register tape is used
5. Twice a year corrections are made on printout, cards punched, and update run - critical data only
6. Report is sent to each Forest --keep involved
7. Work plans are made directly from report
 - a. scion collection
 - b. cone collection

PROGRAMS ARE FLEXIBLE

C. Pollination and Seed Collection Record

1. Provides listing of all seedlots used in FTI program--current and historical.
2. Can be updated at regular intervals 2/yrs.
3. Uses 2 tapes
4. Pollination and S.R.F. - Show form
 - a. Side 1

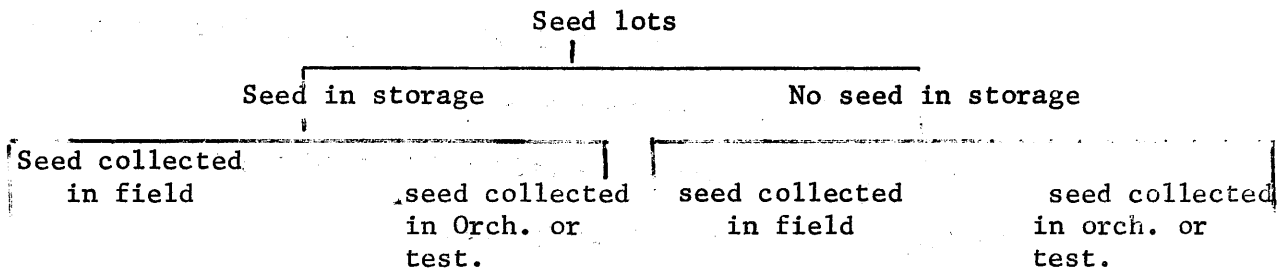
Review data collected

- b. Side 2

Review data collected

- c. Data keypunched directly from form
5. Program groups data as follows:

- a.



- b. Within each of these groups data is sorted by

National Forests

Species

Seed lot

Container number

6. Examples of Printout (exhibit 3)
 7. Updating is done on printout; usually updated twice a year
 8. Program is flexible - headings can be changed number of spaces must remain same

These 3 printouts serve as the basis for our record keeping system for our overall program. They also help keep people informed and are the foundation for workplanning.

The next series of programs deals with recording and summarizing data in individual tests/orchards. The basis for this system is a grid superimposed on the planting--each tree has a unique position.

D. Data Collection Form.

1. Computer printed data collection forms (exhibit 4)
2. 3 options
 - a. Blank form - used for new orchards and tests; people in field complete all items; 24 trees per page
 - b. Tally sheet for measurements; computer prints item 2,3,4 and 21 in sequence punch cards are sorted; 24 trees per page
 - c. Tally sheet for measurements; computer prints item 2,3,4 and 21 in sequence punch cards are sorted; starts new page for each row.
3. The number of trees per page can be changed.

E. Summary 1 - Clone or Family Summary

1. Summarizes items
 - a. Survival
 - b. Height growth
 - c. Flowering record
 - d. Controlled pollination record
 - e. Lammas
 - f. Frost Damage
2. Two options available
 - a. Option 1 - summarize data by family over entire test, use of test is not replicated (exhibit 5)
 2. Option 2 - summarizes data by block by family, used if test is replicated (exhibit 6)

F. Summary 1A - Block Summary

1. Summarizes same items as Summary 1, but by block rather than family.
2. Two options available
 - a. Option 1 Summarizes data by block over entire test (exhibit 7)
 - b. Option 2 Summarizes data by family by block (exhibit 8)

G. Summary 2 - Clone or Family Summary

1. Summarizes items
 - a. Insect and disease damage
 - b. Animal and mechanical damage
 - c. Blister Rust
2. Two options
 - a. Option 1 summarizes data by family over entire test
 - b. Option 2 summarizes data by blocks by family (similar to exhibit 6)

H. Summary 2A - Block Summary

1. Summarizes same items as Summary 2, but by block rather than family
2. Two options
 - a. Option 1 Summarizes data by blocks over entire test
 - b. Option 2 Summarizes data by family by block (similar to exhibit 8)

I. Summary 3 - Clone or family summary

1. Summarizes items
 - a. Stem forms
 - b. DBH
 - c. Need for release
 - d. Height to fork
 - e. Two additional variables redorded in column 24 and 25 at option of user
2. Two options available same as option 1.

J. Summary 4 - Clone or Family Summary

1. Summarizes items recorded in columns 22 and 23 at option of user plus blister rust
2. Only 1 option; summary by family (similar to exhibit 5)

K. WORKLIST

1. Generates a list of work by family, position number and block number
2. Displays work by several characteristics including,
 - a. survival (exhibit 9)
 - b. trees that were control pollinated
 - c. trees damaged by frost
 - d. flowering
3. Works in conjunction with MAP

L. MAP

1. Generates a map that can be used with WORKLIST
- 2 Indicates by row and tree in row various characteristics, including
 - a. Test layout (exhibit 10)
 - b. Survival (exhibit 11)
 - c. Height growth over preselected value (exhibit 11)

M. Random Seed Orchard design

1. Best for use in setting up an initial orchard
2. Generates
 - a. Random placement design
 - b. Crossing pattern design

IV Future Plans

A. Reforestation program - developing program to select optimum contracting bid.

B. Next step with current software is to combine programs into one package. One run gets all desired printouts.

C. Statistics - use stat. pack. We are developing this now to use date on our forms.

D. We look for your suggestions and comments. If you want to work with the programs, I'll send them to you along with test data so you can generate printouts similar to those I have showed you.

If change must be made on internal parts of program, they are best accomplished by original programmer (other than changing headings)

At the risk of repeating myself, I want to emphasize again that the headings can be changed to reflect whatever you want. You can use as little or as much as you wish.

Questions.

SUPERIOR TREE LIST BY FOREST, SPECIES, AND ACCESSION NUMBER

APR 16, 1974

ACCESS #	ST-	TREE	A	HEIGHT	D	VOL	APC	% SUPERIORITY	OBJECTV	ROUND	CROWN	BREN	SELF	SEED	ELEV	DATE								
NO.	P	CITY-	NO.	G	TOT-MER	B	(CU	DOM	CF	APC	PRI-SEC	RATIO	LEN-DIA	ANGL	PRUN	CROP (FT)	MO/YR							
E	C	NP-	E	(FEET)	H	FT)	(3)	TOT-MER	VOL	COM														
		DIST																						
481	94	55-	3-2-2	CH 3	65	85	0	16.6	53	0	0	0	4	6	.00	53	17	1	0	1	0	0/61		
482	94	55-	119-2-3	CH 7	85	81	0	19.3	67	0	21	0	103	0	4	6	.00	55	23	2	2	2	0	3/65
483	94	55-	3-2-2	CH 20	46	69	0	14.2	31	0	13	0	55	0	4	6	.00	32	0	1	12	2	0	3/65
484	94	55-	113-2-4	CH 21	53	76	0	15.0	45	0	21	0	41	0	4	6	.00	50	10	1	10	1	0	12/65
485	94	55-	3-2-2	CH 23	48	61	0	14.1	27	0	13	0	38	0	4	6	.00	43	19	1	19	2	0	1/66
486	94	55-	119-2-3	CH 24	19	38	0	7.7	5	0	19	0	73	0	4	6	.00	30	10	1	10	3	0	8/66
487	94	55-	99-2-1	CH 25	34	48	0	11.3	14	0	23	0	32	0	4	6	.00	35	10	1	0	1	0	0/66
488	94	55-	99-2-1	CH 26	41	53	0	13.3	19	0	10	0	47	0	4	6	.00	32	20	1	10	1	0	0/66
489	94	55-	99-2-1	CH 27	36	57	0	9.6	14	0	31	0	59	0	4	6	.00	41	26	1	12	2	0	0/66
490	94	55-	7-2-4	CH 28	30	56	0	16.4	29	0	10	0	34	0	4	6	.00	32	20	1	0	1	0	0/66
491	94	55-	113-2-4	CH 29	41	72	0	14.1	31	0	10	0	21	0	4	6	.00	45	22	1	6	1	0	0/66
492	94	55-	7-2-5	CH 30	116	100	0	23.0	121	0	43	0	317	0	4	6	.00	60	22	1	0	0	0	0/66
493	94	55-	3-2-2	CH 31	86	78	0	22.2	89	0	11	0	91	0	4	6	.00	61	17	1	16	2	0	0/66
494	94	55-	3-2-2	CH 32	42	66	0	17.0	44	0	10	0	47	0	4	6	.00	51	17	1	10	2	0	11/66
495	94	55-	113-2-4	CH 33	44	78	0	19.4	69	0	42	0	200	0	4	6	.00	36	26	1	7	2	0	11/66
496	94	55-	113-2-4	CH 34	53	72	0	18.0	53	0	11	0	59	0	4	6	.00	52	19	1	6	1	0	1/67
497	94	55-	3-2-2	CH 35	50	65	0	17.0	56	0	20	0	92	0	4	6	.00	43	20	1	7	0	0	1/67
498	94	55-	7-2-5	CH 36	85	85	0	20.6	86	0	17	0	78	0	4	6	.00	50	21	1	5	1	0	1/67
499	94	55-	7-2-5	CH 37	73	80	0	18.2	59	0	11	0	35	0	4	6	.00	55	12	1	3	1	0	1/67
500	94	55-	7-2-5	CH 39	52	82	0	22.6	97	0	13	0	125	0	4	6	.00	55	27	1	13	0	0	3/68
501	94	55-	113-2-4	CH 40	45	73	0	12.4	24	0	11	0	14	0	4	10	.00	41	18	1	5	3	1400	10/69
502	94	55-	3-2-2	CH 41	51	85	0	20.9	86	0	0	0	0	0	4	6	.00	60	20	1	2	3	0	10/69
503	94	55-	113-2-4	CH 42	20	55	0	11.4	16	0	37	0	122	0	4	6	.00	49	10	1	12	3	0	10/69
1002	94	55-	99-2-1	CH 43	44	65	0	15.6	38	0	44	0	192	0	3	6	.00	53	21	1	9	1	1500	5/70
1003	94	55-	113-2-4	CH 44	22	46	0	10.2	11	0	20	0	58	0	1	3	.00	40	16	1	13	3	1400	6/70

SUPERIOR TREE STATUS REPORT - APR 19, 1974

ACC NO	8 ST- P	CITY- C	NF	DIST	TREE LIVE NO	VEGETATIV PROPAGAT GRAFT CUT	SEED ORCHARD SLO 1/2 FULL NAL 3/5 5/5	BRED ARG	RES- ERVE	SEED STOR 1/2 FULL 3/5 5/5	PROG TEST 1/2 FULL 5/5 5/5
481	94	55-	3-	2-2	CH	3	YES				
482	94	55-	119-	2-3	CH	7	YES		X	X	
483	94	55-	1-	2-2	CH	20	YES		X	X	
484	94	55-	113-	2-4	CH	21	YES		X	X	
485	94	55-	1-	2-2	CH	23	YES		X	X	
486	94	55-	119-	2-3	CH	24	YES				
487	94	55-	99-	2-1	CH	25	YES				
488	94	55-	99-	2-1	CH	26	YES		X		
489	94	55-	99-	2-1	CH	27	YES				
490	94	55-	7-	2-4	CH	28	YES		X		
491	94	55-	113-	2-4	CH	29	NO				
492	94	55-	7-	2-5	CH	30	YES				
493	94	55-	1-	2-2	CH	31	YES		X	X	
494	94	55-	1-	2-2	CH	32	NO				
495	94	55-	113-	2-4	CH	33	NO		X		
496	94	55-	113-	2-4	CH	34	YES		X		
497	94	55-	1-	2-2	CH	35	YES		X		
498	94	55-	7-	2-5	CH	36	YES		X		
499	94	55-	7-	2-5	CH	37	YES			X	
500	94	55-	7-	2-5	CH	39	YES		X	X	
501	94	55-	113-	2-4	CH	40	YES			X	
502	94	55-	1-	2-2	CH	41	YES		X	X	
503	94	55-	113-	2-4	CH	42	YES			X	
1002	94	55-	99-	2-1	CH	43	YES		X		
1003	94	55-	113-	2-4	CH	44	YES				
1320	94	55-	99-	2-1	CH	46	YES			X	

POLLINATION AND SEED COLLECTION RECORD

SEED POSIT	FEMAL C	SPE	MALE	G	SPE	TYP	NO	DATE	AGE	YR	DATE	NO	NO	GRAMS	%	TOY	SEED	SEED	COMT	MT	MF
ORCH	NO	E	PAR	E	NO	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN
PRUG	NO	N	NO	N	NO	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN
TEST	NO	N	NO	N	NO	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN	ISN
0	W1337	0	129	00000	0	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	W1337	0	129	00003	0	129	2	3	6	7	0	66	6/25	21	7	0	4/26	3	2	10.3	0
0	W1339	0	129	00000	0	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	W1339	0	129	00003	0	129	2	2	6	10	0	66	6/27	11	7	0	4/26	7	11	16.0	0
0	W1340	0	129	00002	0	129	2	4	6	9	0	66	6/27	17	7	0	4/26	1	13	23.1	0
0	W1341	0	129	00000	0	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	W1341	0	129	00002	0	129	2	5	6	9	0	66	6/27	47	7	0	4/26	20	44	10.3	7
0	W1341	0	129	00003	0	129	2	5	6	9	0	66	6/27	19	7	0	4/26	8	24	10.5	0
0	W1342	0	129	00002	0	129	2	5	6	9	0	66	6/27	28	7	0	4/26	19	14	19.3	0
0	W1342	0	129	00003	0	129	2	5	6	9	0	66	6/27	45	7	0	4/26	10	17	20.7	0
0	W1344	0	129	00002	0	129	2	8	6	10	0	66	6/27	136	7	0	4/25	60	33	14.1	1
0	W1344	0	129	00003	0	129	2	2	6	10	0	66	6/27	37	7	0	4/25	14	13	8.6	0
0	W1345	0	129	00000	0	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	W1345	0	129	00002	0	129	2	5	6	9	0	66	6/24	30	7	0	4/25	2	28	20.0	0
0	W1345	0	129	00003	0	129	2	4	6	9	0	66	6/24	32	7	0	4/25	6	17	10.6	0
0	W1346	0	129	00000	0	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	W1346	0	129	00002	0	129	2	4	6	9	0	66	6/27	50	7	0	4/25	30	18	17.5	19
0	W1347	0	129	00000	0	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	W1347	0	129	00003	0	129	2	5	6	10	0	66	6/27	23	7	0	4/25	5	22	13.0	0
0	W1349	0	129	00000	0	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	W1349	0	129	00003	0	129	2	4	6	9	0	66	6/25	17	7	0	4/26	7	10	10.1	0
0	W1351	0	129	00000	0	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	W1351	0	129	00002	0	129	2	4	6	9	0	66	6/25	35	7	0	4/26	2	12	21.7	0
0	W1353	0	129	00000	0	129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

EXHIBIT 3

SUMMARY 1 OPTION 1 CLONE OR FAMILY SUMMARY
BLOCK NO. = NUMBER OF BLOCKS IN TEST
TEST DATA NO. 998

CLONE:TR: NO. : OR FOR: FAM: DEAD FAM: BL: OR: NO: NO: SEED:	SURVIVAL		TEMP PER: VAC VAC:	CONT PULL :		FLOWERING FEM MALE	FROST DAMAGE		GLAMMAS GROW:		HEIGHT (METERS)		% OF TEST MEAN								
	PUGH GROW	EXC GROW		YES :	NO		BOTH:	NONE	YES :	NO	MEAN TALL EST	SHORT EST									
TEST1	16	4	4	7	0	1	11	0	11	0	0	0	6	4	1	5	6	4,636	6,200	2,800	98.1
TEST2	16	4	2	9	1	0	7	4	7	4	0	0	7	3	1	10	1	3,600	4,400	2,200	76.2
TEST3	16	2	3	10	1	0	11	2	5	1	6	1	10	1	2	4	4	4,305	5,600	2,200	92.6
TEST4	16	1	2	12	1	0	8	6	4	2	4	4	7	5	2	4	5	4,214	5,200	2,600	89.2
TEST5	16	1	3	12	0	0	4	11	3	5	1	6	10	4	1	4	6	4,313	5,600	1,600	91.3
TEST6	16	1	1	14	0	0	4	11	1	6	3	5	14	0	1	2	13	6,793	7,800	3,400	103.8
	96	13	15	64	3	1	45	34	31	18	14	16	50	17	8	44	35	4,728	7,800	1,600	

• FIN

00/6

SUMMARY 1 OPTION 2 CLONE OR FAMILY SUMMARY BY BLOCKS
 TEST DATA NO. 998
 TITLE 3

CLONE:TR: NO. 1	SURVIVAL	POOR	EXC	TEMP	PER:	NO	YES	CONT	PULL	1	FLOWERING	1	FROST	DAMAGE	1	LAMMAS	GROW:	1	NO	YES	1	MEAN	TALL	SHORT
OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD	OR FOR: RAM: DEAD
FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1	FAM: IBL: OR: 1
NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1	NO. INO: SEED: 1
TEST1 1	4	1	1	1	0	1	2	0	2	0	0	0	1	1	1	0	1	1	0	1	1	4,600	6,100	3,100
TEST1 2	4	1	1	2	0	0	3	0	3	0	0	0	2	1	0	1	2	5,133	6,200	3,400	108			
TEST1 3	4	1	1	2	0	0	3	0	3	0	0	0	2	1	0	1	2	4,867	5,800	3,200	103			
TEST1 4	4	1	1	2	0	0	3	0	3	0	0	0	1	1	1	2	1	3,933	5,400	2,800	8			
FAMILY	16	4	4	7	0	1	11	0	11	0	0	0	6	4	1	5	6	4,636	6,200	2,800	9			
TEST2 1	4	1	1	1	1	0	1	1	1	1	0	0	2	0	0	1	1	3,300	4,400	2,200	2			
TEST2 2	4	1	0	3	0	0	2	1	2	1	0	0	3	0	0	3	0	3,867	4,200	3,600	2			
TEST2 3	4	1	0	3	0	0	2	1	2	1	0	0	0	2	1	3	0	3,200	3,800	2,200	2			
TEST2 4	4	1	1	2	0	0	2	1	2	1	0	0	2	1	0	3	0	3,933	4,400	3,200	2			
FAMILY	16	4	2	9	1	0	7	4	7	4	0	0	7	3	1	10	1	3,600	4,400	2,200	2			
TEST3 1	4	1	1	1	1	0	2	0	1	0	1	0	2	0	0	2	0	4,300	5,400	3,200	2			
TEST3 2	4	1	1	2	0	0	2	1	1	0	1	1	2	1	0	2	1	4,667	5,600	3,600	2			
TEST3 3	4	0	1	3	0	0	3	1	1	1	2	0	2	0	2	4	0	3,400	4,600	2,200	2			
TEST3 4	4	0	0	4	0	0	4	0	2	0	2	0	4	0	0	1	3	5,200	5,600	4,800	1			
FAMILY	16	2	3	10	1	0	11	2	5	1	6	1	10	1	2	9	4	4,385	5,600	2,200	2			
TEST4 1	4	1	1	2	0	0	2	1	1	0	1	1	1	1	1	1	2	4,167	5,100	2,800	2			
TEST4 2	4	0	0	3	1	0	2	1	1	0	1	1	1	2	0	2	1	4,200	5,200	2,600	2			
TEST4 3	4	0	0	4	0	0	2	2	1	2	1	0	2	1	1	4	0	3,900	4,800	2,800	2			
TEST4 4	4	0	1	3	0	0	2	2	1	0	1	2	3	1	0	2	2	4,575	5,200	3,200	2			
FAMILY	16	1	2	12	1	0	8	6	4	2	4	4	7	5	2	9	5	4,214	5,200	2,600	2			

SUMMARY 1 OPTION 2 CLONE OR FAMILY SUMMARY BY BLOCKS

TEST DATA NO. 998

TITLE 3

CLONE:TR: NO. 1										SURVIVAL					TEMP PER: NO					CONT POLL 1					FLOWERING					FROST DAMAGE					JLANHAS GROM:					HEIGHT (METERS)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
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• FIN

SUMMARY 1A OPTION 1 BLOCK SUMMARY
 CLONE OR FAMILY NO. = HIGHEST CLONE OR FAMILY IDENTIFICATION NO. IN TEST
 TEST DATA NO. 998

CLONE/STR NO. 1 OR 1001 RAM IDEAD FAM 101 OR 1 NO. 101 SEEDS	SURVIVAL PUOR EXC GROW GROW 2 3	TEMP PER VAC VAC 4 5	CONT POLL YES 1 NO 2	FLOWERING FEM NONE 1 NONE 2	FROST DAMAGE BOTH NONE BOTH 1 NONE 2	FLAMMAS GROW YES 1 NO 2	HEIGHT (METERS) MEAN TALL EST SHORT EST TEST MEAN
1 24 6 6 9 2 1 9 6 5 3 4 3 10 3 2 8 7 4.367 7.100 1.600 92.4							
2 24 3 3 17 1 0 10 10 8 5 2 5 15 5 0 11 9 4.915 7.400 2.400 104.0							
3 24 2 2 20 0 0 12 10 6 7 4 3 13 5 0 14 8 4.682 7.800 2.200 99.1							
4 24 2 4 18 0 0 14 8 10 3 4 5 16 4 2 11 11 4.836 7.600 2.200 102.4							
96 13 15 64 3 1 45 34 31 18 14 14 54 17 8 44 35 4.728 7.800 1.400							

• FIN

SUMMARY 1A OPTION 2 BLOCK SUMMARY BY CLONE OR FAMILY
 TEST DATE NO. 998
 TITLE 3

CLONE/TR: NO. :		SURVIVAL		TEMP PER:		CONT POLL :		FLOWERING		FROST DAMAGE		CLAMMAS GROW:		HEIGHT (METERS)									
FAM :	IBL:	OR :	SEED:	POOR	EXC	GROW	VAC	PER:	NO	YES	NO	BOTH:	MALE	FEM	NO	YES	MEAN	TALL	SHORT	% OF			
TEST1	1	4	1	1	1	0	1	2	0	2	0	0	1	1	1	0	1	1	4,600	6,100	3,100	97.4	
TEST2	1	4	1	1	1	1	0	1	1	1	1	0	0	2	0	0	1	1	3,300	4,400	2,200	69.9	
TEST3	1	4	1	1	1	1	0	2	0	1	0	1	0	1	0	0	2	0	4,300	5,400	3,200	91.0	
TEST4	1	4	1	1	2	0	0	2	1	1	0	1	1	1	1	1	1	2	4,167	5,100	2,800	88.2	
TEST5	1	4	1	1	2	0	0	1	2	0	1	1	1	1	2	1	0	1	2	3,767	5,100	1,600	79.7
TEST6	1	4	1	1	2	0	0	1	2	0	1	1	1	1	2	0	1	2	5,767	7,100	3,400	122.1	
BLOCK		24	6	6	9	2	1	9	6	5	3	0	3	0	3	2	8	7	4,367	7,100	1,600	92.4	
TEST1	2	4	1	1	2	0	0	3	0	3	0	0	0	2	1	0	1	2	5,133	6,200	3,400	108.7	
TEST2	2	4	1	0	3	0	0	2	1	2	1	0	0	3	0	0	3	0	3,867	4,200	3,600	81.9	
TEST3	2	4	1	1	2	0	0	2	1	1	0	1	1	2	1	0	2	1	4,667	5,600	3,600	98.8	
TEST4	2	4	0	0	3	1	0	2	1	1	0	1	1	1	2	0	2	1	4,200	5,200	2,600	88.9	
TEST5	2	4	0	1	3	0	0	0	4	0	2	0	2	3	1	0	3	1	4,375	5,200	3,100	92.6	
TEST6	2	4	0	0	4	0	0	1	3	1	2	0	1	4	0	0	0	4	6,800	7,400	5,800	143.9	
BLOCK		24	3	3	17	1	0	10	10	8	5	2	5	15	5	0	11	9	4,915	7,400	2,600	104.0	
TEST1	3	4	1	1	2	0	0	3	0	3	0	0	0	2	1	0	1	2	4,867	5,800	3,200	103.0	
TEST2	3	4	1	0	3	0	0	2	1	2	1	0	0	1	2	1	3	0	3,200	3,800	2,200	67.7	
TEST3	3	4	0	1	3	0	0	3	1	1	1	2	0	2	0	2	0	0	3,400	4,600	2,200	72.0	
TEST4	3	4	0	0	4	0	0	2	2	1	2	1	0	2	1	1	4	0	3,900	4,800	2,800	82.6	
TEST5	3	4	0	0	4	0	0	1	3	1	1	0	2	3	1	0	2	2	5,050	5,600	4,600	106.9	
TEST6	3	4	0	0	4	0	0	1	3	0	2	1	4	1	0	0	0	4	7,350	7,800	6,800	155.6	
BLOCK		24	2	2	20	0	0	12	10	8	7	4	3	13	5	4	14	8	4,682	7,800	2,200	99.1	

TITLE 3

29.3

[illegible]

TEST NO. 991 SURVIVAL MAP
 TREE NO. 1-SPACE VAC FG=FAIR GROW EXG=EXCELL GROW PV=PERM VAC
 TITLE 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
AA	TEST1	FG	EXG	PV	TEST2	FG	EXG	TEST2	TEST3	FG	EXG	TEST3									
AB	TEST4	FG	EXG	EXG	TEST5	FG	EXG	EXG	TEST6	FG	EXG	EXG									
AC	TEST3	FG	EXG	EXG	EXG	EXG	EXG	TEST4	FG	EXG	EXG	EXG									
AD	EXG	EXG	EXG	EXG	FG	EXG	EXG	TEST1	EXG	EXG	EXG	TEST2									
AE	EXG	EXG	EXG	EXG	EXG	EXG	EXG	EXG	TEST1	EXG	EXG	FG									
AF	TEST2	EXG	EXG	EXG	EXG	EXG	EXG	FG	EXG	EXG	EXG	EXG									
AG	TEST1	FG	EXG	EXG	EXG	EXG	FG	TEST2	EXG	EXG	EXG	EXG									
AH	EXG	FG	EXG	EXG	EXG	EXG	FG	EXG	EXG	EXG	EXG	EXG									
AI																					
AJ																					
AK																					

TEST NO. 998 HEIGHT GROWTH
 TREE NO. 1-SPACE VACANT
 TEST MEAN=4.724 METERS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
AA	V		TEST1	V	V			V	V		TEST3	V									
AB	V			TEST4	V			TEST5	V		TEST6	TEST6									
AC	V			TEST3			TEST4	V			TEST5										
AD	TEST6	TEST6	TEST6	TEST6	TEST1	TEST1	V														
AE	TEST5	TEST5	TEST6	TEST6	TEST6	TEST6	TEST6	V	TEST1	TEST1											
AF	V																				
AG	V		TEST1				V	TEST3	TEST3		TEST3										
AH	TEST4							TEST5	TEST6	TEST6	TEST6	TEST6									
AI																					
AJ																					
AK																					
AL																					

SHORT AND LONG TERM OUTLOOK FOR FERTILIZER AVAILABILITY*

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NEAD, ERS, USDA

Introduction

We all can recall the opening lines of Charles Dickens' A Tale of Two Cities.

