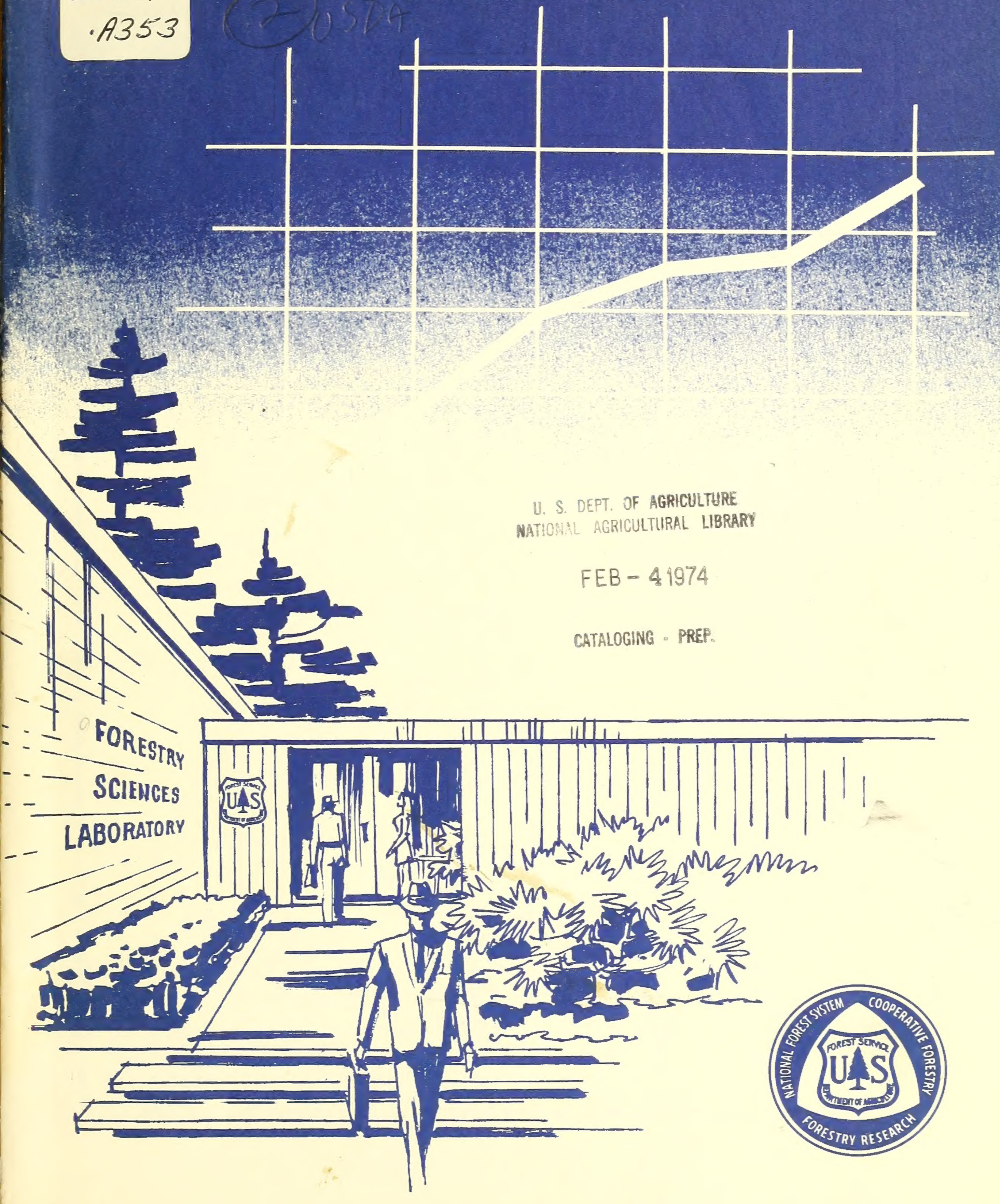
RESEARCH ACCOMPLISHMENTS 1971

FOREST SERVICE U. S. DEPARTMENT OF AGRICULTURE



FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE
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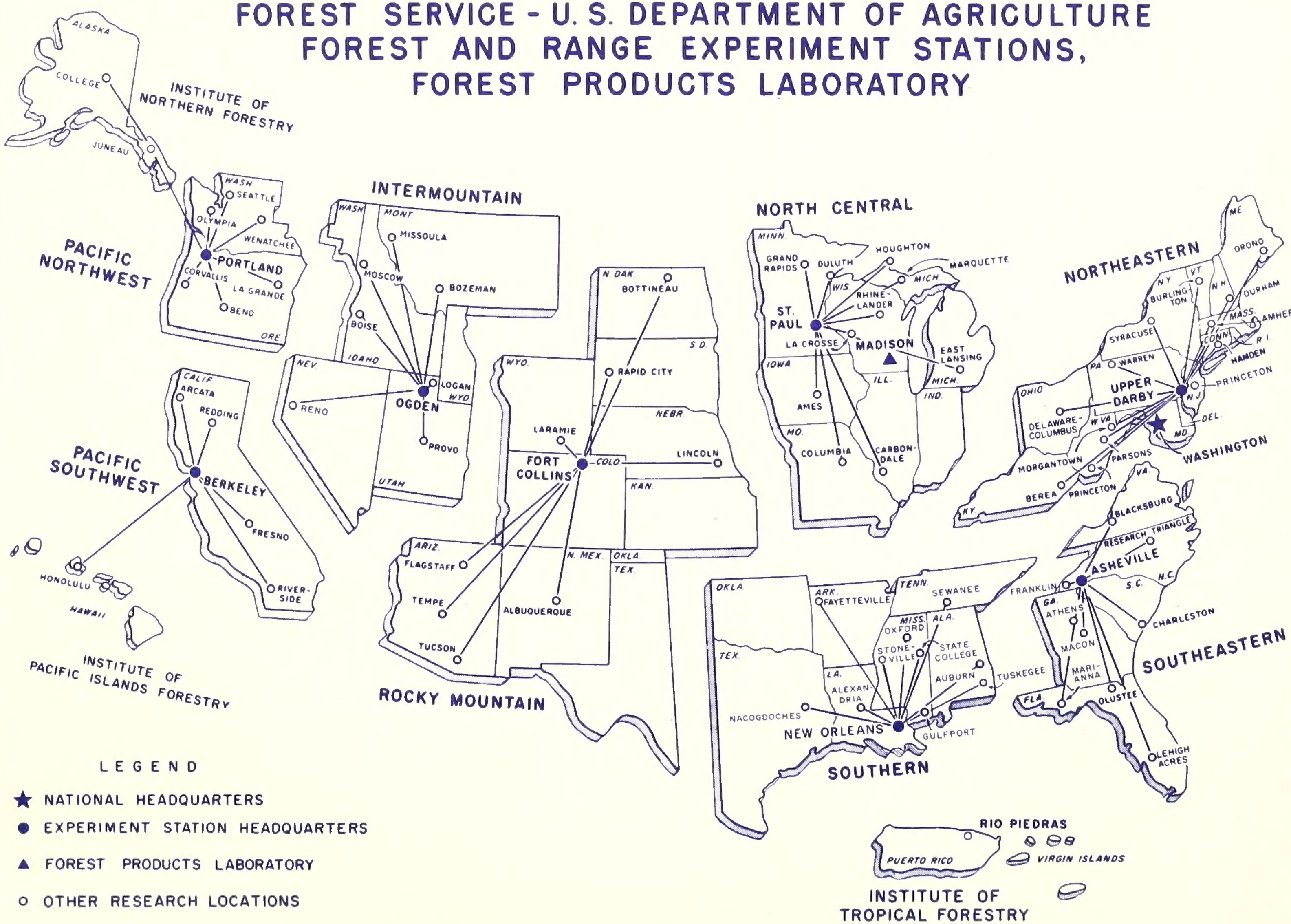

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
WASHINGTON, D.C. 20250

IN REPLY REFER TO
1380 (4000)

Dr. T. K. Cowden
Assistant Secretary
U. S. Department of Agriculture
Washington, D. C. 20250

Dear Dr. Cowden:

I am pleased to send you this report on Forest Service research accomplishments for 1971.

We are proud of the Forest Service's long history as a pioneer and leader in environmental and production research. We continue in that tradition but with a new sense of urgency toward seeking solutions to today's environmental problems and anticipating the problems of tomorrow. Our production related research takes on new meaning with cognizance that wood, a renewable resource, requires much less energy and creates much less pollution in product conversion than do other common materials.

Sincerely,

Edward P. Cliff

EDWARD P. CLIFF
Chief

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U.S. DEPARTMENT OF AGRICULTURE

NOTICE: The identification and description of commercial products in this publication are solely for information purposes. Endorsement of any commercial product is not intended and must not be inferred. Readers are cautioned to handle all pesticides, herbicides, and fungicides mentioned in this publication strictly in accordance with manufacturer's labels. These chemicals are harmful to people, farm animals, wildlife, and fish, and can contaminate water supplies.

FOREWORD

Forest Service research plans are coordinated through the U.S. Department of Agriculture's Office of Science and Education with research in other USDA agencies, with that conducted under the Hatch Act at land grant institutions, and with forestry research under the McIntire-Stennis Act at schools of forestry. Coordination of research with other educational institutions, private enterprises, nonprofit institutions, and other public agencies is maintained mostly through direct contact between people of these organizations and those of the Forest and Range Experiment Stations. Federal, State, industry, and university cooperation in solving mutual problems is achieved through cooperative agreements that provide for joint development and support of the research by the cooperators.

This report is arranged by research subject areas in order that the reader can go directly to the areas of interest to him. Each accomplishment is summarized in a single, short paragraph followed by an abbreviation denoting the Forest Service research unit best able to supply additional, detailed information and copies of the 1,198 publications listed. Underscored numbers in parentheses following unit abbreviations refer to publications listed at the end of each section. The research units and the abbreviations used in keying the accomplishments follow and are also indicated in the lists of publications. Their locations are shown on the map in the inside front cover. For further information, publications, or service, any of these units may be contacted:

PNW - Director,
Pacific Northwest Forest and Range Experiment Station
809 NE 6th Avenue, P. O. Box 3141
Portland, Oregon 97208

PSW - Director,
Pacific Southwest Forest and Range Experiment Station
1960 Addison Street, P. O. Box 245
Berkeley, California 94701

INT - Director,
Intermountain Forest and Range Experiment Station
507 25th Street
Ogden, Utah 84401

RM - Director,
Rocky Mountain Forest and Range Experiment Station
240 West Prospect Street
Fort Collins, Colorado 80521

NC - Director,
North Central Forest Experiment Station
Folwell Avenue
St. Paul, Minnesota 55101

NE - Director,
Northeastern Forest Experiment Station
6816 Market Street
Upper Darby, Pennsylvania 19082

SE - Director,
Southeastern Forest Experiment Station
Post Office Building, P. O. Box 2570
Asheville, North Carolina 28802

SO - Director,
Southern Forest Experiment Station
T - 10210 Federal Building, 701 Loyola Avenue
New Orleans, Louisiana 70113

FPL - Director,
Forest Products Laboratory
North Walnut Street, P. O. Box 5130
Madison, Wisconsin 53705

ITF - Director,
Institute of Tropical Forestry, University of Puerto Rico
Agricultural Experiment Station Grounds, P. O. Box AQ
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CONTENTS

I. IMPROVING THE ENVIRONMENT

A. Reducing Pollution

1. CONTROLLING SOIL EROSION

Seasonal variations in certain chemical properties occurred in soils derived from two parent materials common to central Washington. According to sampling date, basalt and sandstone soils showed significant periodic variation in cation exchange capacity, pH, and Na and K contents. In sandstone soils Ca also varied significantly. Such variations may confound the evaluation of research findings or management prescriptions. PNW (5).

A sediment budget showed that streambank erosion in a pool and riffle stream in Michigan contributed most of the total load increase of 530 percent along 26 miles of stream channel. Total sediment load was measured with a DH-48 sediment sampler at artificial sills placed on the streambed at each of five sampling stations. NC (8).

The magnitude of erosion from simulated rain applied to seven mountain rangeland sites in Utah, Idaho, and Montana depended primarily on the proportion of the soil surface protected from direct raindrop impact. Multiple regression equations for each site related the resultant erosion to cover characteristics, soil properties, and slope gradient. Soil organic matter favored stability of fine-textured soils but apparently increased erodibility of sandy soils. INT (19).

A burned watershed in southern California sprayed with a wetting agent had 16 percent more erosion than an untreated control. Studies are underway to find out why the treatment failed. One hypothesis is that an insufficient amount of wetting agent was applied to the extremely water repellent soils in the study area. PSW (23).

2. UTILIZING SOLID WASTES

Black Douglas-fir sawdust resulting from fermentation and heating in compacted centers of large piles is strongly acid and injurious to shrubs and plants. Its very dark color and acrid odor indicate the hazard of its use for mulching and other horticultural practices. Bark in large, moist piles is subject to similar microbial and chemical transformations. PNW (28).

3. CHEMICALS IN THE FOREST ENVIRONMENT

No adverse effects on soil microbial activity resulted when Zectran or No. 2 fuel oil carrier was applied to soil in concentrations far greater than those used in current operational practices. This indicates that low-volume applications of Zectran as an insecticide for forest use poses no hazard to soil microbes. PNW (29).

In 1965 early summer aerial spraying of DDT on forested rangelands for forest insect control resulted in an initial high residue content on understory plants, decreasing rapidly the following 4 months. During this first period, cattle and deer were consuming forage with high residue content and this was reflected in analyses of animal adipose tissue. Twelve months after spraying, DDT residues on forage plants available to grazing animals were minor or similar to prespray levels. PNW (45).

Frequently, natural or artificial regeneration of northern California coast range Douglas-fir fails because the site is rapidly invaded by tanoak sprouts that shade the seedlings and compete for moisture and nutrients. Foliar sprays of 2,4,5-T alone, or in combination with 2,4-D, applied in August or September, resulted in effective kill of the undesirable hardwood sprouts and a corresponding increase in seedling survival. These findings can assist in achieving rapid regeneration following cutting in this important timber type. PWS (31).

4. AIR POLLUTION EFFECTS AND CONTROL

One of the most important problems in predicting changes in air quality due to prescribed burning operations is in determining source strength as well as transport and diffusion of the smoke plume. This study describes smoke plume movement in relation to meteorological variables and suggests flight plans for light aircraft used in smoke plume studies. Carbon monoxide concentrations coincide reasonably well with smoke plume density, and particulate observations illustrate the magnitude of visibility restrictions in the vicinity of fires. Results of this work will help provide a better understanding of air quality changes that may be expected as a result of prescribed burning operations. PSW (58).

Many states are looking for assistance in preparing regulatory measures to minimize the environmental impacts from open burning of forest wastes. Research in various parts of the country, including the South, Southwest, Northwest, and Rocky Mountains, is directed toward finding out more about the effects of prescribed burning on air quality. These studies are identifying the various combustion products, methods of transport and diffusion and developing a background of knowledge that will make it possible to complete smoke management plans for the various regions. Smoke management plans are in effect in Oregon and Washington and are being considered for other parts of the country as well. These plans will make it possible to complete prescribed burning operations with a minimum of impact from the smoke. PNW (54).

There are certain meteorological variables that are associated with increased concentration of oxidant air pollutants in areas adjacent to the Los Angeles metropolitan area. This study describes the movement and changes in concentration of oxidants in relation to vertical wind profiles, air temperature, humidity, and wind. Photography is used to record visible changes in the polluted airmass. The results of this study extend our capabilities to predict the movement of total air pollution oxidants in the eastern South Coast Basin, California, and perhaps to other regions as well. PSW (51).

Basic information is needed on the production, transport, and dispersion of combustion products coming from broadcast burning operations. In managing smoke from broadcast burning operations, the most important variables to consider are energy release of the fire, atmospheric stability, and upper air characteristics that influence movement of smoke away from smoke sensitive areas. Results of these studies provide the necessary data for formulating smoke management guidelines for mountainous terrain and should minimize the threat of air pollution from prescribed broadcast burning operations. PNW (52, 53, 54, 55, 56, 57, 59).

Smoke from prescribed burning operations frequently invades areas where it becomes a nuisance and a safety hazard to surface and air travel. It is a relatively simple procedure for the land managers to follow a check list of precautionary measures when conducting these burning operations, thereby making the smoke less objectionable from the public's standpoint. Identifying smoke sensitive areas, securing good forecasts, and observing no-burn restrictions during air pollution alerts are all means of more effectively managing the smoke produced from prescribed burning. SE (60).

Open burning restrictions and air quality regulations may cause a reduction in the amount of operational burning that can be done in smoke sensitive areas. On the basis of a study of 2 dry years for a valley area in western Oregon, it was possible to determine where the greatest impact on burning operations would be; the study also indicated that considerable burning could be accomplished under the assumed air quality restrictions without causing undesirable side effects. PSW (49).

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6. DeBano, Leonard F. 1971. The effect of hydrophobic substances on water movement in soil during infiltration. Soil Sci. Soc. Amer. Proc. 35(2): 340-343. (PSW)
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36. Moore, D. G. 1970. Forest fertilization and water quality in the Pacific Northest. (Abstr.) Amer. Soc. Agron. Abs. 1970:160-161. (PNW)

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B. Improving Wildlife Habitat

1. INTEGRATING WILDLIFE AND OTHER LAND USES

Deer browsing reduced the height growth of important timber species after heavy selection cutting on good sites in the Southern Appalachians. After 7 years, the number of stems which exceeded the 4.5-foot level was significantly reduced, but a sufficient number escaped browsing to provide adequate stocking. SE (2).

Browse, mast, and cover produced by Gambel oak over wide areas in the Southwest contribute substantially to sustenance of such wildlife species as Abert's squirrels, band-tailed pigeons, Merriam turkeys, Mearn's quail, javelinas, white-tailed deer, mule deer, and elk. In forest stands with from 10 to 25 percent basal area of oak, timber- and water-yield practices should leave oaks less than 15 inches d.b.h. with more than 80 percent live tops in order to preserve the wildlife resource. RM (6).

Atlantic Piedmont pine lands are often deficient in important wildlife foods. Dense patches of food plants can be created by cutting and burning on areas of low pine production. Once created, the food patches can be maintained by burning periodically to remove accumulated litter and stimulate germination of hard leguminous seed. SE (1).

Thinning increases the understory vegetation of ponderosa pine forests in eastern Washington. After eight growing seasons, total understory yields range from 75 lb/acre in unthinned stands to 417 lb. under 26-foot pine spacing. PNW (5).

Browse production can be increased by thinning pole-stage stands of Appalachian hardwoods. For browse of seedling origin, stands of mixed oak and cove hardwoods should be thinned to 100 and 90-94 sq. ft. per acre respectively. For browse of sprout origin, the mixed oak stands should be thinned to 68-76 sq. ft. of basal area per acre. NE (4).

Bulldozing pinyon and juniper trees in Arizona caused changes in rodent populations. In general, numbers of resident rodents increased and additional species invaded the area. Additional herbaceous cover and dead trees on the ground were the gross habitat changes associated with the changes in rodent populations. RM (7).

2. EVALUATING AND IMPROVING WILDLIFE HABITAT

Quail in south Georgia prefer freshly burned areas and 1-year roughs as late-summer nesting sites. Bluestem grasses are more frequently used as nesting cover and as nest sites, and optimum herbaceous cover appears to be around 50 percent. Burning enhances the condition of ground cover by promoting complexes of plant clumps; these provide adequate screening and passageways of quail. SE (10).

Deer populations on National Forests in Missouri are limited by the carrying capacity of their winter ranges. A survey of 1.36 million acres of forest land indicated that production of deer and turkey foods is low in most forest types because of dense overstories. Deer carrying capacities of most forest types are probably less than 8 per square mile. Current populations may be near carrying capacity. NC (12).

Feeding and nesting activities of Abert's squirrels are closely associated with ponderosa pines that have diameter-breast-heights of 11-30 inches. By delineating stands of this size-class, the preferred habitats of Abert's squirrels can be identified in multiple-use plans for Arizona forests. RM (13).

Two recent symposia consolidate knowledge and offer new ideas and philosophy related to management of white-tailed deer in southern and midwestern forests. The proceedings represent the most complete compendium now available on the southern white-tailed deer. SO (14, 15).

Green leaves, fruits, mast, and mushrooms are all important deer food in the southeastern States. Woody twigs are a relatively minor component of the diet. Virtually all browsing of twigs takes place during the spring and summer. SE (8).

In Oregon, bitterbrush plantations respond more to protection from browsing than to elimination of plant competition. Response shows up more in crown size than in plant height. PNW (9).

Utilization of serviceberry can be estimated from the relationships among length, weight, and diameter of twigs. Relatively small samples of browsed twigs were found to provide precise estimates of browse utilization despite variations related to site, plant size, and twig location. INT (11).

(For additional items relating to I B see paragraphs under I D 1, 2, and 5.)

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Integrating wildlife and other land uses

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14. USDA, Forest Serv. 1969. White-tailed deer in the southern forest habitat. So. Forest Exp. Sta., 130 p. (SO)
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C. Opportunities for Outdoor Recreation

Three methods for estimating economic value of outdoor recreation in lieu of a market mechanism for establishing price were tested in Colorado. The three methods produced remarkably similar estimates of nearly $1 per visitor day. The "monopoly revenue method"--based on level of attendance that would result at each of several progressively higher admission charges--produced figures most nearly comparable to market prices and is most free of uncontrolled bias in application. It is therefore most likely to provide the most accurate valuations for resource allocation decisions. RM (1).

Costs of sprinkling forest campgrounds in Idaho to improve vegetation were much lower when done by an underground sprinkling system. Hauling water by truck and irrigating cost was $150 per campsite. Annual underground sprinkling costs (amortizing the useful physical life of the system for 20 years at 5 percent) were $93 per site, or 26 cents per visitor day. INT (2).

Ground cover vegetation was successfully reestablished on heavily worn, high-altitude campsites in Idaho by seeding, fertilization, and irrigation. Seed alone, seed and water, or seed and fertilizer were not effective. INT (8).

Natural areas provide nearly unique opportunities to study plant and animal communities and relationships where there has been no alteration by man. Basic knowledge on the formation and evolution of peatlands and their vegetation has come from a detailed study of northern Minnesota's Lake Agassiz Peatlands Natural Area. Forest ecologists learned that the kinds of plants and peat found here are influenced by topography, water-flow patterns, the evolution of the landscape, and particularly by water chemistry. From such ecological studies comes better knowledge of our natural surroundings and how mankind was affected his environment NC (5).

Primeval conifer forests of northern North America and their associated broadleaf elements were mostly fire-dependent ecosystems. Fire was the key environmental factor that initiated new successions, controlled the species composition and age structure of the forests, and produced the vegetation patterns upon which the animal components of the ecosystem also depended. Fire has been part of nature for eons--and today's pursuit of a legacy of 50 years of intensive fire prevention campaigns, so far as perpetuation of natural, primeval ecosystems is concerned, is a departure from nature. Where natural ecosystems are desired, fire must be reintroduced. NC (6).

Maintenance and restoration of forest biotic communities requires accurate knowledge of the makeup and ecological factors influencing the plant and animal associations. A sampling scheme to collect, organize, and summarize such data in a form suitable for automatic data processing and further quantitative analysis has been developed. The system is flexible and adaptable to many situations. NC (15).

A study of five heavily used California campgrounds suggests that the wornout appearance may be more apparent than real, and that campground ecosystems may be capable of adjusting to human impact. Photo records show a characteristic sameness between 1961 and 1966 on all sites. Losses of litter, soil, and plants were not evident. Tree growth showed no adverse influence from use. New ground cover species, particularly forbs and sedges, increased, and shrubs fared better on campgrounds than on noncampground sites nearby--possibly because of less competition from tree seedlings, saplings, and poles. PSW (13).

Actual on-the-ground measurements of campground use are prohibitively expensive. For several years forest and park managers have been relating use from highway axle count measurements. A method that can increase the precision and value of use estimates has been developed using regression techniques in which the relationship is nonlinear in the parameters as distinguished from nonlinear in the explanatory variables. On a daily basis, as more and more vehicles enter a campground, less and less additional use will occur. The technique employs three desired properties: Zero intercept, fixed upper limit, and decreasing campground use with increasing axle count. PSW (3).

Techniques have been developed whereby inventory and analysis of the visual resource can be computerized for forest landscape management research and planning. The system permits planners to take into account many alternatives in considering and delineating areas which will receive visual impact from either proposed or existing scenic observer points, scenic roads, or scenic tramways--or proposed high-rise developments in mountainous terrain. The latter has a double impact--that which can be seen from the high rise, and how often the high rise will be seen from other prominent observer positions. PSW (4).

Eucalyptus, when planted to enhance south Florida landscapes, must grow rapidly to withstand first-year frosts and dominate herbaceous vegetation. Fertilizer tablets in the planting holes of *Eucalyptus camaldulensis* stimulated immediate growth superiority. Fertilized trees were 50 percent taller and 83 percent thicker than check trees at 6 months. In a companion study the same species was tested in combination of clearing sod from planting spots, no clearing, fertilization, and no fertilization. Clearing plus fertilization stimulated the fastest growth, but fertilized seedlings in undisturbed sod grew rapidly considering the minimal inputs required. One can sod plant a quart-potted seedling, then, with 10 cents worth of fertilizer and 1 year's time, have an established tree 15 feet tall with a 3-inch trunk. In 2 years such trees can be a major element of a landscape. SE (14).