It was the best of times,
it was the worst of times,
it was the age of wisdom,
it was the age of foolishness,
it was the epoch of belief,
it was the epoch of incredulity,
it was the season of Light,
it was the season of Darkness,
it was the spring of hope,
it was the winter of despair.

These words seem amazingly apropos to the world of 1974, and indeed to the fertilizer situation. Never before has the world produced and consumed so much fertilizer; never before have we experienced such a scramble for available supplies.

In discussing the short and longrun availability of fertilizer, I will first review recent history of the industry, develop the U.S. outlook for 1975 and then for the longer run. I will then relate the U.S. situation to world conditions and project the world situation to 1980. Finally, I will discuss what all this means for you.

*Presented at the Servicewide Silviculture Conference, Sacramento, California, October 27, 1974.

Recent History

The benefits of improving soil fertility have been recognized for centuries, and man has identified and developed numerous methods for releasing and supplementing the growth potential of soil. However, greatest progress has been achieved since the development of chemical fertilizers.

This progress is evident in the increased consumption of chemical fertilizer in the United States. Between 1940 and 1970, consumption of nitrogen (N) increased more than 17-fold in the United States, while phosphates (P_2O_5) rose 5-fold, and potash (K_2O) 9-fold (Table 1). The structure of the fertilizer industry has changed also. Prior to World War II, only seven firms were manufacturing anhydrous ammonia in the United States. The two largest firms accounted for 87 percent of production. By 1969, there were more than 85 firms producing anhydrous ammonia. The four largest firms accounted for less than 18 percent of production.

This rapid expansion in firm numbers resulted primarily from technological changes and expanding market prospects. Introduction of centrifugal compressors for producing nitrogen in the late fifties reduced the cost of production. This stimulated a rush to build new plants through the sixties. But more importantly, the demand for nitrogen was very strong. Most producers believed that the phenomenal increase in U.S. nitrogen consumption would continue in order to produce food to meet domestic requirements and to enable shipments of large quantities of grains to Less Developed Countries (LDC's). Furthermore, fertilizer producers in developed nations felt that the Green Revolution in the LDC's would always provide a lucrative export market for their

product.

In the mid to late sixties the anticipated rise in world fertilizer consumption did not reach expectations and many developing countries expanded their own fertilizer production capacity. By 1968, the capability of the U.S. fertilizer industry to produce and distribute its products far exceeded actual consumption.

Fertilizer prices plummeted. By 1970, the retail price of anhydrous ammonia fell to one-half its earlier level and phosphate and potash prices decreased about 12 percent. Plans to add further capacity were dropped and in some cases construction was halted. Numerous older plants were closed and ownership of other plants changed rapidly. Thus, as the industry tried to recover, virtually all expansion in domestic production capacity ceased.

Through the efforts of numerous development organizations and the governments in developing countries, growth in the use of fertilizers in LDC's continued. Localized droughts in several parts of the world in 1971 compounded with a major widespread drought in 1972 also stimulated many countries to import fertilizer at record levels in an effort to rebuild agricultural production. Moreover, production abilities of the developed nations were challenged as they tried to expand food and fiber production in response to domestic requirements and to supply food to the stricken countries. Consequently, world fertilizer supply and demand moved back into balance much faster than had been anticipated.

The harsh lesson fertilizer producers learned in the sixties made them understandably cautious about rapidly expanding capacity in the seventies. Short natural gas supplies and environmental problems also

frustrated their expansion efforts. Although expansion is now underway, a lead time of two to four years is required to get new plants onstream

The Outlook for 1975

Until capacity can be increased, fertilizer manufacturers must attempt to achieve maximum production from existing facilities. However, with plants running at record high levels, the U.S. still faces an unpropitious situation in the coming year (Table 2). Increasing crop acreages and high crop prices in 1975 will induce an unprecedented demand for fertilizer. Had fertilizer prices remained at June levels, the demand for nitrogen may have been 11 percent above the demand a year earlier, and 17 percent above the level consumed in 1973/74. The phosphate demand, given June prices, was expected to be up 5 percent and 19 percent above actual consumption. Potash demand will be up about 8 percent.

Domestic production of all three nutrients will increase. Nitrogen production is expected to be up 5 percent, barring more than nominal natural gas curtailments. Phosphate production is expected to be up 9 percent and potash production up 11 percent.

Another important influence in fertilizer supplies both domestically and abroad is international trade of fertilizer. The U.S. has traditionally been a nitrogen net importer. Only since 1965/66 when the serious excess capacity materialized, have we been a net exporter (Table 3). The first half of 1974 we were again a net importer, although for the fiscal year exports exceeded imports. In 1974/75 nitrogen exports will exceed imports by a slim margin only if AID financed purchases originate

from the U.S. Otherwise imports could exceed exports slightly.

The U.S. has been a primary world source of phosphate fertilizer for some time, with much of the free world dependent upon our exports. In 1975, exports will approach 1.7 million tons, over one-fifth of domestic production. On the other hand, the U.S. imports well over half of the potash consumed annually, and is expected to import larger quantities in 1974/75.

On balance, there will be no improvement in the nitrogen situation and only negligible improvement in the phosphate situation. If prices were to remain at June levels, the quantity of nitrogen supplied would be short of the quantity demanded by 8 percent while phosphate would be short by 4 percent. However, prices will continue to rise, driving the quantity demanded down to the level of the quantity supplied; in effect driving away customers who cannot justify paying the high price. Although potash availability has been less of a problem, increasing demand, partially because of substitution of potash for nitrogen and phosphate in mixtures, and a constrained supply because of problems of restarting idle capacity and labor disputes will tighten the situation considerably in 1974/75.

Of course we all know what has happened to fertilizer prices. It will be one year ago tomorrow that the fertilizer industry was exempted from price ceilings. By this past September 15, prices of nitrogenous fertilizers had increased from 108 to 142 percent above their October 25, 1973 level (Table 4). Prices of phosphate fertilizers were up 86 to 91 percent while the price of potash was up 54 percent. These increases contrast sharply to the consumer price index for all goods, which showed a 9 percent increase for this same period.

The Longrun Outlook in the United States

As might be expected, these high prices are stimulating investment in new production and distribution facilities. Several companies began building phosphate plants in 1971 and 1972. Some of these plants are now beginning to produce. More will come onstream in 1975. And by the end of 1976 the United States will likely be producing at a rate of 8.3 million tons of P_2O_5 annually; 26 percent above the 6.6 million tons produced in the 1973/74 fertilizer year.

Except for the temporary problems of getting the Canadian potash mines operating nearer capacity, the short and longrun potash outlook is good. Adequate capacity appears to be available until 1980. By then the quantity of potash demanded may approach the quantity that can be supplied with existing capacity. If the additional capacity is to be available by 1980, construction of plants will have to be initiated in the next two years, and it likely will be.

The domestic nitrogen situation is much less optimistic. It will likely be three years before any improvement will be realized, and it is not assured even then. Let's look at three scenarios, based on two uncertainties. The first uncertainty is that of the level of crop production, and consequently crop prices, while the second is the rate at which nitrogen production capacity is increased.

Weather continues to be a primary determinant of crop production. Some climatologists argue that for the past 20 years the weather has been most favorable compared to earlier periods. In addition, they believe we are entering a period of drought that can be expected every 20 years. If correct, poor crop production could well support continued

high commodity prices and the current strong demand for nitrogen fertilizer would remain. Other less pessimistic forecasters do not believe that this year is a preview of things to come. They expect a return to the past trend, and the associated high levels of crop production.

The second uncertainty, concerning the rate of expansion of nitrogen production capacity, focuses upon the availability of natural gas. At current use rates, the known reserves of natural gas in the United States will be depleted in 10 to 12 years. With this high demand upon the supply, nitrogen producers are encountering great difficulties securing natural gas supplies, particularly with the long term natural gas contract desired prior to initiating ammonia plant construction. Some of the announced expansion plans may be aborted if long term natural gas contracts cannot be secured, reducing capacity below that which may otherwise be expected.

The three scenarios are based on various combinations of these two uncertainties. The first scenario consists of the combination of good weather and realization of expansion plans. Good weather would lead to increased crop production, depressed crop prices, and a moderating effect on the demand for nitrogen. Achievement of expansion plans would increase the supply of nitrogen, and the current supply-demand balance problems would be resolved.

The second scenario could be realized by two sets of combinations. The first set consists of good weather but no or little expansion in nitrogen production capacity. This would precipitate a moderated nitrogen demand with little increase in supply. The result would be a tight supply-demand balance, although perhaps not as critical as the current situation. This same outcome could also result from the second

set, that being achievement of expansion plans, but poor weather conditions that lead to continued high commodity prices and a strong nitrogen demand.

The third scenario consists of poor weather and little expansion in nitrogen production capacity. The strong demand and restricted supply that would follow would be more severe than the current situation, and of course, would mean higher nitrogen prices.

What are the probabilities of each of the three scenarios? I suggest you consult your own favorite weather forecaster and establish your weather probabilities. On the natural gas side of the picture, it is not clear at this time that all of the planned ammonia plants will be built. In fact, it is probably safe to say they won't. But it is also safe to expect that most of them will continue through to fruition; some firms have already secured natural gas supplies. If necessary, I believe federal policy will be adjusted so that other prospective ammonia producers will have the opportunity to secure natural gas supplies. I think there is a 75 percent probability of realizing scenario number one. The possibility of continued poor weather induces me to place a 25 percent probability on realizing scenario number two.

Realizing that we have restricted this discussion strictly to the domestic situation, let me submit that foreign trade could greatly enhance our supply-demand balance. Several U.S. companies are building ammonia plants in nearby countries, where natural gas supplies are more plentiful. For example, W. R. Grace and Farmland Industries are building plants in Trinidad and Canada, respectively. Much, probably most, of this ammonia will flow into the U.S. market, supplementing domestic production. Consequently, it appears that only under the most severe scenario, number three, would these expected imports not be sufficient to resolve our currently tight supply-demand balance.

World Fertilizer Outlook

Just as it is more appropriate to consider the North American market than simply the domestic market, it is perhaps most appropriate to consider the world situation. The U.S. situation is functionally related to the world situation. Indeed, barring restrictive trade barriers, the U.S. situation cannot vary significantly from the world situation. In 1973, 46 percent of the phosphate mined in the United States was exported either as rock or as finished fertilizer materials. Approximately 10 percent of our net domestic supply of nitrogen and 71 percent of our net domestic supply of potash was imported this past fertilizer year. With trade being so important, it is apparent that domestic markets will reflect conditions in world markets.

It is no surprise then that the world fertilizer situation virtually parallels the U.S. situation. Farmers in foreign countries have continuously increased their use of fertilizer (Table 5). But since the widespread drought in 1972 and subsequent high crop prices, they have greatly increased their demand for fertilizer. This past fertilizer year, the world nitrogen consumption was estimated to increase 11 percent over 1972/73. Phosphate consumption was expected to increase 7 percent and potash consumption 5 percent.

This strong demand drove world prices up, well above U.S. prices. No world price exists, per se, since each trade contract is negotiated, and the price usually remains confidential. However, prices on AID financed contracts are announced, and since spring f.o.b. prices on AID contracts have been nearly double the retail price in the United States.

As in the United States, high world prices are stimulating expansion in the industry. Numerous developed and developing countries around the world are adding plants. And again the world outlook parallels that for the United States. The rapidly increasing capacity to produce phosphate should alleviate supply problems within two years. The capacity to produce potash is adequate, although production problems may tighten the situation somewhat through the next eight months.

The nitrogen outlook is somewhat less optimistic, but improving. Plans to build new plants are continually being announced. For example, from December 1, 1973, to April 1, 1974, 17 million tons of new capacity were announced; enough to increase the current world supply of nitrogen for fertilizer by 25 percent. Based on existing plants plus announced new plants as of the first of July 1974, a balance of about 3 million tons can be expected by 1977, this will meet the 4 or 5 percent balance that has historically been necessary to assure stable prices and the smooth functioning of the distribution system. And if plans are carried out, we should reach a surplus situation by 1978.

Implication for Forest Fertilization

The implications of this outlook for fertilizing forests is quite clear. In spite of the great benefits that can be expected from forest fertilization, this is not a good time to start absorbing large quantities of fertilizer, either from an economic or moral standpoint. Not only would current prices deplete budgets rapidly, but the redirection of fertilizer from food production to forest fertilization would most certainly precipitate a violent public reaction at a time when food is in short

supply.

However, it is a superb time to initiate a fertilization program, including the research needed to use fertilizer wisely. You, of course, have already made good progress in this area. But compared with the amount of crop-fertilizer research, and its progress, I suspect you have plenty of unanswered questions. By the time you develop some of the essential answers, and develop an operational fertilization program, the fertilizer situation will have turned around. And if surpluses develop, and I believe there is a strong possibility of this, you will not only find yourself in a good position to purchase fertilizer; I suspect the fertilizer industry will be most interested in your efforts.

I commend you on your efforts and wish you success in developing an effective program.

Table 1.--All fertilizer: Total use, primary nutrient use, United States, 1920-74 1/

Year ending	Total use	Primary nutrient use				
		N	Available P ₂ O ₅	K ₂ O	Total	Index 1967=100
		----- 1,000 tons -----				
December 31:						
1920.....	7,296	228	660	257	1,145	8.2
1921.....	4,977	159	443	189	791	5.7
1922.....	5,798	191	516	226	933	6.7
1923.....	6,571	230	591	237	1,058	7.6
1924.....	6,999	252	630	259	1,141	8.2
1925.....	7,503	279	680	283	1,242	8.9
1926.....	7,531	282	695	290	1,267	9.1
1927.....	7,074	271	660	286	1,217	8.7
1928.....	8,215	342	776	333	1,451	10.4
1929.....	8,208	352	774	338	1,464	10.5
1930.....	8,425	378	794	354	1,526	10.9
1931.....	6,541	301	611	275	1,187	8.5
1932.....	4,545	214	413	192	819	5.9
1933.....	5,110	240	464	222	926	6.6
1934.....	5,794	275	530	263	1,068	7.6
1935.....	6,534	312	597	307	1,216	8.7
1936.....	7,222	350	673	350	1,373	9.8
1937.....	8,433	412	794	416	1,622	11.6
1938.....	7,758	384	744	393	1,521	10.9
1939.....	7,993	398	789	409	1,596	11.4
1940.....	8,656	419	912	435	1,766	12.6
1941.....	9,607	458	994	467	1,919	13.7
1942.....	10,331	398.6	1,130.8	547	2,076.4	14.9
June 30:						
1943.....	11,466	440.0	1,270.9	634.6	2,345.5	16.8
1944.....	12,603	617.0	1,296.6	641.8	2,555.4	18.3
1945.....	13,466	630.3	1,353.6	792.2	2,713.1	19.4
1946.....	15,128	701.0	1,552.8	807.3	3,061.1	21.9
1947.....	16,839	783.6	1,735.9	858.5	3,378.0	23.5
1948.....	17,818	856.7	1,853.7	920.7	3,631.1	26.0
1949.....	18,542	919.9	1,941.7	1,073.1	3,934.7	28.2

See footnotes at end of table.

Continued

Table 1.--All fertilizer: Total use, primary nutrient use, United States, 1920-74 ^{1/} --Continued

Year ending	Total use	Primary nutrient use				Index 1967=100
		N	Available P ₂ O ₅	K ₂ O	Total	
		1,000 tons				
1950.....	18,343	1,005.4	1,949.8	1,103.1	4,058.3	29.0
1951.....	20,991	1,237.0	2,109.9	1,379.8	4,726.7	33.8
1952.....	22,432	1,422.1	2,199.4	1,581.5	5,203.0	37.2
1953.....	23,413	1,637.1	2,270.8	1,738.2	5,646.1	40.4
1954.....	22,773	1,847.4	2,234.6	1,813.6	5,895.6	42.2
1955.....	22,726	1,960.5	2,283.7	1,874.9	6,119.1	43.8
1956.....	22,194	1,933.3	2,247.4	1,874.7	6,055.4	43.3
1957.....	22,709	2,135.3	2,305.0	1,936.9	6,377.2	45.6
1958.....	22,516	2,284.4	2,292.9	1,935.1	6,512.4	46.6
1959.....	25,308	2,671.7	2,572.2	2,191.4	7,435.3	53.2
1960.....	24,877	2,738.0	2,572.4	2,153.3	7,463.7	53.4
1961.....	25,567	3,030.8	2,645.1	2,168.5	7,844.4	56.1
1962.....	26,615	3,370.0	2,807.0	2,270.5	8,447.5	60.5
1963.....	28,844	3,929.1	3,072.9	2,503.4	9,505.4	68.0
1964.....	30,681	4,352.8	3,377.8	2,729.7	10,460.3	74.9
1965.....	31,836	4,638.5	3,512.2	2,834.5	10,985.3	78.6
1966.....	34,532	5,326.3	3,897.1	3,221.2	12,444.7	89.1
1967.....	37,082	6,027.1	4,304.7	3,641.8	13,973.6	100.0
1968.....	38,743	6,787.6	4,453.3	3,792.6	15,033.5	107.6
1969.....	38,949	6,957.6	4,665.6	3,891.6	15,514.8	111.0
1970.....	39,591	7,459.2	4,573.9	4,035.7	16,068.8	115.0
1971.....	41,118	8,133.6	4,803.4	4,231.4	17,168.4	122.9
1972.....	41,206	8,016.0	4,783.1	4,332.0	17,168.4	122.9
1973.....	43,059	8,188.9	5,038.8	4,622.2	17,850.0	127.7
1974 2/.....	--	8,880	4,850	5,100	18,830	134.8

^{1/} Includes Puerto Rico.

^{2/} Estimated.

Source: Years 1830-1942 from Historical Statistics of the United States, U.S. Bureau of the Census. Years 1943-59 from "Consumption of Commercial Fertilizers and Primary Plant Nutrients" Stat.Bull. 375, Statistical Reporting Service, June 1966. Years 1960-69 from "Consumption of Commercial Fertilizers and Primary Plant Nutrients", Stat. Bull. 472, Statis. Rptg. Serv., June 1971. Years 1970-72 from "Consumption of Commercial Fertilizers in the United States SpCR 7(10-72) Statis, Rptg. Serv., U.S. Dept. Agr., October 1972 and earlier issues.

Table 2-Fertilizer summary, United States, 1971/72 - 1974/75

Item	1971/72	1972/73	1973/74 1/	1974/75 1/
	1,000 short tons			
Nitrogen:				
Domestic production 2/.....	8,971	9,450	10,002	10,600
Imports.....	843	881	1,007	1,047
Total avail. supply.....	9,814	10,331	11,009	11,647
Exports.....	1,032	1,358	1,333	1,300
Net supply.....	8,782	8,973	9,676	10,347
Demand.....	8,016	8,339	9,300	10,350 3/ 9,300 4/
Unidentified demand 5/.....	766	634	800	800
Total requirements.....			10,100	11,150 10,100
Surplus [deficit].....			[424]	[803] 247
Phosphate (P ₂ O ₅):				
Domestic production 2/.....	6,150	6,387	6,604	7,380
Imports.....	326	312	257	275
Total avail. supply.....	6,476	6,699	6,861	7,655
Exports.....	1,102	1,424	1,560	1,653
Net supply.....	5,374	5,275	5,301	6,002
Demand.....	4,873	5,072	5,500	5,775 3/ 4,923 4/
Unidentified demand 5/.....	501	203	450	450
Total requirements.....			5,950	6,225 5,373
Surplus [deficit].....			[649]	[223] 629
Potash (K ₂ O):				
Domestic production 2/.....	2,432	2,680	2,657	2,950
Imports.....	3,088	3,117	3,996	4,078
Total avail. supply.....	5,520	5,797	6,653	7,028
Exports.....	657	922	1,033	1,070
Net supply.....	4,863	4,875	5,620	5,958
Demand.....	4,332	4,412	4,700	5,067 3/ 4,458 4/
Unidentified demand 5/.....	531	463	540	550
Total requirements.....			5,240	5,617 5,008
Surplus.....			380	341 950

1/ Estimated.

2/ Adjusted for producer inventory changes.

3/ High demand estimate based on June fertilizer and crop prices, i.e. corn at \$3.00 per bushel and wheat at \$3.75 per bushel.