Physical planning for outdoor recreation developments often centers on engineering considerations, site capabilities, and sanitation requirements, with far less thought given to the design requirements for the social aspects of a recreation experience. Take camping, for example. Camping is a process of expressing cultural values and a means of searching for the satisfactory fulfillment of certain social needs. In the process, each person develops has own style of reacting and behaving. For many, social contact with other campers is their major reason for camping. Security, recognition, response from others, and new experience are prominent recreation related social needs. Campground designs which ignore these needs are less likely to be popular, and if in the private sector, less likely to be financially profitable. NE (9).

The increasing demands on outdoor recreation resources are generally thought to arise from the combined effects of more people and more participation per person. A New England study throws doubt on the second assumption. Only 17 percent of a group of 565 campers increased their camping participation over a 4-year period. Thirty-three percent showed a marked decline. Neither life cycle and changing leisure interests, opportunity limitations, nor habit patterns and styles of participation satisfactorily explained the trend. Instead, the results suggest that resource planning has not kept pace with demands; that increasing numbers of people using these resources, dwindling available supply, and reduced environmental attractiveness resulting from heavy use pressures may be a more accurate explanation. The study definitely challenges the assumption that increasing per capita participation is a prime cause of rising demands for outdoor recreation facilities and services. NE (11, 12).

Camping and many other forms of outdoor recreation seem to thrive on myths and romantic half-truths. The outdoors has always been romanticized in popular writing, and heavy emphasis has been placed on man's desire to be like Henry Thoreau--to live simply and to "return to nature." Thoreau should see what's going on today. Only one out of five of the more than 500 campers mentioned above fits the Thoreau ideal. Camper demands for more and more comfort and convenience items in the campground are on the increase, and many of the more successful commercial campgrounds are making sure these desires are being met. They are also deliberately breaking some more "rules in the book." Several campground owners and operators have never gone camping and don't intend to. Several have invested huge sums in developing land that is right next door to a free or low-cost public campground. And a surprising number pack their campers in with little or no privacy, and then proceed to bombard them with fun and games, so that the only way the camper can get away from it all is to return to the relative peace and quiet of his home. NE (10).

The "heavy half" marketing phenomenon continues to be evident in the camping market. In 3 out of 4 years, the heavy half of 535 camping families did more than 80 percent of the camping. One-fourth of the group was consistently in the heavy half. A decreasing trend in camping participation was found to be strongly and inversely related to the number of years a camper was in the heavy half of the camping market. Obviously, these are the people advertisers should try to reach. NE (12).

A study of Michigan vacation homeowners emphasizes the importance of water frontage. Over 55 percent of the homes are located on an inland lake, 24 percent on one of the Great Lakes, and over 10 percent on a river or stream. Sixty-five percent of the homes were less than 200 miles from the owner's primary residence. Nearly 50 percent of the owners were in the "under $10,000" annual income group. The proportion of homeowners along the Great Lakes increases with the age of the owner and his income. The younger age groups tend to prefer inland lake sites, not only because they often cost less, but because of their better water skiing, sail boating, swimming, and other "action" oriented activities. NC (16).

An understanding of natural ecosystems is necessary to provide management a scientific base for future forest vegetation policies--such as restoring a wilderness to its primeval condition. Such research is underway in the Boundary Waters Canoe Area, and already a major question "Was fire a natural factor?" has changed to "How much fire was natural prior to the arrival of Western man?" Carbon deposits in lake sediments indicate a fire history for the full post-glacial time period. The oldest known living stand in the area dates from an A.D. 1595 fire, and major fires recurred at 5- to 50-year intervals to 1920. Most stands have an even-aged overstory dating from the last fire. Fire was probably so frequent that it prevented succession from proceeding very far toward the theoretical spruce-fir-birch climax. Since 1920, due to increased fire protection, only limited areas of the virgin forest have burned, and the ecosystem that may develop with fire exclusion (present practice) is, in a sense, unnatural and largely unknown to science. NC (7).

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D. Developing Range Resources

1. EVALUATING RANGE RESOURCES

A research symposium explored the technology for forage evaluation and remote sensing of range and wildlife resources. Thirty papers provide an in-depth review of many facets of the two subjects. RM (3).

The standing crop of range plants can be estimated from structural characteristics of the plants. Predictive models have been developed for Gambel oak, needle-and-thread, bottlebrush squirreltail, tall bluebell, and white polemonium. The models will be useful in situations where clipping is undesirable. INT (1,2,3).

2. CHARACTERISTICS AND FORAGE VALUES OF RANGE PLANTS

Sedges of the Rocky Mountain and Colorado basin are described in a new illustrated manual. The manual includes keys for identification, the latest nomenclature, and notes on forage values, habitats, and distribution. RM (5).

Seeds of fourwing saltbush, one of the most important shrubs on Western ranges, remain viable many years under dry storage. Usually, only about half the seeds contain embryos. Viability is easily checked with tetrazolium. De-winging the seeds facilitates handling and hastens germination. Seeds should be planted 0.5 to 1 inch deep during spring or summer; seedbed preparation is recommended. Transplants may be used effectively for critical areas. RM (6).

Seeds of longleaf uniola, an important forage grass in the South, remain dormant for a lengthy period after maturity. The speed and completeness of germination are raised to acceptable levels by prechilling caryopses at 2°C for 4 to 6 weeks, then placing them in constant darkness with alternating temperatures of 20 and 40°C. SO (7).

3. LIVESTOCK AND GRAZING MANAGEMENT

One acre of improved pasture replaces 8 to 10 acres of pine-wiregrass ranges, and provides higher quality forage for cattle over a much longer period of the year than the native range. Hence, the trend is toward greater use of improved pasture to supplement the native range. Ranges are used primarily during the winter and spring, pastures during the summer and fall. SE (8).

Sheep grazing can be an effective means of controlling sagebrush that has fewer environmental impacts than herbicides or burning. Heavy late fall grazing of depleted ranges in Idaho resulted in a 36 percent increase in production of palatable forbs and grasses and a 22 percent decrease in production of sagebrush. Heavy grazing in the spring damaged good-condition ranges by reducing herbaceous production by more than 50 percent and increasing sagebrush production by 78 percent. INT (9).

The exclusion of livestock grazing for 10 years did not substantially improve forage production or watershed conditions on a salt-desert shrub range in Colorado. Drought and inherent limitations of the sites were believed responsible for the lack of improvement. On similar ranges where grazing was continued, ground cover declined over the same period of years. RM (10).

4. RANGE ECOLOGY

The adverse effects of heavy grazing on Idaho fescue may be reduced greatly if the competition with other species is reduced concurrently. This Montana study of simulated grazing (clipping) suggests that "heavy" grazing may offer advantages in certain systems of livestock grazing management. INT (11).

In Wyoming, the diet of sheep on alpine ranges is composed of a large number of species. About two-thirds of the average diet is accounted for by whiproot clover, dwarf clover, American bistort, alpine avena, and red fescue. As the summer grazing season progresses the diet shifts from forbs to grasses and sedges. RM (12).

5. RANGE IMPROVEMENTS

Forage production on critical elk winter ranges in Montana can be increased by fertilization. On poor ridgetop sites, 200 pounds of nitrogen per acre appeared to be the most appropriate fertilizer, increasing forage yields 250 percent the first and second year after application. To be effective, fertilization must be used in conjunction with sound management of the elk herd. INT (13).

Lehmann lovegrass becomes established more quickly on semidesert ranges than any other perennial grass species that has been tried on the Santa Rita Experimental Range in Arizona. It is the only perennial grass that has the ability to establish itself in a mesquite stand or to maintain itself on heavily grazed areas. Plants are easily killed by fire but new plants become established quickly from seed already in the soil. It is well adapted to semidesert ranges between 3500 and 4500 feet elevation and 13 to 17 inches rainfall. RM (14).

Native plants growing in phosphorus-deficient soils in south Florida responded favorably to cross-chopping and fertilizing with ground rock phosphate. Availability of soil phosphate remained high throughout the 5-year study. Chopping effectively controlled saw-palmetto and reduced the density of pineland threeawn, while increasing herbage yields, availability, and utilization. Rock phosphate increased herbage yields, raised nutrient levels, and improved palatability of most native plants. SE (15).

Broad, shallow pits last longer than conventional pits and result in greater forage production on seedings of buffelgrass under 6 to 8 inches summer rainfall in southern Arizona. The broad pits are 5 to 8 feet wide, 5 feet long and about 6 inches deep at the deepest point. Average herbage production of buffelgrass over a 4-year period was 2 1/2 times as high on intermediate pits as on conventional pits and 5 times as great as on unpitted range. RM (16).

(For an additional item relating to I D see paragraph under I B 1.)

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E. Trees to Enhance the Environment

Additional sources of income are necessary in regions where employment opportunities are poor or seasonal in nature. Potential revenue producing crops such as tree boughs, ground plants, flowers, fruit, and seed pods for decorative purposes are often overlooked. A new bulletin tells how to recognize such materials found in Appalachian forests, places to go for local assistance in marketing, and any legal restrictions on collecting and shipping plant material. Distribution of this information in rural Appalachia could mean added revenue for many families. NE (4).

Indian tobacco, a wild Appalachian annual, is the source of an alkaloid (lobeline) used in anti-smoking preparations. Demand for lobeline has been increasing while the harvest of wild plants has been declining. Procedures have now been worked out for collecting, storing, sowing, and germinating seed and for planting, cultivating, harvesting, drying, and marketing this product. This information will be useful to those interested in the commercial production and marketing of lobelia, either as a source of raw material or as a source of additional income in rural areas. NE (1, 2).

Pitch pine is one species that can be used for environmental planting on dunes, disturbed areas, and similar harsh sites where other species might not succeed. A complete summary is now available containing abstracts of the information from 590 publications on site requirements, nursery practices, planting methods, and plantation culture for pitch pine. This guide should prove useful to both researchers and land managers. NE (3).

An ideal windbreak tree for the harsh Nebraska climate would have the foilage density of conifers during the summer to disrupt wind patterns and the deciduous nature of hardwood during the winter to prevent excessive snow accumulation. Japanese larch has these characteristics to a considerable degree, and trees from seven sources have been observed for 10 years to determine the ones best adapted to Nebraska conditions. Based on final evaluations, seed from the best sources will be obtained and grown in local nurseries for distribution and planting to enhance the Plains environment. RM (5).

Many windbreaks in the Great Plains region need to be rehabilitated if they are to continue to provide effective wind protection. Results of soil moisture monitoring studies in windbreak plantings indicate that ground water recharge from snow accumulation and current precipitation is adequate to establish trees in old windbreak rows in the eastern plains region. Lack of available moisture in central and western regions may prevent reestablishment of trees except in years of abundant snowfall. Planting failures may be avoided if these guidelines are followed. RM (6).

Firetree, a scrubby tree originally intended as an ornamental, is now a pest in Hawaii and a search is underway for trees of greater utility and attractiveness to supplant it. Among the tropical trees planted in areas where firetree had been killed, Australian toon has survived and grown well for 2 years, and tropical ash survived and grew moderately well. These early results lend encouragement in the search for desirable species and effective methods for enhancing Hawaii's forest environment. PSW (7).

(For additional items relating to I E see paragraphs under III A 2 and 6.)

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II. IMPROVING THE ENVIRONMENT AND PRODUCTIVITY

A. Reducing Fire Losses

1. FIRE PREVENTION AND HAZARD REDUCTION

Slash and debris from thinning operations create difficult control problems when wildfires occur in this fuel type. The extra fuel on the ground results in a fire that is so intense that direct attack is seldom possible and trees that might otherwise survive are frequently killed. These case studies of specific fires emphasize the need to develop improved methods of disposing of this dangerous fuel. PNW(7).

Logging slash creates a fire hazard and may be a barrier to prompt regeneration on clearcut blocks in selectively cut stands, and in stands where precommercial and commercial thinnings have been made. The use of prescribed fire as a means of alleviating this hazard offers an effective economical means of not only getting the area back in production but protecting it from damaging wildfires. Prescription fire, applied to vary the intensity according to the objectives of the burn, offers one of our best alternatives for keeping the land productive. SE (25).

The teaching of fire prevention is a legal requirement in California elementary and secondary schools. To be effective, the instructional program must be designed to convey specific conservation and fire prevention information. This study evaluates such a specific instructional program and compares it with the conventional presentation of these topics in the public schools in one county. Significant changes in learning behavior were observed in response to the use of the new material with the greatest impact occurring in the kindergarten and first grade. PSW (9).

Effective fire prevention continues to be closely associated with identifying those individuals that are responsible for starting the fires, and then reaching this segment of the population with messages that will make them more conscious of preventing fires. This study has identified a group of personal and related characteristics of children who start fires. Findings reject the idea that any single distinguishing attribute can be related to fire starting tendencies in children. If early identification of these characteristics is possible, and it appears that it is, the children that are potential fire starters can be reached with messages and educational materials that will help prevent future fires. (24)

Construction and maintenance of fuel breaks is a presuppression measure critical to successful fire control in certain parts of the country. These breaks need not be totally free of all living vegetation to be effective; in fact, quality yield of timber is compatible with the objectives of the fuel-break system in areas where timber is produced. This study found that fuel breaks constructed on productive timber sites can increase the current growth and quality yield to a point that at least part of the costs of constructing the fuel breaks can be borne by the timber growing benefits over a period of years. This means that cost-effectiveness relationships are enhanced through fuel-break construction, and that the land used for fuel-break construction in timbered areas need no longer be considered as "out of production." PSW (10).

Incendiary fires still account for a large percentage of fires in many parts of the country and more knowledge is needed to adequately meet this difficult fire prevention challenge. In a study of incendiary fires in a Louisiana parish, it was discovered that only about 3 percent of the people were the main cause of the trouble and that these few individuals appeared to be largely out of touch with available sources of information that might change their views. Results of the study indicate that personal contacts with these few individuals would be the most productive means of reducing the incidence of incendiary fires. SO (4).

Fires are frequently started along some of the heavily traveled routes in southern California. The fires generally start in light flashy grass fuels and spread quickly to the heavier fuels. This study has shown that diammonium phosphate, a long-term fire retardant, can be applied to the roadside fuels to bring about a reduction in average fire occurrence. The retardant material is water soluble so should be used in areas where rainfall is low. Treating the roadside fuels in this way can prevent many roadside fires that would otherwise need suppression action. PSW (27).

Fuel breaks have been proved effective in preventing or controlling southern California fires, but for the breaks to be effective they must be largely free of flammable material. Prescribed burning is a safe, economical tool for reducing the fuel concentrations on these breaks and experience indicates that spring burning is more satisfactory than fall burning. Results of this work should provide a means of maintaining the breaks in the most economical manner. PSW (23).

2. FIRE CONTROL METHODS AND SYSTEMS

Evaluating forest fire retardant chemicals is an important first step in a search for the most effective materials for forest firefighting. Rate of fire spread and other indirect measurements of fire intensity have been widely used in the past for evaluating these materials but additional, more reliable, techniques are needed. This study suggests that energy release rate is a more reliable measure and can be computed for experimental fires in either chemically treated or untreated fuels. Since energy release rate is a function of both flaming and glowing combustion; and since some chemicals have an effect on these burning characteristics, measuring energy release rate gives a direct measure of the chemical effectiveness. Results of this study make it possible to screen chemicals more effectively and actually improve our selection capabilities when choosing retardant chemicals for fire control use. INT (32, 33)

Conducting safe, effective burning-out operations on wildfires is critical to successful control of the fire. Preventing spot fires or radiant ignition from broadcast burning operations is also important in using this tool effectively. A light, portable, oscillating sprinkler system has been developed to supply water to nearly one-fourth of a mile of fireline. In this manner, water can be applied to the fuel adjacent to the fireline, and can be used to assist in mopup when the burnout is completed. This technique makes it possible to conduct burning-out operations at the most effective time, and do it with a high degree of success. PSW (28).

The complexities of making objective decisions concerning long-range fire control planning suggests that computer simulation of fire management systems may provide the best alternative for preparation of budget requests and allocation of funds. A computer model that includes fuels, resource values, fire and weather history, topography, and transportation routes is being tested on a representative ranger district. PSW (26).

The fuels that are consumed in fires in the Interior of Alaska exhibit fundamental characteristics that encourage the use of nonviscous liquid concentrate forest fire retardants. In addition to more adequate fuel penetration, the fire retardant appears to be superior from a mixing and cost standpoint, but may present storage problems at low temperatures. PNW (31).

Preparing fire occurrence maps has been a tedious and time consuming task. This study has assembled a computer program that has as its output fire occurrence overlays (scale 1 in. = 1 mi.) for areas where fire location is based on the U.S. public land survey system. With some alterations, the program can be used by fire control agencies utilizing grid systems for fire location. Results of this work make it possible to maintain current, accurate fire occurrence maps for use in fire control planning. SO (1).

3. FOREST FIRE SCIENCE

Calibrated photographic sampling using 35 mm. color transparancies is useful in determining the weight ratios of fine fuels and relative position in the fuel-bed complex. With additional refinements, this technique can be used to largely eliminate the problem of subjective judgment that has made fuel appraisal systems so difficult in the past. PNW (48).

The small components in logging slash are the prime contributors to rate of fire spread in this fuel type. Large-scale, fixed-based photography taken from a helicopter provides a reliable technique for appraising this hazard in terms of available fuel by size class. This information can in turn be used in fire control presuppression planning. PNW (15).

Evaluating the effectiveness of a prescribed burning operation is more important now than it has ever been. By actual measurements following burning on clearcut areas, the rate of fire spread on burned plots was 27 percent of the spread estimated on unburned plots. Differences in rate of spread between burned and unburned plots ended at about 16 years but a significant degree of fire protection can be provided through a planned program of hazard reduction burning. PNW (14).

The problem of predicting mass fire behavior has been with us for many years. This summary report on Project Flambeau, an exploratory study into mass fire phenomena brings together the results of burning 6 large-scale test fires on isolated sites in California and Nevada. The report covers the period 1964-67 and outlines some of the findings concerning the characteristics and behavior of mass fires, the research approach used, and the results obtained. This base of knowledge can now be used to design future experiments and at the same time provide a better understanding of high intensity fires. PSW (44).

Measuring physical fuel properties in a natural environment and using these measurements as a basis for comparison of fuel-bed characteristics has presented some difficult problems in the past. Two closely associated fuel studies have provided a common denominator for describing natural fuel beds. Bulk density and particle spacing is substituted for surface area-to-volume-ratio as a descriptor of fuel, and bulk density is used to describe the vertical fuel distribution in spruce-fir logging slash. Using these measurement techniques, it appears likely that direct comparisons can be made between various fuel complexes. The knowledge will contribute to a more reliable system of fuel appraisal. INT (41, 42)

Observations of small-scale experimental fires frequently reveal a pulsating phenomena in the convection column that, until now, has remained largely unexplained. This study indicates that this pulsation period can best be explained as being proportional to the square root of fire diameter when the buoyancy number is held constant. The results of the study constitute partial verification of scaling laws developed for modeling convective fire behavior and provides another link in better understanding the basic mechanisms of fire. SE (43).

The physical characteristics and extensive distribution of chamise (Adenostoma fasciculatum) makes this chaparral species one of the most hazardous wildland fuels in the Pacific Southwest. Chamise shrubs were analyzed for their structural characteristics, chemical makeup, and heat value. Methods of estimating the characteristics of this fuel in the field make it possible to do a better job of predicting fire behavior. PSW (45).

Fuel appraisal and evaluation has the inherent problem of being subject to personal bias and observational inconsistencies. A dichotomous key has been developed to identify 36 distinct fuel complexes on the basis of expected rates of fire spread and crown fire potential. The key appears to be useful for inventorying fuels for fire planning purposes, scouting conditions on going fires, and for fire control training. It provides an interim tool in the development of a national fuel appraisal system that is designed to provide a uniform approach to considering forest fuels in national fire control planning. PNW (47).

It is important that experimental fires in the laboratory exhibit a high degree of uniformity in burning characteristics--particularly rate of fire spread. A technique has been developed for constructing pine needle fuel beds that largely eliminates errors due to differing techniques of fuel bed construction and personal bias. Fuel beds having essentially the same rate of spread characteristics can now be quickly constructed by different technicians, thereby eliminating the need to rely on one individual to handle all the fuel bed construction work. SE (46).

A graduate and undergraduate program in Forest Fire Science at the University of Washington continues to provide specialized training and research opportunities for individuals interested in forest fires, fire research, and fire control. The Fire Science Academic Program has currently enrolled 7 Ph.D. candidates, 4 candidates for the master's degree, and 2 underclassmen. PNW (67).

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B. Improving Insect and Disease Control

1. LIFE HISTORY AND ECOLOGY OF INSECTS

a. Bark beetles

Radioactively tagged spruce beetles were released in Colorado to determine their dispersal habits. The pattern of attacks from nearby trees to the more distant trees provided quantitative data on rate of attack, dispersal, and some understanding of why outbreaks of this insect develop as they do. RM (49).

Two species of southern *Ips* beetles showed different attack patterns on fresh pine slash in Tennessee. The flight of *I. avulsus* was more highly aggregated than the flight of *I. grandicollis*. Degree of aggregation during flight may be an index of aggressiveness of *Ips* beetles, since it influences attack success on a living host. PNW (35).

A 3-year study of *Ips pini*, a bark beetle which builds up in thinning slash of ponderosa pine, has shown that density of attack in such material varies little with season of cutting. However, more standing trees are infested and killed following spring and summer thinnings than following fall and winter operations. This suggests that the effects of tree and stand conditions on beetle survival are more important in determining subsequent tree killing than is the rate of attack. PNW (48).

The western pine beetle and its predators and parasites are not evenly distributed over the stem of infested trees. These variations in spatial pattern and the interactions between organisms must be taken into account in designing within-tree sampling procedures. This information will lead to more accurate and reliable estimates of beetle numbers and trends. PSW (15).

Survivorship curves and life tables provide a basis for quantitatively analyzing populations of the western pine beetle. Proper analyses reveal which agents (parasites, predators, disease, weather, etc.) cause changes in population numbers. The activity of some of these agents can then be manipulated to suppress and maintain pest populations at low levels. PSW (16).

Blue-stain fungi, commonly associated with the southern pine beetle, have been found to be inhibited in egg galleries and initial larval mines, but they develop rapidly after the beetle larvae move into the middle bark. However, construction of egg galleries and development of larvae are inhibited wherever the fungus has previously colonized the inner bark-outer wood surface. This complex relationship between the beetle and associated fungal organisms is another example of the many factors affecting establishment and survival of this destructive tree killer. SO (5).

A new species of blue-stain fungus was found on the surface of the black turpentine beetle. The fungus may be an important associate of the beetle and of other fungal symbiotes in infested trees. SO (6).

Morphological studies of the round-headed pine beetle revealed two types of gland cells associated with the fungus-carrying tube in the female beetle. These gland cells may secrete substances responsible for keeping fungi alive and in pure culture in the fungal tube. SO (7).

Infestations of the black turpentine beetle occasionally have been observed extending to heights of 15 to 30 feet, with some attacks initiated at 15 to 20 feet. This bark beetle usually attacks the basal 18 inches of a tree. These changes in attack behavior may reflect possible genetic changes in the beetle or simply an inadequate understanding of its behavior. SE (13).

In 1970, the presence of the Dutch elm disease had been confirmed in all States east of Oregon, Washington, Montana, Utah, and New Mexico, except for Louisiana and Florida. Elm bark beetles occurred in all of the contiguous States except Montana, Arizona, and Florida. The extremely widespread distribution of the insect vector suggests that the Dutch elm disease may continue to spread throughout the major elm-growing regions of this country. NE (4).

b. Defoliators

Population density of the jack-pine budworm was studied in three areas in Michigan. Partial life tables were constructed to show rates of survival for each stage of the insect. Fecundity was also calculated. Results of this cooperative study, conducted under a Forest Service research grant, revealed the principal factors causing mortality during each age interval and their ultimate effects on generation survival of the budworm. WO (23).

Increases in populations of the large aspen tortrix depend, in part, upon the availability of quaking aspen foliage. When tortrix larvae are forced to feed on other host plants, significant reductions occur in size and survival of larvae, weight of pupae, and fecundity of adults. These primary effects cause the collapse of populations of this insect. PNW (9).

Pandora moth pupae remain in the soil for up to 5 years with some adults emerging each year. Surveys of pupae to predict abundance of feeding larvae must take this extended diapause and partial emergence into account. PNW (12).

Young caterpillars of the Douglas-fir tussock moth feed most actively on the new foliage of white fir. Larvae often starve when new fir growth is not available and the young larvae are forced to feed on the new needles of ponderosa pine. This causes populations to decline and reduces the severity of damage by this tussock moth. PNW (36).

Antibodies for *Lymantria dispar* and *L. obfuscata* were produced by injecting saline solutions of the insects' eggs into rabbits. Through a series of tests and experiments, it was shown that there were serological differences in the embryonic stage of both insect species. These findings from a cooperative P.L. 480 project in India agreed with earlier form and structure studies which indicated that *L. dispar* and *L. obfuscata* were different species. WO (32).

c. Shoot- and tip-feeding insects

Temperature significantly influences the mating and egg-laying behavior of the Sitka spruce weevil. Also, the weevil lays eggs only on 1-year-old and older stems, never on new terminals or laterals of any age. Fast-growing trees are weeviled more severely than slower growing ones. Discovery of these behavioral traits and patterns of attacks may be useful in developing cultural methods of control. PNW (25).