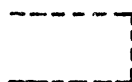
4/ Low demand estimate based on June fertilizer prices but greatly reduced crop prices; i.e. corn - \$1.50 per bushel, wheat - \$2.25 per bushel.

5/ Unidentified demand is an amount of material produced and distributed that cannot be accounted for with the current data system. It may include product loss, changes in retail and farm inventories, and other undetermined items.

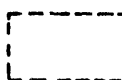
Table 3.--U.S. imports and exports of primary plant nutrients, 1951-52 through 1973-74

Fertilizer Year	N		P ₂ O ₅		K ₂ O	
	Imports	Exports	Imports	Exports	Imports	Exports
1951-52	290	73	39	94	264	63
1952-53	429	44	41	74	159	54
1953-54	421	62	62	88	121	54
1954-55	373	141	61	154	139	91
1955-56	330	255	56	153	170	180
1956-57	294	268	54	256	179	315
1957-58	305	227	59	246	213	252
1958-59	294	223	64	204	238	310
1959-60	298	188	82	177	282	418
1960-61	276	213	67	238	285	484
1961-62	337	234	87	283	282	503
1962-63	344	196	117	275	486	411
1963-64	453	264	100	400	691	526
1964-65	470	392	98	432	884	625
1965-66	529	546	125	441	1,332	664
1966-67	669	749	165	787	1,643	678
1967-68	675	1,045	169	1,145	2,225	714
1968-69	690	1,594	183	995	1,944	798
1969-70	855	1,328	273	845	2,646	681
1970-71	929	1,077	283	898	2,510	620
1971-72	843	1,032	326	1,102	3,088	657
1972-73	881	1,358	312	1,424	3,117	922
1973-74*	1,007	1,333	257	1,560	3,996	1,033

* Estimated.



Import Balance



Export Balance

Source: The Fertilizer Supply, 1973-74, ASCS, USDA, Washington, D.C., July, 1974.

Table 4.--Fertilizer retail price increases since October 1973

Product	Nov. 9	Dec. 10	Jan. 21	Feb. 18	Mar. 18	Apr. 18	May 10	July 15	Sept. 15
	<u>Percent</u>								
Anhydrous ammonia.....	39	49	71	83	95	104	110	124	142
ammonium nitrate.....	33	48	55	70	71	79	79	101	108
Urea.....	36	57	69	83	101	104	112	115	136
Nitrogen solutions.....	35	40	57	71	81	88	86	111	120
Triple superphosphate.....	25	35	42	46	49	55	59	71	86
Diammonium phosphate.....	28	31	41	49	51	53	57	77	91
Potassium chloride.....	15	15	26	28	32	35	35	44	54
Mixed fertilizer.....	23	28	40	47	47	49	53	67	78

Sources: ASCS, USDA.

Table 5.--World production and consumption of
fertilizers since 1960

Year	Nitrogen 1/		Phosphate 2/		Potash 3/		Total	
	Pro- duction	Con- sumption	Pro- duction	Con- sumption	Pro- duction	Con- sumption	Pro- duction	Con- sumption
: - - - - - Million metric tons, nutrient basis - - - - -								
1960	9.9	9.2	9.7	9.6	8.7	8.2	28.4	27.0
1961	10.9	10.2	10.1	10.0	8.8	8.5	29.8	28.7
1962	11.9	11.0	10.4	10.4	9.4	8.7	31.7	30.1
1963	13.1	12.4	11.1	11.0	9.8	9.3	34.0	32.7
1964	14.9	14.0	12.5	12.2	10.8	10.0	38.2	36.3
1965	16.8	15.3	14.0	13.4	12.1	10.9	42.9	39.6
1966	20.0	18.8	15.6	14.8	13.8	12.2	49.4	45.8
1967	22.4	21.8	17.0	16.1	14.5	13.0	54.0	50.9
1968	25.6	23.9	18.0	17.0	15.3	13.9	58.9	54.9
1969	28.4	26.6	18.6	18.2	15.9	14.6	62.9	59.4
1970	30.2	28.7	19.3	18.8	16.7	15.4	66.2	62.9
1971	33.0	31.7	20.8	19.9	17.7	16.5	71.5	68.1
1972	35.1	33.3	22.5	21.2	19.5	17.6	77.1	72.1
1973	37.9	36.0	23.8	22.8	20.2	18.7	81.9	77.5

1/ N 2/ P₂O₅ 3/ K₂O

Note: FAO data consistently shows an excess of production over consumption. Roughly a 4 or 5 percent excess is required for a normal market with stable prices, historically.

Source: 1960, 1961, 1962, 1963, 1964, 1965, and 1966 from FAO, Annual Fertilizer Review, issues for 1965, 1966, 1967, 1968, 1969, 1970, and 1971 respectively; 1967, 1968, 1969, 1970, 1971 from FAO, Annual Fertilizer Review, 1972; 1972 and 1973 from FAO, Monthly Bulletin of Agricultural Economics and Statistics, March 1974. Year refers to the last year of the split year; i.e., 1973 refers to the 1972/73 fertilizer year.

Table 6--World Fertilizer Balance, 1974-1980

	Balance 1/			Balance as a Percent of Consumption					
	N 2/	P ₂ O ₅ 3/	K ₂ O 3/	N 2/	P ₂ O ₅ 3/	K ₂ O 3/			
	Million short tons			Percent					
1974.....	1,100	1,181	2,943	2.0	3.9	12.5			
1975.....	1,398	3,349	2,222	3.0	12.0	9.7			
1976.....	1,335	4,233	2,375	2.7	14.4	9.8			
1977.....	2,895	4,091	2,164	5.5	13.6	8.6			
1978.....	6,484	3,371	1,953	11.5	10.7	7.5			
1979.....	10,313	1,950	1,742	17.4	5.9	6.4			
1980.....	7,822	1,056	1,531	13.1	3.1	5.5			

1/ Production minus consumption equals balance.

2/ Included plants announced through June 1974.

3/ Data includes announcements of new plants through April, 1974. Since new plants have since been announced, and additional plants likely, the projected decline in the balance for 1980 will most likely not be realized.

Source: TVA, Quarterly Review, First quarter 1974, and unpublished TVA and USDA data.

FOREST FERTILIZATION: REGIONAL ADVICE^{1/}

THE NORTHEAST

Lew Auchmoody, NE For. Exp. Stn., Warren, Pa.

Hardwoods

1. "We have a large study in 50-70-year-old black cherry stands in which we are measuring response to N, P, and K (treatments: C, N, NP, NPK). The study has large plots (1.2 acres) about 9000 trees, and is well replicated over the Allegheny NF on soils that comprise about 60-65 percent of NF holdings. We do not have growth results from this test yet, but we will have the data analyzed by this summer and can then speculate quite accurately on the potential of fertilization in unmanaged cherry stands that are approaching maturity here in Northern Pennsylvania."
2. "We have a large test out in young stands (3-12 years old) that has now completed one growing season. Here we tested levels of N, P, and K on 1/10 acre plots (N, 0-600; P, 0-300; K, 0-100), and it is here that response has been particularly spectacular. Although we have not yet done final calculations on response, it is in the order of 400 percent increase in BA and just slightly less than that for height in the 'optimum' treatment (N₃P₁K₀). But, perhaps the most important point here is that fertilization of natural regeneration on clear-cut sites will greatly (if not completely) insure successful establishment of a new stand after harvesting (in light of an exceptionally heavy deer population) by greatly increasing browse production, and stimulating growth of seedlings so that they get above the reach of deer in one season. In many cases I am sure it will mean the difference between a good stand or no stand at all - a case where one could hardly dispute the economics involved."
3. "In connection with the fertilization work in West Virginia (yellow-poplar, red oak, basswood)" ... "there needs to be more work done in this area before recommendations for operational use can be prescribed."

Ray Leonard, NE For. Exp. Stn., Durham, New Hamp.

1. Fertilization is an energy additive which triggers dynamic events; the user should be aware of and monitor these multiple-effects. Particularly in the East, desirable and undesirable changes in species composition could occur.

^{1/} Acknowledgment: In preparing for my presentation at the 1974 conference, I sought the help of as many of my colleagues working in forest fertilization as time permitted. I present their "advice" which I extracted in telephone conversations and subsequent letters which they sent me. I thank them for their candid and timely information and apologize to other colleagues whom I failed to contact.

FOREST FERTILIZATION: REGIONAL ADVICE

THE SOUTHEAST

Carol G. Wells, SE For. Exp. Stn., Research Triangle Park, N. Caro.

Loblolly and slash pines

Research status:

1. "Both soil and foliar analyses are useful for prediction of P deficient soil. However, more work is needed. We have obtained good response to P on pine 10 years after planting. To be the most effective application should be made at planting. Application of 50 lbs. P/A will probably be sufficient for a short rotation (25 years) on most of the deficient soils."
2. "Nitrogen research has been done mainly on trees 5 to 20 years old. Recent studies do show a good response to N + P at planting."
3. "Results from the Fertilization Cooperatives at North Carolina State and Florida indicate that similar response from fertilization will be obtained on many studies. Separation of sites into response classes remains a big problem for N. Also N fertilization at planting requires further study with regard to techniques and economics."

Proposed operational:

1. "In the Southeastern Coastal Plain, fertilize with P at planting or in stands to 10 years age on the basis of soils tests or foliar analysis. Continued consultation with forest fertilization specialist in the area is advised. Pilot (limited) N operational fertilization could be done in the same way on both Coastal Plain and Piedmont sites. A NFS regional specialist in fertilization is needed."

Administrative studies:

1. "A greater technical input in the form of trained foresters from the NFS will improve the quality of information and understanding by NFS personnel."
2. "Out studies on the Croatan National Forest, North Carolina are not formal administrative studies but instead are studies we installed on the National Forest. The District has benefited from these studies as demonstrations and has followed with small-scale operational fertilization (approximately 300 A). This is probably the main benefit from administrative studies and we in research should accept the fact."
3. "We should try to remove administrative hurdles to make the cooperative efforts easier and more useful. An exchange or detailing of personnel may be the way to go."

FOREST FERTILIZATION: REGIONAL ADVICE

Wayne Haines, Director: N.C. State For. Fert. Coop. (NCSFFC), N. Caro. State Univ., Raleigh, N. Caro.

Loblolly and slash pines

1. "These P-deficient sites exist primarily in the Atlantic Lower Coastal Plain region, which extends from Virginia into Florida. There are also P-deficient sites along the Gulf Coastal region, primarily in the panhandle section of Florida. The Croatan and Francis Marion in North Carolina and South Carolina, respectively, are in P-deficient regions. I have no estimate of the acreage that would respond to P. The Olustee National Forest in northcentral Florida is comprised largely of P-deficient sands which are known to respond to P."
2. "There are many examples of the interaction of site preparation (in this case, bedding) and response to fertilization. There is still much that we do not know concerning fertilizer placement and the duration of response to treatments, including N fertilization and bedding. The trend is toward an application of N + P, rather than P alone, on what we still consider P-deficient soils. The N + P treatments results in much better growth than P alone on these sites."
3. "Fertilization will have to be integrated with other silvicultural treatments (i. e., bedding and thinning, as well as the utilization of the best genetic strains) if its maximum potential is to be obtained. Stand and age, are probably just as important as the soil characteristics when selecting stands for fertilization. For example, from our own work we have observed stands on the same soil type, some of which responded while others did not. The lack of response has been attributed to stand conditions, rather than soil differences."
4. "The current status of the art of operational fertilization in the Southeast may be summed up as follows: Wet P-deficient sites may be identified either by soil or foliage analysis with a very high level of reliability. However, neither soil nor foliage analytical procedures are reliable for determining P-deficient sites if the soils are moderately to well drained. Thus, there is a need for continued research in this area."
5. "Nitrogen response is being obtained on most upland sites (Middle and Upper Coastal Plain and Piedmont soils), and some of these responses are very encouraging (i. e., three cords per acre increase over a three-year period). However, the duration of response, which appears to be related to soil characteristics, is variable and as yet undetermined. Thus, there is a need for continuing studies in this area."

FOREST FERTILIZATION: REGIONAL ADVICE

Bill Pritchett, Coordinator: Cooperative Research in Forest Fertilization (CRIFF),
Univ. of Flor., Gainesville, Flor.

Loblolly and slash pines

Provided a manuscript: "Fertilizer recommendations for southern pines in the lower Coastal Plain."

Ray Brendemuehl, SE For. Exp. Stn., Mariana, Flor.

Sand and slash pines

1. "The Forest Service has begun to apply fertilizers on an operational scale on both the Osceola and Apalachicola N.F. in Florida. To date about 10,000 acres have been fertilized with the first applications being made in 1971. Here too activity is increasing with about 7,500 acres scheduled for an application of fertilizer in 1974. The Forest Service is fertilizing slash pine plantations ranging from about 2 to 30-years in total age. Some of the older plantations have grown very slowly until fertilized and now show a remarkable response to the material applied."

2. "Best responses have occurred in the following situations,

Soils: Poorly drained to very poorly drained acid flatwood soils which are very deficient in phosphorus.

Typical soil series:

Leon - hardpan at 18 to 30 inches.

Rains, Bladen, Weston series - lack hardpan

Fertilizers applied: Usually some form of P such as 0-20-0 or 0-46-0. In some instances the materials have been applied in conjunction with the site preparation operation but in most instances P has been applied about 1 to 3 years after plantation establishment. A partially acidulated form of rock phosphate is being developed by TVA for use on soils where loss of P by leaching may be a problem (Leon series).

Materials such as 18-46-0 are being applied to young plantations, 8 to 15-years age range, and N alone to plantations and natural stands that are about 20 years old. Where N alone is being applied growth has been acceptable. Response to the N applied usually is of sufficient magnitude to justify the investment since costs will only have to be carried for 5 to 10-years rather than an entire rotation.

Rates of P application - about 100 lbs. P_2O_5/A .

Rates of N application - about 100 lbs. N/A .

FOREST FERTILIZATION: REGIONAL ADVICE

Method of application: Usually some form of aerial application so fertilizer materials are not mixed with soil.

Species: Primarily slash pine in Florida with both loblolly and slash being fertilized in Georgia and South Carolina's coastal plain areas."

Donald Marx, SE For. Exp. Stn., Athens, Ga.

Mycorrhizae

1. "Also enclosed are two slides that should explain a great deal! Slide #1 shows typical root systems of pine seedlings grown throughout the United States under current nursery practices. Sixty percent of the feeder roots are mycorrhizal from naturally occurring fungi which colonize recently fumigated soil via airborne basidiospores. Slide #5 shows typical root systems of pine seedlings grown in nursery soil infested with pure cultures of Pisolithus tinctorius ectomycorrhizae prior to planting. The consequences of this tailored ectomycorrhizal development is a 50 to 150% increase in growth (depending on pine species), as well as--we hope--improved field performance.

Miller's note: This is a new research finding of great practical significance ... another production tool.

SOUTH (GULF STATES)

Gene Shoulders, SO For. Exp. Stn., Pineville, La.

Slash pine

1. In the west Gulf States, average site quality is much higher than that in the southeastern coastal plains; our forest fertilization experience is limited, so we can't recommend operational treatment.
2. Fertilization at planting (without weed control) generally increases weed competition and reduces seedling survival.
3. Need to speed-up our field testing through cooperative research of administrative studies.
4. Need to screen our pine genotypes for those that are most responsive to fertilizers.

FOREST FERTILIZATION: REGIONAL ADVICE

Paul Duffy, SO For. Exp. Stn., Oxford, Miss.

Loblolly pine

1. "Loblolly pine is the only tree species that I have fertilized and I worked only on the upper Coastal Plain. Observations on response have been restricted to the first 2 to 3 years after planting and my primary concern has been that of increasing loblolly's erosion control effectiveness."
2. "By putting together some ideas from study and non-study observations I would say that generally fertilizing does not limit pine survival on most upper Coastal Plain soils. High bulk density and moisture availability are the determining factors. We also believe that fertilization with N would increase growth but response would be highly variable. A problem, particularly on old fields, is that fertilization may increase growth of competitive grasses."
3. "At the present I don't believe we are ready to prescribe fertilization for our forests. I believe applications of N at 150 lbs./acre would produce response in some stand but the amount, time, and location of these responses would be unpredictable. The complex soil arrangement because of geologic formation and past land use (agriculture) makes prediction particularly troublesome. We need more information on upper Coastal Plain soils so we can extend to stands knowledge gained from fertilization research on the lower Coastal Plain. I might add that one private corporation is fertilizing on the Upper Coastal Plain. I do not know what they are using and I don't know if they have much information to support the operation at present."

Bobby Blackman, SO For. Exp. Stn., Stoneville, Miss.

Southern hardwoods

1. "Most fertilization work with eastern cottonwood up to the present time has been limited to the Mississippi River Floodplain. ... nitrogen deficiency is a key factor limiting growth on soils that were previously in agricultural crop production. Responses as large as 200% over untreated controls have been measured in plantations ranging from 6 to 10 years old and growing on old-field Commerce soils. Rate studies indicate peak responses at 150 to 300 pounds of N per acre. On one site, however, the response curve remained linear through 600 pounds per acre, the highest rate tested."
2. "Fertilizer responses are apparently being maintained at least through the second season after treatment. High rates of N (i.e., 300 and 600 lbs/ac) result in longer response duration than lower rates (i.e., 75 and 150 lbs/ac). In the 7-year-old stand, the greatest actual volume growth over two seasons following application amounted to almost 500 cu. ft. per acre, compared to about 200 cu. ft. for the unfertilized controls. In the 10-year-old stand (growing on the same soil series, but with somewhat different properties), maximum response occurred at the 600-pound rate. On plots treated with 600 pounds of nitrogen per acre, 2-year volume growth was 725 cu. ft. per acre, and about 225 cu. ft. on the untreated plots, a 220-percent increase."

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3. "Our experience and data also indicate that fertilization should be delayed until at least the third or fourth growing season. Little, if any, response can be expected until the trees begin to compete with each other for nutrients."

4. "In 1972, measurements were taken in a fertilization study established in 1958 in a natural, 20-year-old gum-oak stand. These data indicate that six increments of 150 pounds of nitrogen per acre, applied during a 10-year period, have resulted in an 11-cd./A or a 2.2-M bd. ft./A volume increase (based on a complete conversion from cu. ft. volume) over the control at stand age 35. Assuming sawlog stumpage of \$90 per thousand bd. ft., this increase provides a \$198/A (6-percent) return on an \$81/A fertilization investment. Six applications of 75 pounds of nitrogen per acre failed to increase volume over the control, while 300 pounds of nitrogen per acre resulted in volume increases comparable to the 150-N treatment."

THE LAKE STATES

Dave Alban, NC For. Exp. Stn., Grand Rapids, Minn.

Black spruce and red pine

1. "Almost no fertilizer trials have been established for the tree species we are concerned with at our project (northern conifers and aspen). This is undoubtedly because of the low value product (pulp) most of the species are used for. Red pine is perhaps the species with the highest potential value per acre."

2. "I think its likely that fertilizer response (a biological response) can be expected in perhaps one-third of the red pine stands. It seems to me that a response is even more likely to fertilization of aspen and to upland spruce-fir."

3. "But what is clearly needed is a systematic series of fertilizer trials to establish, at least in general, the extent and magnitude of fertilizer responses to be expected in the Lake States."

4. "We have recently remeasured the black spruce study and found that 10 years after fertilization height growth on the heavily fertilized plots is still about twice as great as on the control (16 cm/yr vs 8 cm/yr). ... This study is on an extremely poor site and the hope is that fertilization may make the stand commercially harvestable. We know that such poor organic sites are extensive in northern Minnesota but have no good ideas on what percent of poor sites (or the better sites for that matter) would respond to fertilization."

Will Carmean, NC For. Exp. Stn., St. Paul, Minn.

Sugar and red maple

1. "A fully stocked, 50-year-old stand of mixed sugar and red maples in northern Wisconsin was fertilized in 1966. Treatments were: (1) check; (2) P; (3) N; (4) N+P; and (5) N+P+K. ... 150 lbs./acre of each element

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were applied. ... Diameter growth increased each year for 5 years on all plots receiving nitrogen fertilizer. Increased growth was closely related to initial diameter. Dominant maples fertilized with nitrogen had about double the growth of unfertilized dominant trees; codominant trees also responded, but less than dominants; intermediate and suppressed trees grew slowly and showed little growth response."

2. "... the results from this study are encouraging, and they agree well with past maple fertilization studies--Mitchell and Chandler, Mader. Thus I think we are now in a position where we might try some small scale 'pilot plant' applications using soils and stands similar to those of this study. However, we still have a long way to go before we have the quantity of information now available in the PNW and the Southeast. Therefore, we should go slow before getting involved in a regionwide 'fertilizer dumping' program. We need many more field research studies involving different soils, different hardwood species, and different rates and kinds of fertilizer. Hopefully, we may develop an integrated regionwide program for hardwoods similar to that already underway for Douglas-fir and southern pine."

THE CENTRAL STATES

Bob Phares, NC For. Exp. Stn., Carbondale, Ill.

Black walnut

1. "... most of our fertilization work is still in the research stages. We are a long way from practical application. With the potential impact of fertilizers on the environment, and the recent inflationary increase in price of fertilizers, it's more important than ever that we establish a solid research base for forest fertilization before going 'applied' as has been done in certain parts of the country."

2. "Our fertilization studies fall into two broad categories. First, we have a number of studies where we are evaluating the effects of fertilizers on newly planted seedlings and young trees (up to age 10). The purpose of fertilization in these studies is to promote faster early growth. Black walnut is characteristically a slow early starter. Through better weed control practices and proper choice of sites, we have greatly shortened this 'establishment' period, but fertilization may help us shorten it even more. Good sites are scarce, however, so we are going to have to start evaluating limiting factors on less-than-best sites; it's on these less-than-best sites where fertilizers may be most effective."

3. "... our cooperative fertilization study at Fort Campbell, Kentucky, gives some preliminary results from fertilization of young trees. We have a duplicate study on F.S. land adjacent to Fort Leonard Wood in central Missouri. Both show essentially the same results: limiting has little or a slight detrimental effect on height growth, nitrogen produces the greatest response, phosphorous has little effect. We generally do not an NP interaction though; with added P we get greater response to N."

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4. "... in the management of older trees (pole-size and larger) ... fertilization is combined with release and thinning. The research is directed at speeding up growth and nut production of individual trees. Nitrogen is the element studied most intensively. ... response is erratic; thus, we are reluctant to make any broad-scale recommendations on the practicality of fertilization of walnut growing on these good to excellent sites."

5. "I regret that I haven't any final publications from our fertilization research to send to you. We are still evaluating responses, developing diagnostic criteria, and trying to get an overall feel of the growth variation in response to fertilization on different soils before we make any broad-scale recommendations concerning its potential."

Dick Watt, NC For. Exp. Stn., Columbia, Mo.

Oak-hickory

1. "In 1968, I installed a test of 0, 300, 600, and 900 pounds of elemental N as urea and 0, 200, 400, and 600 pounds of phosphate as treble superphosphate in 5 widely separated locations on the Clark and Mark Twain National Forests in thinned, small sawtimber oak stands 70 years old. Species were mostly black oak, but some scarlet were tested. ... No response was obtained by any level of phosphate application, either singly or in conjunction with nitrogen. Table 1 shows the response to nitrogen for the first 4 seasons."

Table 1.--Diameter growth response as percent of growth before fertilization

Season of growth	Pounds of elemental N per acre			
	$\frac{1}{0}$	300	600	900
1969	100	104	114	118
1970	100	119	141	162
1971	100	121	133	151
1972	100	104	118	132

$\frac{1}{0}$ 0 level growth adjusted to 100 percent and other levels changed proportionately.

2. "I conclude that we can firmly recommend fertilization of our oak-hickory stands with nitrogen in the Ozarks of Missouri. These results were obtained on a variety of the more common soils of the Central Ozarks of southeastern Missouri in several locations. It is still too early to give recommendations on the application of other elements."

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INTERMOUNTAIN

Jim Lotan, Int. For. and Range Exp. Stn., Bozeman, Mont. Larch and lodgepole pine

1. Need further evaluation of existing trials.
2. Need additional, systematic field trials before operational fertilization is feasible. These trials should consider time of application (to minimize uptake by competing vegetation).

NORTHERN CALIFORNIA

Bob Powers, PSW For. and Range Exp. Stn., Redding, Calif. Mixed conifers

1. "I conclude ... you'd like some slides documenting general or specific forest sites in California where fertilizer applications are likely to give good results. Unfortunately, we've some to go here before general guides can, or should, be given. Serious nutrition research is just beginning and I'm the only PSW researcher studying the interrelationships of soil fertility and the growth of commercial forests."
2. "Three R-5 National Forests began administrative studies in forest fertilization within the last couple of years. Plots have been established in plantations and natural stands on ponderosa and Jeffrey pine, mostly in areas of low precipitation, but to date there is little to report."
3. "I doubt that fertilizer work will be very rewarding in California where soil moisture is the major limiting factor. Thus, I've focused my efforts on better sites. Results of pot studies help confirm this."
4. "I'm now running an NP fertilizer trial in a high site mixed-conifer plantation at our Challenge Experimental Forest (slides 8-10), and relating soil and foliar nutrient levels to the capacities of differing species to respond to nutrient change. I'll also be monitoring foliage moisture tension and response of understory vegetation to fertilizer. Nearby I have a spacing x N test in ponderosa pine in which 0, 200, and 400 lbs. N per acre applied over 17 spacings ranging from 13 to 339 ft.² growing space per tree."
5. "I think we need pay much more attention to our non-renewable basic natural resource--soil. We need to drive home an appreciation that soil is a fragile medium and one that must be conserved and, where practical, improved."

THE PACIFIC NORTHWEST

Pat Cochran, PNW For. and Range Exp. Stn., Bend Ore. Ponderosa and lodgepole pine

1. We have limited number of field trials, but results are very encouraging and justify pilot scale applications.
2. In both pines, apply 200 pounds N per acre, preferably to thinned stands.

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3. NPS fertilizer increased understory grass production by 2- to 10-fold.

Dick Miller, PNW For. and Range Exp. Stn., Olympia, Wash. Coastal Douglas-fir

1. Since 1950, fertilizer tests have been installed at more than 300 locations in coastal Douglas-fir.
2. Since 1965, 475,000 acres have been operationally fertilized.
3. Consider an A, B, C Strategy:

APPLY existing information. Initially restrict operational fertilization projects to soils and stands most similar to those of reliable and successful fertilizer trials. Broadcast fertilization of seedlings is not recommended. 150 to 200 pounds of nitrogen per acre to established stands is a generally reliable prescription. Consult with industrial or state foresters who have operational experience.

BALANCE fertilizer-usage with other production tools. Manipulating stand density may be necessary to optimize response from both thinning and fertilizing.

COLLECT and analyze new information to improve our decision making. Additional research, administrative, and operation-monitoring studies are necessary.

Existing and new information about the response of trees (or the soil) to fertilization and other management practices must be efficiently stored and retrieved. Even today, the district forester needs to know: What is known about fertilizing soil No. 87 or any other soil with similar characteristics? How can he get this information? How rapidly? Eventually, every ranger district will have a computer-terminal to retrieve information stored in a computer. How rapidly and effectively is the U.S. Forest Service progressing toward this eventuality?

Sacramento, CA. Oct. 21-25, 1974.

EVALUATING FERTILIZER PROGRAMS

USING SOIL ANALYSIS, FOLIAR ANALYSIS, AND BIOASSAY METHODS

Robert F. Powers
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My role in this silviculture conference is to outline and evaluate traditional and not-so-traditional methods for testing forests so we can gauge their capacity to respond to fertilization. My background is as a biologist studying plant/soil relationships--not an economist studying costs and benefits. I weigh results in biological units, not economic ones. But one fact seems plain to me. If, 30 years ago, economists had foreseen that fertilization someday would be a practical silvicultural tool, today we'd have many more answers to fertilization questions. Unfortunately, most of our experience has come recently. Of some 95 ongoing eastern studies, for example, 72 percent are less than six years old (Auchmoody and Filip 1973).

Forest fertilization isn't an elixir, but in certain situations it can be a potent medicine. The trick is in finding where. Once stocking control has been applied to its fullest and current increment has peaked for a site, fertilization remains one of the few ways we have short of irrigation and a major reshuffling of the gene pool of actually increasing site quality. And since forest land is not increasing, but world demand for forest products is, this is a very important principle. Let's see what fertilization can do.

Scanning the literature quickly shows that gains from forest fertilization can be both real and impressive. For example, a 20-year-old plantation of Pinus elliottii treated with NPK at 420 lbs per acre produced 329 cu. ft. more wood per acre over a 10-year period than did controls (Broerman 1968), and gave a marginal rate of economic return of 12.5 percent, and rates as high as 18 percent have been reported. In the northeast, mixed 50-year-old upland oaks showed 5-year volume growth increases of around 45 percent over controls (30-45 cu. ft. per acre) following N and Ca applications of 180 and 1,000 lbs/acre, respectively (Ward and Bowersox 1970). In the Douglas-fir (Pseudotsuga menziesii) region of the Pacific Northwest, Weyerhaeuser reported 10-year volume increases of from 21 to 56 percent over controls in Douglas-fir at age 20 (Steinbrenner 1968). This equates to between 229 and 590 cu. ft. per acre, at fertilizer levels up to 1000 lbs per acre. Two-year results of the University of Washington's Regional Forest Nutrition Study show mean volume increases ranging between 36 and 118 cu. ft. per acre for N at 200 lbs, and between 28 and 144 cu. ft. per acre for N at 400 lbs/acre, depending on site quality (Atkinson 1974). Recently, Miller and Pienaar (1973) found that in 35-year-old stands 280 lbs N per acre produced a 649 cu. ft. per acre net volume increase over controls. Here in California, our project ran N trials in old-growth Douglas-fir (about 1/3 of the trees had d.b.h.'s greater than 4 ft.) and found that 10-year basal area growth pertree had nearly doubled at fertilizer levels between 400 and 600 lbs. N per acre, but was unaffected by 200 lbs. N per acre--at least for initial stand densities below 300 sq. ft. basal

1 area per acre.^{1/} Agee and Biswell (1970) found that in a young Site II
2 sawtimber stand of ponderosa pine (Pinus ponderosa), basal area growth
3 on plots treated with about 1800 lbs. ammonium sulfate per acre exceeded
4 controls by some 400 percent over a 13-year period, and increased the
5 growth of thinned stands by nearly 50 percent. Results of a study I
6 began recently in young mixed-conifer species at our very high site
7 Challenge Experimental Forest in the Sierras show that height growth
was significantly affected by NP treatment after one growing season with
Abies concolor showing height growth increases as great as 260 percent
and Pinus lambertiana as much as 127 percent over controls.^{2/} Here, it's
interesting to note that trees growing on what surely is one of the best
inland sites in the west are capable of responding to further nutrient
additions.

So the literature surely shows that important gains can result when
fertilizing becomes a silvicultural practice. But I caution you to
read the literature critically. Because unlike some silvicultural treat-
ments, like thinning, that nearly always cause some positive response,
fertilization does not always work. Further, results that are completely
reliable for one region or one forest cannot be extrapolated easily to
others differing in regional climate and geology. For example, experiences
gained on the P-deficient sands of the southeastern pine forests may bear

^{1/} Unpublished study on file at the USDA Forest Service Pacific
Southwest Forest and Range Experiment Station 1615 Continental St.,
Redding, Ca.

^{2/} Ibid.

little relevancy to conditions on glacial tills in western Washington, or those to conditions on the granitic soils and mixed conifer forests of the Sierra Nevada.

If we're critical, the literature can give us general guides for an extensive program of forest fertilization. But in the final analysis we must judge each site on its own merits. Several analytic tools are available to help us. They are field trials, soil chemical tests, plant analysis, and soil bioassays.

FIELD TRIALS

Field fertilizer trials are absolute prerequisites to any operational fertilization program. Theory and laboratory tests mean nothing if they can't be validated in the real world. And field trials are the means we have of doing this.

You don't step into a hot tub without testing the water first. And with today's fertilizer prices, and concerns for environmental quality, we shouldn't leap into operational forest fertilization programs without first testing our skill at predicting forest nutrient needs.

The day of the "let's-throw-it-on-and-see-what-happens" approach is past. Even when fertilizers were cheap, this was a poor way of doing things. Results, both positive and negative, could never be explained well. This leads to a Pandora's Box of problems compounded again and again depending on the variability of the treated forest.

The importance of well-designed, well-coordinated field trials cannot be overstated. They're the final filters that we test scientific hypotheses against. They're the biological feedback systems that tell

1 us whether or not we are judging forest nutrition correctly. They are
2 absolutely essential. But they must be well-designed, and well-implemented.

3 So how do we pick the stands to test? And once chosen, how do we
4 pick the nutrients to use? How do we know if nutrition may be limiting
5 at all? Let's explore these topics further.

PICKING THE STANDS

6
7
8 Some sort of resource inventory is needed on any National Forest
9 considering a fertilizer program. I see timber type and condition
10 class maps as a bare minimum requirement. To that I would add an over-
11 lay of broad site classes. Thirdly, a soils overlay at the series level,
12 if possible, but at least showing parent material and soil depth. I
13 would then stratify my forest into units of similarity, say pure pine
14 stands on Site II, pure pine on Site I, mixed conifer on Site II, mixed
15 conifer on Site I, etc. I would next stratify by broad age or size
16 classes (saplings, poles, young sawtimber). Then I would concentrate
17 my efforts on medium to better sites, where small increases in increment
18 may make major changes in volume. Leonard, Leaf, and Berglund (1972)
19 put it well in advocating more work on better sites because on poor
20 sites, "100-percent increase of near-nothing is still near nothing."
21 Recent results of University of Washington work contradicts this state-
22 ment somewhat (Atkinson 1974), showing that poorer sites not only were
23 more likely to respond to nitrogen fertilizers (as you might expect),
24 but over the short run gave the greatest absolute volume response too.
25 One possibility here is that N might have been the predominant limiting

factor on poor sites in Washington, but that some other untested factor was limiting on good sites (Davey 1968).

But perhaps the real key is response duration. Poor sites generally are poor for a variety of reasons, and nutrition may be but one. In California, poor sites often are associated with shallow, skeletal soils, and with areas of low precipitation. In theory, such sites are very poorly buffered, and nutrients poured into the system may cause spectacular growth increases for a short time, but because the system is buffered poorly, they will be lost from the system over the long haul (fig. 1). Good sites tend to have better soil development, more organic matter, and higher populations of microbial organisms. Thus, they have the capacity to retain nutrient inputs over longer periods of time. And the duration of fertilizer response should be longer there. Also, soil moisture is low and limiting on many inland sites, owing to low rainfall, poor soil development, or both. Growth on better sites is less likely limited by moisture availability, particularly if stocking control is exercised. At Challenge, for instance, we have strong evidence that soil moisture has little influence on the length of the growing season. Trees on medium to better sites fertilized with the proper nutrients should have longer growing seasons in which to respond.

Secondly, I'd concentrate on younger stands between sapling and sawtimber size. These size classes bracket the most rapid growth stage where nutrient uptake is greatest and internal nutrient transfer is still low (Ovington 1959; Switzer and Nelson 1972). Such age/size classes depend greatly on current annual nutrient uptake, and so they are especially sensitive to nutrient availability in the soil. Also, they should be stands where stocking density is not so low that a heavy

understory of shrubs has developed, and not so high that live crowns cover less than 40-percent of the bole. Stands meeting these criteria will have the best capacity to respond to fertilizers.

Thirdly, if choices are possible, high-value species should take precedence over low-value ones. Application costs are largely fixed, but species values are not (Hughes and Post 1973). In choosing between hardwoods and conifers, it is generally believed that hardwoods make greater nutrient demands on the site, and thus have the greater capacity for growth response to nutrient change (Davey 1968). Their greater economic value relative to conifers gives them fertilizer priority where choices exist.

SOIL CHEMICAL ANALYSIS

Ever since the keystones of modern chemistry were set at the close of the 18th century, agronomists have been grinding, shaking, cooking, and extracting things from soils to find out why plants grow as they do. Sometimes they find out useful things. And sometimes they do not.

The basic principle of soil analysis is that what's in the soil is in the plant, but this is often not true. We know that plants can be quite selective in the kinds of elements they absorb (Epstein 1972). We further know that of the total pool of elements present in a soil, only a small fraction are available for absorption at any one time. The rest are locked tightly in crystalline or organic forms not directly available to higher plants. For this reason, "total" amounts of soil

nutrients rarely correlate well, or directly, with biological processes (Ralston 1964; LeTacon 1972; but see Viro 1961).

The trick then is to choose chemical methods with extractive properties related to those of the species you are managing. But nearly all our lore on soil chemistry and plant nutrition is based on studies of agronomic crops. Selection pressures on these plants have been for production on relatively fertile soils, not survival on relatively sterile wildland soils. The plants we're concerned with have evolved ways of obtaining nutrients from soils that are extremely infertile by agricultural standards (Ralston 1964; Waring and Youngberg 1972).

For example, in 1949 Frank Bingham reported a soil testing method for relating "available" soil phosphorus to the growth of California field crops. His method measured P present in the soil solution and was rather easy to run as far as soil tests go. Bingham tested his method through fertilizer trials in 108 California fields. Of 72 fields testing 0.40 ppm or less water-soluble P, 86 percent showed crop response to added P. Of those testing greater than 0.40 ppm only 8 percent showed response. Forest soils of California average about 0.3 ppm water-soluble P in surface horizons (Colwell 1960). Thus, many would be P-deficient by the Bingham test.

I devised an interesting way of testing the Bingham and other P-extraction methods against uptake by forest trees by first selecting two forest soils that are common in the state, but markedly different in chemical and physical features. They were the Cohasset soil series, which is quite productive, and the Sheetiron series, which is not.

1 Next, I determined the capacity of each soil to sorb P by adding
2 P in increments, equilibrating the soil, and measuring P in the soil
3 solution. Considerable P could be added before large changes in solution
4 P were noted. I then ran pot tests of ponderosa pine and white fir on
5 each of these soils with one treatment a control and three additions of
6 P in increasing amounts so that the highest levels brought the soil to
7 P sorption capacity. "Available" soil P as estimated by different
8 extractants was then related to seedling yield. The Bingham method
9 (working so well on field crops) showed no relationship to conifer
10 seedling weight, though the best treatments caused weight increases
11 between 36 and 114 percent over controls (fig. 2).

Other extractants showed much better biological correlations. For
example, the best one tested was sodium bicarbonate (Olsen and Dean
1965) which produced a sharp calibration curve suggesting that both
ponderosa pine and white fir will show similar responses to P additions,
even on very different soils, when "available P" by this method tests
less than 25 ppm (fig. 3). This implies that soil tests exist that
correlate well with conifer nutrition, and the trick is in identifying
them. And while it's tempting to use soil test standards like these
to gauge fertility, other results lead me to question the general utility
of soil analysis.

For example, another soil extractant I tested that gave good bio-
logical correlations was ammonium fluoride in hydrochloric acid (Olsen
and Dean 1965; fig. 4). From these results I conclude that conifer
seedlings on soils testing less than about 22 ppm soluble P can respond

to further additions of P, but are not likely to if soluble P exceeds this. Yet, in Canada the same testing method showed Douglas-fir responding positively to levels at least 600 percent higher (van den Driessche 1969).

Therefore, not only are there problems in applying tests developed for agricultural soils to forest tree nutrition, but tests working well for one region or group of species may not work well for others. Other problems with soil analysis include the very large sample sizes often needed to handle soil variability (Hammond et al. 1958; Troedsson and Tamm 1969), and applying laboratory results (which are based on soil fine fractions) to the field (where soil textures range from coarse gravels to fine clays). Humphreys (1964), for example, has shown that soils judged adequate for Ca in laboratory tests may prove deficient in the field because of excessive stoniness that limits rooting space. Soil nutrients should be expressed on a soil area or volume basis to be meaningful (Leaf and Madgwick 1960; Zinke 1960). And what part of the vertical soil profile do you sample? Soil nutrient content varies

vertically as well as horizontally, and soil samples taken from one depth may hold little biological relevancy if tree roots are either higher or lower in the vertical profile.

In conclusion, soil chemical analyses can be helpful, but they are far from being the panacea that many traditionalists believe them to be (Tamm 1964). They are time-consuming and costly. And to be useful in respect to current nutrition we must (1) choose methods that correlate with the nutrient extracting ability of the species, even varieties, that we are working with; (2) take soil variability into account by analyzing several composites of samples drawn randomly over the plot; (3) select our samples from soil depths actually inhabited by roots; and (4) take stoniness and soil bulk density into account by expressing laboratory results on the basis of soil volume or area, such as gms per unit surface area of the site. But the expense and potential imprecision of all this must be weighed against other analytic methods that may work as well or even better, and possibly at less cost.

PLANT ANALYSIS

Plants are the final integrators of all the factors of site (Ulrich 1948; Tamm 1964). Soil tests that indicate adequate supplies of nutrients mean little if the nutrients are not in the plants. And what's in the plants relates to how well they grow.

Paul Macy in 1936 described a diminishing returns curve for plants relating their internal nutrient content to their growth (fig. 5). He stated that for each nutrient in each plant there exists a "critical

1 percentage," or concentration, above which lay a zone of "luxury con-
2 sumption," and below which fell a zone of "poverty adjustment." Cali-
3 bration curves like Macy's have been developed by plant physiologists
4 for many agronomic species and a wide range of nutrients. Ulrich at
5 the University of California, probably the foremost authority on the
6 subject, has defined the term "critical level" as the nutrient concen-
7 tration in a particular plant organ associated with 90 percent maximum
8 yield when other factors are not limiting (Ulrich 1948). As internal
9 nutrient concentrations fall to the critical level, nutrient stress
10 occurs and growth is depressed. Calibration curves defining critical
11 levels are best developed under well-controlled conditions where all
essential elements are in adequate supply except one. Several workers
have developed calibration curves of certain nutrients for forest trees,
most notably Swan (1960), Ingestad (1960), and Fowells and Krauss (1959).
For the past two years I've been working on calibration curves for
several western forest species and populations.

Though plant analysis has been an extremely useful tool in agronomy
for over two decades, it's been slow to catch in forestry. Several
arguments have been raised for not putting more serious effort into
plant analysis.

1. We don't know what to sample. This argument simply is not true.
Leaves are the primary sinks for plant nutrients. This has been demon-
strated conclusively for domestic crops (Epstein 1972) and is no less
true for forest trees. This makes sense, since (1) wood growth is a
function of photosynthate production, (2) leaves are the site of photosynthesis,

1 (3) leaves contain higher concentrations of most nutrients than do other
2 plant parts, and (4) when leaf nutrients are low, photosynthesis falls
3 off.

4 And though inconvenient in tall trees or closed canopies, sampling
5 should focus on illuminated portions of at least the upper third of the
6 crown (Gessel et al. 1960), preferably the upper three whorls for conifers
7 (Lavender 1970). Physiological processes are most active here and are
8 depressed in shaded, lower parts of the crown. Thus, the upper crown
9 is sensitive to current nutritional conditions. Borrowing a concept
10 from agronomy, I advocate we sample the most recently-matured leaves of
11 the current year (fig. 6). More intensive efforts would also analyze
12 separately leaves of the previous year in evergreens to determine if
13 levels are falling dangerously low there.

14 Further, we should confine our sampling ^{to} ~~from~~ trees that will form
15 the future crop. In other words, dominant and codominant crown classes.
16 These are the trees best expressing the true potential of the site.

17 2. We don't know when to sample. A little more controversy exists
18 over this. In forestry, sampling has been confined almost entirely to
19 fall or early winter. The justification for this seems to stem from
20 early work by Tamm (1955), who found that foliar nutrient concentrations
21 were most stable and sampling variation lowest during dormancy. But
22 concentrations during dormancy probably only show nutrient stress under
23 the most extreme conditions. For example, trees reaching the critical
24 level early in the growing season may suffer heavy growth reduction and
25 stress, but those reaching the critical level near the end of the season

1 will not likely suffer at all. Conceivably, both stands might test
2 similarly if sampled during dormancy.

3 Ideally, a stand should be sampled early, in the middle, and toward
4 the end of the growing season. As a bare minimum, a single sample during
5 the period of rapid growth when demand is greatest should be a major
6 improvement over dormancy sampling (Waring and Youngberg 1972; Leaf
7 1973). Sampling intensity will vary with plot size, site variability,
8 and study objectives. And general guides are available to help us
9 decide on the number of trees to sample (Metz et al. 1966; Lavender 1970).

10 3. We don't know how to interpret the data. While it's true that
11 the final chapter on critical nutrient levels in forest trees has yet
12 to be written, this is no excuse not to begin based on what we have to
13 date. For example, a search of the literature can supply us with foliar
14 nutrient concentration ranges that describe deficiency and sufficiency
(Table 1). In practice, a complete chemical analysis would be made of
15 foliar samples from each study plot. Results would be screened for
16 the nutrient most likely limiting growth.

17 Research funding is needed badly to pin down critical levels for
18 each essential element. And, since some elements (like N) exist in a
19 variety of forms in the plant, identifying the forms most indicative
20 of a plant's nutritional state is an important, but poorly funded,
21 research goal. Still, we can procede with what we have.

22 4. Foliar analysis will not reveal multiple deficiencies. This
23 is true, since a strong and prolonged deficiency of one nutrient may
24 allow another, also in low supply, gradually to accumulate in foliar

Table 1.--Foliar nutrient concentrations reported for deficient and healthy forest trees and agricultural crops

		: Nutrient concentration in leaves when concentration is--					
	Nutrient	Deficient			Adequate		
		Conifers	Hardwoods	Field crops	Conifers	Hardwoods	Field crops
----- percent of dry weight -----							
MACRO-NUTRIENTS	N	<1.1	<1.0	<1.5	1.3-3	1.0-4.0	1.5-5
	P	<0.09	<0.09	<0.1	0.1-0.3	0.1-0.28	0.2-0.34
	K	<0.4	<0.5	<1.4	0.5-1.6	0.5-1.5	1 - 5
	S	<0.1	<0.15	<0.1	0.15-0.3	0.15-0.3	0.1-0.24
	Ca	<0.12	<0.2	<0.15	0.12-0.7	0.3-2.2	0.5-7
	Mg	<0.05	<0.08	<0.1	0.07-0.2	0.1-0.4	0.15-1.8
----- parts per million dry weight -----							
MICRO-NUTRIENTS	Fe	<30	<30	<30	50-100	50-100	50-450
	Mn			<10	100-5000	100-5000	25-300
	Zn	<5	<5	<13	10-125	10-125	15-95
	Cu	<3	<3	<3	4-12	4-12	5-65
	Mo			<0.2	0.05-0.25	0.05-0.15	0.6-5
	B	<3		<3	10-100	10-100	6-20
	Cl			<100	10-3000		100-4000

tissues, giving the appearance of adequacy. Still, it will isolate the primary nutrient most limiting growth. Once this has been corrected, perhaps by quick tests such as pot bioassays, the next limiting factor can be isolated, and so on.

5. Foliar analysis cannot prescribe how much fertilizer is needed.

This also is true. Foliar analysis will show if a deficiency exists, and give a measure of its severity, but short-term bioassays or long-term field trials are the best means at present for judging how much is needed.