Closely associated species of pine-infesting weevils in the genera *Hylobius*, *Pachylobius*, and *Pissodes* can be readily identified with a new field key developed in Wisconsin. SE (26).

Life history and host selection studies have shown that two distinct *Conophthorus* spp. attack the shoots and cones of jack and red pine in Michigan. *C. banksianae* attacks the shoots of jack, red, Scotch, and ponderosa pines, but progency develop only in jack pine shoots. It may have two generations per year. *C. resinosae* prefers to attack cones and develops best in red pine. It has a single generation each year. This information explains observed differences in insect behavior and damage to the respective hosts although the insects appear to be the same. NC (38, 39).

d. Sucking insects

Cambial activity was studied in grand and subalpine firs infested by the balsam woolly aphid and in uninfested trees. The relative amounts of xylem and phloem present at any given time during the growing season were the same regardless of the presence or absence of the aphid. The rate of cell division showed no significant difference between samples of infested and noninfested trees of either species. Apparently this insect does not influence radial growth. PNW (51).

A 2-year study of balsam woolly aphids in North Carolina revealed that condition of host trees was the most important factor limiting number of aphids. Weather and predation killed many eggs, but these losses were of little consequence in determining population trend. Radial growth rate may be used to predict the potential of populations of aphids in advance of infestation. SE (1).

Trends in infestations of the balsam woolly aphid on European silver fir were followed over a 7-year period in North Carolina. Infestations occasionally increased to high levels, but these declined within 1 or 2 years without killing the trees. This is striking evidence of the resistance of *Abies alba* to prolonged aphid infestation. SE (3).

e. Cone and seed insects

Emergence and flight of adult seedworms, *Laspeyresia ingens* and *L. toreuta*, were influenced by rainfall and evening temperatures in northeastern Georgia. These environmental conditions also affected cone closure. This information will be useful in predicting the occurrence of attacks in the spring in Georgia seed orchards. SE (68).

The seasonal flight activity of five important moths infesting pine cones was determined during a 3-year study in north Florida. This information, and the use of blacklight traps, will help in determining the presence of these moths and in improving the timing of applications of insecticides and other control measures in southern seed orchards. SE (41).

Analysis has shown that the cone moth, *Dioryctria amatella*, has five larval instars in north Florida. Using this information researchers can determine the age of the larvae of this destructive insect. SE (18).

The reproductive organs of the cone moth, *Dioryctria abietella*, have been studied and described. Knowledge of the structure and function of the reproductive system is needed for studies of the effects of chermosterilants, production of sex pheromones, and sperm transmission. SE (20).

f. Wood-products and boring insects

Recent studies in Ohio and Kentucky have shown that the red oak borer, *Enaphalodes rufulus*, a major pest of red oaks in the Central States, has a

2-year life cycle. Adult beetles emerge from trees only in odd-numbered years. This knowledge of the timing of attack and symptoms of infestation is vital in planning silvicultural control. NE (28).

The Formosan termite generally survived better than two native subterranean termites on sawdust of 11 species of wood. Survival of all three termites varied by species of wood and, in some cases, between sawdust and wood blocks from the same tree species. This information demonstrates the host preference of different termite species. SO (53).

In feeding tests, the same three termite species preferred sound wood from two southern pines and sugar maple over other woods. Survival and feeding behavior in other wood species varied between heartwood and sapwood samples, and between trees of the same species. These differences may be intimately related to the gut-inhabiting symbiotic protozoa and their ability to digest or detoxify different woody foods. SO (54).

Worker termites of *Reticulitermes flavipes*, when exposed to both decayed and sound wood of six species, ate more decayed than nondecayed wood. They were most attracted to wood or extractives from wood of all six species after decay by the fungus *Lenzites trabea*. However, the most attractive food generally decreased survival of the insects. This emphasizes the unresolved question of the usefulness of the fungus to the termite under natural conditions. SO (55).

Colonies of Formosan termites forage over extensive areas. A colony in Louisiana less than 10 years old constructed galleries extending more than 200 feet from the original food source. Both living and dead trees were attacked. The ability of this foreign pest to adapt to environmental conditions in the southern United States is of increasing concern. SO (31).

g. Mathematical models

A mathematical model has been developed to describe the effect of sterilization of males in an insect population having overlapping generations. The model provides a tool for evaluating the effects of five different parameters on population control. NE (58).

h. Miscellaneous

Information about 16 major insect pests of yellow-poplar, their damage, and life histories have been summarized. Damage is illustrated and the role of parasites and predators in controlling the pests is noted. NE (10).

A large number of insects are associated with dwarf mistletoes of western conifers. Together they may or may not damage their host trees. Some insects feed on the parasitic plant. It is possible that the latter insects could be manipulated to achieve biological control of dwarf mistletoe. RM (59).

The stinging apparatus of the Texas leaf-cutting ant functions only to deposit a trail-following substance. In order to defend the colony, major workers depend on biting with their mandibles rather than stinging. This evolution of defensive mechanisms is of considerable interest in understanding the behavior of Atta texana and other leaf-cutting ants. SO (30).

An insect helps to feed big game. The poplar and willow borer, Sternochetus lapathi, infests willows more than 1 inch in diameter causing a flush of sprouts to develop. These provide a temporary increase in available browse for big game. INT (33).

2. INSECT PHYSIOLOGY, NUTRITION, AND REARING

In the laboratory and field, freshly cut pine disks or stumps are more attractive to the pales weevil than are pine seedlings. This behavioral response may be useful to lure weevils away from seedlings to traps in newly planted, cutover areas. SE (76).

An improved cage, featuring continuous flow of air from females to males and a light-to-dark illumination change has enhanced mating of the European pine shoot moth. Limited success has also been achieved with matings of the ponderosa pine tip moth and black-headed budworm. These procedures will facilitate biological studies and investigations of the use of sex pheromones and chemosterilants. PNW (72).

In the laboratory, the F_2 generation of the elm spanworm was affected by the type of foliage upon which the previous generation of spanworms had fed. Larvae feeding on normal red oak foliage produced lighter pupae. Weight of pupae and fecundity of female moths were higher for spanworms reared on hickory, particularly on juvenile foliage. Under nutritional stress fecundity may be sacrificed for food reserves, which, in turn, would encourage moth dispersal. SE (74).

An artificial medium has been developed for rearing successive generations of the cone moth, Dioryctria abietella, in the laboratory. Survival, fecundity, and growth rate were greater than in cones. This method of rearing will permit mass production of insects needed for studies of sex pheromones, feeding stimulants, egg laying stimulants, and bioassay of insecticides. SE (75).

The cone moth, Dioryctria abietella, now can be reared continuously on an artificial medium in the laboratory under sterile conditions. This new method eliminates contaminating microorganisms and reduces mortality previously experienced. Colonies of aseptic insects can now be reared in sufficient numbers for studies of nutrition, diseases, and transmission of plant diseases by the moth. SE (19).

Working under a grant from the Forest Service, university scientists reared larvae of Ips calligraphus on semi-artificial diets. These contained slash pine foliage produced in the previous year (mature) or current year (immature) or both together. Survival to the adult stage was better and developmental times were shorter when diets contained mature foliage or foliage of both ages. Apparently, older foliage contains substances that are more favorable to brood development and survival. WO (82).

Plastic-foam cups with plastic lids were found to be suitable for rearing larvae of the fall webworm. They are inexpensive, lightweight, rigid, and translucent. They also protect the contents from rapid fluctuations in temperature. NE (71).

A method has been developed which eliminates or reduces the need for anesthesia while separating, counting, and using small photopositive insects. This technique is useful when working with tiny insects such as parasitic wasps. NE (77).

Nineteen amino acids and two amides occur in the hemolymph of late-stage larvae of the smaller European elm bark beetle. These findings are basic to an understanding of the nutrition of this vector of Dutch elm disease. NE (78).

Study of the physiology and biochemistry of *Ips* engraver beetles under a Forest Service grant showed that the major fatty acids in all stages of *Ips calligraphus* were 16- and 18-carbon acids. Identification of these compounds and a knowledge of their distribution in different stages of development and sexes provides information of nutritional and physiological importance. WO (81).

Bioassays of sucrose, fructose, glucose, and extracts from loblolly pine inner bark revealed strong feeding stimulation for the pales weevil when sucrose and an inner bark lipid were present together. Synergism apparently occurs between sucrose and other fractions of the inner bark. The optimal concentration of sugars, the identity of the feeding stimulants, and other factors are being investigated to permit a full understanding of pales weevil feeding behavior. SE (84).

Several sugars and amino acids in honey locust leaves stimulate feeding of the mimosa webworm, *Homadaula anisocentra*. An additional unidentified chemical fraction apparently synergizes the activity of these sugars and other water-soluble constituents. These chemical stimulants largely determine host selection by the webworm. NE (80).

3. BIOLOGICAL CONTROL OF INSECTS

a. Invertebrate parasites and predators

Peak emergence of adults of the predator *Medetera aldrichii* was found to occur 20 to 30 days prior to the mass emergence of the mountain pine beetle. Average emergence ranged from less than 1 to more than 6 individuals per square foot of bark. Because of its poor synchrony, *M. aldrichii* is generally not an efficient predator. RM (107).

Larvae of the predator Enoclerus sphegeus require a longer feeding period when fed entirely on small mountain pine beetle larvae. Larvae fed on medium- to large-sized larvae of the beetle developed in a shorter period of time. These data demonstrate that food quantity affects the larval biology and consumption of prey by this predator. INT (86).

Adults of Enoclerus sphegeus, a predator of the mountain pine beetle, are most abundant on beetle-infested trees in May and June. Activity is concentrated on the basal 5 feet of the trunk. Larvae of the predator develop at all heights, but are most numerous at the 1.5-ft. height in July. In the laboratory, each adult kills about one bark beetle per day; each larva kills about 25 bark beetle larvae and pupae during its feeding period. Thus, adults affect less than 1 percent of the adult bark beetle population while larvae kill approximately 5-17 percent of the beetles. RM (108).

Predators of the balsam woolly aphid may be identified in the field with the aid of new identification keys developed in North Carolina. SE (87).

In a special study in Colorado, no mites were found preying on the mountain pine beetle or spruce beetle. Mites of the genera Iponemus and Digamasellus were predaceous on the eggs of six Ips bark beetle species. A detailed biological study of Iponemus truncatus clarified its role in the biology of Ips pini and I. plastographus. RM (89).

Three species of predatory mites, Acarocheyla impolita, Prosocheyla acanthus, and A. virginiensis, have been described and illustrated. They were collected during a study of the seasonal history of the southern pine beetle in loblolly pine in central Louisiana. None of these mites are thought to have a direct effect on pine bark beetles, but they feed and multiply on other insects associated with beetles in host trees. SO (110).

Five new species of Anoetus mites and one new species of Bonomoia have been described as associates of North American bark beetles. Special attention was given to characters useful in distinguishing each stage from other anoetids and in clearing up the nomenclature on Histiostoma and Anoetus. SO (115).

Six species of ants preyed on jack-pine budworms which had been dislodged from their feeding sites and had fallen to the ground. This finding, along with records of ant predation on other defoliators, indicates that ants may be a factor in the population dynamics of this insect. NC (94).

Two new species of Corticeus have been found to be associated with the southern pine beetle in Mexico and Honduras. Their roles are poorly understood, but they are abundant and are probably omnivorous. SO (113).

Laboratory tests with the DD-136 strain of the parasitic nematode Neoaplectana carpocapsae resulted in a southern pine beetle brood reduction of 40-50 percent in infested pine bolts. Additional tests will focus on developing drying retardants since a moist environment is critical to early nematode establishment and survival. SE (100).

Almost 2,000 larvae from various species of *Pissodes* weevils were examined for nematode parasites or associates. Several new species were found, most of which were internal parasites. Several of these nematode associates are also commonly found with bark beetles. This relationship could be exploited to improve the biological control of the weevils and bark beetles. RM (98).

Two new parasitic nematodes were collected from the eastern subterranean termite. One species, collected from the gut, may be important in its effect upon the protozoan complement in the termite stomach and the insect's nutrition. RM (99).

Larvae and pupae of the pales weevil were found to be infested with nematodes in the field. This is the first known instance of nematodes of the genus *Neoaplectana* attacking this insect. It may be feasible to use nematodes against the weevil as a control practice. SE (112).

A total of 5,365 *Itoplectis quadricingulatus* were released in a 40-acre infestation of European pine shoot moth in Oregon. Approximately 30 percent of the shoot moth pupae were killed. Use of the parasite should be considered in integrated control programs in selected areas. PNW (106).

Parasites emerged from approximately 75 percent of the wax moth pupae attacked either once or twice by either *Apechthis ontario* or *Itoplectis quadricingulatus*. When second attacks on multiparasitized hosts occurred at least 3 days after the first attack, the parasite which attacked first was usually the sole survivor. *A. ontario* but not *I. quadricingulatus* tended to reject hosts containing a developing parasite. It was concluded that *A. ontario* was inherently a better parasite and tended to avoid cocoons which were already parasitized. PNW (105).

The southern pine beetle was found to have at least 98 other insects associated with it in East Texas. Many of these functioned as parasites, predators, and competitors, but others had no direct effect on the beetle. They varied in number, seasonal abundance and with height on the infested trees. Understanding the interrelationships of these insects will be necessary in studies of bark beetle population fluctuations. SO (103).

b. Vertebrate predators

Northern three-toed and hairy woodpeckers consumed from 2 to 20 percent of the spruce beetle brood in an infestation in Colorado. Predation reduced survival of beetle broods by 13 to 25 percent. This study supported the view that the degree of woodpecker predation depends upon the density of bark beetles. RM (96).

Woodpecker predation on spruce beetles and *Ips* engraver beetles in Engelmann spruce logs is affected by stand density. Comparisons of predation in dense, semi-open, and open forest conditions revealed that reductions of broods of the spruce beetle were greatest in semi-open conditions. This study suggests that spruce beetle populations can be reduced to a greater degree by woodpeckers in selectively logged areas than in lightly cut or uncut areas. RM (109).

Woodpeckers significantly reduced populations of several insect borers in southern hardwoods. Borers that attack smaller trees, particularly those less than 6 inches in diameter, were most likely to be eaten. Predation by woodpeckers was greatest during the dormant season when other food sources were limited. SO (111).

c. Insect pathogens

An outbreak of the Douglas-fir tussock moth collapsed in northern California. Survivorship curves and a partial life table illustrated that the population decline was primarily due to the natural occurrence of a virus disease. The incidence of disease was most prevalent in heavy populations. PNW (97).

Two distinct nuclear polyhedrosis viruses affect the Douglas-fir tussock moth. One induces formation of polyhedral bodies containing single rod-shaped virus particles, each within its own envelope. The other produces polyhedra with bundles of several rods within a common envelope. Both viruses affect the same tissues of the host. Future epizootiological studies must take into account the occurrence of these two viruses. PNW (93).

Studies at the University of Minnesota under a Forest Service grant have demonstrated that the nuclear polyhedrosis virus of the forest tent caterpillar has considerable promise for control of this insect. Since the disease does not spread easily, repeated coverage of threatened forest areas may be necessary to insure establishment of the virus. Field studies are needed to explore different formulations, methods and rates of application, requirements of the virus for establishment, efficacy, and persistence of infectious material. WO (104).

Pathogenic bacteria and fungi killed an average of 22 percent of the broods of southern pine beetle in five geographic areas of North Carolina over a 3-year period. Though brood density was relatively low, the effect of pathogenic organisms on brood survival was of considerable significance in maintaining populations at low levels. SE (102).

A technique has been developed for detecting internal and nonsporulating organisms in pine bark beetles. Exposure of the beetles to a 15-watt source of ultraviolet light was as effective as chemical surface sterilization in eliminating saprophytic fungi. The insect pathogens *Beauveria bassiana*, *Aspergillus flavus*, *Penicillium* sp., and *Fusarium solani* were subsequently recovered from dead beetles. These now are being tested against healthy adults of the southern pine beetle. SE (101).

A series of helicopter spray tests provided information on equipment for safe and efficient application of microbial insecticides to control destructive forest defoliators. A spray system with spinning nozzles has been developed. It produces a fine spray and an application rate of 0.2 gallon per acre. Another spray system, using conventional nozzles, has been developed for producing coarse sprays and application rates of 1 to 2 gallons per acre. This information will be used in fabricating equipment for applying different microbial materials. PNW (90).

4. CHEMICAL CONTROL OF INSECTS

a. Insecticides

Two consecutive years of spraying with methoxychlor, applied either with a helicopter or with a mist blower, curtailed the rate of spread of Dutch elm disease. From 1969 to 1970, incidence of the disease decreased by 32 percent in plots sprayed by helicopter and by 34 percent in plots sprayed by mist blower. Incidence of the disease increased by 94 percent in untreated plots. Bioassays indicated that the residual life of methoxylor exceeded one year. Continuing investigations will explore: preventive spraying to protect all elm trees against disease inoculation; refinement of application methods; and the possibility of buildup of methoxychlor residues following several years of spraying. NE (116).

Responses to several concentrations of DDT and methoxychlor by the smaller European elm bark beetle and a parasite, *Dendrosoter protuberans*, were measured in laboratory assays. About 100 times more methoxychlor than DDT was required to affect 50 percent of both insects. Most important, these results show that deposits that are toxic to the beetle will probably be equally toxic to the parasite. NE (125).

In the Pacific Northwest, populations of the western spruce budworm were reduced to low levels by spraying with DDT in 1951, but oscillations in numbers have occurred in succeeding years. Parasitism of small larvae remained stable or increased slightly 1 or 2 years after spraying, then parasitism increased to levels comparable to prespraying years. Parasitism of large larvae one year after spraying varied but was high in some areas. Thus, the spraying effectively suppressed the budworm population and reduced damage while having only temporary effects on the complex of parasites. PNW (118).

A low concentration of Lannate topically applied to 6th stage larvae of the western spruce budworm caused hyperactivity, regurgitation, bleeding, and prostration. Fifth and 6th stage larvae lost hemolymph and gut fluid equaling 28 percent of their body weight. Larvae surviving treatment with Lannate in the 6th stage showed lower weights as pupae and reduced fertility as adults. Sublethal doses of this material may be useful for control of the budworm. PSW (130).

Six insecticides were tested in the laboratory as aerosols against larvae of the larch casebearer. Direct contact tests, using the equivalent of 1.5 ounces per acre, revealed that Zectran, malathion, and Sumithion were the most effective materials. PSW (135).

Spraying with 2 percent lindane in diesel oil prevented attacks by the western pine beetle and mountain pine beetle on ponderosa pine for 36 months in California. A 2-percent emulsion of lindane in water was 90 to 99 percent effective for 22 months. Though highly effective, the practical use of these sprays in preventive control would depend on other factors such as value of the tree and environmental impact. PSW (141).

Lindane in diesel oil reduced mountain pine beetle survival by 92 to 97 percent in infested ponderosa pine in Colorado. It was as effective as the commonly used ethylene dibromide but only 10 percent as much total spray was required. The necessity to fell and buck trees prior to treatment also reduces environmental contamination. RM (142).

Cacodylic acid (Silvisar 510) was highly effective in preventing brood development of the mountain pine beetle in ponderosa pines that were infested about 2 weeks before treatment. Treating costs were about $2.00 per tree, considerably lower than costs for other methods of direct control. Timing of the treatment was critical, and studies are continuing to refine this element. RM (123).

Four systemic insecticides, dimethoate, oxydemeton-methyl, discrotophos, and Monitor, implanted in trunks of slash pines in early May significantly reduced infestation by *Dioryctria* cone moth and *Laspeyresia* seedworm. Additional tests are needed to provide sufficient data to support registration of these pesticide uses. SE (137).

The systemic activity of several structurally modified carbamate, organosphosphate, and triazole pesticides has been evaluated. All insecticides investigated except malonyl-, succinyl-, and glutaryl-trichlorfon, moved in only one direction in the transpirational stream. Some pesticides failed to move downward with the photosynthate because membranes in the phloem were impermeable to them. However, if the compound contained a functional labile acid group, then uptake and long-distance translocation occurred. These results have broad application in developing herbicides, fungicides, and growth regulators that will move effectively in plants. PSW (124).

Bioassays indicated that technical Bidrin was not effectively absorbed and translocated into stems and new growth when applied as a soil drench around 2-year-old, potted loblolly pines. High pales weevil mortality was limited to insects feeding on roots indicating limited absorption. The poor movement or rapid degradation of Bidrin in pine seedlings and the short residual life of this insecticide indicate that no further evaluation of this material applied as a soil drench would be desirable. SE (145)

A field study of two forest soils, one mineral and one organic, indicated that high residues of the systemic insecticide Bidrin were present in the upper 6 inches of soil for only 15 days following treatment. Thereafter, leaching of the insecticide was fastest in the mineral soil. After 90 days, total residue level was low and approximately equal in both soils. Thus, Bidrin does not persist for extended periods in mineral and organic soils. SE (144).

Neither Zectran nor No. 2 fuel oil, applied to soil in concentrations greater than those used in operational programs, affected activity of microbes in the soil. Therefore, it is unlikely that low volumes of this insecticide to control forest defoliators will be harmful to soil organisms. PNW (117).

The persistence of aldrin, chlordane, dieldrin, and heptachlor in soils from seven different locations in the U.S. was compared. Greater insecticide losses occurred from surface layers than from the subsoil. The most complete conversion of aldrin and heptachlor into related compounds, dieldrin and heptachlor epoxide, occurred in soil from Hawaii. A second degradation product of heptachlor, 1-hydroxychlordene, was found in all samples after weathering for 3 months. Heptachlor was the component of technical chlordane affected most by weathering. These patterns of degradation of insecticides may have considerable significance in recommendations on control of termites by using soil poisons. SO (119, 120).

Initial penetration of chlorinated hydrocarbons was found to be least in arid soils (e.g., Arizona, Oregon) and greatest in moist soils (e.g., Missouri) at time of application. Laboratory tests confirmed that penetration depended upon both the type of soil and its level of moisture at the time of application. Other experiments showed that the amount and distribution of insecticide residues and degradation products varied considerably by location and associated weather conditions. These findings will effect termite control recommendations in different areas of the nation. SO (121, 122).

Mist blower applications of four insecticides were shown to be effective for the control of Dioryctria coneworms and a seedworm, Laspeyresia ingens, on longleaf pine in north Florida. Best control was achieved with three monthly sprays, starting in mid-April, of a 1.0 percent water emulsion of Guthion applied at the rate of 2 gallons per tree. The estimated value of increased seed yield more than offset the cost of treatment. SE (126).

At concentrations of 0.01 percent, three carbamates, Matacil, Union Carbide 10854, and Zectran, and three organophosphate compounds, Bayer 46676, fenthion, and Sumithion, killed all young larvae of the elm spanworm in 48 hours. At the same concentration, Matacil and Zectran also killed all 4th and 5th stage larvae in 48 hours. All of the above compounds should be considered for field testing as alternatives for DDT in controlling the elm spanworm. SE (127).

Several insecticides were applied topically to late-stage larvae of the fall cankerworm. Pyrethrins, Zectran, and Gardona were more toxic than DDT. These materials should be good candidates for field trials. PSW (133).

The transfer of very small amounts of radioactive dimethylamine can be avoided by using a simple method developed to synthesize aryl dimethylurea herbicides (III), such as monuron and fenuron. These compounds are being used to study structural characteristics of chemicals in the translocation of systemic pesticides in trees. PSW (132).

(For an additional item relating to II B 4a see paragraph under I A 3.)

b. Natural products

Fifty-five insecticides were tested in the laboratory for their toxicity to larvae of the Douglas-fir tussock moth. Pyrethrins, Dursban, Zectran, and dichlorvos were significantly more toxic to the insect than DDT. Field tests are needed to evaluate their effectiveness under natural conditions. PSW (134).

Large numbers of orange tortrix, *Argyrotaenia citrana*, were successfully reared on an artificial diet of wheat embryo for screening of insecticides. Topical application of four compounds to 5th stage larvae showed that pyrethrins and Zectran were more toxic than DDT or malathion. PSW (139).

Five insecticides were tested by topical application to 3rd and 4th stage larvae of the California oakworm. Results with pyrethrins, Zectran, and malathion were good enough to warrant field testing. PSW (140).

A new stabilized formulation of pyrethrins has been successfully field tested against the western hemlock looper in Washington. Effectiveness was markedly influenced by initial exposure of the insects to the insecticide. Effectiveness of the stabilized pyrethrins in a natural forest environment will therefore depend to a large extent on the accuracy and thoroughness with which the insecticide can be delivered to the target insect. PNW (136).

5. SILVICULTURAL AND MECHANICAL CONTROL OF INSECTS

Four management alternatives have been proposed for regulating mountain pine beetle populations in Rocky Mountain lodgepole pine stands. These include: (1) converting stands to subalpine fir--Engelmann spruce or to Douglas-fir; (2) shortening cutting cycles to lessen the risk of loss due to the mountain pine beetle; (3) mixing species that would probably produce more wood than pure lodgepole pine stands while lessening susceptibility to the beetle; and (4) establishing stands with several age classes so as to minimize the occurrence of large, vigorous, susceptible trees and facilitate prompt removal of infested trees. INT (148).