6. Forest trees are different. Theodore Broyer, Professor Emeritus at Berkeley, is fond of saying that "protoplasm is protoplasm." This seemingly simple statement means that on a cellular level, biological processes are amazingly similar for a variety of organisms. The critical level of K for cabbage is probably not very different from cucumber tree, if critical levels for each are known (Table 1). The basic difference lies in the ability of each organism to satisfy its needs. In other words uptake differences exist through differences in root development or root physiology, all of which strengthens the argument against universally meaningful soil analyses in forest nutrition. There is no doubt that important differences exist both at the species and race level in nutrient extracting ability (Beaton et al. 1965; Wright et al. 1969). But even such extreme edaphic ecotypes as those occurring on serpentine seem not to differ importantly from their domestic cousins when their respective critical levels are compared (Walker et al. 1955). I don't doubt that statistical differences can be shown between species or races in critical nutrient levels. But I doubt that important ones exist (Table 1).

SOIL BIOASSAYS

The most common soil bioassay method is the pot test used extensively by Mitscherlich (1930), Jenny et al. (1950), and others. Pot tests are micro-simulations of field tests but are done in the greenhouse or growth chamber. Soil samples from the field are brought to the laboratory, placed in pots, planted with seedlings of some test species, given a series of fertilizer treatments, and left to grow under favorable conditions. Eventually, plants are harvested, weighed, and treatment yields compared with controls. The particular fertilizer combination and level giving the optimal yield is judged the one to use in the field.

Pot test bioassays have certain obvious advantages over field tests and soil or plant analysis. For one, they don't tie up scattered units of land for long periods of time. And because they're compact, a large number of soils and a great variety of treatments can be tested in a relatively small area. For example, a test I ran recently covered only a small bench, but included two species, two soils, and four fertilizer treatments--everything replicated three times, for a total of 48 combinations of "things."

And since the growth environment is more favorable than that found in nature, pot test bioassays give results much sooner than we can expect from field trials. Further, bioassays are improvements over chemical soil tests because in the latter you must decide which extractant to use to estimate nutrient availability, but in the former the plant does it for you. Another example of "natural is better."

Finally, bioassays can give strong clues to the amounts and combinations of fertilizers needed in the field to bracket the response range, or to produce a particular response. And as a bonus, when coupled with foliar analysis they can detect subtle problems occurring under certain conditions. For example, figure 7 shows yield vs. added phosphorus for white fir in the pot test P fertilizer series I mentioned earlier. The differences between the two curves reflect the basic properties of the two contrasting soils. But this figure shows something else as well. Note the depression in yield at the heaviest level of added P on the Sheetiron soil. Studying results in more detail (fig. 8) shows that seedlings on the Cohasset series were in the deficiency zone of foliar P (Table 1) for all but the highest fertilizer levels. But on the Sheetiron soil, seedlings were just bordering deficiency prior to treatment, and adding small excess amounts of phosphorus to the soil depressed growth considerably. I'm reasonably certain that this was not due to a P toxicity, but rather to a chemical precipitation of available Cu, Zn, Mn, or Fe by P so that an induced deficiency of micronutrients results. This suggests that slightly overfertilizing certain poor soils with P can cause micronutrient problems, but that better soils may be well-buffered against this.

A drawback of pot test bioassays is that they obviously are artificial. Traditionally, soils are taken at some standard depth in the field, composited, sieved to remove large materials, planted with some test crop like barley or lettuce, and grown under unnaturally

favorable conditions (Terman et al. 1966; Jenny et al. 1950). And while all of this makes for great uniformity in experimental material, the true meaning of test results is a little hazy.

As an alternative I suggest tests using intact soil profile cores, rather than composited and sieved soil samples. This retains some of the natural variability of the field plot and brings it into the laboratory. Cores should be drawn from, or extend to, the current rooting zone, though this may be impossible in rocky soils. Cores should be planted with stratified seed not only of the same species, but of as comparable a genotype as possible to that growing in the field. At present I'm running an experiment using intact cores taken with an impact sampler designed by a coworker and myself. The sampler gives us cores that fit precisely in half-gallon milk cartons (very cheap "flower pots"), and allows compact and meaningful tests to be made.

PUTTING IT ALL TOGETHER

Just as there are "no free lunches," so are there no utopian diagnostic methods in plant nutrition. Each of those I've described has weaknesses. But I think that by sorting the wheat from the chaff a sound preliminary fertilization program can emerge for the National Forest system, and lead to an operational one. I see this proceeding in six stages (fig. 9).

1. Inventory. First, a sound resource inventory is needed on each participating National Forest. Soil, stand condition, and forest type maps can be used to delineate medium and better sites, responsive

size classes, and species of high relative value.

2. Foliar pre-sample. Secondly, I'd pre-sample crop tree foliage from prospective fertilizer trial sites, and run complete (or at least macronutrient) analyses on them. Results would be compared against standards, such as Table 1. This will indicate the nutrients primarily limiting forest growth, and will screen out those stands not likely to benefit from fertilization.

3. Bioassay. In this stage, intact soil cores would be drawn from the rooting zone of the candidate stands showing deficiencies in the pre-sample analysis. On rocky soils, bulk samples to the rooting zone would be substituted for cores. Field samples would be fitted to containers and placed in the greenhouse, sown with stratified seed of an appropriate type, and left to develop under 16-hour photoperiods and favorable soil moisture. Once seedlings have grown beyond the cotyledonary stage they'd be thinned to 3-5 per pot.

A fertilizer series would then be run over at least three levels of the limiting nutrient including a control. Also, I'd routinely include an N series even if N was not shown to be the primary limiting nutrient. Nitrogen plays a major role in mobilizing many soil nutrients by stimulating the decomposition of soil organic matter.

Plants would be grown for at least four months to allow treatments to take effect. Then plants would be harvested, dried, weighed, and if optimal response was less than some standard (less than 50-percent gain over controls, say), foliar nutrient concentrations could be determined again, and results would again be compared with

standards. At this point, secondary nutrient deficiencies should show if any exist. If they appear serious, a second bioassay series should be run with the fertilizer containing the primary limiting nutrient held at the optimal level determined by the first test, and the level of the secondary limiting nutrient varied.

4. Field trials. Here we enter the field trial program outlined earlier by Dr. Miller. And because we have established a sound, scientific basis for our actions, we can apply the proper fertilizers and the proper amounts of them to stands that are likely to respond.

5. Foliar post-sampling. Following field treatment I'd continue running analyses on at least two composite foliage samples per field plot taken annually or biannually during the growing season until foliar nutrients return to their deficiency levels, as described earlier (Table 1).

6. Operational program. Within a decade of initiating this program we should have enough information for a decision to be made on beginning an operational forest fertilization program, perhaps limited at first, but expanding as our experience grows.

In summary, "sitting tight" because of what we don't know about forest nutrition is simply a cop-out. There is too much that we do know and can apply to make this a viable alternative. Neither should we fly into operational work prematurely, fertilizing indiscriminately, or analyzing everything that lends itself to analysis. Rather, the Regions should work toward an operational program in well-organized stages in cooperation with the Experiment Stations. And, through a

sound, scientific approach, applying what we know or suspect to be true, we should minimize our mistakes and maximize our rewards.

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FIGURE CAPTIONS

Figure 1.--Nutrient retention model for high and low sites. Total nutrient capital approaches pre-treatment level much more rapidly on low sites than high ones.

Figure 2.--Relative growth performance (biomass) of ponderosa pine (solid dots) and white fir (open circles) as a function of water-soluble P by the Bingham method. Yields are relative to those from the best treatment (100-percent).

Figure 3.--Relative growth performance (biomass) of ponderosa pine (solid dots) and white fir (open circles) as a function of bicarbonate-soluble soil P. Arrow marks soluble P level showing 90-percent relative yield.

Figure 4.--Relative growth performance (biomass) of ponderosa pine (solid dots) and white fir (open circles) as a function of ammonium fluoride/HCl - soluble soil P. Arrow marks soluble P level showing 90-percent relative yield.

Figure 5.--Generalized calibration curve of growth in relation to internal nutrient level showing zones of poverty adjustment and luxury consumption. Critical value corresponds to nutrient level producing 90-percent relative yield.

Figure 6.--Standard sampling points on forest trees. Mature leaves of the current year (bracketed) are sampled from primary and secondary branches (arrows) in the upper two or three whorls.

Figure 7.--Yield of white fir in pot bioassay of two contrasting forest soils. Note yield depression at highest P level on Sheet-iron series.

Figure 8.--Relative yield (biomass) in relation to total foliar P of white fir from experiment shown in figure 1. Each point is a mean of three seedlings. Note growth depression at foliar levels above 0.11-percent P (mainly on Sheetiron soil series). At depression, the relationship probably is not cause and effect.

Figure 9.--Flow chart of steps leading to an operational fertilization program.