The lower peninsula of Michigan has been divided into low, medium, and high hazard zones for infestation and damage by the pine root collar weevil. New plantings should not be established less than one mile from a weevil infestation in the high hazard zone or less than one-half mile in the medium hazard zone. This will lessen the probability of such plantings becoming heavily infested. NC (149).

Early basal pruning of the bottom 1 to 1 1/2 feet of the stem will help control the European pine shoot moth, the pine root collar weevil, and Scleroderris canker. The cost of early basal pruning compares favorably with insecticide spraying costs and provides an alternative to the use of chemicals. NC (150, 151).

Vulnerability to excessive damage by the western spruce budworm in the northern Rocky Mountains can be reduced through stand management. Recommended practices include maintenance of relatively open stands of thrifty trees along with logging of favored hosts, true fir and Douglas-fir, in order to leave nonhost trees. PSW (152).

6. HOST RESISTANCE TO INSECTS AND TREE PHYSIOLOGY

Analyses were made of the seasonal changes in free amino acids, other ninhydrin positive compounds, and carbohydrates occurring in the inner bark of loblolly pine. Five free carbohydrates were detected during the study. Total concentration of carbohydrates increased during the fall. Twenty-eight free amino acids and related ninhydrin positive compounds were also found. Definite seasonal changes in the concentrations of certain amino acids were noted. These findings will be useful in future studies of the diet of beetles feeding in the inner bark of southern pines. SE (154).

The number and concentration of soluble carbohydrates, free amino acids, fatty acids, and major inorganic constituents vary during maturation of pignut hickory and southern red oak leaves. An understanding of these chemical changes is needed in studies of the nutrition of important southeastern hardwood defoliators. SE (155).

The inorganic composition of inner bark and needles of loblolly pine varies with tree height and soil series. These differences are important in studies of insect nutrition and the influence of chemical changes on brood development and survival of insects feeding in the inner bark or foliage of loblolly pine. SE (161).

In bark infected for 5 weeks with blue stain fungus, *Ceratocystis minor*, total amino nitrogen decreased 36 percent and soluble carbohydrate decreased 80 percent. Fructose, glucose, and sucrose were nearly depleted. A three-fold increase in free fatty acids occurred. These chemical changes are important in understanding interrelationships among bark beetles, blue stains, and host tissues. SE (158).

A detailed and comprehensive analysis has been made of transport of materials in the phloem of plants. Citing some 700 contributions, the authors have drawn new conclusions about the physical and chemical factors associated with the transport of solutes, including insecticides, in trees. They lay a foundation for the eventual explanation of mechanisms facilitating movement in all plant tissues. Every factor related directly or indirectly to phloem transport is discussed, documented, and interpreted. PSW (156).

The increased use of systemic chemicals to control forest insects prompted Southeastern entomologists to investigate the movement and distribution of injected dye in five species of southern pines. Acid fuchsin dye ascended upward in the trunks of all species in a clockwise, spiral pattern. In the branches, the flow of dye was parallel to the branch axis. Studies of the uptake, translocation, and distribution of systemic chemicals should take these distribution patterns into account. SE (160).

Large local and regional variations in the monoterpenes of ponderosa pine have been found. There is an indication that the western pine beetle is a more serious pest in regions where there is a more equitable concentration of the five major monoterpenes--α-pinene, β-pinene, 3-carene, myrcene, and limonene. The insect is less important in regions where the concentration of one of these terpenes is markedly greater than the others. PSW (159).

7. INSECT SAMPLING AND SURVEY METHODS

An experimental rating scheme has been developed for ranking the impact of insects on multiresource values of natural forests in the North Central States. Total numerical ratings are obtained for specific pest insects as they affect timber, recreation, wildlife, and water values. Both biological and economic factors are taken into account. Judgment of individual ratings is essentially subjective, based on historical data and experience. NC (162).

A serial method has been developed for sampling "within-tree" populations of the western pine beetle and associated insects. Bark is collected repeatedly from selected trees, and density of the insects is determined from radiographs. Analyses of the data acquired indicate the magnitude and causes of variation in density of populations. Survivorship curves, life tables, and models of population dynamics are then constructed. These portray the changing populations of beetles and provide a basis for predicting trends. PSW (163).

To obtain estimates of the broods of the western pine beetle within a 10 percent error special precautions must be taken in sampling. A number of heights must be included in the sampling scheme. A pair of large disks of bark should be taken at 5-ft. intervals from a plot of 3 to 5 trees. This information points to an optimum sampling strategy to measure variation in density of beetles. PSW (167).

Populations of the mountain pine beetle were measured using two types of sample units, a single gallery and a 6-by 6-inch square of bark. Each sample was measured and statistically analyzed in different ways to provide several types of biological information. Data from single galleries reflected all of the biological and behavioral characteristics of a single female beetle. Data from square samples of bark expressed total numerical change in the population, the degree of larval competition between and within galleries, and the effect of the density of attack on the egg-laying behavior of parent female beetles. Percent survival was rather consistent between measurement units regardless of time of sampling. The study showed that selection of a measurement unit should be dependent upon the information desired. INT (164).

Concentrations of the hemlock sawfly can be classified rapidly by a sequential sampling scheme. Branch samples are taken from the upper crowns of western hemlocks having intermediate crowns and examined only until a single egg is found. This greatly reduces the amount of field time needed to classify an infestation. The upper limit for an endemic to light population is when one-third of the trees sampled have an egg. The lower limit for a moderate to heavy population is when half of the sampled trees are infested. PNW (168).

A flexible, efficient method has been developed for sequential sampling of the western budworm. Budworm infestations are grouped into four classes of defoliation based on number of new egg masses per 24-inch branch. A minimum of 50 samples, two branches from each of 25 trees, must be taken from each survey plot. Based on successive counts of new egg masses, a reference table is consulted to determine if the infestation can be classified immediately, or if more branches must be examined. This produces faster and more reliable surveys. RM (172).

A new computer program eliminates much of the work associated with sequential analysis. This program applies to the problem commonly encountered by forest entomologists of deciding whether an infestation or damage should be classified as light, medium, or heavy. The program can also be used to obtain the required statistics for a decision as to whether or not to control a pest. NE (173).

A standardized procedure for sampling the Douglas-fir tussock moth has been developed. Densities of populations are estimated and expressed in terms of the number of eggs or larvae per 1,000 square inches of branch area. While larvae are found over the entire tree and are especially concentrated in the top of the crown, their density in the middle of the crown is representative of the whole tree. Because eggs are clumped in masses and larvae are dispersed over the foliage, the density of larvae can be estimated more easily and precisely than egg density. PNW (171).

The use of large-scale color photography permits accurate appraisal of mortality of white fir following defoliation by the Douglas-fir tussock moth. Photography takes less time and costs less than ground methods. Comparison of photointerpretations with a ground survey has given high correlations for detection of tree mortality and top killing. Mortality estimated from photos of a particular study area was within 5 percent of the estimate from a ground cruise. PNW (176).

The application of thermal techniques in detecting stress in plants is still in the developmental stage. Until advanced infrared systems are available, resource managers will need to rely on multiple channels of simultaneously registered infrared data. The most successful method for detecting insect attacks, diseases, or air pollution damage by remote sensors has been with a 3-channel combination of two reflective infrared channels with one thermal channel. PSW (174).

Airborne multispectral remote sensing and automatic multispectral processing have much potential in the previsual detection of damage from insect infestations, disease outbreaks, and oxidant air pollution. Optical mechanical line scanners have been flown over instrumented ground test sites in several different forest communities and remote sensing data collected. Reflective and emissive differences among stress-induced trees have been well documented from ground measurements. These techniques have been described in terms of how they perform in detecting plant stress. PSW (175).

Applications of airborne multispectral remote sensing and the potential of automatic multispectral processing were investigated in the Black Hills of South Dakota. Multispectral imagery of excellent quality was obtained from three altitudes and at four different times of day. Multiple channel processing of data was achieved in two spectral areas, and specialized single channel processing was used for thermal infrared data. Classification errors were reduced by adding data from thermal infrared imagery to data from visible and near infrared imagery. These improved techniques permit improved detection of trees under stress from insects or diseases. PSW (169).

Tree-ring measurements may be used to estimate the loss caused by defoliating insects, to date older insect outbreaks, and to predict the potential damage caused by outbreaks of defoliators. Defoliations by the lodgepole needle miner, Douglas-fir tussock moth, and various other defoliators produce distinctive ring patterns in their hosts which can be used for such purposes. PSW (170).

A "stick" trap, utilizing female sex pheromone as bait, was developed for capturing males of the European pine shoot moth. Through a new procedure, duration of attractiveness of the bait was extended threefold. Males responded to the female pheromones over distances of at least 100 yards. The traps are particularly useful in detecting moths in areas with low populations. PNW (165).

Inconspicuous damage by the seed bugs, *Leptoglossus corculus* and *Tetyra bipunctata*, can be detected radiographically. This permits evaluation of larger seed samples and gives a truer estimate of seed damage. SE (166).

8. ROOT DISEASES

a. Annosus root rot

Scientists from North America and Europe produced an up-to-date analysis of the worldwide annosus root rot situation. Twenty-four papers and summaries of seven panel discussions on this destructive disease were recently published by the Forest Service. The cooperative effort is expected to yield far-reaching benefits through improved disease prevention and control on a global scale. SE (184).

Annosus root rot continues to be a serious problem of pines in the South, but control is now feasible. A comprehensive review of the situation suggests that future losses can be reduced through integrated control, by restricting thinning to the hot summer months, and by treating freshly cut stumps with powdered borax. Disease prevention can help sustain the high productivity of southern pine forests. SE (182, 183, 205).

Annosus root rot could become a serious problem in the Pacific Northwest. The pathogen is a natural component of these forests, usually occurring as a trunk rot. Worldwide experience suggests that annosus root rot may increase in response to intensive timber harvesting. Research is urgently needed to assess the potential of this disease and to develop means of preventing intolerable losses in this region of high timber productivity. PNW (212).

Borax has been registered as a treatment to prevent infection of pine and fir stumps by annosus root rot in California. Borax treatment greatly reduced invasion of the annosus root rot pathogen into freshly cut white fir stumps and offers a means of preventing intensification of this serious disease. Without protection, this fungus is expected to reduce the productivity and esthetic values of pine and fir forests in Western States. PSW (214).

Injuries at the base of loblolly pine stumps must be treated with borax to prevent annosus root rot. Powdered borax applied to the stump surface only penetrates 1 to 2 inches and would not prevent infection through wounds at the root collar. This finding should greatly increase the effectiveness of control treatments. SE (187).

Seedlings of pine species commonly planted in the South were easily killed in infection trials with the annosus root rot pathogen. In the same experiment, many eastern redcedars and all yellow-poplars and sycamores survived. These findings suggest that converting to trees other than pines may help avoid serious losses on annosus-infected forest sites. SE (189).

A new technique allows study of the annosus root rot in pines in the complete absence of other organisms. This provides a standardized system for studying host-parasite relations that may yield new methods of disease control. SE (186).

Bark is an effective barrier to fungal invasion because of its complex chemical nature. The annosus root rot fungus as well as 30 other fungi could not successfully decompose bark. This helps explain why tree felling and wounding, which expose the wood, increase the chances of infection by annosus. SE (188).

b. Poria root rot

Poria root rot, the most damaging root disease in Douglas-fir forests in Oregon and Washington, persists and attacks each successive forest crop. Effective control methods are lacking. Advances in knowledge of the fungus and of beneficial soil organisms should provide bases for developing effective biological controls. PNW (177, 178, 213).

Beneficial soil organisms may limit damage by the Poria root rot fungus. Special forms of nitrogen when added to the soil encouraged beneficial organisms thus reducing survival of the Poria fungus. This research suggests that biological control of Poria root rot may be possible in the forests. PNW (199).

Red alder may act as a biological control agent for Poria root rot in Douglas-fir forests. Compounds produced in red alder tissues and nitrate nitrogen are added to forest soils by root excretions and leaf litter. These materials inhibit the root rot fungus. Methods to isolate these compounds from red alder and from forest soils provide a breakthrough in developing effective biological controls. PNW (190, 191).

c. Nursery problems

Scientists in India working on PL 480 contracts have found fungicides that will successfully control damping-off of pine seedlings. Blitox, zineb, and cuman controlled the disease and were not phytotoxic. Additional research is needed to devise prescriptions for using fungicides in pine nurseries of India. WO (206).

Application of fungicides to prevent damping-off of ponderosa pine seedlings must be closely regulated to avoid reductions in seed germination. Excess fungicide is especially toxic to seeds at high temperatures. More efficient production of planting stock will result from careful use of fungicides in forest nurseries. RM (204).

Nearly one-third of planted slash and loblolly pine seed did not produce satisfactory seedlings in Georgia nurseries. These losses were largely caused by failure in seed germination, damping-off, fusiform rust, sunscald, and mineral spirits burn. Additional seed must be planted to compensate for expected losses. SE (209).

The need for frequent fumigation of seedbeds to control black root rot of slash pine may be reduced by manipulating soil properties. Mulching, frequent irrigation during hot seasons, and minimal nitrogen fertilization during the first 2 months after seeding reduce root rot severity. Fewer fumigations will reduce the cost of producing nursery seedlings. SE (210).

A new assay technique improves evaluations of soil fumigation for the control of the charcoal root rot of ponderosa pine seedlings in forest nurseries. Through a special sieving and flotation process, direct counts of the causal fungus can be made. Application of this technique has already shown that seedbeds need not be fumigated every year. PSW (215, 218, 219).

At least three species of the *Cylindrocladium* fungus can cause root rot of yellow-poplar seedlings. Species of this fungus isolated from yellow-poplar and from peanuts caused especially severe forms of root rot. These diseases must be prevented to produce hardwood planting stock efficiently. SO (179).

d. Nematodes

Experiments demonstrated the parasitic nature of 5 species of nematodes in ponderosa pine. Although populations of these nematodes were maintained for 13 months, the pine seedlings suffered no loss of growth. Parasitic nematodes are not always serious pathogens. RM (207).

Fumigation of nursery beds with methyl bromide successfully controlled the lance nematode. This parasite has caused considerable damage to ponderosa pine in nurseries in the Great Plains. Soil fumigation may greatly aid in producing healthy planting stock. RM (203).

Another species of lance nematode was found to parasitize root cells of mycorrhizae of shortleaf and loblolly pines. It is suspected that nematodes may upset the beneficial physiological aspects of mycorrhizae and allow entry of other root pathogens. SE (211).

e. Mycorrhizal antagonism

Inoculation with mycorrhizal fungi greatly stimulated growth of pines planted in Puerto Rico. Pine seedlings inoculated either with soil from southeastern United States or with pure cultures of mycorrhizal fungi exhibited markedly superior growth. Survival and growth of certain trees may be attributed in part to protection of roots from pathogens by ectomycorrhizae. WO (181).

Experiments demonstrated that mycorrhizae provide protection from attack by the root pathogen that helps cause littleleaf disease of shortleaf pine. The fungal component of the mycorrhizal association creates an antagonistic barrier to infection by the root pathogen. New avenues to biological control of root diseases may be feasible with a better understanding of the biology of mycorrhizae. SE (192).

Numerous new species of mycorrhizal fungi in the Pacific Northwest are being discovered. Indications are that more species of mycorrhizal fungi occur in that area than in any other area of the world. Identification of the many mycorrhizal fungi is a prelude to selecting for use those most beneficial to trees. PNW (217), WO (197, 198).

Root chemistry and temperature influence the ability of fungi to form mycorrhizae on tree roots. Basic physiological studies show the role of particular chemical compounds in stimulating mycorrhizal fungi. Experiments indicate that different mycorrhizal associations may be favored at different prevailing temperatures. An improved understanding of mycorrhizal physiology will enable the establishment of the most beneficial mycorrhizae for each situation. SE (194, 195), WO (201).

f. Miscellaneous

The ecology of major root diseases of forest and tropical plantation crops is discussed in a book edited by Forest Service scientists. PSW (216).

A reduction of food reserves in roots of sugar maple occurs as a result of drought and premature defoliation. This may explain why root pathogens can attack maples under stress. NE (202).

9. STEM CANKERS

a. White pine blister rust

New knowledge on the mechanism of resistance to blister rust and its associated genetic control is an important breakthrough in the Forest Service program to maintain western white pine forests. Recent research at the Intermountain Station indicates that several kinds of reactions are involved in resistance. One important mechanism involves premature shedding of infected needles. Others occur within needles or bark of resistant trees. Preliminary indications suggest that some of the resistance reactions are likely to be quite stable. With this new information, breeding of white pines with long-lived resistance should be much more feasible. INT (222, 237).

A two-stage, international program to test for blister rust resistance has been proposed. First, "naturally" resistant Eurasian white pines would be reevaluated. Next, North American white pines developed by artificial selection and controlled crossing would be subjected to more sophisticated tests. Key test centers are needed in Siberia, south-central Asia, the Baltic-North Sea countries, and in eastern and western North America. Initial inquiries indicate that five core cooperators could commence testing in the near future. INT (223).

The tuberculina purple mold, an agent for biological control of white pine blister rust, retains its infectivity and pathogenicity through many generations in cultures and for as long as 5 years. Also, the fungus can reproduce itself after only a short (2 to 7 weeks) incubation in rust cankers. These attributes are desirable in biological control agents, but more information is required before control potentials can be assessed. INT (251, 252).

Many years of analyses have confirmed that the antibiotics Phytoactin and cycloheximide were unsatisfactory for control of blister rust in forest situations. These antibiotics affected physiology of both fungus and host in ways that temporarily masked disease symptoms, but ultimately they did not save rust-infected trees. INT, NC (225, 241).

The spread of blister rust in a natural stand of white pine in North Carolina was followed over a 20-year period, starting about 10 years after the initial infection. Seedlings and saplings suffering heavy losses to rust were virtually eliminated from the stand. Mortality of older trees increased steadily during the 20 years. Almost half of the largest and most valuable trees were dead or dying from the disease at the end of the study. SE (242).

Detailed procedures for culturing healthy and blister rust-infected pine tissues have been published. Cultures of western white pines can sustain rust growth indefinitely with subculturing. The fungus can also infect Douglas-fir tissue cultures, but both die within a few months. The fungus cannot grow in absence of host tissues, but it remains viable up to 120 days on media with diffusates from host tissue. Tissue cultures are one key to a better understanding of the basic physiology of blister rust. INT (224, 226, 227, 228, 229, 253).

The occurrence of blister rust in white pine needles reduces their ability to form roots. Rooting dropped from 63 percent in bundles of noninfected needles to 44 percent in bundles of needles with typical spots signifying infection by blister rust. Evidently, infection affected the physiology of the needle bundle. INT (236).

b. Fusiform rust

Fusiform rust galls differ greatly from healthy tissue in chemistry and in physiological activity. Cytokinin activity was ten times greater in gall tissue indicating that hormones may be active in gall stimulation. As galls increase in size and age, phenols and heartwood area increase at the expense of water-conducting sapwood. These findings greatly increase our basic understanding of how this destructive rust affects its host. SO (243, 244, 245).

A new means of inoculating pines at precise points was developed using precast basidiospores of the fusiform rust fungus. Spores concentrated onto millipore filters may be stored up to 8 weeks with little loss in infectivity. Fine glass rods are used to transfer a relatively constant number of spores onto seedlings at specific points. An advantage in using stored spores is that plants can be inoculated with a uniform source of inoculum over a period of weeks. This is an important technique for furthering our understanding of rust fungi and for standardizing inoculations with this tree killer. SE (238).

c. Western gall and limb rusts

Western gall rust was found to be epidemic periodically in pines in the Rocky Mountains. Epidemics are often only a few miles in extent, but occasional "wave" years are detectable over regions involving several States. Wave years appear to be governed mainly by climatic factors occurring during aeciospore dispersal in late spring or early summer. This disease is potentially one of the more devastating diseases of western pines and outbreaks must be taken seriously by forest managers. RM (240).

The occurrence of western gall rust in northeastern United States and in southern Michigan was confirmed. The fungus causing the Woodgate gall rust of Scotch pine in New York was found to be identical to the western gall rust fungus. The gall rust fungus on Jeffrey pine in southern Michigan also was like the western rust fungus and has the same pine-to-pine infection cycle. Western gall rust now must be recognized as a serious disease of hard pines from coast to coast. INT (233).

Cytological evidence shows that the Inyo limb rust of Jeffrey pine has a pine-to-pine infection cycle similar to that of western gall rust. This suggests that sanitation harvests in stands infected with Inyo limb rust may aid in reducing future losses and in salvaging valuable trees before they are killed. INT (234).

d. Other canker diseases

Fungicide sprays were developed to avoid Scleroderris cankers in red pine nursery stock. Considerable infection by this serious disease was found in 1970 on red pine in a Lake States nursery. Experiments proved that Maneb and Ziram can effectively control this disease in nurseries. Only disease-free nursery stock is suitable for distribution. NC (247).

Aerial photography can be used to detect the beech bark disease. Changes in foliar symptoms were detected readily with both true-color and infrared-color films. Aerial photography has a great potential for examining and recording disease changes over large areas. NE (232).

Moderate control of crown gall of hybrid poplars was achieved by application of Bacticin. One year after treatment, about half of the trees remained healthy. Bacticin appears to have a high affinity for galled tissues, and it possesses chemotherapeutic properties. NE (231).

10. DWARF MISTLETOES

The world literature on the biology and taxonomy of dwarf mistletoes was reviewed, and problems in nomenclature, host ranges, and theories of evolution were analyzed. A new system of classification was proposed that should standardize worldwide concepts of the dwarf mistletoes. RM (255).

Two dwarf mistletoes parasitize pinyon and ponderosa pines in the western part of Texas. The more highly productive pine stands to the east remain free of these pathogens. RM (254).

Five new species of pine dwarf mistletoes were described. Two occur in western United States, two in Central America, and one in China. A better understanding of the many dwarf mistletoes can aid in improving the worldwide supply of softwoods. RM (256).

Brewer spruce is now known to be attacked by three species of dwarf mistletoe. Surveys in six Brewer spruce forests in southern Oregon and northern California show 36 percent of the trees were parasitized. Dwarf mistletoes are apparently the most serious disease of this rare tree. RM (257).

Insects and dwarf mistletoes have a close relationship. The mistletoes may increase the susceptibility of trees to bark beetles. Some insects pollinate the mistletoes and still others feed on the aerial shoots. By manipulating the population of insects that pollinate or feed on dwarf mistletoes, it may be possible to develop biological controls for these parasitic plants. RM (260).

Effective controls for dwarf mistletoes depend on basic knowledge of these parasites. Methods now have been developed to investigate viability and germination and infection at all seasons of the year. PNW, PSW (258, 259).

11. VASCULAR WILTS

Physiological studies indicate that the Dutch elm disease alters mineral balances within affected trees. Both phosphorus and potassium decreased in foliage of wilting trees. Nitrogen content was greater in resistant than in susceptible trees. Nutrients apparently influence fungus physiology and the process of wilting. Chemical analyses of candidate trees may be useful when searching for resistance. NE (264).

As of 1969, scientists knew of Dutch elm disease in six counties of Colorado. The most serious outbreak of this wilt disease is in ornamental trees in the city of Denver. The disease is intensifying and expected to cause considerable damage. RM (261).

12. FOLIAGE DISEASES

a. Conifer needle diseases

Reduction of damage by needle blight in the Great Plains seems feasible with use of resistant pines. Evaluation of Austrian pine from 21 geographic sources indicates that some individuals from 16 sources are highly resistant. One source from central Yugoslavia shows universally high resistance. Genetic resistance is probably the most promising technique for controlling this disease without creating harmful side effects. RM (276).

Growth of longleaf pine could be doubled in Louisiana through use of genetically improved planting stock that would remain only lightly infected by brown spot. Variation in resistance was noted early during a 30-year study near Bogalusa. Those trees that were only lightly infected survived and grew better. By the time the plantation was 30 years old, lightly infested trees had produced 1.7 to 2.4 times as much pulpwood as more severely diseased trees. SO (279).

Dothistroma needle blight is now known in India on Monterey and blue pines. This disease poses a serious threat to young pines in humid regions. WO (265).

The brown spot needle disease of Scotch pine is now known to occur in Wisconsin, Minnesota, Iowa, and Nebraska. Since this disease is especially harmful to the short-needled varieties that are favored for Christmas trees, it is of serious concern. University, State, and Federal scientists are combining research efforts to improve control measures for growers of Christmas trees. NC (272, 274, 278).

A needle cast disease that commonly damages pines in nurseries of the Lake States was found on Scotch pines in a Christmas tree plantation in Michigan. This disease can be held in check in nurseries by frequent application of fungicides during the growing season but similar treatment of plantations would not be feasible. The potential of this disease in plantations should be assessed since planting is so universally used in the silviculture of pines in the Lake States. NC (271, 273).

Knowledge of Elytroderma needle blight was recently updated. This continues to be the most important needle disease of ponderosa pine in the Pacific Northwest. Control by sanitation-salvage cuttings is recommended to reduce losses. PNW (267).

Scientists in California found a needle cast fungus on bristlecone fir. This is the first disease reported in natural stands of this rare tree. The fungus probably is native to the area and not too damaging. PSW (277).

(For an additional item relating to II B 12a see paragraph under III A 3.)

b. Hardwood leaf diseases

Anthracnose reached epidemic proportions on sycamores in the Mississippi-Yazoo Delta in 1970. Approximately one-third of the larger sycamores in the Delta were attacked by the disease, and defoliation was often severe. If this disease continues to intensify, it could be extremely harmful to one of the fastest growing trees of the Delta. SO (270).

A careful study of tar spot on bigleaf maple in western Washington provided a clear understanding of this common disease. The fungus is well adapted to climatic conditions in the Pacific Northwest, but it seldom causes serious damage in natural stands. INT (280).

A virus could not be found in overcup oak seedlings having symptoms of a viruslike disease. Badly disfigured leaves, resembling those of the mosaic virus disease of oak in Europe, occurred on many seedlings grown from acorns in Alabama. All attempts to transmit the disorder failed. Electron microscope examination revealed no evidence of a virus causal agent. NE (269).

The Marssonina leaf fungus was shown to lose its pathogenicity rapidly when grown in culture. Much greater virulence was maintained when spores on leaves were stored for 3 years at -12° C in deflated plastic bags. This finding should have application in experimental studies of the Marssonina leaf disease of poplars. WO (275).

13. AIR POLLUTION DAMAGE

Air pollution appears to be an ever-increasing problem for trees in the United States. Ozone, sulfur dioxide, and fluoride are of special significance in our contaminated air. Implementing high standards of air quality is necessary to alleviate this serious problem. NE, PSW (284, 286, 287, 289).

Fumigation experiments with ozone ad sulfur dioxide proved their injurious nature to jack, red, and white pines. Both gases produced injury on needles ranging from flecking to tipburn. Jack pine was the most sensitive to ozone, and red pine was relatively tolerant of sulfur dioxide. Relative sensitivity to pollutants may determine the species of trees to be planted in various regions. SE (282, 283).

Air pollution now causes severe damage to plantations of Christmas trees in the East. Chronic air pollution symptoms have been found on Scotch pine in Ohio, and on Scotch pine, Norway spruce, Douglas-fir, Virginia pine, and eastern white pine in Maryland and West Virginia. Damage to trees is expected to increase unless air quality improves. NE (285).

A compilation was made of trees and shrubs that are either tolerant or sensitive to air pollutants. Professional landscapers and horticulturists should find this to be a valuable guide to planting ornamentals in urban areas. NE (284).

Topography and weather affect movement of polluted air resulting in particularly serious damage to the conifer forests on the mountains east of Los Angeles. Measurements at ground stations and by instrumented aircraft indicate that pollutants usually are concentrated in air from about midslope in the chaparral zone to the mountain crest. Forests in these mountains will continue to be affected as long as chronic air pollution exists. PSW (288, 290).

Brush seems to be replacing ponderosa pines lost to air pollution damage in southern California. Ecological studies in the San Bernardino Mountains indicate that more resistant conifers, such as sugar pine, are not replacing damaged ponderosa pines, especially on exposed sites. If chronic air pollution continues, dramatic changes in native vegetation can be expected. PSW (289).

14. DETERIORATION OF WOOD

Establishment of heartrot in trees appears to be strongly influenced by dynamic changes in the physical, chemical, and microbial components of injured wood. Bacteria and nonrotting fungi apparently invade wood and change it. The result is that infected wood is more easily decayed by rot fungi. The final result is a badly decayed central core of wood surrounded by a discolored zone. A better understanding of the nature of decay in living trees will lead to better means of appraising heartrots and of prescribing techniques for control. NE, WO (311, 314, 315, 317).

Butt rots that allowed large hackberry trees to break and fall in Alabama were linked to mechanical damage inflicted during logging operations. Previous information had associated this kind of hackberry rot only with fire scars. To avoid this butt rot and premature tree fall both fire and mechanical wounds should be minimized in hackberry stands. SO (308).

Red rot was present in 68 percent of a representative sample of ponderosa pines in the Black Hills. In an analysis of 498 trees, 8.6 percent of the timber volume was defective because of red rot, and 7.3 percent was defective because of brown rots. This new information on the amount of defect is being used to obtain a more accurate estimate of the usable wood resource of the Black Hills. RM (303).

Deodar cedar is attached by a serious butt and trunk rot in a plantation in Aleo Bihal, India. Indian forest pathologists, working under a PL 480 grant, were able to determine the fungus causing decay and its extent. Techniques were developed to enable cutting of logs to salvage maximum amounts of sound wood. WO (294).

Paraformaldehyde inserted into the taphole can increase the yield of sugar maple sap, but it also increases the hazard of invasion by heartrots. Unfortunately, the chemical interferes with the wound-healing process. Eventually, a variety of organisms, including heartrotting fungi, invade the wood. NE (316).

An anaerobic bacterium may be implicated in the process leading to heartrot in oak. This bacterium was isolated from fluids exuding from freshly cut, discolored wood associated commonly with galleries made by wood-boring insects. The bacterium itself does not cause decay, but as a result of its effects on living cells in wood, it may increase susceptibility to other organisms, including wood-rotters. NE (318).

Research is underway to determine if bacteria occur in healthy wood even before wounds are made. Researchers at the Southern Station found several kinds of bacteria and nonrotting fungi in healthy sapwood of longleaf pines. It appears that pioneer microbes begin the succession of organisms that lead to wood decay before wounding occurs. SO (298).

The period of spore release for heartrot fungi varied among species in the South. For one fungus, sporulation was greatest near midday. Spore release for another peaked near midnight. Fruiting bodies of wood-rotting fungi produce tremendous numbers of spores when placed in favorable temperature and moisture conditions. Improved knowledge on sporulation provides insights useful for advising on cultural techniques that inadvertently cause wounds. SO (309, 310).

The tree surgeon's technique of filling tree cavities with polyurethane was made more practical by introducing burlap and fungicides into the plastic. Burlap increases strength characteristics of the plastic and reduces the amount needed to fill tree cavities. Several fungicides are compatible with the foaming process if temperatures are over 50 degrees F. This is an effective technique for ornamental trees. WO (313).

The natural decay resistance of 30 species of Peruvian woods having possible commercial significance was evaluated. The tests, using blocks of wood placed in soil, indicated that 25 percent of the species would be resistant or highly resistant if used in contact with soil. About 50 percent of the species would be resistant or highly resistant for use above ground. FPL (302).

Veneer bolts of southern pine and yellow-poplar may sour from bacterial attack when stored in water. Experiments indicate that bacterial attack can occur in bolts stored in water with 0.5 percent sodium pentachlorophenate unless the bolts are free of bacterial infection when placed in the solution. Prolonged pond storage may reduce the quality of the veneer. FPL (301).

Nine fungi were found to cause decay of poles of major importance in the United States. This knowledge will simplify tests of the effectiveness of chemical preservatives. FPL (299).

Five of 12 applications of preservatives at the groundline have been effective in preventing failure in southern pine poles. The application of an effective preservative to the billions of poles in service can significantly reduce costs to the user and, of course, can considerably extend our timber resources. FPL (296).

Alkaline treatment of wood at elevated temperatures destroys thiamine and renders the wood resistant to the thiamine-requiring, brown-rot fungi, but it does not provide resistance to the thiamine requiring, white-rot fungi. Putting thiamine back into pine blocks failed to overcome the resistance of the blocks to brown-rot attack. These results suggest that the resistance imparted to wood by treatment with alkali involves more than just dethiaminization. FPL (300).

Hydrogen peroxide was implicated in enzyme activity of wood-rotting fungi. Fungi causing both brown rots and white rots produced extracellular hydrogen peroxide. This might be involved in the breakdown of cellulose. Only fungi causing white rots produced extracellular hydrogen peroxide plus peroxidase. This system may be involved in degradation of lignin. SE (305, 306).

Not all isolates of a single decay fungus are equal in their ability to decay wood. A model of genetic variation was proposed and partially substantiated by physiological experiments and cytological study. SO (292, 293).

15. MISCELLANEOUS STUDIES

The potential for damage by extraterrestrial materials to plant life on earth is being intensely evaluated by a team led by a Forest Service scientist at NASA's Lunar Receiving Laboratory, in Houston. Special chambers are used to challenge terrestrial plants with lunar materials without hazard of escape of dangerous entities into the earth's biosphere. None of the lunar materials collected by the crews of Apollo XI and XII contained any trace of microorganisms or any substance harmful to 35 representative species of plants, including three pines from North America. WO (328, 329, 333, 334, 335, 336, 338).

Recent advances in electronic data retrieval techniques and services were reviewed for the American Phytopathological Society in a special issue of Phytopathology News. New services and search procedures make literature reviews less time consuming and more comprehensive than ever before. This improves the basis for evaluating research needs and for building research programs. SE (322).

A new spore sampler was designed to study periodicity of fungal sporulation. Spores are collected in discrete zones at time intervals that can be varied from 5 to 60 minutes. This will aid research on disease epidemiology. SO (321).

Intense microbial fermentation in large piles of sawdust or bark produces blackened, strongly acid material and injures plants. Its very dark color and acrid odor should warn against use in mulching and other horticultural purposes. PNW (319).

In nursery plots subjected to five treatments--no snow, deep snow, compacted snow, winter rain, and normal snow cover--no evidence was found that any of these winter treatments caused either terminal dieback or stem lesions on red pine nursery stock. NC (332).

A relationship was shown between season and resistance to heat injury in trees. Injury often was noted first in leaf chloroplasts and proceeded until all cell contents except starch grains were destroyed. Evergreens were generally less resistant than deciduous trees. NE (331).

Cone rust was discovered on blue spruce in Utah. Experiments indicated that this rust can severely limit seed dispersal as well as reduce seed viability. Therefore, this rust could be a serious obstacle to regeneration of spruce. INT (330).

The major hardwood disease problems of the eastern United States were reviewed and evaluated. Suggestions were also made for preventing widespread loss of southern pines to disease by integrating strategies based on silviculture, genetics, and applied plant pathology. SO (320), NE (326).

Large trees can now be more easily cut and lowered by rope to avoid damage to surrounding trees and property. Procedures employing a system of letdown ropes, pulleys, and manpower were described to fulfill these needs. This system provides near maximum safety, entails a minimum cost, and can be used in a wide variety of forested environments. INT (327).

A new species of Penicillium fungus was found on an old fruiting body of a common decay fungus in New York. SE (325).

The field of forest pathology has made major accomplishments in improving human welfare. Some of the more tangible results of disease research involve predicting and minimizing disease losses and improving the quality and service of wood products. Forest pathologists seek the forest or the forest product that will not become diseased rather than toward expensive protectants or therapeutics for use only after trees become sick. WO (323).

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C. Accelerating Forest Resource Surveys

1. FOREST INVENTORY

Approximately 46 million acres of commercial forest land were reinventoried during the past year under a current resurvey cycle averaging about 11 years. Field surveys were conducted in Alaska, California, Georgia, Hawaii, Maine, Missouri, New Mexico, and Tennessee. Reports appraising the forest situation were issued for 12 States or portions of States.

Forests continue to be the dominant land use in Arkansas, covering 55 percent of the State. However, substantial changes occurred in timber resources in the decade 1959-69. One-eighth of the forest land was lost to competing land uses. Inventories of hardwoods declined 7 percent between surveys due mainly to clearing for cropland in the Delta and for pasture in the Ozarks. The softwood inventory gained 16 percent. In 1968 softwood growing stock growth was 390 million cubic feet and removals 281 million cubic feet. Hardwood growth was 368 million cubic feet and removals 289 million cubic feet. SO (8, 22).

The eight-county Puget Sound area lying between the Sound and the crest of the Cascade Range contains 3.3 million acres of commercial forest land and 74.6 billion board feet of sawtimber, nearly one-third of the total volume in western Washington. This area also contains the largest and most rapidly growing metropolitan area in the State. Since 1953, 260,000 acres of commercial forest land have been converted to uses incompatible with timber growing. Substantial areas of formerly high yielding conifer sites have been taken over by hardwoods following logging and fire and are currently yielding substantially less timber volume than the sites are capable of. Current net annual growth averages 412 board feet per acre. Average annual timber removals of 429 board feet per acre exceed growth by about 4 percent. Annual mortality exceeds 121 board feet per acre, about one-third of which is hemlock in old-growth stands. PNW (2).

A reinventory of Ohio completed in 1967 shows that the area of commercial forest land increased from 5.4 to 6.3 million acres between 1952 and 1968. Volume of growing stock increased 31 percent from 3.2 billion cubic feet in 1952 to 4.2 billion in 1968. Sawtimber growth of 422 million board feet exceeded removals by 212 million board feet. NE (10).

Projections of the California forest situation industry picture indicate that total timber harvest will decline nearly 20 percent by 2020. Lumber and plywood industries will decline while the pulp, paper, and board industries will grow. Employment is likely to rise, however, primarily in secondary manufacturing activities such as millwork and paper product fabrication, more than enough to offset losses in rural areas where primary manufacturing is centered. PNW (13).

A second Forest Survey in New York shows commercial forest land now totals 14.3 million acres, an increase of almost 14 percent in 18 years. Growing stock volume amounts to 12.2 billion cubic feet, an increase of 20 percent between inventories. Net annual sawtimber growth in 1967 of 656 million board feet exceeded timber removals by 193 million board feet. Currently hardwoods make up about three-quarters of the growing stock inventory volume. NE (7).

2. TIMBER PRODUCTION

Oregon continues to lead in output of lumber and softwood plywood--two of the Nation's most important timber products. Oregon's 1968 lumber output was more than one-fifth of the national total and plywood output more than one-half. Oregon is among the leading States in woodpulp production and the primary producer of particleboard. Oregon also provided 20 percent of the country's log exports. PNW (36).

Southern pulpwood production increased 10 percent in 1969 to a new high of nearly 41 million cords. The South now accounts for two-thirds of the Nation's total output of pulpwood. Southern forests supplied wood to 121 pulpmills, 105 of which are located in the Region. Five additional mills with a daily capacity of 1780 tons were under construction at the end of 1969. SE (49).

Pulpwood production in the Lake States in 1969 recovered to a more "normal" level after being depressed in 1968 by a one-quarter million cord cutback in Wisconsin pulpwood inventories. This production was nearly 7 percent of the national total. NC (29, 30).

More than half the veneer logs made in the eastern United States are cut in the Midsouth. Softwood veneer log output in 1969 totaled 1,123 million board feet. Hardwood veneer log production was 217 million. During the past decade veneer log output shifted from nearly all hardwood to chiefly pine as a result of initiation of large-scale manufacture of southern pine plywood starting in 1963. Midsouth forest still provide about one-quarter of the hardwood veneer logs cut in the United States, but output dropped 13 percent and the number of hardwood veneer plants declined by 20 percent and between 1963 and 1969. SO (46).

Forest industries used 390 million cubic feet of Arkansas roundwood during 1968, about 42 percent more than 1958. Two-thirds of the output was softwoods. Although the number of primary wood-using plants in Arkansas declined from about 1100 to less than 600 between 1958 and 1968, total production of forest products increased. More than half the roundwood output from Arkansas was sawlogs. SO (24, 26).

Average prices paid for pulpwood bolts in the Southeast increased 5 percent in 1969. Roundwood prices averaged $20.90 per cord for pine and $16.35 for hardwood. Prices paid for chips averaged $8.45 per ton for pine and $6.75 for hardwood. Since 1962, average prices paid for pulpwood have increased by over 25 percent. Pulpmills paid over $410 million for pulpwood produced in the Southeast during 1969. SE (35).

Output of roundwood products in Idaho increased from 316 million cubic feet in 1966 to 340 million cubic feet in 1969. Unused plant residues (including bark) from the lumber, and veneer and plywood industries totaled 78 million cubic feet in 1969, compared with 131 million cubic feet of residues used for pulpwood and fuel. INT (44).

A survey of the veneer industry in the Northeast for 1968 revealed a drop in the number of container veneer plants which was offset by an increase in the number of other types of veneer plants. Veneer log production increased 15 percent between 1963 and 1968. In both years the volume of veneer logs shipped out of the Northeast exceeded log receipts from outside the Region. NE (32).

Pulpwood production in the Northeast increased to a record level of 6.2 million cords in 1969 or more than 4 percent above 1968 production. This new record was due mainly to the addition of new mills and increased production of chips from plant residues. Roundwood production from softwood trees continued to decline, but increases in both hardwood roundwood and plant residues were more than offsetting. NE (31).

3. SURVEY TECHNIQUES

A simple equation was found superior for relating bark thickness on the upper stem to its thickness measured 4.5 above the ground for trees in western Montana. Use of this equation will facilitate computing wood volumes in standing trees. INT (53).

Procedures for rating yield capability of forest land have been evaluated and converted to computer programs to permit efficient compilation of data on yield capability of Rocky Mountain forest lands. INT (52).

A comprehensive computer program (TRAS) that calculates annual changes in numbers of trees by 2-inch diameter classes has been developed and improved to meet the need to update inventories to a common data for periodic national compilations of timber resource statistics, to help analyze and interpret changes in the timber resource between surveys, and to project future timber supplies under alternative management assumptions. WO (54)

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D. Economics of Forest Management

1. TIMBER GROWING ECONOMICS

Cottonwood plantations offer a promising alternative for reversing the decline in forest resources in the Mississippi Delta. This species yields high annual outputs of all classes of timber products, with financial returns from planting and cultural investments ranging up to 16 percent. Cottonwood combined with soybean or corn production promises even greater financial rewards. However, large capital investments are required and only the better soils, which are also highly valued for agricultural production, can grow cottonwood economically. SO (1, 2, 3).

Variation in estimates of costs and returns, timing of harvests, and interest rates can greatly affect attractiveness of investments in timber production. Partial derivatives and graphs have been developed to measure and illustrate the impact of such variations on present net worth of potential investments. A computer routine to perform the necessary computations is included. NC (10).

Two biological growth functions have been fitted to site index curves for 11 Lake States tree species: red, jack, and white pine, balsam fir, white and black spruce, tamarack, whitecedar, aspen, red oak, and paper birch. These functions, with an accompanying table of height factors, are useful alternatives to site index curves in evaluations of management opportunities. NC (8).

Natural regeneration with precommercial thinning is often an economic method for obtaining desirable stocking in southern pine stands. Precommercial thinning preferably should be done by mowing seedlings at age 2 or 3. At these ages fire hazard problems are minimal and costs are low. Many present stands are too old to thin precommercially because costs will be high and growth response relatively small. SO (6).

An analysis of the cooperative forest management program in Pennsylvania has provided some economic guides for priority ranking of timber production program activities. These included programs of planting, timber stand improvement, and harvesting and marketing assistance. Calculated rates of return provide financial ratings for a variety of investment possibilities. NE (9).

2. MULTIPLE-USE ECONOMICS

A framework of analysis for putting multiple-use concepts into practice has been developed for the Beaver Creek watershed in northern Arizona. Preliminary production functions have been identified for alternative land treatments. These treatments are designed to increase water yields within a multiple-use framework which includes timber, wildlife habitat, herbage, recreation, sediment and environmental quality. RM (20).

Costs of converting alligator juniper watersheds to herbaceous cover in Arizona averaged about $45 an acre. Sensitivity analysis and other study results indicate that costs could be reduced substantially by improved organization and changing prescriptions and techniques. RM (17, 18).

3. IMPACTS ON FOREST INDUSTRY AND REGIONAL ECONOMIES

Analysis of cutting schedules for a management unit in the Douglas-fir region of western Oregon and western Washington has revealed that shifting from Scribner log rule to cubic-foot measure will reduce but not eliminate a falldown in allowable cut at the end of an old-growth conversion period. Effects of both shortening rotations and intensifying timber management on size of falldown can be significant. PSW (32, 33).

Studies of accelerated road construction in the Tillamook Resource Area in Oregon indicated that further acceleration would not be economically feasible. Doubling the current rate of construction would increase thinning yields, but added stumpage revenues would not compensate for interest charges, timber sale administration, and road maintenance. PNW (34).

A typical timber loan client of the New Orleans Federal Land Bank is married with three children in his middle fifties. He farms, either full or part-time, owns an average of about 750 acres of woodland, and has borrowed almost $20,000 from the Land Bank. Half of the borrowers used part or all of their loans for forestry purposes. One-fourth planned to use more credit to expand their timber operations. SO (11).

Log-quality indexes have been calculated for white ash, beech, black cherry, hard maple, red oak, soft maple, white oak, yellow-poplar, and birch. Methods are given for evaluating saw logs at mills and in the standing tree. NE (31).

An analysis of sawtimber marketed in 992 sales on National Forests in Mississippi, Alabama, Louisiana, Arkansas, and Texas showed stumpage prices to be highly variable. Nevertheless, 75 percent of the variation was caused by four variables--national lumber price changes, number of sale bids, total volume of sale, and quality of timber. SO (28).

Studies of labor productivity show major gains over the past 20 years. The number of sawmills in the United States has been drastically reduced but productivity of surviving mills greatly increased. Most mills have been modernized with improved equipment and technology. SO (29).

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E. Improving Engineering Systems

Predicted fiber shortage prompted research on the use of flotation segregation of aspen wood and bark chips as a means of enabling broader use of logging residues. Studies showed that moisture of wood continued to increase throughout 12 days of soaking while bark moisture reached maximum in 2 days and remained constant. The density difference between wood and bark was great enough so that bark would sink and the wood float in a medium of proper density. This flotation technique holds promise for capturing large volumes of undebarked logging residues. NC (12, 13).

Skyline logging systems are used extensively for harvesting timber in rough terrain. Although they have been used for years, design details of these systems were largely ignored in the past. Static and dynamic characteristics of the systems have now been described, and solution of equations, using known parameters and stand variables in skyline design problems, with a desk-top computer has been made possible. This will foster more efficient use of skylines. PNW (8, 9, 10, 18).

Tire life on wheeled skidders varies widely. Use and abuse of tires were analyzed and procedures developed to avoid the most damaging conditions. By following these the logger should get longer life from his tires, fewer flats, less down time, and more economical operation. These factors, in conjunction with the effects of wheel weights and liquid fill, also give the logger information for proper tire selection. NE (2, 3, 4, 6).

The broader use of shears for cutting trees is handicapped by lack of technical information. Power requirements for shearing roundwood bolts were evaluated for basswood, aspen, white spruce, yellow birch, and hard maple. Thickness, bevel angle, and anvil design, as well as the effects of wood temperature, specific gravity, and cutting speed were investigated. These data provide information needed for advancing this promising felling practice. NC (1).

Log loading in Appalachia can be accomplished with relatively low cost, reasonable speed, and in a small working space using a heavy duty farm tractor with a front-end loader as demonstrated in a recent study. These findings should benefit designers of logging equipment. NE (19, 20).

Past attempts to mechanize logging concentrated on single work functions. Recent studies in Michigan, directed toward development of multi-functional logging equipment provided information on variables that affect machine operation. Dynamic forces and moments four times as great as those developed statically can occur with tree harvesting machines. This information, plus prediction equations developed for estimating tree weights and centers of gravity of quaking aspen, provides a better foundation for designing logging equipment for the Lake States. NC (24, 25).

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F. Improving Water Quality and Yield

1. IMPROVING WATER YIELDS

Contour trenches for watershed rehabilitation in Utah increased snow accumulation slightly, which appeared to be more significant to revegetation than to water yield. The trenches studied are on a wind-swept southwest exposure where snow redistribution by wind is important. INT (18).

Water yield increased substantially on two small chaparral watersheds in central Arizona following brush control and conversion to grass. Yield increases are insignificant, however, when annual precipitation is less than 16 inches. Winter precipitation is the major source of water yield. RM (25).

Aerial photographs taken at 10-day intervals to record snow-cover depletion on gaged watersheds in Fraser Experimental Forest have been useful in establishing relations between snow disappearance and streamflow. Snow-cover depletion curves were developed for watersheds and subareas within watersheds. The highest conversion of snowmelt to streamflow occurs at time of peak discharge. RM (29).

A drastic treatment imposed on a previously undisturbed watershed in central New Hampshire caused large increases in streamflow and in amounts of particulate matter and dissolved ions in the stream water. All timber and woody vegetation were felled and left intact in a 39-acre watershed and herbicides applied for 3 successive years to eliminate vegetative regrowth. Streamflow increases ranged from 9.5 to 13.6 inches per water-year. Nitrate concentration increased by an average of 50 times, major cation levels rose three- to twenty-fold, and particulate matter losses increased 9 times. The study points to the need for additional knowledge concerning less drastic contemporary forest land practices and their impact on water quality. NE (39).

In western Oregon, increases in water yield following timber harvest roughly conform to the proportion of the area cleared. Clear-cut logging can increase annual water yield by 18 inches in high precipitation areas. Approximately 80% of the increase occurs during the October to March season. PNW (41).

In southwestern Wisconsin frost penetrated faster and deeper and thawed sooner in a sand than in a silt, an example of how soil frost may affect the hydrologic behavior of northern watersheds. During the spring thaw, frost persisted in the silt 3 weeks longer than in the sand. NC (42).

Tests with large fences to control snow accumulation in alpine areas of central Colorado revealed that upslope approaches gave short, deep lee drift, whereas downslope approaches gave longer and shallower drifts. Volume of snow in shallower drifts may exceed that of the deeper drifts, however. The desired gap beneath the fences was difficult to maintain for those located downwind from ridges and terrain breaks. RM (45).