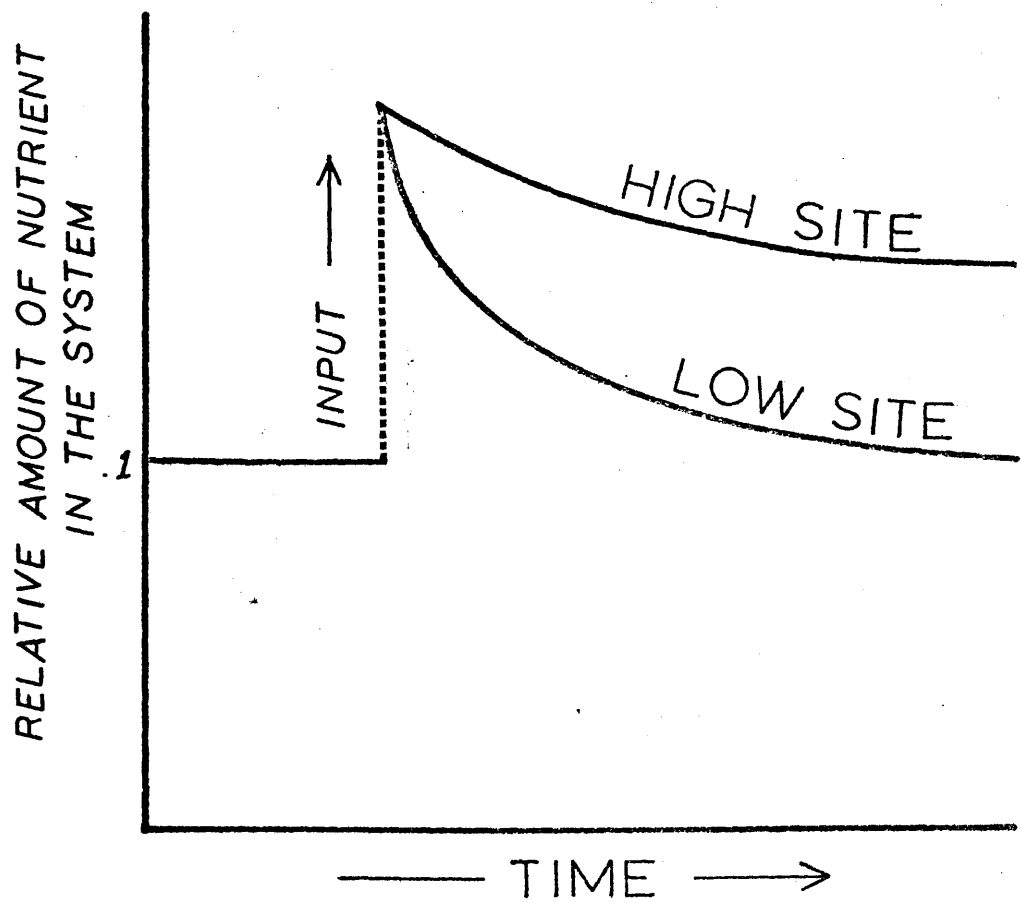


Fig. 2

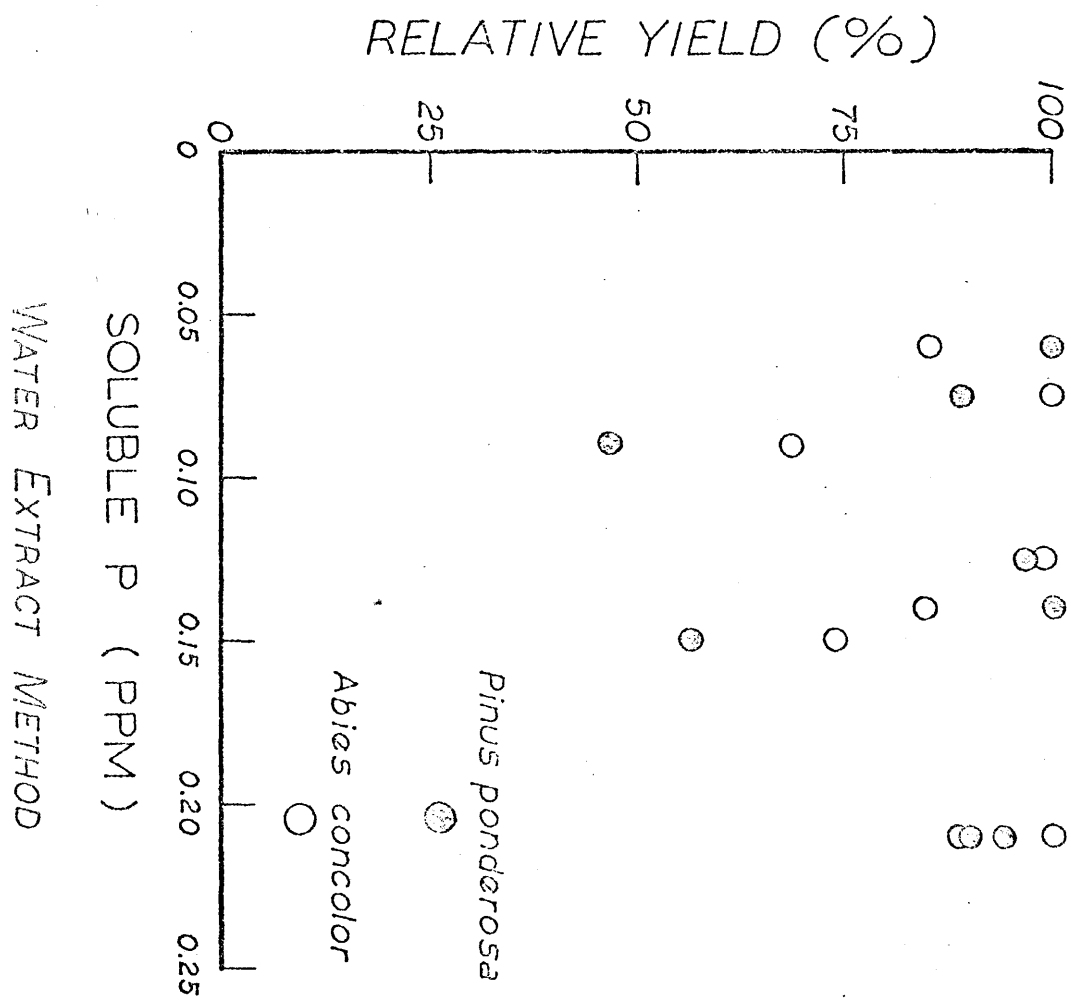


Fig. 2

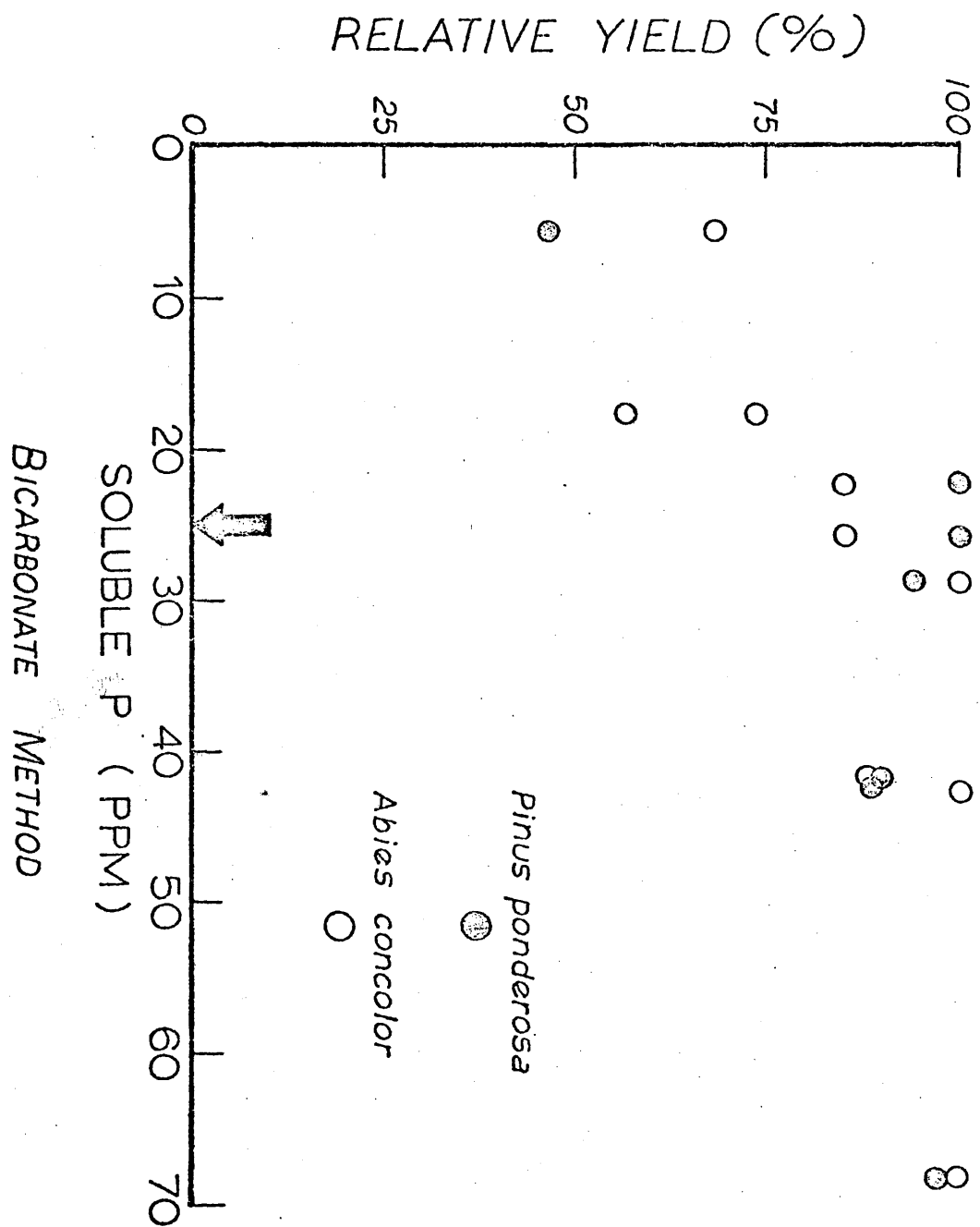


Fig. 3 15.6

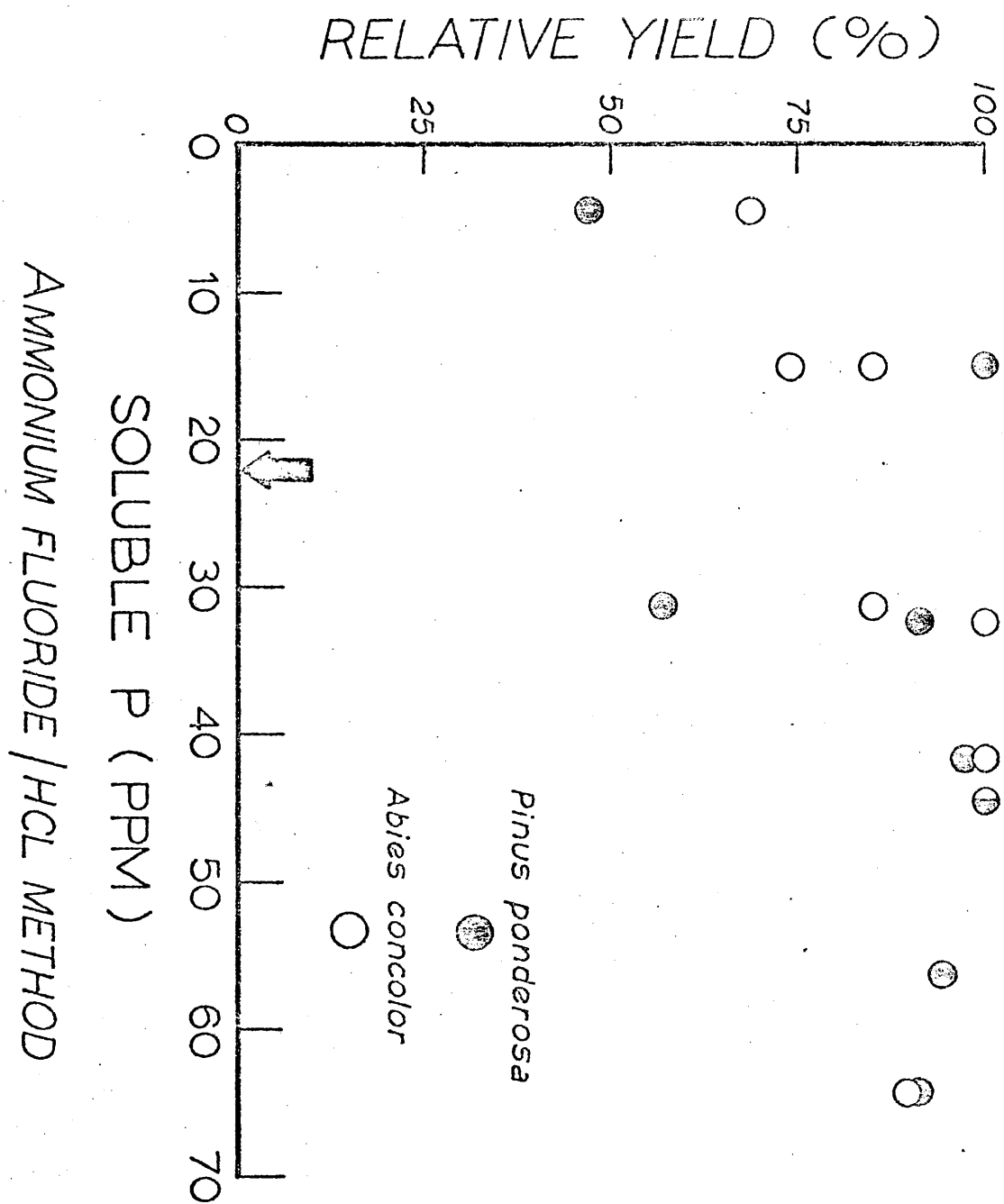


Fig. 4

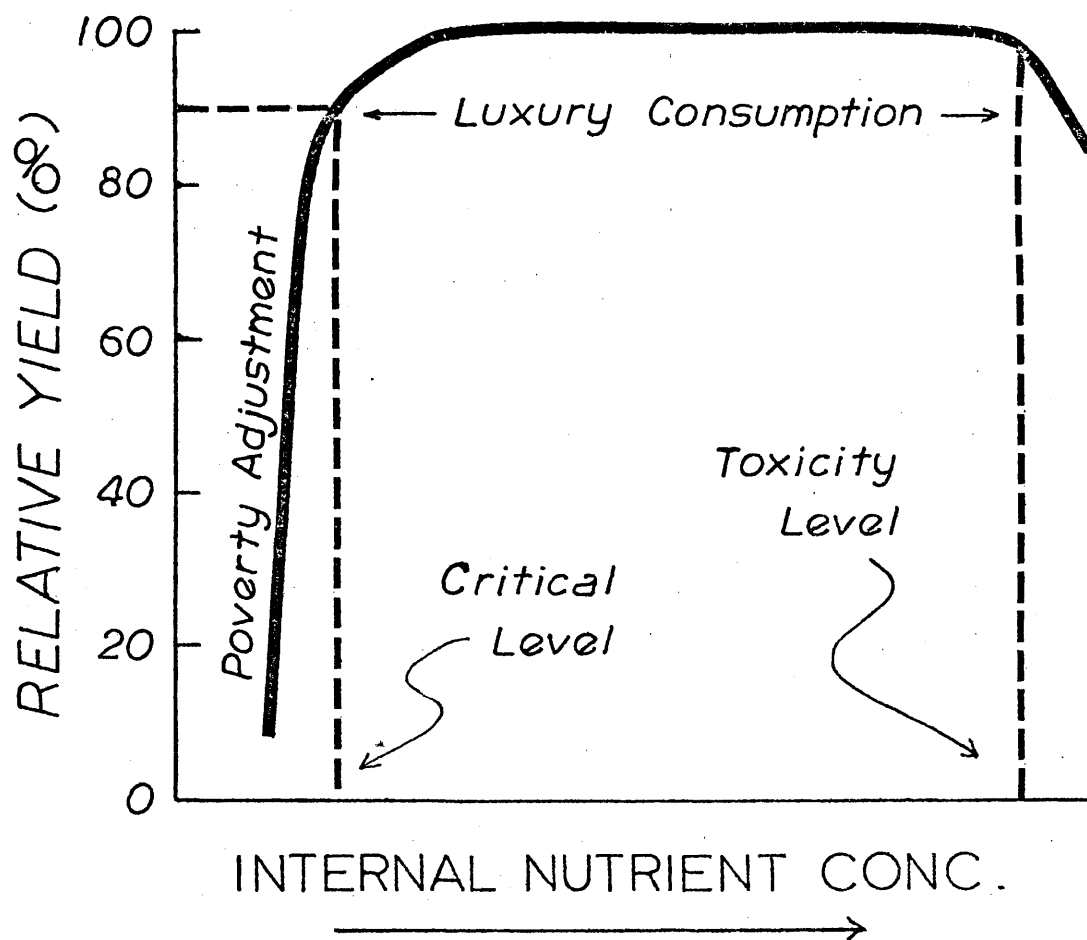


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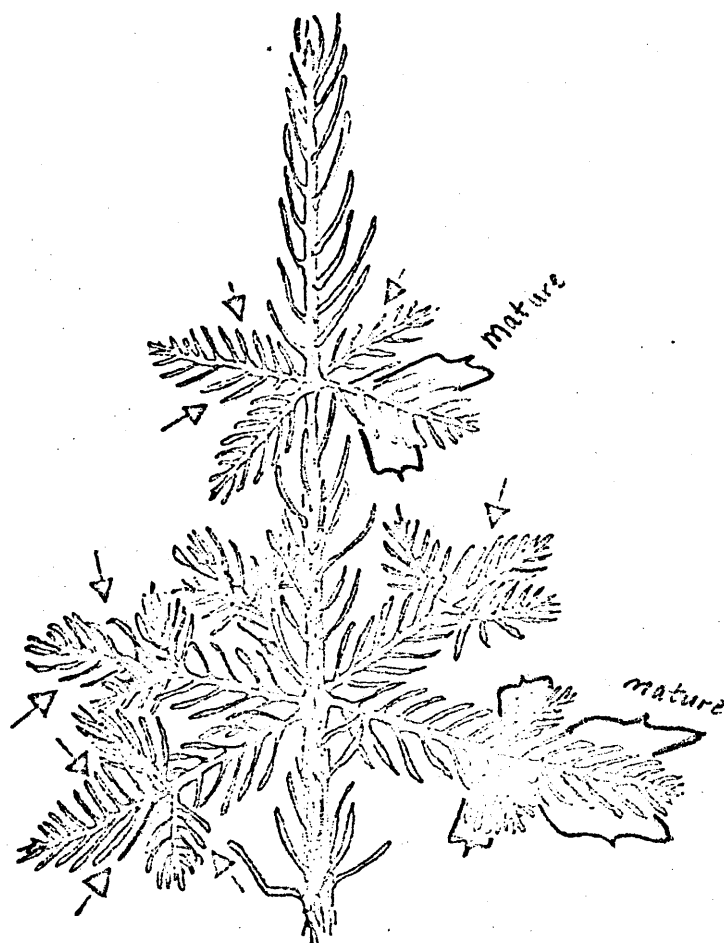


Fig 6

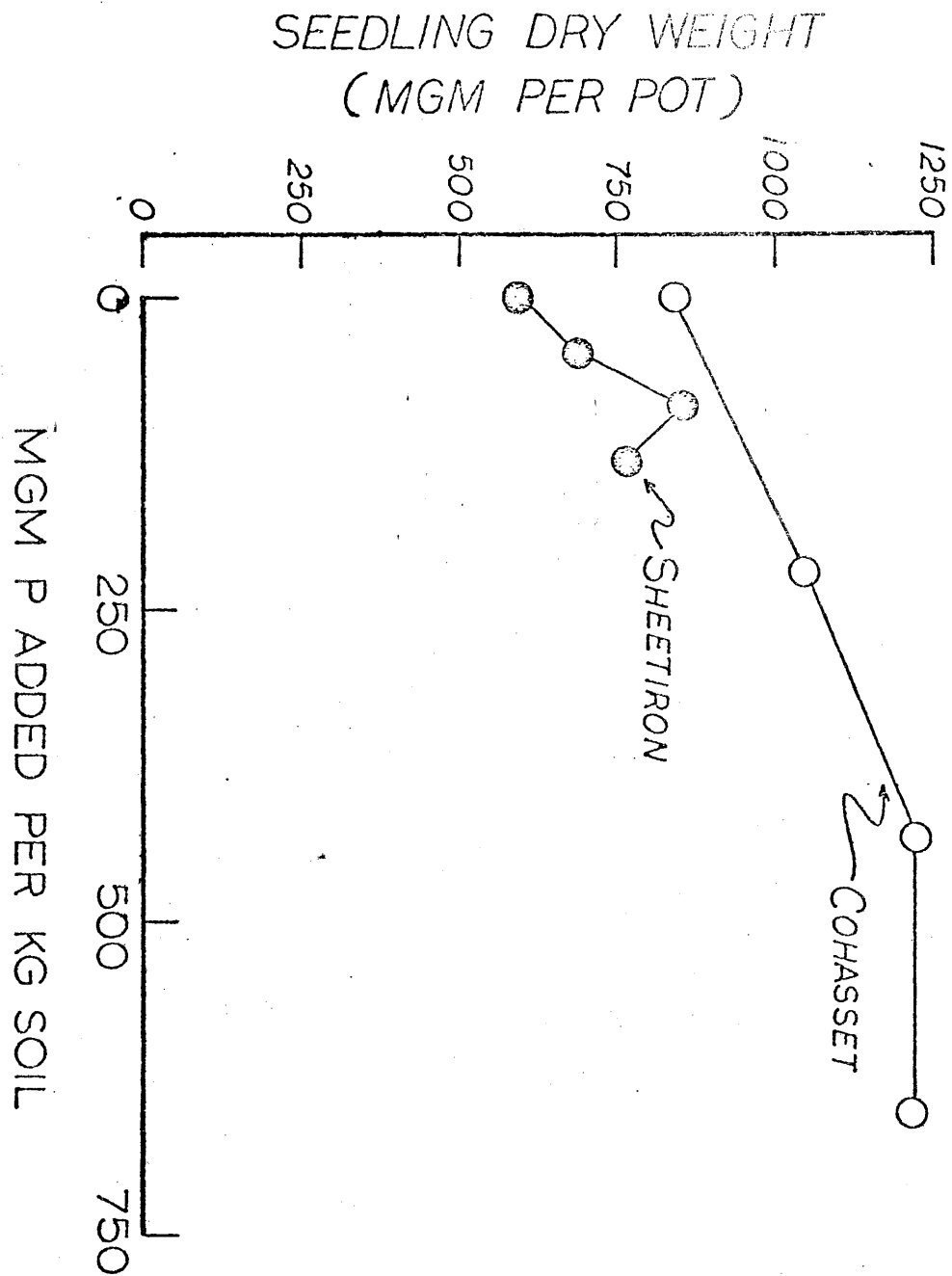


Fig. 7

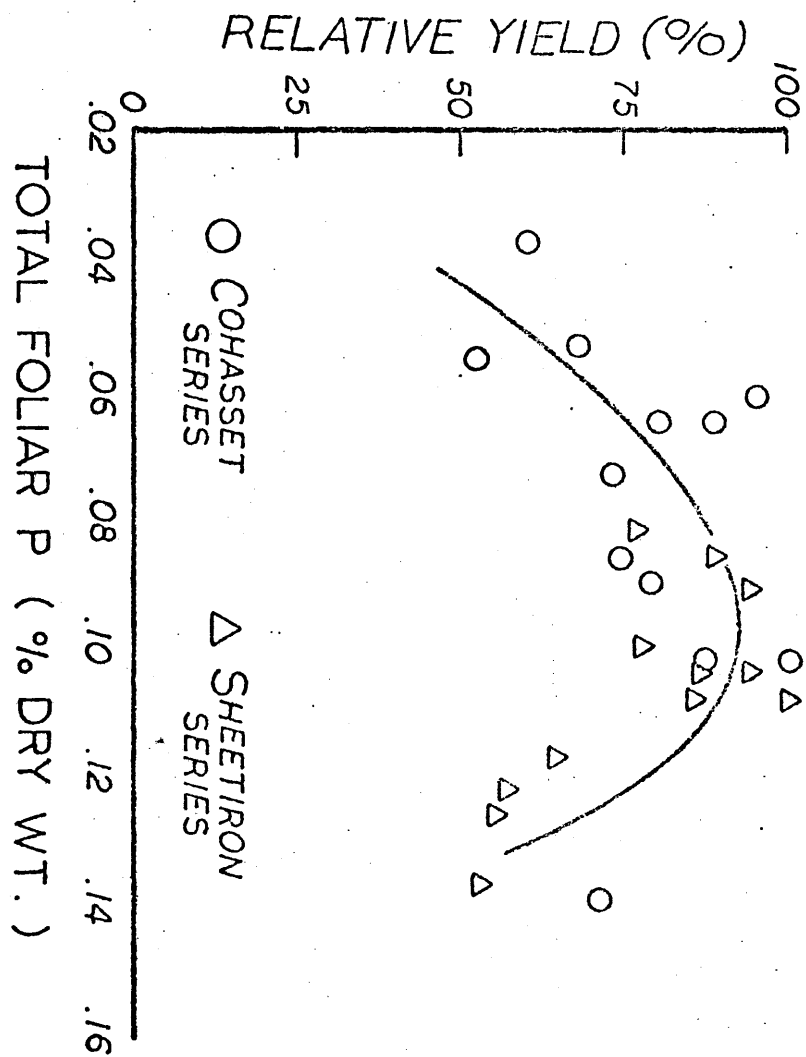


Fig. 8

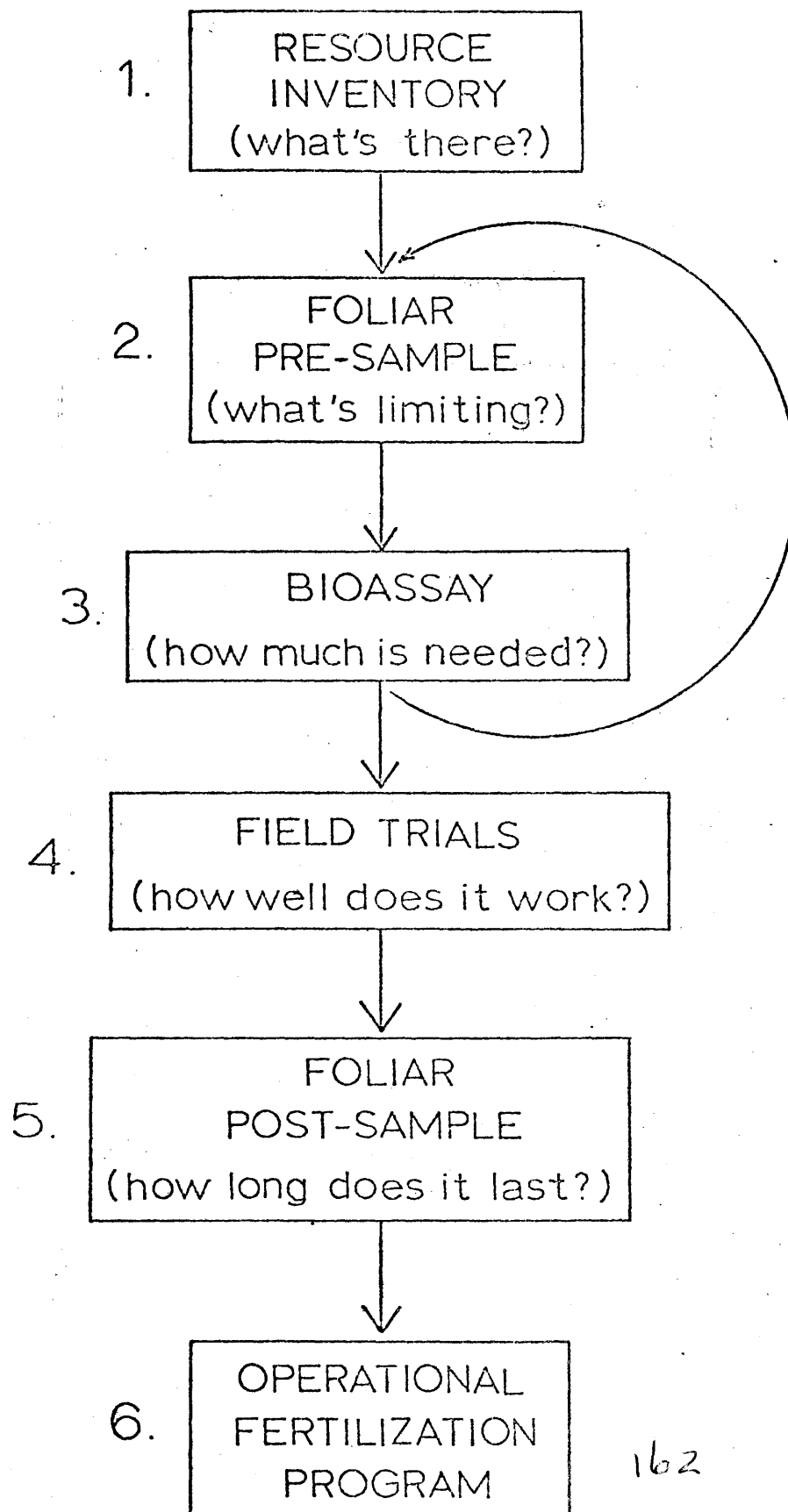


Fig. 9

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FERTILIZATION PRACTICES WITH GENETICALLY IMPROVED PLANTING STOCK

Presented by C. B. Davey

Both genetic variability and response to fertilization have been demonstrated for most major forest species grown in the United States. Specific differential response of families or clones within species to fertilizers is the subject of this discussion.

If forest production is to be maximized, important genotype by environment interactions must be identified, quantified, and, if appropriately large, exploited. The "largeness" is a product of both biological response and economic gain. The intra-species difference in magnitude of response is primarily a reflection of the inherent genetic heterogeneity.

Genotype by environment interaction, by definition, infers a change in rank among genotypes as the environment varies. However, as indicated above, we are interested in rank changes which are of sufficient magnitude to have both biological and economical importance.

Many studies reported in the literature indicate either favorable or unfavorable response to fertilization without any indication of what criteria were used in arriving at the kind or amount of "fertilizer" to use. Fertilizer testing without first determining the soil fertility status is ill-advised. For example, a study of nitrogen rate or form conducted on a phosphorus deficient site will be very misleading. As nitrogen is applied to such a soil, the nutrient imbalance increases and the phosphorus deficiency is intensified and very often a growth reduction (rather than a stimulation) will be the result. Conversely, if the phosphorus need were predetermined and corrected in advance,

very substantial growth increases might be realized from the same nitrogen additions.

There are two principal methods for determining the soil fertility status; soil testing and tissue testing. Both methods are useful. In some situations one or the other may be preferred but generally they compliment each other in detecting and confirming nutrient needs. Three areas on the fertility scale should be identified; deficiency, adequacy, and luxury. The deficiency level indicates that little or no growth will take place without the addition of a nutrient supplement. The adequacy level represents a fertility range over which growth may be considered adequate but within which an economically significant growth response to nutrient additions is possible. The luxury level is reached when little or no growth response results from the addition of some nutrient when all other essential nutrients are within the adequacy range. Beyond the luxury level is the toxicity level, but this is only rarely found in forest situations.

In this discussion of the response of genetically improved stock to fertilization, we should keep in mind that we are affecting the plant in many ways. It is not sufficient to think only in terms of changes in height and DBH. Many other parameters of growth of both biological and economical importance are affected.

Diameter increase is usually greatest immediately below the live crown and not at DBH. Thus stem form is improved and the volume increment is greater than height and DBH alone would indicate.

In addition, several wood properties are affected. These include specific gravity and proportion of earlywood and latewood, the content of certain extractives, and the properties of individual fibers (length, wall thickness, lumen diameter, etc.). In the South, the extractives content of pine is becoming of considerable interest since one cord of properly grown and handled wood may contain \$15 worth of tall oil and turpentine. All of these wood properties are subject to manipulation through breeding and fertilization.

In a detailed study of 160 genotypes, Posey (1965) reported that in the Piedmont of North Carolina fertilization with at least 80 pounds/acre of nitrogen caused a significant decrease in wood specific gravity, summerwood radial double-wall thickness, and trachied length. Paper produced from such wood should have high density, low opacity, uniform formation, smooth surface, and high burst and tensile strength but low tear resistance when compared to paper prepared from the same genotypes but which had not been fertilized. Further, he reported that there would be a decrease in the weight yield of trachieds per cubic foot of wood produced but more than sufficient extra cubic feet of wood produced to compensate for the small weight loss per cubic foot. In the ten years following fertilization, the yield increase caused by fertilization was 10 cords per acre (i.e., one cord/acre/year difference).

The above comments from Posey's (1965) study are for the average genotype studied. There were, however, almost 25% of the fertilized trees which did not follow the average. Most of these trees showed one major difference from the average: they increased in trachied length. Thus paper made from such trees would have the properties

listed above except that they would also have increased tear resistance in comparison with non-fertilized trees. Such trees are very valuable to certain wood users.

Finally, he noted that a comparison of the rate of change in wood properties following fertilization with before-fertilization values showed that genotypes with initially high specific gravity, long trachieds, and thick radial walls had a greater reduction than those with low specific gravity, thin radial walls, and short trachieds. Thus fertilization tended to narrow the range in properties exhibited by the various genotypes. Work by other investigators has tended to confirm this general observation that environmental optimization tends to decrease the range of genotypic expression.

Fertilization of genetically improved stock may affect the resistance to insect or disease pests. It has been said that the entire cost of the loblolly pine tree improvement program headquartered at N. C. State University has been more than repaid by the development of resistance to fusiform rust within the species. It has also been observed that fertilization of loblolly pine tends to increase its susceptibility to the disease. Fortunately, the disease resistance is quite strong and the enhanced susceptibility is quite weak with the improved stock. Thus it is quite satisfactory to accept a small amount of additional disease in return for greatly increased yield. The increase in disease is particularly small when soil fertility is balanced properly. The new fusiform rust testing center set up by the Forest Service at

Asheville, North Carolina, is now serving the South in evaluating progeny for their susceptibility to this disease. This test is run in a matter of weeks in the greenhouse and thus greatly speeds up the testing of progeny.

Susceptibility to attack by insects has been far more difficult to evaluate. It has been observed in one seed orchard that one clone, when heavily fertilized annually, became highly susceptible to one insect. No other clone in the orchard exhibited similar response. On the other hand, early attempts to find individual progeny that were resistant to attack by the Southern Pine Beetle were fruitless because no beetle was ever found at the progeny test sites.

"Flowering" and seed production in loblolly pine seed orchards have been almost universally increased significantly by fertilization. However, it should be noted that seed production across clones always is more variable than across fertilization levels. This indicates that the genetic component of the genotype by fertilizer system is stronger than the nutritional component.

Progeny testing or genetic selection in general have not reached the stage where root form and abundance are observed or even considered. However, it is quite obvious that roots are very important to tree growth and health. To complicate matters, roots form important beneficial associations with certain fungi to produce structures which we call mycorrhizae. The importance of mycorrhizae to forestry is well documented in the literature and need not be recited here. Two recent studies conducted at North Carolina State have a bearing on this subject, however.

A selection of 16 full sib families of loblolly pine were studied for mycorrhiza formation by selected fungi. The results indicated that the host plant affected both the abundance and form of mycorrhizae which were produced. Conversely, however, the fungi tended to decrease the range of genetic heterogeneity exhibited by the pines. Fortunately, the effect was to produce more uniformity and an increase in the rate growth; a beneficial effect to be sure.

The second study involved the effect of forest fertilization on the formation of mycorrhizal roots by loblolly pines in plantations. There were reports in the literature that forest fertilization would result in reduced formation of mycorrhizae and thus reduce the value of the fertilization. The study revealed that during the first growing season following fertilization, there is a reduction in both the abundance and variety of mycorrhizae. This effect disappears by the second year while the fertilizer effect continues for about five years. Thus, the result appears to be well worth the small risk. The overall conclusion from the two studies is that we will be able to manipulate tree roots and mycorrhizae both genetically and environmentally. We may sacrifice some expression of genetic heterogeneity in the process, however. In most cases, the latter effect appears to be advantageous rather than detrimental.

The cumulative evidence from a large number of fertilizer trials with non-selected stock and progeny tests (both fertilized and non-fertilized) is that fertilization hastens expression of dominance and

consequently increases mortality of suppressed trees. Thus, within certain stocking levels, fertilization may be used to thin stands from below.

In addition, in many progeny tests with loblolly pine in which half of the replications are properly fertilized and half are not fertilized, it has been observed that: (1) nearly all trees respond positively to fertilization; (2) fertilization results in only minor changes in ranking among progeny for growth; and (3) fertilization does reduce the range of differences in growth (i.e., reduces expression of genetic differences). These results have been obtained so consistently with so little significant genotype by fertilization interaction that beginning with progeny testing in 1975, the N.C. State Tree Improvement Cooperative is no longer suggesting fertilizing half of the replications. The new guidelines will be to fertilize all progeny being tested. This recommendation is based on two precepts: First, since fertilization reduces the range of genotypic expression, it provides a more rigorous test for truly outstanding genotypes; and Second, it is assumed that fertilization will soon be the norm in forest management in the South and progeny should be evaluated under realistic conditions.

The overall conclusion to be reached from the above discussion is that genetic selection and proper fertilization are synergistic--each enhances the value of the other.

Economics have not been mentioned in this discussion, but perhaps it is appropriate to at least comment on the subject. Nationwide, nitrogen is the chief element which will generate the greatest amount of additional growth. A rough rule of thumb is that one pound of

nitrogen will produce one cubic foot of wood. Where that relationship holds, even at today's depressed wood market and inflated fertilizer costs, the inescapable conclusion is that proper fertilization of genetically improved stock is a very profitable venture.

The attached tables, figures, and literature list are useful in considering some of the points offered in this discussion.

Table 1. Response of five open-pollinated families of loblolly pine from select parents and commercial check to fertilization after two growing seasons.

Female parent	Height (Feet)		Survival (%)	
	Control	Fertilized	Control	Fertilized
A	3.8	4.0	96	100
B	3.7	3.9	100	85
C	3.6	3.3	92	91
D	3.3	3.4	94	95
E	2.7	2.8	96	90
$\bar{X}$	3.4	3.5	96	92
Commercial Check	2.8	2.8	74	74

N.C. State-Industry Tree Improvement Program. Test by American Can Co., Butler, Alabama.