An accurate snow gage system, adaptable for remote operation, has been developed for measuring snow density and depth in $\frac{1}{2}$-inch increments by vertical profiling of a snowpack. The gage consists of a small radioactive source and a detector drawn through two access tubes extending from ground line. Snowfall timing, intensity of snowfall, snowpack depth, snowpack density at all points, and the occurrence of rainfall may be determined. PSW (48).

2. MANAGING, REHABILITATING, AND IMPROVING WATERSHEDS

Hydroseeding for establishing cover quickly on steep, rocky anthracite coal mine sites in Pennsylvania failed on coal-breaker refuse but was partially successful on strip-mine spoils. Seeds from selected species of legumes, grasses, and trees were mixed in a slurry containing hydrated lime, fertilizer, and wood-fiber mulch and hydroseeded on 32 plots representing eight conditions. NE (68).

Pure plantings of eastern redcedar, loblolly pine, and shortleaf pine plus mixtures of the three species were established on eroded field land in northern Mississippi to determine which mixture or pure stand would most improve the physical and chemical properties of soil and litter. Much more litter accumulated and water transmission rates increased far more under pure pine treatments than under pure redcedar stands. Mixtures of pine and redcedar offered no apparent advantages over the pure pine stands. SO (77).

Weeping lovegrass is useful for revegetating strip-mine spoils in Appalachia because it provides quick cover on a wide range of soil conditions. It is more tolerant of extremely acid spoils (pH 4.0-4.5) and of dry sites and summer conditions than most of the commonly used cool-season grasses and legumes. Although relatively short lived, it works well in mixtures with slower developing, long-lived grasses and legumes. NE (82).

3. PREVENTING WATERSHED DAMAGE

Landslides were the predominant source of increased sedimentation of streams following road construction and timber harvest in steep headwater drainages in western Oregon. Patch-cut logging with forest roads increased sedimentation more than 100 times over a 9-year period. Landslide erosion was greatest where roads crossed high gradient stream channels. PNW (90).

Complete soil saturation during periods of excessive rainfall, slopes in excess of 34°, and the absence of the anchoring effect of tree roots in a noncohesive soil were the principal causes of debris avalanching at three southeast Alaska sites. This conclusion resulted from the study of a shallow, permeable till soil common to the area using standard soil mechanics techniques. PNW (95).

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G. Bettering Silvicultural Systems

1. NATURAL REGENERATION

Information on natural seed production is necessary for planning natural regeneration and seed collections. A study in southwestern Maine showed that a mature eastern white pine stand thinned to an intermediate density of 120 square feet of basal area per acre (27.5 m^2/ha.) produced 59 pounds (26.8 kg.) of seed per acre during a good seed year. This was 50 percent more than heavily stocked or lightly stocked stands. These results point up an effective way to increase white pine seed production. NE (2).

Because natural seed production is often relied upon to restock large areas to ponderosa pine, seed supply can be a matter of critical importance. In central Arizona, large cone crops occurred in 3 years out of 10. Large trees 28 to 40 inches (71 to 102 centimeters) in diameter produced 218 to 446 cones per year, which was more than 10 times the yield from trees 12 to 20 inches (30.5 to 51 centimeters) in diameter. Abert squirrels reduced 10-year cone production by 1/5. These results will help managers to decide between natural seeding or tree planting for the reestablishment of ponderosa pines on harvested lands. RM (3).

Data on cone and seed production in white spruce stands of interior Alaska have been limited. Observations between 1957 and 1968 indicate that very good seed years may come at 10- to 12-year intervals, although individual stands may produce from one to several fair or good cone crops. In the bumper year of 1958, an undisturbed stand on Bonanza Creek produced 16.5 million seeds per acre, 65 percent of them sound. Foresters can anticipate that the lack of frequent good seed crops will result in some delay in natural regeneration of this species. PNW (8).

Research and practical experience provide general prescriptions for reproducing oaks, yellow-poplar, sweetgum, and black walnut by natural means, but general prescriptions do not yield consistent results. A survey of research results summarizes current knowledge about regenerating these species, for example that oaks are regenerated before the harvest cut, not after. Guides are given for correlating current knowledge with basic ecological principles and, where followed, will greatly increase the success of attempts to achieve satisfactory reproduction and stand composition. NC (1)

Five years after clearcutting all stems more than 4.5 feet (1.4 meters) tall in a mature Southern Appalachian hardwood stand, more than 500 desirable stems per acre of yellow-poplar, sweet birch, red oak, chestnut oak, and white ash regeneration were found free-to-grow. The new stand is still too young to judge the need for precommercial cultural practices. SE (5).

Shade competition from border trees may reduce growth of intolerant saplings near the edge of openings clearcut to promote natural regeneration, but the effect varies from place to place and in different size openings. In Appalachian Mountains in West Virginia intolerant regeneration grew rapidly with no evidence of "border effect" in openings larger than 1/4-acre. These results indicate that openings as small as 1/4-acre may be used to regenerate Appalachian hardwoods without sacrificing early growth, at least in areas with adequate soil moisture during the growing season. NE (7).

In a rapidly developing sapling stand, some trees grow but the majority die before they reach pole size. How many stems of reproduction are required to ensure adequate composition of the pole stand? A model based on negative exponential curves of natural mortality and probable diameter distribution of survivors has been developed for northern hardwood stands in New Hampshire. This model predicts the probabilities of future numbers of trees by diameter classes and forms the basis for regeneration stocking guides for young northern hardwood stands. NE (4).

Establishment of new stands of coastal California redwoods is made easy when large numbers of sprouts develop from fresh stumps, yet some stumps fail to sprout. Study showed that sprouting was rare if trees were older than 400 years, if the stumps were scraped or torn during logging, if the soil had been greatly disturbed, or if the trees were growing on steep slopes. Burning of logging slash had little effect on sprouting. If redwood stands less than 400 years old are harvested carefully, sprouts will help to reforest the harvested area quickly. PSW (6)

2. SILVICULTURAL METHODS

Red and white fir comprise about one-fourth of the timber volume in California, and have advanced steadily in market value. To guide harvesting operations in the true fir type, results of 12 years of regeneration research have been summarized into recommendations on regeneration methods. Adequate seed dispersal occurs only within 100 feet (30.5 meters) of a seed source, and the new seedlings need some shade. Hence clearcut areas or strips should be kept narrow, or shelterwood or seed-tree systems should be used to insure the presence of sufficient sound seed-producing trees. PSW (9).

A recent USDA Production Research Report summarizes current information, based on both research and experience, concerning the natural regeneration requirements of Engelmann spruce following harvest cutting. The report also presents guidelines and management alternatives for developing successful regeneration practices (natural and artificial) in the Intermountain and central Rocky Mountain areas. RM (12).

About 200,000 acres of red pine stands in northern Minnesota, which will be ready for thinning in the next 10 years, can be thinned economically and with probable enhancement of their high recreation and esthetic values. A strip thinning technique was developed which provided ready access by efficient rubber-tired timber harvesters. This technique can be used late in a sawtimber rotation with minimal effects on the forest--only seven residual trees were visibly injured in a 20-acre stand after 100 thousand board feet had been harvested. The resulting strips and the patches made for slash disposal are usable for wildlife openings, overflow campgrounds, and hunting sites. NC (13)

Renewal of hardwood stands on the highly productive bottomlands and loessal uplands of the South is complicated because of the complexity of species, sites, and ecological relationships involved. A summary of current knowledge has been prepared to guide selection of regeneration systems and silvicultural techniques that will favor establishment of natural stands and plantations according to natural factors that affect success. SO (10).

Clearcutting offers many biological and economical advantages as a regeneration method, but it is temporarily unsightly and offends many viewers. Adverse public reaction to clearcutting can be reduced by improved harvesting patterns, better logging equipment, better "housekeeping" by loggers, reducing the greening-up period, and improving public understanding.

3. ECOLOGICAL RELATIONSHIPS

Choice of forest management practices to achieve multiple-use objectives requires knowledge of successional trends and other ecological responses under different silvicultural systems. A study of the effects of single-tree selection cutting in West Virginia shows that the percentage of pole-sized yellow-poplar, northern red oak, black cherry, and other cove hardwoods has decreased from about 60 percent to less than 40 percent in only 20 years. During the same period, the percentage of pole-sized sugar maple, red maple, sweet birch, and beech has increased from less than 30 percent to more than 50. As species composition changes, growth rates and potential uses may be expected to change also, and such changes must be considered in determining management methods and long-range uses. NE (23).

Species composition is an important ecological factor affecting timber, water, wildlife, recreational, esthetic, and other forest values, but changes of composition with time are extremely difficult to predict. Two simulation models developed in New Hampshire, one based on species birth and death rates, the other on rates related to population density, indicate that in the absence of management, species variety in northern hardwood stands will be reduced ultimately to beech-maple-hemlock, with the loss of birches, ash, spruce, and other species. This method of simulation provides a means for analyzing successional change, predicting species extinction, and reconstructing ecological history. NE (16).

Soils derived from siliceous sandstone and siltstone in southwestern Virginia differed little regardless of aspect or slope position; in contrast, soils in North Carolina derived from granitic biottite gneiss showed a high degree of profile differentiation at different slopes and aspects. Such knowledge of soil development and characteristics as affected by parent material and climatic factors is basic to understanding natural processes, such as nutrient cycling, in forest ecosystems. NC (18).

When forest fuels such as litter or green needles are burned, what becomes of the nitrogen released? Focusing on loblolly pine, North Carolina researchers concluded that only small amounts of nitrogen released by forest fires could be returned to the soil via precipitation. Most nitrogen in organic matter is presumably volatilized as nitrogen gas. Such studies lead to a better understanding of the cycling of nutrients in an ecosystem. SE (15).

Planning for wildfire control and for use of prescribed fire requires an understanding of the natural role of fire in northern Rocky Mountain forest ecosystems. Analysis of historical records indicates that wildfires have probably been catastrophic in nature on 80 percent of the forested lands, and that these severe fires have resulted in an abundance of preclimax (transitory) tree species, most of which are also of major economic importance, in contrast to climax species. INT (24).

Forest growth rates depend upon the proportion of incident solar energy that is converted to chemical energy and stored in forest vegetation, but few estimates of the ecological efficiency have been possible. A study in New Hampshire reveals that northern hardwood stands use less than 1/2 percent of net solar radiation for wood, leaf, and seed production, and only about 1/10 to 1/5 percent for production of merchantable wood. These results increase our knowledge of biological production and processes and point out the need to understand and capture more of the largely unused solar energy. NE (17).

Estimates of total productivity and energy conversion in ecosystems require methods for measuring production of various components. A study of leaf production in yellow-poplar stands in the southern Appalachians revealed little year-to-year variation. Therefore, better precision and quicker results can be obtained by sampling many stands in one year than by sampling a few stands over several years. SE (20).

Sprouting on trees exposed by thinning or improvement cutting is commonly blamed on increased light reaching the boles. In Michigan a study of released sugar maple trees showed that increased exposure of the tree crown or decapitation of the crown resulted in increased bole sprouting even when light was prevented from reaching the stem. Evidently epicormic sprouting is associated with physiological relationships controlled by the crown. NC (14).

Following timber harvest in the coastal forests of the Pacific Northwest, salmonberry often develops into dense thickets and delays or prevents forest regeneration of Douglas-fir, Sitka spruce, and western hemlock. Dense thickets also develop in forest openings after thinning, spreading after harvest. Studies in coastal Oregon and Washington showed that salmonberry is very tolerant, and established readily in moderate to dense shade. Once established, it grows most rapidly and forms the densest thickets in full sunlight. Repeated thinnings contemplated as part of intensive management will surely lead to increased salmonberry cover in coastal forests, and control measures will be needed. PNW (22).

Rosebay rhododendron is an esthetic asset in the southern Appalachians, but uncontrolled it often forms dense thickets that usurp extensive areas of productive land and prevent regeneration of desirable high-forest trees. Results of studies in North Carolina show that prescribed burning to weaken and kill the above-ground parts, followed 2 years later by herbicide treatment to kill the sprouts, is a highly effective method of control. SE (21).

Insects, diseases, and parasites impose a great drain on forest resources. A parasitic annual weed known as senna seymeria (*Seymeria cassioides*) was recently found infecting the living roots of slash pine in Florida. The weed, a figwort, is a threat throughout most of the southern pine region; it spreads rapidly by means of light, wind- and water-borne seed, and has killed tree seedlings as tall as 7 feet (2.1 meters). Early detection and treatment with low concentration herbicidal sprays are the keys to control of this parasitic weed. SO (19).

(For additonal items relating to II G, see paragraphs under IE, and III A 1-6.)

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I. Remote Sensing Methods

One of the great potential benefits of remote sensing from space is the increased ability to inventory and evaluate earth resources, including forest resources. A pilot timber inventory was conducted on 10 million acres of land in Arkansas, Georgia, Louisiana, and Mississippi by using photography taken from the Apollo 9 spacecraft. The space photos, used with conventional aerial photos in a stratified sampling design, resulted in more accurate timber surveys, and at the same time contributed toward the development of a resource information system for forestry and agriculture. PSW (1).

Fire control agencies vary widely in their approach to evaluating the effectiveness of fire detection systems--tower, aircraft, or aircraft-electronic. This study presents a framework of operating rules for evaluating an infrared forest fire detection system. Fire and weather data are used with simulated detection patrols that consider time, location, and altitude. Operating rules are evaluated in terms of cost and a common criterion of effectiveness. A model of this type can be utilized to evaluate any detection system, or combination of systems in terms of cost and effectiveness. INT (2).

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I. Weather Modification and Weather Effects

1. WEATHER MODIFICATION

Understanding the fire-setting characteristics of lightning discharges is complicated by the fact that it is difficult to bring together the instrumentation necessary for documentation, the lightning discharge, and the fire-setting event. This study summarizes 16 documented lightning discharges, 11 of which caused forest fires in western Montana forests. The 11 discharges starting fires exhibited a long-continuing current (LCC) of at least 40 milliseconds duration. Of the five nonfire discharges, two were LCC and three had no LCC phase. Results of this work indicate that while the majority of fires are probably started by the LCC discharges, the other types of discharges cannot be entirely precluded as sources of fuel ignition. INT (1).

2. FIRE AND FOREST METEOROLOGY

The fine herbaceous fuels are important contributors to the spread of a fire and must be considered as one of inputs to the fire-danger rating system. This study relates the state of the herbaceous vegetation to fuel moisture and predicted fire behavior, using as one example the condition where all the living vegetation is consumed by the fire; in another, the vegetation is not burned as the flaming fire front moves through it. Results of this work make it possible to more accurately incorporate the concept of fuel moisture and seasonal change of fine herbaceous fuels into the national system of fire-danger rating. RM (8).

Predicting fuel moisture response is complicated by many factors but must be accomplished in order to predict fire behavior in wildfires and fuel consumption on prescribed burning operations. This study relates standard drying conditions in the laboratory to diurnal fluctuations of temperature and humidity. It is now possible to more accurately predict fuel moisture change for a specified time and predict the time required for a fuel under field conditions to reach a specified moisture content. Results of this work will greatly strengthen that segment of the National Fire-Danger Rating System that deals directly with fuel moisture measurement and prediction. RM (11).

Lightning is a widespread, national phenomena that has a profound effect on forested regions of the world. Lightning causes more than 10,000 fires a year in North America and it is estimated that forests of the world receive some half-million cloud-to-ground discharges per day. In addition to starting fires, lightning causes structural and physiological damage to trees, but may at the same time be considered as a beneficial agent when it destroys an overmature tree or results in natural thinning of a forest stand. Understanding lightning is more important than the ability to completely exclude lightning as a natural environmental event. INT (23).

Most rain gages are reasonably accurate when recording moderate amounts of rainfall, but when rainfall intensity increases, some of the rain gages--particularly the tipping-bucket type, fail to accurately record rainfall rates. This study evaluated 20 rain gages and found that most of them failed to meet the specifications with respect to rainfall rate versus instrument error. All the instruments tested needed modification before they were able to meet the rainfall rate tests. Results of these tests make it possible to suggest design changes in the manufacture of rainfall recording instruments. SE (17).

Large destructive wildfires are generally the result of an unusual set of critical fire-weather conditions. The fires that occurred in the Upper Midwest 100 years ago were some of the most dramatic ever experienced in the United States. Reconstruction of the weather patterns associated with this series of fires indicates that the fires were mostly within the warm sector of a developing open wave. This fire-weather pattern appeared to have produced a well-developed, low-level jet that caused the extreme fire behavior. Results of this study make it possible to more accurately identify similar situations when they occur and adjust fire suppression forces to handle the situation. NC (9).

Relating the various components of the National Fire-Danger Rating System to forest fire activity has not always yielded conclusive results. This study of the relationship between the Fire Spread Component of the National Fire-Danger Rating System and fire activity indicates that while the correlation between fire spread and acres per fire is not high, there was good evidence that the spread component could be used as a good approximation of ignition. Seasonal differences were also evident. The results of this work help provide a better understanding of the Fire Spread Component--its advantages as well as its limitations. NC (10).

Although not in final form, an interim manual of instruction has been prepared covering the 1970 field trial use of the National Fire-Danger Rating System. This manual provides the instructions for making the necessary computations from input parameters. Following field trials, the manual will be revised and made available to cooperators involved in field testing the National Fire-Danger Rating System. RM (12).

Maintenance calibration of anemometers is necessary to insure accurate windspeed measurements but simple calibration equipment is presently not available in locations where it is needed. A device for calibrating wind instruments has been developed at a cost of approximately

$50. Through the use of centrifugal blowers the calibrator generates discrete forces which are calibrated in terms of true laminar windspeed. Turning-rate curves are available to accommodate the Stewart-type anemometer but other types of wind instruments can also be accommodated. SE (19).

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III. IMPROVING TIMBER PRODUCTIVITY AND EXTENDING SUPPLIES

A. Intensive Culture Methods

1. Site Evaluation and Soil Improvement

Site index determinations are time consuming and, in young stands, notably imprecise. Simple equations developed for natural white pine stands in the southern Appalachians will predict site index from the amount the tree grew in height during a 3-year or 5-year period after it reached breast height. In older stands, the method is not quite as accurate as the conventional method based on polymorphic site index curves, but it eliminates the need for age determinations and the errors associated therewith. In stands less than 15 years of age, the growth-intercept method is at least as accurate as the conventional and easier to apply. SE (1).

Predicting productivity of forest stands requires an evaluation of site quality, usually by estimation of site index based on harmonized site curves that assume a monomorphic growth pattern for the species. Recent studies show, however, that growth patterns of black oak, black walnut, and probably other hardwoods are polymorphic, differing on different sites and in different parts of the species' range. This means that harmonized site index curves must be applied with care, and that much more precise curves will be required as species culture becomes more intensive. NC (4).

Careful evaluation of soil and site factors to determine site quality is time consuming and may require expensive field measurements or laboratory analyses. In the southern Appalachians the most important site characteristics seem to be related to elevation, slope position, aspect, and the degree of shelter provided by surrounding land forms. Five site classes based on these factors are relatively easy to establish by field examination and should provide adequate accuracy for most forest management purposes. SE (8).

Establishing or favoring the species best adapted to a particular site will promote healthier forests and increase timber yields, but little information is available by which species performance can be compared. A study of site index comparisons in the midsouth provides this information for a number of species: sweetgum, cottonwood, green ash, and cherrybark, nuttall, water, and willow oaks. If the site index for any of these species is known or can be measured on a site, the site index for the others can be determined from graphs. SO (3).

Sound timber management requires reliable estimates of the productive potential of the land. In Vermont's Green Mountains, site index of northern hardwoods was most accurately estimated by using elevation, latitude, aspect, drainage class, soil depth, texture, and thickness; the standard error of estimate was 4.7 feet (1.4 meters) and the relationship accounted for 82 percent of the variation in site index. Armed with these equations, foresters can now more accurately predict the productivity of Green Mountain forest land. NE (14).

Intelligent prescriptions of forest fertilization must be based on quantitative response data. Seven-year-old, slow-growing loblolly pine stands on an eroded sandy loam in the Piedmont of South Carolina received 200 pounds of nitrogen per acre. Two years later foliar nitrogen content was greater, and height and diameter growth had increased 25 and 35 percent, respectively. In contrast 120 and 240 pounds of potassium per acre did not affect growth at all, even though foliar potassium had doubled (from 0.25 to 0.50 percent). SE (17).

During the grass stage, which lasts several years, longleaf pine seedlings are subject not only to brown-spot needle disease but to damage by hogs and cattle. A Georgia fertilization test showed that phosphorus significantly improved early seedling growth in a cultivated plantation on sand and loamy sand soils in the Coastal Plain. Thus, fertilization and cultivation provide land managers a means of shortening the vulnerable period and reducing the damage from disease and animals. SE (7).

Site amelioration techniques must be developed to make timber production feasible on many depleted lands. In a study on the eroded phase of the Memphis soil series in Mississippi, height growth of yellow-poplar seedlings over a 3-year period was increased up to 44 percent by heavy application of NPK fertilizer. Hence refinement of fertilization techniques, probably combined with other site improvement measures, has considerable potential for increasing timber yield on these eroded silty uplands. SO (2).

Information on the nutrient status of red spruce is needed to develop fertilization recommendations for natural stands. Foliar nitrogen levels were increased only slightly by adding 400 pounds of nitrogen per acre and were nearly back to pre-fertilization levels at the end of the second growing season in a Maine study. This brief foliar response differs from results with other conifers and provides useful data to scientists planning future studies. NE (16).

Disposing of waste waters without polluting streams is a major concern to pulp and paper mills, which typically discharge 20 to 50 million gallons daily. The results of a Louisiana study of irrigating slash pine seedlings with 20 or 40 inches (51 or 102 centimeters) of effluents annually from pulp and from paper mills indicated that pulp mill effluents were not suitable for irrigation purposes due to high concentrations of lignins and salts. However, 20 inches (51 centimeters) of paper mill effluent per year for 5 years produced no mortality or significant decrease in pine growth. Greater amounts reduced growth through soil saturation.

Such research may contribute to the beneficial use of what is now considered a harmful pollutant. SO (9).

Information on nutrient cycling and soil nutrient status is essential for effective soil management. A North Carolina survey of the concentration of nitrogen, phosphorus, potassium, calcium, magnesium, aluminum, manganese, zinc, iron, and copper in inner bark and needles of loblolly pines and the soils in which they grew revealed that potassium, aluminum, and manganese concentrations in the bark differed significantly on four soils. However, the needles showed significant differences in magnesium, zinc, copper as well, indicating that the nutrient status of the soil can be assessed more completely by needle samples than by bark samples. SE (18).

The development of forest humus is important in maintaining the fertility of forest soils. In a PL-480 study in Finland, it was found that certain lignin-decomposing fungi form pale-colored humus called white rot humus, which is characterized by rapid decomposition, high nitrogen content, low carbon-nitrogen ratio, and high acidity. The rapid liberation of nitrogen occurring in white rot humus is important, since this element is often a limiting factor in forest nutrition. WO (6).

Population dynamics of forest soil microbes are just coming under intensive study. Summer populations in two South Carolina swamp soils averaged 88 million per gram of alluvial swamp soil and 75 million per gram of nonalluvial swamp soil (lower in organic matter, pH, and nutrients). Such information on the kinds and numbers of soil organisms is of increasing importance; microbes decompose litter and thereby cycle nutrients. They also have important effects on accumulation of toxic substances such as carbon dioxide and organic acids. SE (15).

How does prescribed burning affect soil microorganism populations? After 20 years of annual burning in loblolly pine stands on a sandy loam Coastal Plain soil in South Carolina, there was no reduction in the number of fungi per gram of soil, although burning reduced their total numbers by decreasing the weight of the organic horizon of the soil surface. In this same layer the number of bacteria and actinomycetes was reduced by annual burning; however, burning did not affect populations in the mineral soil. Thus, prescribed burning did not adversely alter the composition or reduce the number of soil microorganisms to the degree that soil metabolic processes were impaired. SE (10).

Although the forest floor appears to be dead organic debris, in reality it teems with life. The organisms, many of them mites, help in the decomposition of leaves and wood. Fundamental research in North Carolina pine and hardwood stands has documented the changes in mite populations over a period of 42 months among loblolly pine, white oak, and dogwood leaves. Of 41 genera of mites collected, 19 were common in both pine and hardwood forests, 9 genera were found only in the pine stand, and 13 genera were collected only in the hardwood stand. Such studies will lead to an understanding of the role played by various decomposer organisms in nutrient cycling of forest ecosystems. SE (13).

Poorly drained flatwoods soils of the West Gulf Coastal Plain are frequently saturated for extended periods; consequently, trees are difficult to establish and their growth is generally slow. A laboratory study of the effects of submergence on soil chemical properties revealed that flooding made the soils less acid and reduced the levels of exchangeable aluminum, calcium, and magnesium. This information--suggesting that mineral nutrients are less available to plants under saturated soil conditions--is needed to develop sound fertilization programs and to relate tree growth to soil nutrient levels. SO (11).