Table 2. Ranking by response to site preparation treatment of six crosses of loblolly pine.

Rank	Treatment					
	Control		Cultivated		Fertilized	
	ΔHt	ΣHt	ΔHt	ΣHt	ΔHt	ΣHt
	(Cross number)					
1	6	1	4	1	1	2
2	4	6	6	2	4	1
3	1	3	1	4	2	4
4	5	5	2	6	3	3
5	3	4	3	3	5	5
6	2	2	5	5	6	6

ΔHt = Height growth during 1974.

ΣHt = Present total height after 3 growing seasons in the field.

N.C. Forest Fertilization Cooperative Study GS-13-05.

Table 3. Relative ranking in performance for four characteristics for fast- and slowly-growing control-pollinated loblolly pine families under three fertilizer regimes^{1/}

Cross	Height (feet)			Diameter (inches)			Volume (cu.ft/tree)			Straightness (score) ^{2/}		
	Hi	Opt	None	Hi	Opt	None	Hi	Opt	None	Hi	Opt	None
(Fast growers)	(Rank)											
A	1	4	1	1	5	4	3	5	1	6	2	4
B	2	2	2	3	4	3	9	10	9	3	6	3
C	3	1	3	2	1	2	2	1	2	2	1	2
D	4	3	5	4	3	9	2	4	7	4	5	4
(Slow growers)												
E	10	9	11	10	8	11	11	8	11	7	5	4
F	11	10	10	9	12	10	9	10	10	3	5	1
G	13	14	9	14	14	8	14	13	9	5	9	5
Mean (actual values)	17.0	17.9	15.9	3.3	3.5	3.0	.59	.58	.46	3.6	3.6	3.4

^{1/} Hi = High fertilizer rate (1000 lbs. lime/acre + 12 oz. 5-10-10 per tree)
 Opt = Optimum fertilizer rate (1000 lbs. lime/acre + 4 oz. 5-10-10 per tree)
 None = No fertilization. Fertilizer applied once, soon after planting.

^{2/} Ranked on a scale of 1 to 6; 1 being straightest. N.C. State-Industry Tree Improvement Program. Test by International Paper Co., Georgetown, S.C.

Table 4. Cone counts by clone in Piedmont loblolly pine seed orchard fertilizer-irrigation study.

Clone	Treatment			
	Control	Irrigated (I)	Fertilized (F)	I + F
	Cones/Clone			
A	55	55	52	35
B	53	26	109	209
C	94	102	224	84
D	59	174	275	737

Irrigation need determined by soil tensiometers. Fertilization included 250 lbs. N, 22 lbs. P, 42 lbs. K per acre per year. N.C. State-Industry Tree Improvement Program. Test by Hoerner-Waldorf Co., Tillery, N.C. Clone B was typical of many other clones. Clones A and C were atypical. Clone D was typical except for magnitude of response.

Table 5. Overall means of control and fertilized plantings and superiority of the fertilized progeny expressed as percentage of the control (Progeny tests planted 1964 and 1965 at North Coastal Plain)

A. Progeny planted 1964, after 8 years in the field

Characteristic	Unit	Overall means		Superiority ^a of
		Control	Fert.	Fert. %
Diameter at breast height	inch.	2.99	3.11	4.01**
Height	feet	16.05	16.08	.19*
Volume	c.f.	.3705	.3925	5.94**
Fusiform rust infection	(score)	1.44	1.59	-10.41**
Crown form	(score)	3.45	3.57	-2.32
Straightness	(score)	3.68	3.79	-2.99
Number of individuals		496	379	

B. Progeny planted 1965, after 8 years in the field

Diameter at breast height	inch.	3.53	3.77	6.8**
Height	feet	18.31	18.89	3.17**
Volume	c.f.	.5276	.6042	14.16**
Fusiform rust infection	(score)	1.82	1.67	8.20
Crown form	(score)	3.64	3.75	-3.02
Straightness	(score)	3.68	3.87	-5.16**
Number of individuals		662	702	

^a** Statistically significant at the .01 level.

* Statistically significant at the .05 level.

N.C. State-Industry Tree Improvement Program. Test by Weyerhaeuser Co.
Data from unpublished manuscript by D.I. Matziris and B.J. Zobel.

Table 6. Overall means of control and fertilized plantings and superiority of the fertilized progeny expressed as percentage of the control (Progeny tests planted 1964 and 1965 at South Coastal Plain)

A. Progeny planted 1964, after 8 years in the field

Characteristic	Unit	Overall Means		Superiority ^a of
		Control	Fert.	Fert. %
Diameter at breast height	inch	2.27	3.68	62.11**
Height	feet	12.80	18.40	43.75**
Volume	c.f.	.2135	.5699	166.93**
Fusiform rust infection	(score)	1.23	1.47	-19.51**
Crown form	(score)	3.34	3.28	1.79
Straightness	(score)	3.34	3.27	2.09
Number of individuals		335	379	

B. Progeny planted 1965, after 8 years in the field

Diameter at breast height	inch	1.67	2.85	70.65**
Height	feet	10.62	14.95	40.77**
Volume	c.f.	.1127	.3105	175.51**
Fusiform rust infection	(score)	1.20	1.29	-7.50*
Crown form	(score)	3.27	3.18	-2.75*
Straightness	(score)	3.27	3.13	4.28
Number of individuals		791	829	

^a** Statistically significant at the .01 level.

* Statistically significant at the .05 level.

N.C. State-Industry Tree Improvement Program. Test by Weyerhaeuser Co.
Data from unpublished manuscript by D.I. Matziris and B.J. Zobel.

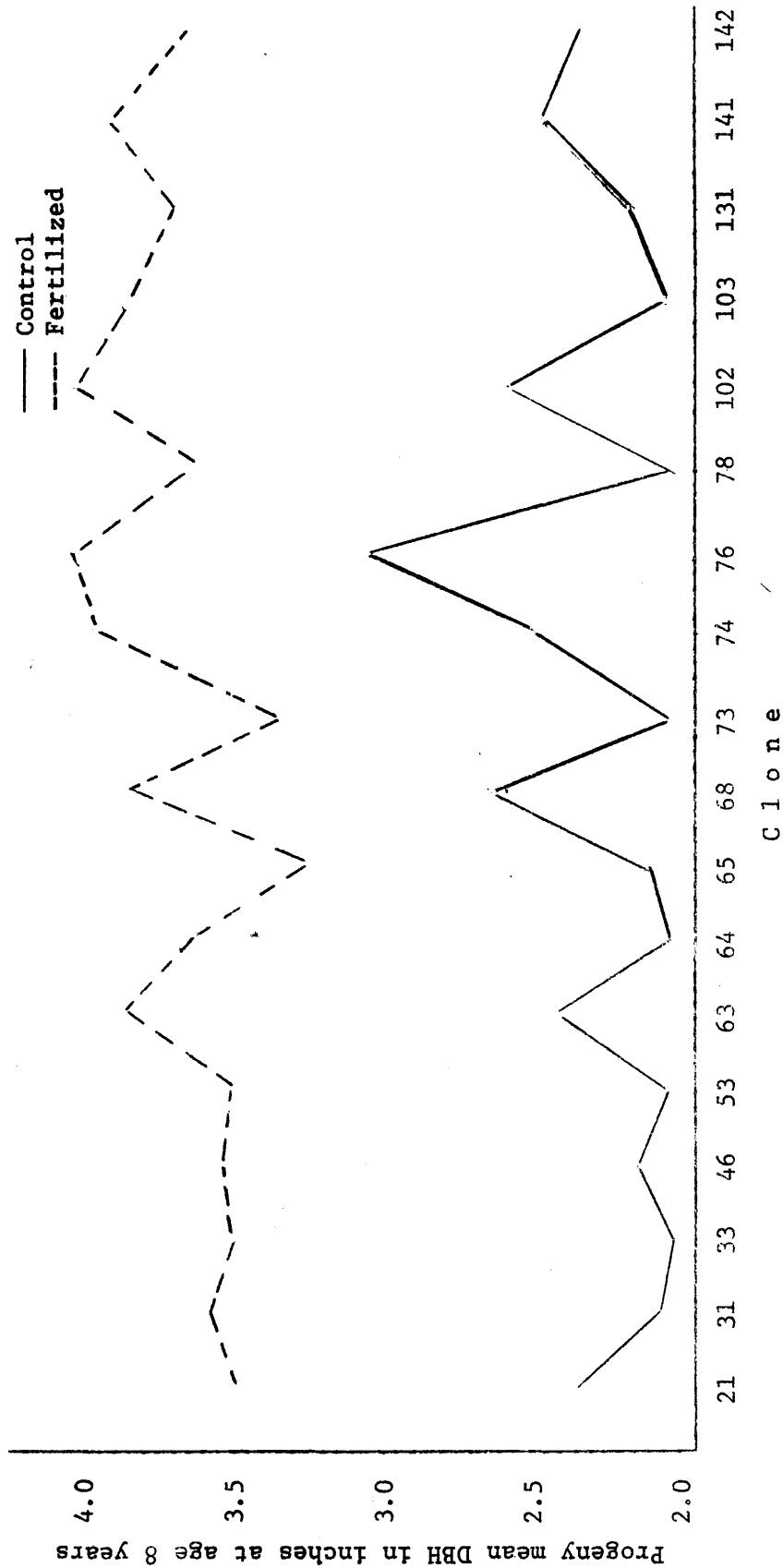


Figure 1 Eight-year-old half sib progeny diameter means (1964 South Coastal Plain progeny test)

N.C. State-Industry Tree Improvement Program. Test by Weyerhaeuser Co.
Date from unpublished manuscript by D.I. Matziris and B.J. Zobel.

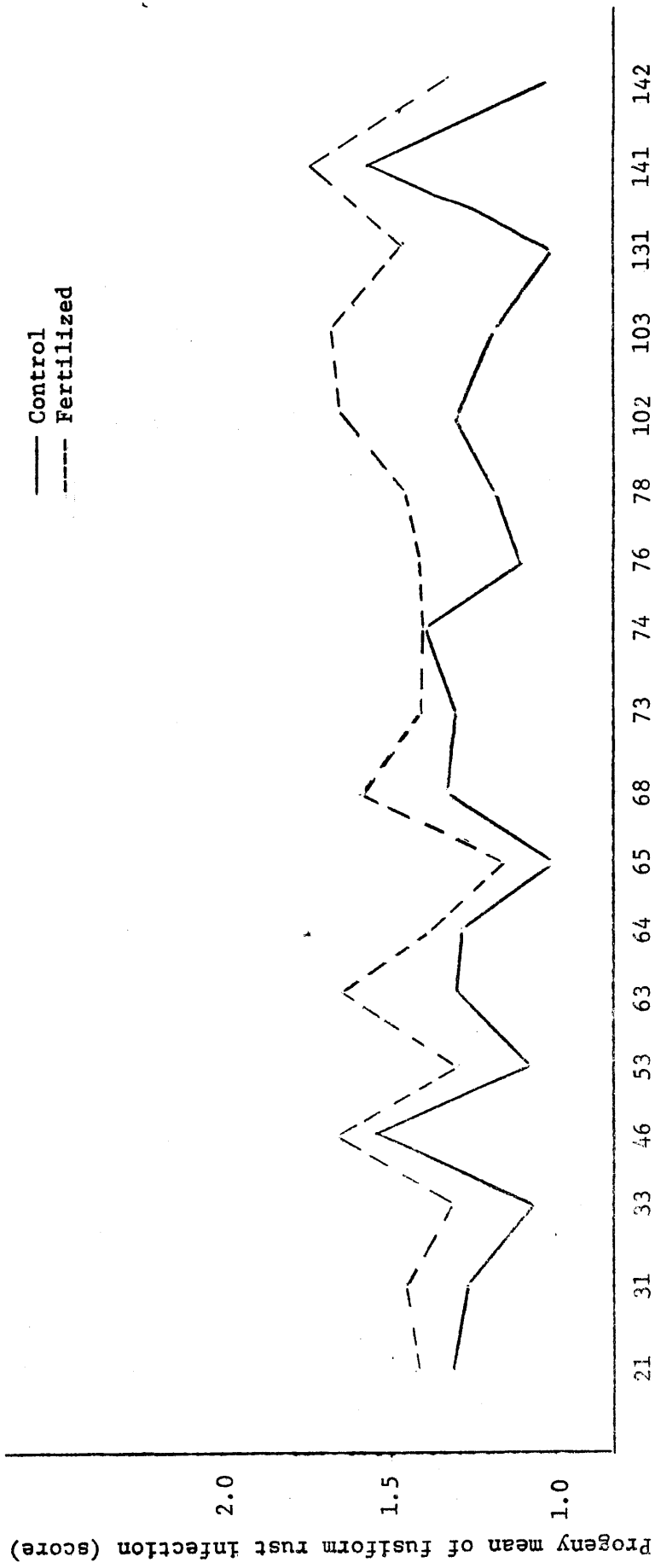
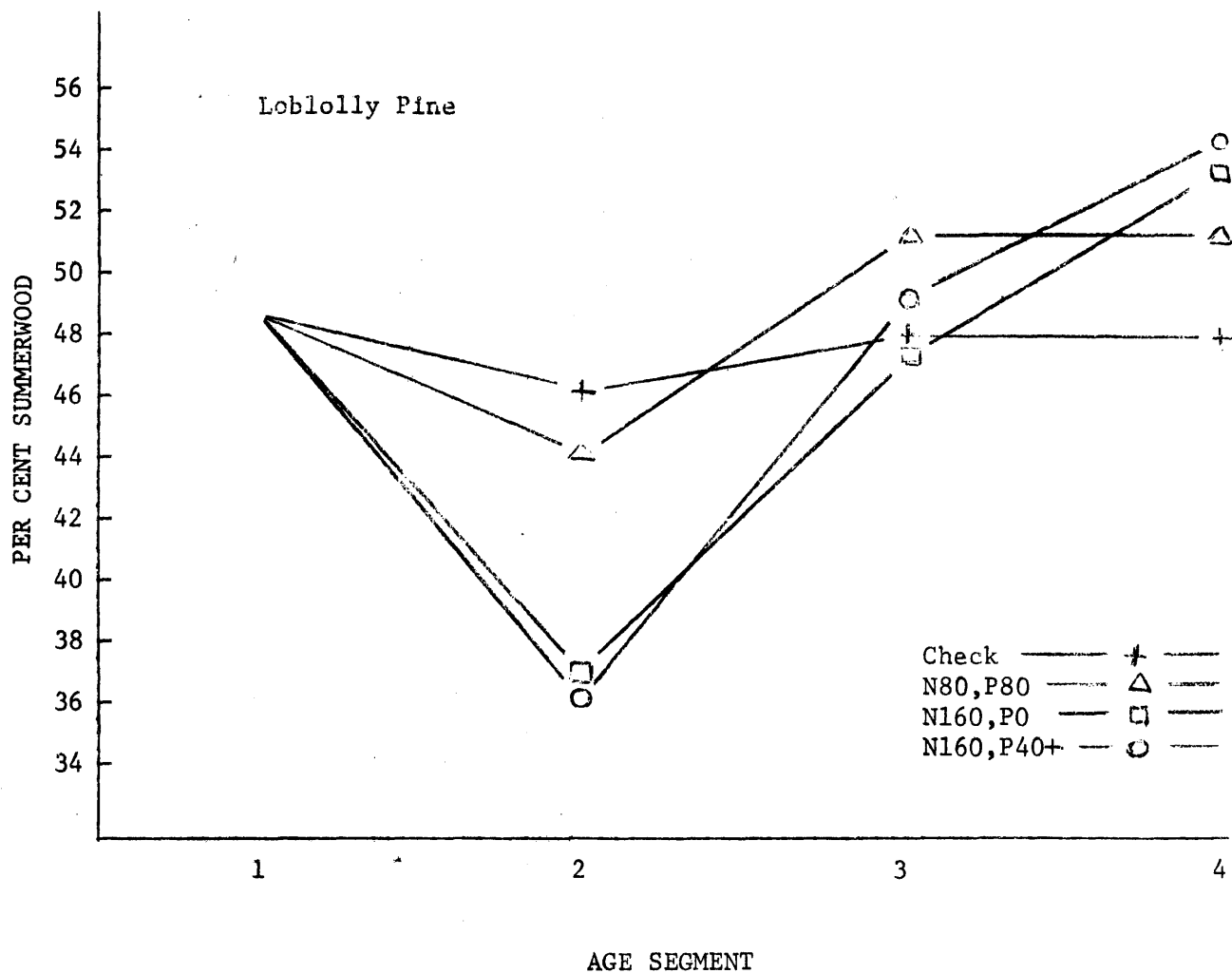


Figure 2. Eight-year-old half sib progeny means for fusiform rust infection (score) (1964 South Coastal Plain progeny test)

N.C. State-Industry Tree Improvement Program. Test by Weyerhaeuser Co.
Data from unpublished manuscript by D.I. Matziris and B.J. Zobel.



Age Segment 1 = Before Treatment (1949 + 1950)
 Age Segment 2 = During Treatment (1952 + 1953)
 Age Segment 3 = After Treatment (1955 + 1956)
 Age Segment 4 = After Treatment (1958 + 1959)

Figure 3. The effects of fertilizers on proportion of summerwood using data adjusted for differences in initial summerwood per cent. N.C. State-Industry Tree Improvement Program. Data from C.E. Posey, Tech. Rept. 22, School of Forest Resources, N.C. State University, 1965.

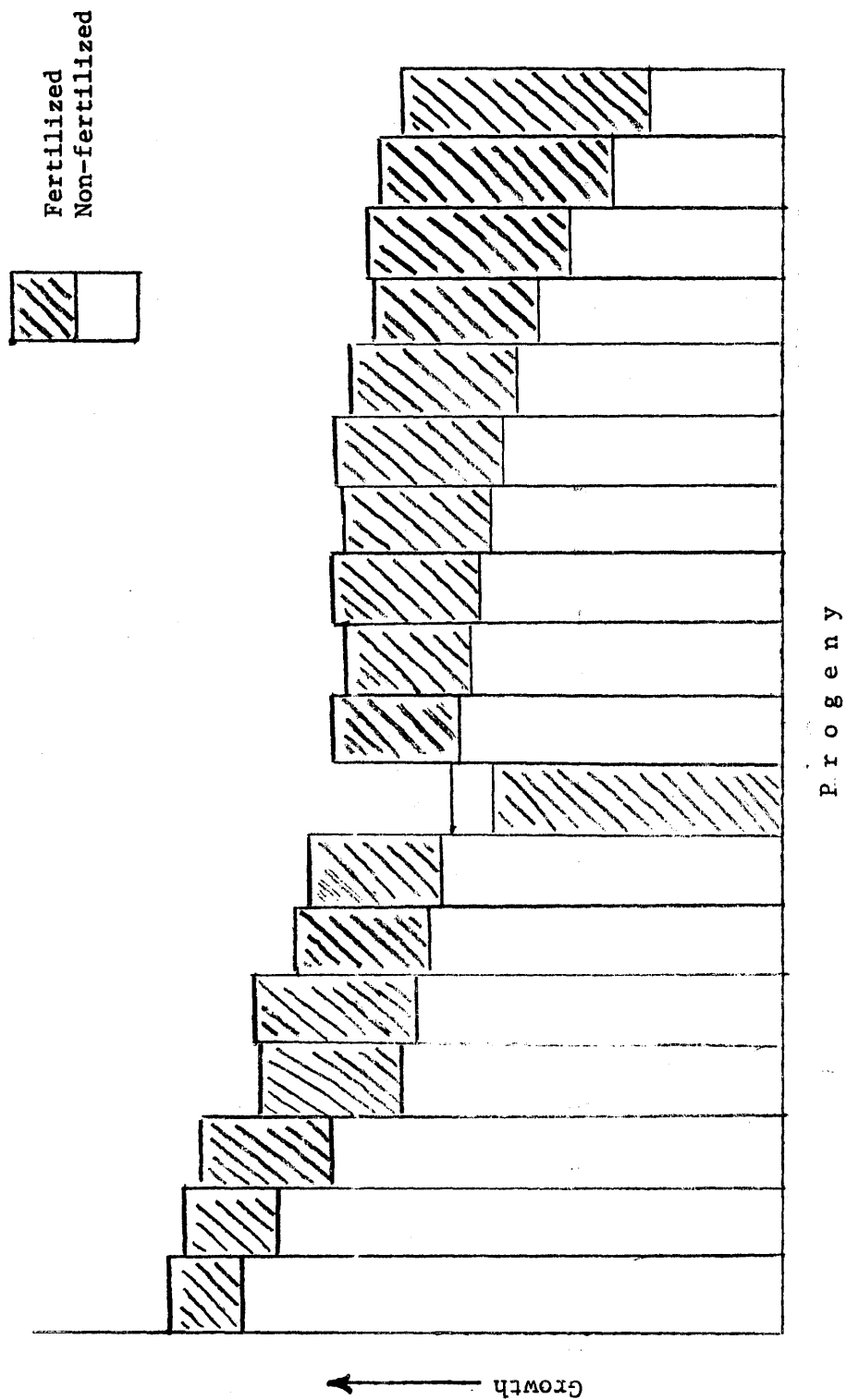


Figure 4. Schematic representation of progeny ranked for growth on a non-fertilized site and their growth response to fertilization.

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MULTIPLOY: A Computerized Method of Evaluating Forestry Investments

by

George Dutrow

Presented at:

Sacramento, California--October 24, 1974

I would like to divide this introduction to system MULTIPLOY into two blocks, keeping only a segment of the audience captive for the full two hours. During the first portion of the discussion, I would like to direct my remarks to everyone interested in what I can assure you will become one of the most used and handiest tools available to measure the economic potential of forestry practices. This first hour will be devoted to explaining what MULTIPLOY can and can't do, how it does what it does, and how you as a decision-maker can benefit from frequent use of MULTIPLOY. The second hour will be devoted to discussing the intricacies of actually using the program and calling forth the various functions and subroutines in system MULTIPLOY. As the second portion will be directed to those of us who actually punch the cards and set up the various problems, you who are not interested in this degree of detail may wish to attend to other matters 'til 3:0'clock. However, you are more than welcome to remain with us and give us the benefit of your questions and suggestions.

As we discuss MULTIPLOY today, feel free to ask questions and propose additions or changes that you feel should be included in the system. Although not a computer expert by any stretch of the imagination, I will try to handle your questions. If I don't know the answer or if

you are dissatisfied with my response, please direct your question to Clark Row, author of MULTIPLOY and leader of the Forest Economics Research Group in the Washington Office. I understand that Don Funking will coordinate incoming questions from the field as they arise and will disseminate to the Regions any changes or updates of MULTIPLOY. Also, appendix IV gives instructions for obtaining updated information from the Fort Collins Computer Center. I will be handing out the user's manual during the second hour, and this appendix IV is included.

Another preliminary point that I'd like to make concerns our tendency to become enamored with highly sophisticated and complex computer programs. There is a common proclivity to be fascinated with the smooth--almost humming--sound of simultaneous equations being solved and the mounting up of sometimes endless pages of printout. At the risk of boring you with an oft aired word of warning, these programs are only as good as the information we feed into them. No computer system can overcome poor data, poor estimates, or poor assumptions. A mistake in setting yields, prices, costs, or interest rates can totally invalidate an economic analysis despite the highly impressive nature of the results gushing from the computer.

However, this need not be the case. A systematic approach to problem solving, such as demanded by MULTIPLOY, encourages decision-makers to itemize their assumptions, specify their estimating techniques, and take a long hard look at their data. This process of close scrutiny and attempt to verify input information will minimize errors and will increase the likelihood that valid economic criteria will evolve.

Let me turn now to the specific purposes and features of system MULTIPLOY.

Any investment analysis, and MULTIPLOY is no exception, attempts to compare costs and returns at a common point in time. No more than this no less. However, the manner in which these costs and returns are derived often complicates what appears to be a simple procedure. Forest investments become extremely complex, as both incomes and expenditures are subject to wide fluctuations, both in amount and duration. A major contribution of MULTIPLOY is not that it avoids these complexities, but that regardless of the difficulty of a situation input instructions for the user are simple, straightforward, and require only minimal knowledge of computers. This ability to handle the most intricate economic analysis when presented conversational input statements is, to me, a major advance.

At this point, I'd like to emphasize the purposes of MULTIPLOY, or, more simply, what it does. In order to place a dollar value on the outputs of a forest, those outputs must be defined. MULTIPLOY simulates both timber and a number of nontimber products of a forest for subsequent financial evaluation. Furthermore, economic operations that are normally isolated in separate computer programs are combined in MULTIPLOY, new functions are added, and the overall package is designed for convenience.

Two types of problems are frequently recurring in forestry, and MULTIPLOY serves as an excellent analytical tool for their resolution. In formulating long-term forestry policies, managers must examine the effect of timber conditions, economic situations, and the effect of their own decisions on the financial rewards obtainable from forests.

MULTIPLOY pinpoints these effects. The second type of problem pertains to managers faced with a number of short-term products and budget restrictions that force him to allocate priorities. MULTIPLOY enables him to set these priorities by determining the likely economic returns for each project.

Although forest managers will find numerous occasions to apply MULTIPLOY to the foregoing types of problems, the system is versatile enough to handle a number of other uses. For example, MULTIPLOY enables land managers to estimate dollar-value increases attributable to gains from genetic improvement or fertilization. This feature alone is of great importance to me, as I will be measuring individual landowner and Regional gains from southern tree improvement programs. Another feature in MULTIPLOY is that the forest manager can estimate the value productivity of land and use this measure as a basis for negotiating land purchases or exchanges. And, MULTIPLOY allows him to estimate dollar values of losses to fire, insect, or disease, and to examine the risk of forestry investments in dollar terms.

Subroutines in MULTIPLOY develop further flexibility by reading conventional timber yield tables, or by simulating, within the computer, the development of a timber stand and related outputs. Other subroutines estimate costs in accordance with conditions existing when the costs occur; derive prices that vary with size and quality of timber and other products of the forest; and, predict probable losses from fire, storm, insects, and disease.

A final purpose of MULTIPLOY, one of importance to many forest managers in the West, is to produce yields, costs, and revenues in proper format for subsequent use as input for management programs on large planning areas. Or, to provide input for computerized resource allocation models, such as the Forest Service's TIMBER-RAM. Here, it might be helpful to emphasize that MULTIPLOY does not replace land allocation models, but serves as a complementary tool to fill the analytical gap between yield tables and land allocation models.

I'd like to turn now from the general purposes of MULTIPLOY to some specific features that should prove beneficial to you.

As I mentioned earlier, financial evaluation, in its simplest form, requires extracting yields from existing tables through the end of a rotation or a planning horizon, pricing these yields by an expected or estimated average stumpage price, and contrasting these returns with the average costs for regeneration and various silvicultural treatments. Resultant values, then, are discounted to the present and the financial package expressed as present net worth, annual equivalent income, benefit-cost, or internal rate of return.

There are several general financial evaluation programs that incorporate one or more of these measures and have been found adequate for Regional appraisals of investment opportunities. Their shortcoming, however, is a failure to consider a sufficient number of elements important in distinguishing between individual investment projects. Absence or exclusion of these elements may bias rankings of investment among timber types, multiple-use conditions, and situations where risks of loss vary. On the other hand, when the analysis includes more than a few such elements,

such as variable costs, prices, losses, and multiple uses, computational complications can become restrictive. MULTIPLOY offers a distinct advantage here in its ability to handle a number of factors automatically, and I'd like to enumerate these automatic features.

The first automatic feature:

1. Individual or Custom Yield Estimates. MULTIPLOY offers the user a choice of either yield tables or simulations. It can retain and employ information as many as 8 yield tables; or, it can simulate timber stands from internally supplied simulators or from growth equations provided by the user.

2. Variable Prices. Statistical and economic analysis have shown that stumpage prices vary with timber size, grade, and harvest per acre, as well as with market conditions and location. The subroutine structure of MULTIPLOY provides flexibility in establishing price criteria. A virtually unlimited selection of prices, ranging from fixed levels to estimating formulas designed by the user, can be incorporated.

3. Variable Costs. Certain costs, such as regeneration and silvicultural treatments, vary with the difficulty of the situation or with the intensity of treatment. Other costs, however, vary with the amount of timber harvested, which, in turn, may depend on the yields simulated. Since an economic appraisal may wish to categorize and evaluate projects individually, MULTIPLOY presents and varies each cost as the user specifies.

4. Allowance for Losses. There are two types of losses that may significantly influence timber growing opportunities. The first involves a loss of productive land. Land withdrawn from forest production for roads or administrative purposes or land where rock outcrops, ridgelines, or creek bottoms prevent achievement of desired stocking levels falls into this first category of loss. The second category of loss includes fire, storm, insects, or diseases. MULTIPLOY provides subroutines for either of these loss categories. The user can specify the proportion of yield lost due to land withdrawal in the first case, and can, in the second case, compute periodic losses that depend on user-provided factors regarding stand age, stocking, size of tract, and other conditions. Volume and value recovered by salvage can also be calculated.

5. Allowances for Genetic and Silvicultural Growth Gains. Forest tree-improvement programs and site-improvement measures, such as fertilization, change height growth, diameter growth, plantation survival, and tree quality. MULTIPLOY incorporates provisions to estimate the impacts on physical output and economic returns of changes in these various growth measures. These features operate, however, only when growth is estimated by simulation subroutines, not when yield tables are the basis of growth.

6. Inclusion of Non-timber Yields. A fact which we are all well aware is that timber harvests are not the only product of forest land. For example, managers may wish to estimate yields of forage and water and include them in economic evaluations of management practices if the values of the forage or water can be established. MULTIPLOY includes subroutines that estimate yields and values of forage and water. The

Forest manager is required to assist by providing coefficients that indicate how the level of these yields are affected by various attributes of the timber stand.

7. Additional Financial Factors. MULTIPLOY also furnishes options for including the initial cost of land, the value of the land after final harvest, and the effects of allowable cut stipulations. A subroutine has also been developed for adjusting schedules of costs and returns for Federal income taxes.

The 8th and final automatic feature is:

8. Alternative measures of economic returns. Earlier I mentioned that available economic analyses offer one or two of the more common financial criteria. MULTIPLOY offers all four, namely; Present net worth, annual equivalent income, benefit cost ratio, and internal rate of return.

This list of features that MULTIPLOY can provide automatically makes the system an extremely useful tool for forest managers in their day-to-day operations as well as for the long-run plans that must be formulated to make optimal use of the lands committed to their stewardship. An additional feature that enhances the usefulness of the system is the manner in which the computations are presented. I'd like to briefly describe this output to you now.

Most trials or evaluations by MULTIPLOY fall into three general categories. First, an individual project analysis; second, a class of projects on the same type of land; third, the economic effect of varying an important variable. For each of these categories, MULTIPLOY

can produce three types of information, each displayed in a different table. Moreover, there is a summary table in which the user is able to designate the information that he wants displayed.

The first of the three printouts is the Timber Stand Output Table. This table is a chronological record of the characteristics of the timber stand as it develops and of the harvests that occur. Outputs of forage, browse, water, and sediment are listed along with the timber production. Proportionate losses to fire, storm, insect, and disease are calculated and printed in this table along with cumulative survival rates. Total revenues and total costs for each period are also depicted.

Variables displayed in this table include: Investment age of the stand, age of dominant trees in the stand, total height of dominant trees, basal area of all trees, number of trees, average diameter breast high, quality index, total volume, merchantable volume, value of timber stand if cut; forage, browse, water, and sediment outputs; and finally, losses to insects, disease, fire, storm, and the cumulative survival. Obviously, these factors would be instrumental in any forestry decision.

The second printout is entitled the Trial Summary. This table presents the results of each trial or evaluation. Namely, timber inventory, timber harvest, other outputs, values, and values after adjusting for continuing use of land lost are listed. "Timber Inventory," the first, provides a summary of average standing timber in merchantable units and dollar values throughout the trial. As you know, such values are essential for determining the existing capital investment in timber

growing and the dollar values subject to loss from fire, storm, insect, or disease.

"Timber Harvest," and "other outputs" lists the outputs in physical totals, annual production averages per acre, and average unit values. The "value" column lists resultant economic measures assuming that the area lost to the various causes is not regenerated. "Values after adjusting for continuing use of land lost" reverses this regeneration assumption. Here, the economic measures are computed on the assumption that immediate regeneration takes place, and, consequently, provides a measure of the financial returns of lands managed for sustained yields.

The final option in this table is to list the cards printed for input to the TIMBER-RAM program.

The third table is the Revenue and Cost Schedule. All revenues and costs employed to calculate the foregoing values are listed here; positive values are revenues, negative values are costs. Time, duration, and frequency of the income or expense are also itemized in this table.

The final table, Problem Summary, presents the results of all trial run for comparison. MULTIPLOY saves 20 results of each trial, and any combination can be listed in the order selected by the user. Ratios between the results, such as revenue-to-cost per year, can also be displayed.

I think that you will agree with me that the calculations and the tabular output generated by MULTIPLOY provide information that is essential to formulating policy and achieving forestry goals. But, before all this information is available, the user of MULTIPLOY must get his data into the computer. With many programs this phase is complicated and painstaking. With MULTIPLOY, the step is easy to understand and

easy to accomplish.

MULTIPLOY has evolved into a forestry simulation language primarily intended for management planners, analysts, and economists. Such professionals are not expert data processors and are usually too busy to keep up with the complexities of a large computer system. Furthermore, some users will have available only keyboard-type terminals on which input in fixed-column form is difficult to construct.

The format-free input presented in MULTIPLOY called the "memo" form, is designed for such users. It consists of more than 100 types of statements, with several hundred permissible variations, that read like simple instructions in English or relatively simple equations. "Memo" input begins like the intragovernment memorandum or informal letter with the first three cards reading: TO.....FROM..... SUBJECT.....following these three introductory cards, the messages required by MULTIPLOY fall into three general types.

The first type is called Instructions. These statements begin with a verb and direct the computer to do something, e.g.,

Plant NN seedlings.

The second type of message or input statement required by MULTIPLOY is a Specification. These statements begin with a noun and provide MULTIPLOY with costs, prices, yields, and other values necessary to solve the problem. An example might be:

Cost of Planting is \$NN an Acre.

The third type of statement is an Alphanumeric name. Here, the statement begins with a word followed by a colon. MULTIPLOY copies and retains the information after the colon. e.g.,

Species: Douglas-fir

The fourth and last type of statement that the user needs to prepare for the system is the "Run" or "Stop" command. A statement such as:

Run Problem please

instructs MULTIPLOY to stop reading directions, begin editing input statements, and to process the problem. Such statements also direct MULTIPLOY at a later stage to either expect an additional problem or to stop all calculations and print the output.

Time concepts incorporated in the MULTIPLOY system are also important. Long time periods and complex schedules of treatments, regeneration, and harvests are unique to forestry. MULTIPLOY keeps tabs on these with simple instructions provided by the Analyst. The categories of time are the actual or investment time, with the present year as year zero; The rotation time, which is the time since the last harvest, including regeneration period; and the tree or stand age, which is the average age of dominant and codominant trees in the stand. For plantations, this is the time since planting. Hopefully, this wide variety of times will enable each manager to strictly define his situation and the options faced.

To give you more insight into the operations of MULTIPLOY and how you might utilize the system as a tool, I would like to discuss specifications of values, costs, and some economic criteria for management decisions.

In determining revenues, MULTIPLOY will accept either constant level prices or values computed from a price equation. Before multiplying price times quantity and coming up with a value, several other user options exist.

The potential yield of the tract can be reduced by "holes," i.e., the decimal reduction in merchantable yield due to land withdrawn from production.

Minimum specifications for product or size can be set. Output levels less than this minimum will not be valued.

Since local price anticipations may differ from Regional levels, MULTIPLOY offers the user an option of increasing or decreasing the price to reflect local conditions. Unless the user specifies only one product, if timber harvests meet both sawtimber and pulpwood criteria, MULTIPLOY assumes that it will be sold for the most valuable product.

A final revenue option enables the user to vary the price over time, either linearly or at a compounded rate.

Specifying costs presents the analyst with similar alternatives. Costs can be introduced as a flat rate or by formula, and fixed costs can be declared and prorated over the stated acreage. Costs can be stipulated for the following treatments as applicable: Type conversion, site preparation, planting, precommercial thinning, cull tree removal, spraying, prescribed burning, and fertilization.

Four non-treatment costs can be included. They are: Sales Administration, marking for thinning, annual management expenditures, and a user-specified cost. Costs, like prices, can be changed over the simulation time, and a measure of difficulty of treatment can be introduced.

Computing the criteria for management decisions adds an extra degree of flexibility to MULTIPLOY. The forest manager can specify the rate at which revenues and costs are discounted. This criterion is frequently referred to as the alternative rate of return. If no rate is specified, MULTIPLOY discounts at a default value of seven percent to calculate PNW, B-C, or AEI.

Although I mentioned earlier that MULTIPLOY provides all four economic criteria automatically, this is not quite true. Internal rates of return must be specified by the user as a desired output. A primary reason for this is that it adds substantially to the cost of a computer run.

When land must be purchased for the forestry investment, its value can be included by an appropriate input statement. Also, the land in forestry can be assumed to remain there, used in some other productive enterprise, or sold. MULTIPLOY assumes that forest land will remain as such unless the user specified either of the other two options.

The allowable cut level can also be introduced as a management criterion. The user must specify the value of the allowable cut per unit, the duration of time that the allowable cut level will apply, and the allowable cut minimum. MULTIPLOY will compare the level of the yield with the specified minimum cut level, and credit revenues with the appropriate value if the yield exceeds the minimum.

The last two major areas that I would like to familiarize you with are the use of yield tables and simulated growth. As mentioned earlier, MULTIPLOY can handle up to eight yield tables, which the user must insert and designate when to use. Ordinarily the following sequence and number of yield tables could apply:

INITIAL ROTATION WITH TREATMENT--BEFORE AND AFTER THINNING
SUBSEQUENT ROTATIONS WITH TREATMENT--BEFORE AND AFTER
THINNING

INITIAL ROTATION WITHOUT TREATMENT--BEFORE AND AFTER THINNING
SUBSEQUENT ROTATIONS WITHOUT TREATMENT--BEFORE AND AFTER
THINNING

Yield tables for all-aged management need entries for years between the present and the periodic harvest; then, the last entry of attributes and volumes is assumed to apply into the future.

Growth simulators in MULTIPLOY overcome some of the inflexibility of yield tables. Yield tables are suitable for situations where the number of trees, the thinnings, and the size of trees left to grow are closely controlled. Simulators, on the other hand, offer "customized" yields. The user can specify the number of seedlings planted and allow MULTIPLOY to calculate survival and basal area at the age when the stand is assumed established; or, he can stipulate values that override the MULTIPLOY calculations.

To generate a simulated yield, the user need only declare the species name (only Loblolly pine, slash pine, ponderosa pine, or Douglas-fir at the present time) and specify the appropriate growth procedure. The growth procedures programed into MULTIPLOY are:

Return to normality, plantation beta function, and the basal area growth equation. In addition, statements defining site index and declaring the degree of thinning are also required.

Nontimber outputs are also simulated in the process if the user provides certain basic information. A necessary item for each nontimber product is a formula that relates the production levels to changes in the timber stand attributes as the trees mature. If the user also presents a price or a price formula for the nontimber outputs, MULTIPLOY will compute both physical and value yields of these products. These items, as you know, often have significant value. There are numerous cases where sufficient value is attached to nontimber outputs to affect the choice of an acceptable timber management goal.

Loss simulation routines are also available in MULTIPLOY calculations. MULTIPLOY simulates losses from fire, storm, insect, or disease from information in user-supplied formulas. These formulas are normally expressed in terms of the proportion of an area likely to be totally destroyed each year. MULTIPLOY presents the results in terms of the proportion of stands expected to be lost and the cumulative survival rate. Since losses reduce the amount of timber than can be harvested, yields are reduced accordingly. However, some of the losses can be salvaged. MULTIPLOY will handle both losses and recovery if the user supplies appropriate estimates of their rates. A further loss option is presented. The user can specify whether the lands subject to loss will be returned to forest production as soon as possible, or if these acres will lay idle until the next rotation. MULTIPLOY calculates the cost of such decisions.

In concluding this first hour, I'd like to describe several useful extensions of MULTIPLOY which I'm sure you will be able to use. These extensions fall into a general category of group evaluations. First, there are "series of cases or projects" which represent a number of opportunities to which we can apply the same forest management treatments. The user need only enter the number of cases and the stand attributes of each case. MULTIPLOY then evaluates each project independently, stores the results, and prints them out upon demand.

The second extension enables the user to run "sensitivty tests". These tests evaluate the effect of differences in one control variable while all other factors remain the same. The user need only write a statement to MULTIPLOY designating the variable to be tested, the range of different values to be assigned, and the number of steps comprising the range.

The final variation is termed "random variation tests." This procedure randomly varies a number of factors to simulate fluctuations in financial returns that owners might expect. Factors which can be randomly varied to generate financial fluctuations include height growth, diameter growth, prices, costs, and the probability of regeneration success.

I realize that I have glossed over many important facets of MULTIPLOY and items of importance to you as forest managers. Hopefully, however, I have sufficiently defined the assets of MULTIPLOY so that you can realize the potential of this system as an analytical tool and as a means to quantify and measure the effects of your forest management decisions.

AGENDA-SILVICULTURE SERVICEWIDE WORK CONFERENCE

October 21 - 25, 1974

Monday - October 21

1:00 P.M.	Welcome	Worthington Ted Koskella
	Opening remarks by Tom Nelson.	
1:30 P.M.	Overview of Tree Improvement	Bill Libby
2:30 P.M.	Coffee	
3:00 P.M.	Overview of Genetic Research that is pertinent to NFS	Research Stan Krugman & Project Leaders, et al.
	End of day.	

Tuesday - October 22

8:30 A.M.	Announcements	
8:35 A.M.	Tree Improvement - A review each Region 20 minutes with a 10 minute discussion period	Mustain, Moderator Each Region
	(a) Rationale for program (b) Goals of program (c) Level of program development (d) Program organization (e) Problems	
	Regions 1, 2, 3, (10 minutes)	
10:00 A.M.	Coffee	
	(Review Continues)	
Noon		
	(Review Continues)	
2:30 P.M.	An ADP program to Maintaining Tree Improvement Records - Dick Miller, R-9	
3:30 P.M.	A general discussion related to accelerating the program	
	(a) Opportunities and Constraints (b) Specialists and their career development	

Field Trip for National Silvicultural

Meeting - Wednesday October 23, 1974.

0800 Lv Sacramento

0900 Ar Placerville Nursery

- Nursery Program and Facilities
(Elliot & Parks)

1000^{or}

1030 Ar Institute of Forest Genetics (coffee)

- Testing rust resistant sugar pine
- Variation in open pollinated ponderosa pine & Abies families
- Altitudinal variation in ponderosa pine
- Arboretum and hybrids
(King, Jenkinson, Johnson, Kimlock)

Catered lunch

1400 (approximately) - White fir provenance test at Camino.

1500 Ar Badger Hill Breeding Orchard

- Hybrid production - use of lift
- Rust resistant sugar pine close bank and breeding program (Parks)

1630 Depart for Sacramento

1800 Ar Sacramento

Wednesday - October 23

Field Trip - Region 5

Thursday - October 24 (Morning)

Fertilization

8:30 A.M.	Outlook for Fertilizer Availability Short term and long term	ERS-Dave Bell
9:00 A.M.	Fertilizer trials as a basis for operational programs	Dick Miller, PNW
10:00 A.M.	Coffee	
10:30 A.M.	Use of Soil and Foliar Analysis to determine need for fertilization	Robert Powers
.	Fertilization Practices with Im- proved Planting Stock. Progress to date, etc.	Charles B. Davey of NC State

Thursday Afternoon

1:00 P.M.	Technique for analyzing invest- ments in growing timber (2 hours)	George Dutrow
3:00 P.M.	Group discussion to develop re- commendations to facilitate implementa- tion of tree improvements and fertiliza- tion programs	A. P. Mustain, Jr.
	End of Meeting.	

Copies sent names marked.

SERVICEWIDE SILVICULTURE CONFERENCE
October 21-25, 1974
List of Those Attending

ORGANIZATION	LOCATION	NAME
WO	Washington, D.C. ✓	Tom Nelson
WO - TM	" "	✓ R. E. Worthington
	" "	✓ Stan Undi
	" "	✓ A. P. Mustian
	" "	Bob Pearl
	" "	✓ Don Funking
WO - WM	" "	✓ Bob Meurisse ✓
WO - Research	" "	✓ Stan Krugman ✓
WO - S&PF	" "	✓ Pieter E. Hoekstra ✓
	" "	✓ Roger Sandquist ✓
<u>S. Area</u>	Atlanta, Ga.	✓ Robert G. Hitt
<u>N. Area</u> ✓	Upper Darby, Pa.	✓ Clyde M. Hunt
<u>SE Area</u> <i>Sta</i>	Athens, Ga.	✓ George Dutrow ✓
<u>RM Sta.</u>	Glagstaff, Ariz. ✓	Gilbert H. Schubert
<u>NE Sta.</u>	Durham, NH	✓ Daniel M. Schmitt
<u>NC Sta.</u>	Rhineland, Wis.	✓ David H. Dawson
<u>PNW Sta.</u>	Portland, Or.	✓ Roy Silen
	Olympia, Wa.	, ✓ Dick Miller ✓
<u>PSW Sta.</u>	Berkeley, Ca.	Jim King
	"	Tom Conkle
	"	Jim Jenkinson
	"	Bro Linloch
	"	Bob Echols
	Placerville, Ca	✓ Leroy Johnson ✓
	Redding, Ca	✓ Bob Powers ✓
<u>Region 1</u>	Missoula, Mont	Bill Beaufait
	" "	George E. Howe
	Coeur D'Alene, Idaho	Pete Laird
<u>Region 2</u>	Denver, Colo	Richard A. Cunningham
	Cody, Wyo	Theodore V. Russell
	Monte Vista, Co	Robert L. Jackson
	Steamboat Springs, Colorado	Al Rogers

Region 3	Albuquerque, NM " "	Wesley C. Bates John A. Pitcher
Region 4	Odgen, Ut Salmon, Id ?	Bob Patee John Emerson John Scholtes
Region 5	San Francisco " " " " " " " Yreka Placerville Redding, S Fran " " San Francisco Eldorado NF " " " " Lassen (S.D.U.)	Ted Koskella Norman Gould Will Charter John Tappeiner Jay Kitzmiller Mitch Knight Glenn Davies Bob Gustafson John Alden Gaylord Parks John Shumay Larry Balley Andy Level (Soils and Watershed Staff) Harry Hopkins Bud Veirs Boyd Elliott Garry Fiddler
Region 6	Portland, Or " " "	Pete Thiesen Jack Usher Aza Twombly
Region 8	Atlanta, Ga " "	W. A. Tuttle T. F. Swofford
Region 9	Milwaukee, Wis " " " "	John R. Castles C. R. Blomquist Richard G. Miller
Region 10	Juneau, Al	David Johnson
ERS	Washington, D.C.	✓ Dave Bell ✓
UC	Berkeley, Ca	✓ Bill Libby ✓
NC State	Raleigh, NC	✓ Charles B. Davey ✓
CDF	Sacramento, Ca " "	✓ Ron Adams ✓ L. E. Hartzell

*California
Department
of Forestry*