On wet sites of the Lower Coastal Plain, growth of planted or seeded slash pine is usually greater on elevated beds than on undisturbed land, but the response is erratic. A study on poorly drained silt loam soil in central Louisiana showed that depth to the water table and the degree of soil aeration were major factors determining the height growth of planted 1-0 seedlings. Six years after planting, trees on elevated beds average 18.1 feet in height (5.5 meters) and trees on flat disked and on untreated sites were only 16.0 feet (4.8 meters). SO (12).

Culture of lowland hardwoods requires knowledge of the effects of many factors, including species sensitivity to soil nutrient differences and to flooding regimes. In the South Carolina lowcountry, neither swamp nor water tupelos grew well in stagnant water, which had higher CO_2 levels than moving water. Soil nutrient differences had no effect on swamp tupelo, but the water tupelo growth was 1.8 times greater in the more fertile of two soils tested. These findings will help to predict the results of cultural measures and the effects of natural site factors on tree growth. SE (5).

2. ARTIFICIAL REGENERATION

Rapidly intensifying forest practices for production of hardwoods will require artificial regeneration, often with improved strains, but methods for collecting, handling, and storing hardwoods seeds are relatively primitive. A summary of available information has been prepared to provide general guides to the present state-of-the-art in hardwood seed collection and treatment and to point out problems needing research. SO (20).

Collecting sweetgum seed during the relatively short interval between ripening and dissemination, especially from widely separated sources, has long been a problem to nurserymen or commercial collectors, and immature seed has often been sown with consequent loss of nursery production. Studies in Mississippi show that sweetgum seed may be collected as early as late July and artificially ripened by storage under a combination of low temperature and high moisture. This method may be used to salvage sweetgum seed collected prematurely and permits a greatly lengthened collection period. SO (19).

Nursery stock grades have not usually been based directly on seedling survival in the field; essentially the smaller seedlings or seedlings with large top-root ratios are discarded to achieve higher average planting success. A new system for grading seedlings based on their expected root growth following planting has been developed. Monthly tests of root growth capacity of seedlings lifted prior to and during the shipping season along with data on air temperature in the nursery are involved. The new system enables the prediction of root growth for specific planting dates, and should eliminate planting failures caused by the use of stock whose seasonal root growth is not adapted to the planting site environment. PSW (36).

Yellow birch plantations are difficult to establish because of seedling mortality. In two field trials in northern Michigan, clipping the tops from newly planted yellow birch seedlings resulted in higher survival, faster growth, better form, and an appearance of greater vigor than in unclipped seedlings. If these results are confirmed in larger scale plantations, they can be used to increase the amount of desirable yellow birch in northern hardwood forests. NC (24).

Successful rehabilitation of the depleted forests of the Cumberland Plateau and Highland Rim regions of Tennessee and Alabama requires a knowledge of species to plant, planting techniques, and site evaluations. Results of a 10-year series of studies have identified general site characteristics where yellow-poplar can be successfully established using standard techniques of planting and competition control. It is estimated that more than a third of the region is average or better site quality for yellow-poplar. SO (34).

Successful plantations of fine hardwoods are difficult to establish. A study of planting stock grades in Indiana showed that, even with intensive site preparation and clean cultivation, the lower grades of stock had poor survival and growth; grades 8/32 and larger should be used for planting. A study in Illinois showed that necessary weed control can be satisfactorily achieved by cultivation or by herbicides. Herbicides are cheaper and more effective but should be applied in spots or strips to minimize environmental impact. Application of these findings will help ensure success in black walnut plantings. NC (29, 43).

Because of its rapid growth and high yield, cottonwood is being increasingly planted for timber production, especially in the South, but successful plantations and high product yields require the application of intensive culture techniques that have been developed for the species. Many years' research and experience have been synthesized into a guide that will help ensure successful establishment and management of cottonwood in commercial plantations. SO (30).

Stimulation of rooting on hardwood cuttings generally requires application of rooting hormone, although the most effective type and concentration has not been determined for most species. Treating softwood stem cuttings of sugar maple with growth regulators stimulated rooting in some trees but inhibited rooting in others. The possibility of tree differences in the response of cuttings to applied auxins will be important in any program for vegetatively propagating selected sugar maple trees. NE (22).

Artificial reforestation is necessary in much of the Southwest to re-establish ponderosa pine stands, but specific recommendations on planting and seeding practices and on cultural methods have been scattered in many research reports or mentally filed as "experience." Now a reforestation handbook is available, summarizing information on seed and seedling requirements, site preparation, planting, direct seeding, and plantation care. Adherence to these recommendations should substantially increase the chances of successful plantings. RM (35).

Douglas-fir plantations have consistently failed on some of the drier sites in southwestern Oregon. When 2-year-old Douglas-fir seedlings were auger planted on an old cutover, with either live or dead shade, or no shade, shade proved essential to survival. On this severe site, only 10 percent of the unshaded seedlings survived, compared to 47 to 60 percent of the shaded seedlings. Because dead shade (piles of rock or bark) was more expensive to provide than live shade, planting under existing brush plants may be the best alternative for increasing seedling survival. PNW (32).

Heavy frost occasionally damages nursery stock severely, and nurserymen usually cull the frosted seedlings even though unsure of how frost damage affects field survival and growth. In a study in Washington, frosted Douglas-fir seedlings were the fastest growing ones before they were damaged, and resumed their vigorous growth even after damage. These results show that heavy culling of frost damaged Douglas-fir seedlings should be avoided, else seedlings with excellent juvenile growth potential will be discarded. PNW (23).

Questions have arisen over the effectiveness of tree planting on terraces or cut banks. Five years of planting tests with ponderosa pine in central Idaho, involving brush removal and careful handling of nursery stock planted on contoured terraces, revealed that with site preparation 5-year survival ranged from 79 to 95 percent. Trees planted 2 to 3 feet (0.6 to 0.9 meter) from a cut bank grew taller than trees planted 6 to 7 feet (1.8 to 2.1 meters) from the bank; height growth increased steadily during the 10 years after planting. Careful handling of good nursery stock and adequate site preparation will often determine the success or failure of these planting programs. INT (26).

Reforesting brushy lowlands by planting black spruce has been largely unsuccessful in the Lake States. Forest scientists in Minnesota recently reported that survival of 2-2 spruce planted in live sphagnum moss was 96 percent, compared to only 62 percent on plots lacking the sphagnum. Such information indicates that spruce should be planted in patches of living sphagnum and released from competing vegetation to successfully convert some 3 1/2 million acres of brush to productive forests. NC (27).

Reforestation of the great swamps in southern United States requires species that can survive and grow despite periodic flooding and siltation. Studies in Mississippi show that water tupelo is well adapted to shallow flooding. Complete submersion, moderate flooding until late in the growing season, reflooding, and moderate siltation reduced growth, but most seedlings survived. Water tupelo has good potential as a species to plant for restocking the swamp areas. SO (28).

Hawaiian soils and climates promote excellent tree growth, but little information exists on the adaptability and utility of nonnative species to island environments or on the proper spacing for effective reforestation. Eight-year results on planting and spacing studies show that Australian toon, loblolly pine, and tropical ash survive and grow rapidly at a range of spacing from 6 to 12 feet (1.8 to 3.7 meters). Another species, Batai (*Albizia falcataria*) grows extremely fast, and if equally successful in large-scale planting could greatly increase the supply of locally available wood products. These results supply some of the guidelines needed to re-establish or revitalize Hawaii's forests. PSW (21, 39, 41, 42).

Direct seeding, if successful, is less expensive than planting as a means of reforestation. In Hawaii studies, direct-seeded West Indies mahogany and monkey pod had good survival and height growth, and lemon-gum eucalyptus had fair survival and growth after one year. Redwood and brushbox had poor survival and growth. These results indicate the possibility of developing successful direct seeding techniques, and more efficient reforestation, for some tropical hardwoods in Hawaii. PSW (37, 38).

Thousands of acres of Appalachian mountain sites that once supported or will support productive, rapidly growing white pine stands are now difficult to regenerate because of an overstory of brush and low quality hardwoods. Studies in West Virginia show that conversion of these sites to white pine is feasible by clearing and direct seeding or planting, or by underplanting hardwood canopies followed by later removal of the overstory. Underplanting and overstory removal seems best; it is cheaper and surviving pines usually need no subsequent release. NE (40).

A recent Southern Station research paper updates the prescriptions for direct-seeding longleaf pine. New techniques have resulted from new research in the past 15 years coupled with experience from the practical operations of sowing more than 200,000 acres on a wide array of sites across the South. The recommendations cover all phases of a direct-seeding operation from initial planning to appraisal of results. The paper contains sufficient detail to guide a forester with no previous experience through his first operation. SO (31).

Planting pine to rehabilitate depleted forests on the steep, chert-strewn slopes of the western Highland Rim is difficult and expensive. Studies in Tennessee show that direct seeding of prepared sites using treated loblolly and Virginia pine seed is a successful, cheaper alternative. Spot seeding is more economical of seed, but broadcast sowing is faster. SO (33).

Afforestation of brush-covered land in New England has been hindered by high costs and lack of effective methods or equipment. A furrow-seeder has been developed that successfully direct-seeds pine on rough, stony, and brushy land at about one-third the cost of planting. This development should speed regeneration and conversion to productive forest of thousands of acres of idle land. NE (25).

3. STAND IMPROVEMENT

Do hardwood understories invading southern pine stands reduce the growth of the pines? In a 53-year-old pine stand in Arkansas, removal of the hardwood understory increased average annual yields by 14.3 cubic feet (123 board feet) per acre over a 14-year period; yields of a 47-year old stand were increased by 32.6 cubic feet (342 board feet) per acre. Such data show that timber yields can often be increased considerably by reducing understory vegetation especially where growing-season moisture is a limiting factor. SO (47).

Forest managers must know how trees and shrubs react to the control of tree spacing and understory vegetation density. A ponderosa pine spacing study in central Oregon showed that saplings will respond to a wide range of spacings but maximum wood-producing benefits from thinning are gained only by also suppressing understory vegetation, an operation that, in addition, increases forage and water yields. Diameter and height growth of the trees were reduced 40 percent at the widest spacing by competition from understory vegetation; other products such as forage were increased by thinning and understory control. The options presented here help the manager to determine the optimum mix of forest products to satisfy varied management objectives. PNW (44).

Firetree (*Myrica faya*), an introduced species, now infests more than 40,000 acres of potentially productive range and forest land in Hawaii, and environmentally acceptable methods must be found to eradicate it before desirable species can be established. Injecting individual firetrees with Tordon gave rapid and complete canopy kill and 99 percent control of sprouts. The method, which limits application to the specific target pest, promises great effectiveness in preparing firetree sites for establishment of more desirable species without adverse environmental impact. PSW (51).

Dense shrubs can seriously interfere with the establishment and growth of desirable tree species. Two herbicides, dicamba and picloram, used alone or in mixture with 2, 4-D, gave substantial control of six shrub species common in northern Idaho brushfields. Selective herbicides used in this way permit the planting of tree seedlings without mechanical brush control. INT (49).

Herbicides offer the forester a way to control unwanted plants without resorting to heavy mechanized equipment that could damage the site. While seeking ways to reduce the dosage of herbicide needed to do the job, scientists in Louisiana found that adding ammonium nitrate to 2,4,5-T foliar sprays more than doubled absorption of the herbicide by the leaves of sweetgum, post oak, and red maple. These greenhouse results suggest that the effectiveness of 2,4,5-T sprays can be increased by use of the proper additives, so that less weed killer may be needed. SO (45).

Under some circumstances, fertilizers make herbicides less effective than normal. Hardwoods growing in pine plantations--sweetgum, post oak, and red maple--were less than normally susceptible to 2,4,5-T foliar sprays if they were growing on fertilized land. Implications of this Louisiana study are that brush control measures may have to be modified for use in releasing fertilized pine plantations. SO (46).

Intensive site preparation is becoming more prevalent on all types of sites in the South, but often without information on expected growth responses or the best treatment for a particular soil type. In a Louisiana study on poorly drained Caddo-Beauregard silt loam soils, mound disking (bedding) increased growth of planted slash and loblolly pines the equivalent of 1 year's growth over the untreated checks by age 8. Flat disking, as effective as mound disking with loblolly, had no effect on the growth of slash pine. SO (48).

Brown-spot needle blight kills many longleaf pine seedlings and reduces growth on many surviving trees. An unusually long-term study in Louisiana of the effects of degree of infection showed that by age 30, stands of trees that had been only lightly infected had outsurvived and out-grown moderate to heavily infected stands of trees. Lightly infected trees produced averages of 1.7 to 2.4 times as much pulpwood as trees moderately to heavily infected. These findings help to quantify the long-term impact of the disease, and clearly demonstrate the need to continue the practice of prescribed burning to reduce brown-spot infection until a resistant strain of longleaf pine can be located or developed by breeding. SO (50).

(For an additional item relating to III-3 see paragraph under II B 12a.)

4. ANIMAL DAMAGE

Animal damage to growing trees sometimes comes from unexpected sources. A survey of Pacific Northwest Ranger Districts has revealed that pocket gophers are far more damaging than previously recognized--gophers and porcupines ranked second to deer as animals damaging to trees. As efforts to reforest recently logged lands and rehabilitate older nonstocked areas are intensified, more gopher damage may be anticipated because of the gopher populations of these areas. PNW (52).

Accurate information on both the cause and the effect of animal damage can reduce expenditures for control measures. Careful study in a Washington Douglas-fir plantation showed that clipping by hares soon after planting caused height-growth reductions avering 2.7 feet (0.8 meter) in

10 years--a loss of 2 to 3 years' growth--whereas subsequent severe deer browsing reduced neither survival nor height growth. Thus measures to control deer browsing would have wasted time and money. PNW (53).

Foraging ruminants in young stands of Douglas-fir have strong preference for the young growing tips relative to the mature needles. A study at the University of California (domestic grant) showed that the young growing tips of Douglas-fir have lower concentrations of monoterpene alcohols and carbonyl compounds than the mature needles, and this difference may be related to the degree of palatability. The results also demonstrate a gradual increase in concentrations of these components as the growth matures. Marked differences in the balance of nutrients vs. terpenes occurred in both young foliage and year-old needles when trees were fertilized with urea and gypsum. This balance may also be a factor in the palatability of foliage for ruminant animals. WO (55).

Damage to seedlings of southern pine can be extensive where large concentrations of rabbits are found. Timber growers in such areas often use expensive applications of various repellents to control damage, but such repellents may be unnecessary according to a Louisiana study of the effects of rabbit damage based on 30 years of observations. The adverse effects of first-year damage to slash, loblolly, and shortleaf pine seedlings on survival, growth, and degree of dominance after 30 years were negligible. These findings indicate that costly repellents need not be applied to planting stock unless severe rabbit damage is expected immediately after planting. SO (58).

Red-headed and pileated woodpeckers cause serious damage to utility poles in the southern and eastern parts of the country, but no one knows how to prevent the attacks. Louisiana-based studies indicate that decoy poles, preservative treatments, and chemical repellents have been unsuccessful in keeping the big birds from feeding or nest building. Although mechanical guards such as hardware cloth may be torn open, coatings and wraps offer some protection. Ornithologists are also concerned; one reason for a reported decline in the red-headed woodpecker population is that eggs laid in creosoted poles may fail to hatch. SO (54, 56, 57).

5. GROWTH REQUIREMENTS

Planting of Engelmann spruce in the central Rocky Mountains at elevations of 9,000 to 11,000 feet (2,740 to 3,350 meters) is generally not successful. Early investigations indicated that neither drought, frost heaving, nor animal damage were important causes of planted spruce mortality. In more recent studies in Colorado, chlorosis and death of seedlings was found to be caused by high light intensities of up to 16,000 foot-candles (solarization). Chlorosis was not related to nitrogen deficiency. Shading of healthy seedlings in the field doubled the survival rate, although shading of seedlings in the nursery or hardening bed prior to lifting did not increase field survival. Water deficits of seedlings during the growing season were nearly the same for open-grown and shaded spruces. Solarization under high light intensities appears to be responsible for the high mortality of spruce seedlings at high altitudes. RM (83, 85, 86).

Engelmann spruce--a high-elevation, cold-climate species--grows so slowly in forest nurseries that seedlings are not ready for outplanting until at least 3 years old. A study in the Caltech phytotron of growth responses to temperature regimes showed that increased night temperatures markedly increased seedling growth: 73° F. (23° C.) at night coupled with a 66° F. (19° C.) daytime temperature yielded the heaviest and tallest seedlings. These results suggest that the time required to grow planting stock to a suitable size can be shortened by artificially maintaining higher than usual nighttime temperatures in the nursery. RM (72).

It has often been difficult to reestablish Engelmann spruce in clearcut areas in the Rocky Mountains. Observations in 5 Colorado National Forests over a 6-year period revealed that good crops of 100,000 or more seed per acre were produced once in 4 or 5 years on three areas; elsewhere seed crops were good in 2 of 6 years. In spite of the reasonably good seed production, openings generally contained less than 300 seedlings per acre. Seedling establishment is evidently limited more by environmental factors (such as high light intensity, high temperatures, and dessication) that reduce seed germination and seedling survival than by seed supply. Studies under controlled conditions show that few Engelmann spruce seedlings will survive the first year with less than 2 inches of rainfall per month. RM (59, 84).

Many red fir plantations at 6,000 to 8,000 foot (1,830 to 2,440 meter) elevations in California have had low survival. Heavy deer browsing kills some planted trees, but does not explain most mortality. A recent study in central California showed that red fir seedlings benefited from shading during the first year, probably because shade reduced high soil surface temperatures. The extra cost of artificial shade may not be justified in all situations, but the practice is probably worthwhile when planting difficult sites, and where maximum survival is important. PSW (68).

Little is known of the biochemical changes occurring during germination of the seeds of southern pine. A Louisiana study with longleaf and slash pine showed that protein synthesis was slower in longleaf than slash pine, indicating that the metabolic pathways of the two species are differentially used during germination and seedling development. These differences may be related to the stemtip dormancy in longleaf pine, and may aid in clarifying the problem of the retarded early growth or "grass stage" in longleaf pine by indicating an apparent inhibition of protein synthesis. SO (62).

Studies of the germination requirements of longleaf pine in Louisiana indicate that red light promotes germination but far-red light inhibits germination, suggesting that germination is controlled by the photoreversible reaction of the pigment, phytochrome. However, longleaf pine seeds must imbibe at least some water to respond to light, although complete inhibition of water at 41° F. (5° C.) for 28 days essentially removed the light requirements for germination. Results of these studies will be of benefit in better understanding environmental factors that affect germination of longleaf pine seed used in artificial regeneration activities. SO (76).

Prompt germination of southern pine seed is important in direct seeding and nursery operations. Unstratified seed exhibits seed dormancy, which varies greatly by species and seed lot. The causes of this seed dormancy may be related to chemical or physical properties of the seed or seedcoat. In a Louisiana study, bioassays of seed extracts and leachates revealed no evidence of a germination inhibitor in seeds or seedcoats of slash, shortleaf, spruce, or Ocala sand pine. Inhibitory activity was found in loblolly pine seed, but was not the major cause of dormancy in these seeds. Other factors, such as seedcoat permeability to oxygen and mechanical restraint, contribute as much or more to the dormancy of loblolly pine seeds. SO (61).

Slow germination of conifer seeds causes unpredictable losses in nursery and direct seeding operations. Treatment with 30-percent hydrogen peroxide has been used to speed germination of some western conifer seeds, and shorten the time ungerminated seeds are exposed to damaging agents. However, studies in Oregon showed that this treatment adversely affected the first-year growth of seedlings of Douglas-fir, ponderosa pine, and western larch, and cannot be recommended. PNW (65).

To fully understand the growth requirements of tree seedlings, more information about the metabolism of seeds and seedlings is urgently needed. In PL-480 research in Poland, *Fraxinus excelsior* seedlings which grew from unchilled embryos were found to be dwarfed when compared to those growing from chilled embryos. The dwarfed seedlings contained fewer gibberellin-type substances than the normal seedlings, as well as smaller total amounts of gibberellins. The dwarfness of the seedlings probably was caused by an impaired mechanism of gibberellin synthesis which could be attributed to the unfulfilled cold requirements of the plants. WO (75).

Studies of the nutrition of tree seedlings and the distribution of important elements in the organs of the seedlings provide needed information for successful tree culture. Two studies done in Spain under PL-480 document the complex nutritional requirements of *Pinus radiata* and *Eucalyptus globulus* seedlings when grown in hydroponic culture. The findings for *Pinus radiata* indicate that foliar diagnosis of seedlings under boron-toxic conditions should be based on complete element analysis, including N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, S, and B. WO (77, 78).

A chief characteristic of conifers is their resin production. However, conifers also produce other secretions, and there are many conflicting opinions about the nature and mode of the secretory cell development and about the composition of the secreted substances other than oleoresin. PL-480 sponsored researchers in Israel found secretory cells in embryos, seedling roots, the hypocotyl and cotyledons of seedlings, and the roots of older plants of Pinus halepensis. The secreted substances were found to be polyphenols, mainly leucoanthocyanins. Such basic investigations contribute to our understanding of the nature of secretions from trees that may be conductors of organic substances within a tree, or influence the soil environment, when secretions enter the soil from roots. WO (92).

Past work with coniferous trees suggests that both auxin and gibberellin may play an important role in maintaining apical dominance. Basic research with decapitated Scots pine in Poland (PL-480) demonstrated a strong interaction (synergism) between gibberellic acid and indole auxins in maintaining apical dominance. The mode of action of gibberellic acid may be through an enhancement of auxin synthesis from tryptophan and other indoles, and a stimulation of auxin transport. Such work provides insight into the development and growth of pines and other conifers. WO (91).

Hormones in seeds regulate germination; gibberellins and cytokinins allow germination and growth of dormant embryos, whereas abscisic acid prevents these processes. To gain information about the mode of actions of these hormones, the changes in certain storage nutrients during germination of white ash seeds were observed, and the effects of added gibberellic acid and abscisic acid were determined. The results of this grant research performed at Syracuse University showed that certain water-soluble glucosides fulfill definite functions in the germination and growth of white ash embryos, and that gibberellic acid and abscisic acid can exert a regulatory effect on the metabolism of these glucosides. Such research in basic physiology will provide new insights into the problem of breaking seed dormancy in important tree species. WO (87, 88).

The ability to culture various plant organs on artificial media is an important stage in studying the developmental biology of woody plants. Techniques evolved during 3 years of study of sterile culture of apical meristems and embryonic shoots of Norway spruce are discussed. Such culture is not tissue culture, but organ culture; growth and development is organized and much closer to that of the intact plant than that of callus masses. The techniques described can serve as a standard of comparison and departure for future studies on physical and biochemical control of development at the shoot apex. Sufficient detail is provided so that these procedures can be adapted to other studies, and other genera of conifers, with a minimum of preliminary work. WO(SE) (81).

Control of plant growth and development is largely centered at the shoot apex. Large quantities of shoot apical meristems of Norway spruce and other conifers can be cultured on simple culture media, and their culture provides basic knowledge of growth processes in trees. Studies of the type and concentration of agar in the culture medium revealed that dry weight yield of tissue increases as agar concentration decreases. Some of the adverse agar effect can be eliminated by substituting glucose and fructose for sucrose in the medium. These techniques permit study of response of growing points to controlled environments and to chemical substances. WO (82).

Plant tissue culture is especially useful in the study of tree physiology because trees are large and long-lived, making the mass culture of tree tissue in the laboratory a decided advantage. Research in Poland (PL-480) with the culture of callus tissue of Scots pine shows that the tissue can be successfully grown on modified White, and Linsmaier and Skoog media. The Linsmaier and Skoog media are preferable because they do not require the addition of organic nitrogen. Such research aids in the solution of practical problems regarding vegetative propagation of species which are difficult to root. WO (80).

Mechanisms promoting secondary growth of tree stems are influenced by natural cytological events and the stage of development of anatomical features in the cambium. Studies of these factors are essential in understanding stem growth. Cambial activity in white spruce in Alaska was observed during a 2-year period in 50 to 60-year-old natural stands. There were three distinct growing season periods: early, grand, and late. Production of the first new xylem and phloem elements marked the beginning of the grand period, during which about 80 percent of annual xylem and phloem increment occurred. There was a drop in the number of cambial zone cells per radial file at the beginning of the late period. Complete termination of cambial activity was gradual, extending into September. WO (69).

A better understanding of the elongation process could lead to improved methods for increasing height growth of trees. During periods of reasonably good growing conditions (primarily soil moisture) about three times as much of the variation in flush length was due to number of nodes as was due to internode elongation in longleaf pine. An inverse relationship was observed between summer growth and spring growth the following season. This may be a matter of timing: trees growing late into the summer may have less reserves and less time remaining in the growing season for winter bud formation. Such relationships would tend to increase the amount of variation in terminal growth from one year to the next. SO (60).

Tree growth is affected not only by site productivity but by weather conditions during the growing season. Analysis of loblolly pine shoot growth in North Carolina's Piedmont revealed that air temperature, in terms of cumulative heat sums, was the principal factor relating to changes in growth rate, both during the day and at night. The daytime threshold temperature for shoot growth was about 50° F. (10° C.). Knowledge of the physiology of tree growth may eventually lead to greater productivity or shortened rotations. SO (64).

Growing seedlings in controlled environments may reduce the time from seeding to outplanting by two-thirds. Ponderosa pine and blue spruce grown for 10 months in the greenhouse were comparable in size to 3-year-old nursery-grown seedlings in North Dakota. Greenhouse culture offers several advantages, such as faster growth, year-round operation, and location of physical plant near planting sites; however, production problems such as cost of greenhouse culture on a large scale, optimum environment for each species, and shipping costs for potted trees, need to be resolved. RM (89).

Plastic film with red flouorescent dye is available for greenhouse shading, and the red light produced should be a more efficient energy source for photosynthesis than is green light. Research in North Dakota indicates that seedlings of ponderosa pine, white spruce, and blue spruce grown under red fluorescent plastic film tend to be larger and heavier than seedlings grown under clear plastic. Results also indicate that each species and each tree family within a species may respond differently to changes in light quality. More information of this nature is necessary to evaluate the benefits of greenhouse culture of forest trees. RM (90).

Competition between grass and small seedlings is considered economically important and it has been suggested previously that fertilization is more beneficial to competing vegetation than it is to conifers. Results of a study in Poland with Norway spruce and grass grown in the same container indicate that roots of grass are more adsorptive (4 times as much labeled phosphorous in 24 hours) than spruce roots. The better the nutritional conditions in the soil, the more serious the competition problem. This explains why fertilization in the presence of grass is not beneficial to conifer seedlings and why this practice should always be coupled with effective weed control. WO (66).

The importance of mycorrhizae on tree roots to the growth and development of trees is well established. For years it was believed that endomycorrhizae in maple roots caused the intermittent constrictions of the roots known as beaded root development. Research in Maryland shows that beaded roots develop on maple lacking mycorrhizae. Growth of plant organs and formation of root hairs were related to nitrogen and phosphorus concentrations in the growth medium, but growth of individual beaded root segments was related only to the concentration of phosphorus. WO (63).

Swamp tupelo and water tupelo can survive under flooded or near-flooded conditions in the southeastern and southern Coastal Plain, but their growth has been unpredictable. Type of flooding (moving or stagnant water), depth of flood water, and duration of flooding have a considerable effect on tupelo growth, but not on survival. Controlled experiments in South Carolina showed that height growth in moving water was about double that in stagnant water, and total dry weight growth was 2 to 5 times greater. Height growth was reduced under all flooding treatments in late spring, but more in stagnant water than in moving water. In the Coastal Plain, swamps that originate in oxbows and ponds typically have stagnant water, whereas sloughs along major streams and headwaters have moving water. Knowledge of the growth performance of tupelo from these experiments will aid in the site classification and management of tupelo stands. SE (74).

Aeration of interior tissues in the stems of woody plants is poorly understood, but such knowledge is necessary for the development of optimal cultural practices for trees growing on continuously and intermittently flooded soils. Seedlings of swamp tupelo were grown under controlled conditions on flooded and nonflooded soil near Charleston, S.C.; flooded seedlings developed lenticels with ample intercellular spaces, which appear to aid in oxygen exchange, and water roots, which increased the absorption area and gave support to the trees. Because lenticels collapse in the absence of water, and closing layers typically develop on all but continuously flooded lenticels, there is a reduction in gas exchanged via lenticels shortly after a water table recedes. These results suggest that swamp tupelo is adaptable to various water regimes, and can tolerate considerable variations in soil flooding and aeration. SE (73).

Soil compaction caused by heavy logging equipment is of growing importance in the southeastern Coastal Plain. Bulk densities of surface soils increased from 23 to 52 percent on skid trails and log decks, and infiltration capacity was drastically reduced on all classes of disturbance. Such disturbance is most injurious to the establishment and growth of loblolly pine when severe compaction is coupled with excessive soil moisture. Field and greenhouse experiments near Charleston, S.C., showed that establishment and early growth of loblolly pine were greatly reduced on compacted soils because of poor soil aeration and mechanical resistance to root growth. The deleterious effects of logging can be reduced by not logging during extremely wet weather, and dispersing logging traffic. Heavily used areas, such as logging decks and skid trails, may be restored by cultivation. SE (70, 71).

During intermediate cuttings in southern pine stands, skidding with large crawler tractors disturbs soil and tree roots, especially in wet weather. In a recent study in Arkansas, diameter growth of small sawlog-size loblolly pine growing on imperfectly drained soils was reduced following wet weather logging. In addition, the soil structure was puddled and sealed over, and bulk density in the 0- to 2-inch layer of the skid trails was 13 percent greater than on adjacent undisturbed areas. Neither tree growth nor soil physical properties were impaired following dry weather logging on the same type of soil. On imperfectly drained soils such as those described, skidding of logs should only be done during dry weather. SO (79).

Rates of photosynthesis and respiration in green leaves are strongly controlled by leaf temperature, but it is extremely difficult to obtain precise measurements of leaf temperature in the field. A thermocouple contact thermometer has been developed with an ease of attachment and rapid equilibration which allows up to six determinations to be made per minute. The performance of the contact thermometer compares well with that of a thermocouple inserted within the leaf mesophyll and with measurements made with an infrared radiation thermometer. WO (67).

6. GROWTH AND YIELD

Commonly used yield tables for eastern white pine are inadequate to reflect site, stocking, and modern utilization standards. New yield tables and equations developed through a cooperative study with the Universities of Maine, New Hampshire, and Massachusetts predict cubic-foot and board-foot yields by age, site index, and percent stocking for unmanaged white pine stands in New England. These tables provide a more accurate basis for evaluating timber management opportunities for white pine. NE (104).

Typical yield tables are valuable assists to forest land managers, but they do not provide detailed information on stand structure as influenced by age, site, and stand density that is necessary for the most efficient management planning. Such information is now available for old-field plantations of slash pine in Georgia and Florida, and includes yields expressed both for multiple products (sawtimber and pulpwood) and for all pulpwood. SE (95).

Yield tables, commonly available for slash pine plantations, have not been available for managed natural stands of this valuable species. A new management aid, applicable to stands in Georgia and Florida thinned at least once, gives cubic- and board-foot yield estimates for various age-site-density combinations. Included are both predicted yields for given stand conditions and projected yields from known stocking levels. SE (94).

Commonly used volume tables are not applicable for young, planted cottonwood trees. New volume tables, based on measurements of 650 trees in the Mississippi Valley, have been prepared listing total cubic foot volume inside and outside bark, volume outside bark to a 3 1/2 inch (8.9 cm.) top, and volume inside bark to a 3 inch (7.6 cm.) top for plantation-grown cottonwoods up to 10 inches (25.4 cm.) d.b.h. These tables will be useful in calculating volumes as a guide for commercial thinnings of thousands of acres of cottonwood plantations. SO (106).

Determining the "best" spacing for plantations requires consideration of subsequent growth rates and yields. Five year results of a cottonwood spacing study in southern Illinois show that wide spacing (14 X 14 feet or more) maintains the most rapid growth rates and will provide large products on short rotations. Closer spacings will produce more wood volume sooner because, although the trees are smaller, there are more of them. Closer spacings are thus better for pulpwood production. NC (105).

An increasingly valuable record of Douglas-fir growth is provided by early plantations established in Washington in 1925 on site IV (low to medium) at spacings of 4 X 4 to 12 X 12 feet. At age 43, the merchantable volume (4-inch top) is nearly three times as great at the widest spacing as at the closest. The 100 largest trees per acre average 12.1 and 7.3 inches in diameter respectively, and the wide-spaced trees are 39 percent taller (79 vs. 57 feet). The results show the large potential benefits from spacing control in yield of Douglas-fir on sites of this quality. They also show the confounding effect of stand density on site quality estimates derived from height and age for sites of this quality. PNW (98, 109).

Growth data for loblolly pine plantations in the West Gulf Coastal Plain have been scarce. However, information from central Louisiana plantings shows that wide plantation spacing (up to 10 X 10 feet) and heavy thinnings result in trees 2 - 3 inches larger in d.b.h. at 40 years than trees grown at closer spacings. This gain must be weighed against a loss of about 5 cords per acre in the 20 years since thinning began. This study gives forest owners alternatives to choose the thinning practices that produce either larger trees or greater volumes of wood fiber. SO (99).

Wide spacing in plantations permits continued rapid tree growth and may eliminate the need for noncommercial thinnings, if form and quality are not seriously reduced by lack of early competition. After 22 years, a Michigan jack pine plantation planted at the widest spacing tried (9 X 9 feet) contained the largest trees and the most volume, and the wide spacing did not result in excessive crown or branch size. At least for a pulpwood objective, this wider-than-usual spacing should reduce establishment costs and achieve short rotations on suitable sites. NC (102).

Two Michigan tests showed that while age and site affected red pines response to treatment, growth and cone production were increased more by thinning than by fertilizing in 53- and 55-year-old natural stands on medium sites as well as in a 20-year-old plantation on a good site. Interpretation of these results suggests that while thinning is necessary for cone production, it is most successful with young stands on good sites. Stand-by-stand determinations are necessary to evaluate the need for and probable success from fertilization. NC (97).

Early thinning in young even-aged sapling stands is desirable to improve species composition and increase diameter growth, but the optimum stand density to achieve rapid diameter growth without adverse effect on other stand values is difficult to determine. A study of different degrees of thinning in sapling stands of oak and yellow-poplar in southeastern Ohio verifies that thinning increases diameter growth but that heavy thinning can markedly decrease height growth. This provides a guide for thinning in such stands: thinning to a residual stand density of 60 percent of full stocking, but avoiding total release of crop trees, will achieve rapid diameter growth without sacrificing height growth. NE (93).

Thinnings increase growth rate of residual trees and reduce the time required to grow merchantable products, but the amounts of such changes in relation to the degree and timing of thinnings in oak stands have been unknown. Twenty year results from a large series of stand density studies in central hardwoods have made it possible to prepare yield tables for managed stands, showing intermediate and final yields attainable 10 to 50 years in the future under a standard thinning regime on three classes of site and with the initial thinning made at various stand ages. From these results the forest manager can compare future yields and returns of alternative management possibilities for any initially well-stocked stand. NE (101).

Thinning increases growth rate but may also increase defects by promoting sprouting of dormant buds on residual trees. A study in Michigan reveals that the number of such defects in thinned northern hardwood stands is inversely related to residual stand density. Thinning pole stands to 85 square feet of basal area per acre (19.5 m^2/ha.) is established as an acceptable guide for achieving increased growth without serious degrade. NC (103).

Epicormic branching can seriously degrade trees exposed by a thinning made to increase growth rates, but the physiological mechanisms controlling epicormic branching are poorly understood and no feasible means of artificial control have yet been found. The forester can restrict sprouting of dormant buds by controlling stand density and initiation of thinnings and by his selection of residual trees. A promising method for the future is the selection and breeding of improved trees resistant to sprouting over a wide range of stand conditions. SE (96).

A study of co-dominant red oak and yellow-poplar exposed by regeneration cutting in West Virginia showed that bole-sprouting was more severe on red oak than on yellow-poplar, that bud sprouting increased with height on the bole, and that most sprouting occurred during the first two growing seasons. An average of six new sprouts appeared on the butt log of exposed co-dominant red oak, indicating a significant potential for degrade depending on how long the sprouts persist. This factor must be considered in setting the minimum size opening to use for hardwood regeneration, particularly in group selection silviculture. NE (112).

Heavy snow accumulations often bend over young trees. A 10-year photographic comparison of stems of sugar and ponderosa pine seedlings severely bent after a 1958 snowstorm showed that all the trees recovered rapidly, with no subsequent stem crooks. While some loss in height growth is expected, the tree form was unaffected by heavy snow during seedling stage. PSW (107).

Plantation yields can be drastically reduced if snowstorms result in stem breakage. Such damaged in a California plantation of pole-sized ponderosa pine was found to be related to stand density. No damage was found at less than 120 sq. ft. of basal area per acre; damage increased with increasing densities, always with the dominant trees most frequently broken. Early thinnings are recommended to prevent extreme stand density and to reduce the likelihood of severe snow breakage. PSW (108).

Species mixtures in forest plantations offer some insurance against risks of monoculture. One of the relatively few mixed plantings of southern pines had loblolly and slash pines in alternating 3-row bands on a silt loam river terrace in Louisiana. The species grew at about equal rates on this site, but slash pine had markedly higher stem infections of fusiform rust. Overall growth rate during the period of this study was unaffected by favoring one species or the other in thinnings. SO (111).

Present trends in forestry are toward short rotations and complete utilization of forest products, requiring research on maximization of yield, harvesting, debarking, chipping, and pulping of young trees, and on dry matter distribution within each tree. A biomass study of aspen in northern Wisconsin revealed that the high proportion of stem wood in codominant trees (70%) makes them more desirable than dominant trees (62%) in a complete tree utilization system. NC (113).

Present forestry practices on a dwindling land base may not meet future wood requirements in the Northeast. Short-rotation forestry could be used to produce larger quantities of fiber on smaller acreages, and a list has been compiled of promising species and hybrids together with spacings, cultural practices, and cutting schedules needed to maximize fiber, boltwood, and timber production through this means. As demands on the land other than wood production increase, this and other new techniques will comprise the intensive forest culture of the future. NE (110).

Much emphasis has been placed on Chinese chestnut alone or hybridized with American chestnut for amenity uses, but little work has been done to evaluate the species as a potential timber tree. After 17 years, a planting comprised of four seedlots averages almost 40 feet (12.2 m) in height and 4 inches (10.2 cm) in diameter. Several trees have good timber form and nearly all are free of disease despite severe chestnut blight on nearby native chestnut plantings. This species probably deserves to be planted more extensively if additional seedlots can be obtained. NC (100).

7. FOREST MEASUREMENTS

Mathematical expressions of the relative density of timber stands are an essential tool in forest management, but their interrelationships are not well understood. Many stand density measures can be regarded as comparisons of average area available to trees of a stand, relative to that occupied by trees growing under a standard density condition and comparable in d.b.h. or other measure of average size. Either the open-grown or normal condition can be used as the standard and lead to similar results. Differences are introduced by use of stand average diameter, height, or site and age as alternative bases for referring observed stands to the comparable stand condition. Otherwise, choice among these measures is a matter of information available, conveniences in computation, and ready understanding, rather than of fundamental differences in meaning or precision. PNW (115).

Timber growers and users have long sought improved units of timber measure to replace empirical estimates based mainly on expected yields of sawn lumber. In earlier research, Grosenbaugh showed that total cubic volume, surface area, and length are the important primary units of tree measure, and that they could be used to estimate amounts of lumber, veneer, pulp, or other products. Current studies in the Northwest have shown how the three primary measures can be related to traditional log rules. They can also be used to estimate other quantities of interest related to log and tree size, such as sawing time, hauling costs, and log weight. The three primary units of measure have the further advantage that they can be obtained repeatedly by different observers. PNW (114).

Growth and yield information is urgently needed for the complex forests of the Cascade Mountains in Oregon and Washington. From stem analysis data at 54 locations, site index curves for noble fir were developed; they indicate greater sustained height growth after 150 years than do site index curves for most other species. By comparing growth patterns among species, foresters can better decide what species or combination of species to favor for particular sites in the Cascades. PNW (116, 117).

Forest managers have an increasing need for accurate volume estimates for small trees, but downward extrapolation from existing tables often yields erroneous results. Volume tables were constructed during thinning operations of slash, loblolly, and longleaf pine plantations in Mississippi. The tables should prove useful to researchers and managers in the South Coastal Plain region. SO (118).

Tree growth rates cannot be determined from increment cores if the growth rings cannot be identified. Treatment with phloroglucinal readily revealed growth rings in sapwood of acacia koa, but not in heartwood. However, growth rings were not annual rings in this native Hawaiian tree and could not be used as indicators of age or growth rate. Other means must be found to determine koa growth rates. PSW (119).

8. MANAGEMENT PLANNING

As the land base for commercial timber production shrinks, available commercial forest must be regulated with increasing efficiency. Computerized linear programing has been used to develop cutting strategies for maximum sustained yield of timber products from even-aged northern hardwood stands while producing balanced age distribution by the end of the first rotation. This technique is being pilot tested in an allowable-cut analysis for the White Mountain National Forest in New Hampshire. NE (120).

Timber management planning presents complex scheduling problems because harvesting, thinning, and other operations today affect yields 10 to 100 years in the future. Computer programs have been formulated which will compute actual and optimum growing stocks and allowable cuts, and calculate the future flow of products for alternate management programs. Computed timber volumes and forest areas are summarized in a timber management guide that replaces a conventional management plan. Such planning aids provide decision makers with sound ways to compare and rank various management alternatives. RM (121).

Many forest managers are faced with decisions on whether to invest, or how much to invest, in site preparation or other promising cultural treatments. Graphic aids for plantation management alternatives are now available for slash pine on sites of different productivity. The charts relate increased survival and growth to costs of cultural treatments, including compounded interest, and show how similar graphs can be constructed for other timber species. The technique should prove valuable to forest managers, landowners, and others faced with the problems of management planning. SE (122).

9. MAPLE SIRUP PRODUCTION

Maple sirup producers usually leave from 4 to 6 inches (10 to 15 centimeters) between tapholes in a horizontal direction around the tree stem. A study in Vermont indicates that there is no basis for using such guidelines. Equal volumes of sap were produced from holes located 1 to 6 inches (2.5 to 15 centimeters) from older tapholes and no reduction in sap-sugar concentrations occurred. NE (123).

Increased wood damage may result from using paraformaldehyde pellets to stimulate sap flow in sugar maple. In a study in Vermont examination of wood surrounding treated and untreated tapholes indicated that pellets kill a large area of tissue which is then more susceptible to invasion by fungi and bacteria. Eight inches (20.3 centimeters) of discolored wood was associated with pelleted tapholes at the end of 6 weeks as compared to 2 inches (5.1 centimeters) for unpelleted tapholes. In deciding whether or not to use pellets for increased sap yields, an operator should consider the possibility that he will increase rates of decay also. NE (124).

10. NAVAL STORES

New techniques to improve efficiency and reduce costs have been developed for the naval stores industry. A new black acid paste with a longer storage life has been introduced. Inexpensive plastic lined paper bags for gum collection can replace the metal cups and eliminate objectionable metal that now reaches the plywood and pulpwood mills. A prototype mechanical gum harvester with hydraulically powered hacks and tackers and large storage vat has been woods tested. High gum-yielding trees available at State nurseries are being recommended for planting open lands and replacing worked out stands. SE (126, 128).

The prospect of using paper instead of metal cups for the collection of pine oleoresin has revived interest in the use of 2,4-D to replace sulfuric acid as a gum flow stimulant. The herbicide gave as good or better results than the sulfuric acid treatment without any of the adverse effects. Repeated applications of herbicide may be lethal to longleaf pine and will require biweekly application to slash pine, but the chemical has excellent possibilities for increased resin production where it can be used and if the use of paper cups increases. SE (125)

Viscosity of pine oleoresin affects the flow rate following wounding and is strongly heritable. A technique for determining viscosity in slash pine has been developed. The measurements are made under controlled temperature in specially designed tubes and are based on movement of an air bubble through freshly collected oleoresin. This method can be used to screen parent tree candidates for naval stores breeding programs. SE (130).

A system has been developed for continuously monitoring oleoresin exudation pressure at several sample points in slash pine. The system converts resistance changes from potentiometer-type pressure transducers to voltage changes and records the information on a strip chart recorder. Readings from 25 transducers can be monitored by use of a scanning device. Oleoresin exudation pressures are useful in studying hydration cycles in pine trees. SE (129).

A study of differences in oleoresin composition of individual pine trees has clarified the within-tree variation in trees of equal age and common genetic origin. Trees with the same parents did not differ significantly in any chemical component, but the monoterpene hydrocarbon composition varied greatly from one part of the tree to another. Variability occurred in tissue types and within the wood of individual trees. This study suggests that work reporting "trunk oleoresin composition" of slash pine should specify the height at which the sample was taken, age, total height of the tree, and evidence of previous wounding. In future studies, comparison of "trunk oleoresin" from different trees should be made from comparable trunk locations and proximity to wounds because it is now clear that considerable tree-to-tree, and within-tree variations exist. SE (131).

Manufacturers have become increasingly involved with the recovery of tall oil, a mixture of fatty acids and resin acids, as a byproduct of the wood pulping process. Because of high correlations between oleoresin, wood extractives, and tall oil yields of slash pine, genetic selection for increased oleoresin production of living trees has been accompanied by a 12 percent increase in tall oil recovery from the wood. This increases the overall value of selected strains because it increases the multiple-production potential. SE (127).

(For additional items relating to III A see paragraphs under I E, II B 9a, II G, and III B 2.)

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B. Breeding Improved Trees

1. DISTRIBUTION AND CLASSIFICATION OF FOREST TREES

To improve planting success and growth rate, geneticists recommend using tree seed from local seed parents. To standardize the reporting of geographic origins in California, the State was divided into six physiographic regions and 85 seed collection zones. The seed zone number plus the elevation of the collection site will identify seed lots. Use of the standardized seed zones and labeling system will provide a basis for testing the classification scheme and for determining any necessary adjustments in seed zone boundaries. PSW (1)

Information on geographic distribution of tree species is critical to many kinds of ecological research, and is important in programs to preserve native species for scientific study and for germ plasm exchange. The first volume of a new Atlas of U.S. Trees contains about 300 large maps showing the natural range of 200 native tree species of continental United States, scale 1:10, 000, 000, with county boundaries. For correlation of occurrence with the environment, there are 9 transparent overlays that provide information on the climatic and physical characteristics of the habitat. WO (2).

A comparison of tree species found on Puerto Rico and surrounding islands and continents has provided interesting information on the island's history and on probable migration routes of trees. South America appears to have contributed the largest number of tree species to the flora of Puerto Rico but nearly one-third (61) of the trees found on the island are not found elsewhere. WO (3).

2. INHERENT VARIATION

Himalayan blue pine is one of the most important coniferous species in the Himalayan region and has potential value in pest resistance breeding or planting programs in Canada and the United States. Little was known about the natural variation in this species until the Pakistan Forest Institute initiated a morphological study. Examination of a number of foliage, cone, and seed characteristics from widely scattered stands gives insight into the magnitude of within- and between-stand variation. Further work on genotype-environment interaction is planned. WO (4).

The wide geographic range and diverse conditions over which black walnut is found suggest the strong possibility of genetic variation in this valuable species. A study at Ames, Iowa, looking at patterns of variation in 456 families from 69 sources indicated a continuous type pattern for most characters. Early results indicate that southern sources grow well in northern areas and that genetic gains may be possible using southern trees in northern breeding programs. NC (5, 6).

The breeder interested in comparing wood quality of improved varieties with native trees must have prior knowledge on variation of anatomical characters within and among individual trees. A study of wood samples from good quality trees of natural origin indicates that most of the important wood characteristics of black walnut are correlated with growth rate. Since the determination of specific wood characteristics would be difficult and costly, it is recommended that breeding programs with this species be concerned with other features such as growth rate, straightness of bole, and apical dominance. NC (7).

A method of assessing graft incompatibility in forest trees by visual means would be extremely useful. The relationship between delayed vegetative bud development and internal graft incompatibility was checked in 116 Douglas-fir clones. One hundred seventy-four of 186 grafts labeled delayed were anatomically incompatible. From these results it would appear that stage of bud development in Douglas-fir can be used to increase the percent compatibility achieved in the orchards. PNW (8).

Brown-spot needle blight is a serious seedling disease that has discouraged the use of longleaf pine in some areas. Studies now indicate that resistance to this blight is a transmissible genetic trait. In one planting 70 percent of the progeny from resistant x resistant parents were resistant when exposed to natural infection. Resistance in progeny from resistant x open-pollinated parents was approximately 30 percent and resistance in progency from nonresistant x open-pollinated trees was only 6 percent. SO (9).

Lack of adequate moisture reduces specific gravity, fiber length, and growth of cottonwood and may therefore seriously reduce yields and returns from cottonwood plantings. A study in Mississippi shows that drought resistance in cottonwood is heritable and should be selected for in breeding programs seeking improved strains for planting. Since thousands of acres of cottonwood are planted annually and are commonly subject to late summer drought, even a small improvement in drought resistance can significantly increase yield and value. SO (10).

Genetic differentiation has been observed in provenance trials of Norway spruce, and selection of appropriate seed sources is a recommended practice. Very little information was available to indicate how various provenances would respond to application of nutrients, so a study of phosphorus uptake by 20 Polish sources was undertaken. Results indicate that the requirements of spruces of various races for phosphorus are different, and a fertilization level that may be optimum for one race may prove inhibitive for another. Forest managers considering intensive culture involving fertilization should request seed sources that will respond to such treatments. WO (11).

A study of slash pine seed sources grown in a number of locations indicates that growers should use seed from northern and western sources in the northern part of the range and use only central Florida sources in southern Florida in preference to local seed. Selection for gum yield and resistance to fusiform rust will be most productive on an individual tree basis and little gain can be expected from seed source selection alone. SE (12).

Seed Collectors have been cautioned against using wide-crowned "wolf trees" as seed sources on the theory that such trees might pass undesirable features on to their progency. However, in a study that compared loblolly pine progenies from "wolf tree" phenotypes with nursery-run seedlings from commercial stands, there were no significant differences in any of the traits observed. Results indicate that the form of the selected trees was more a function of environment than genetic constitution. SO (13).

The genus *Picea* contains about 40 species, all in the northern hemisphere, that hybridize when morphologically similar species have overlapping ranges. This has often led to confusion in identifying species for purposes of forest management, tree improvement, or systematic studies. Chromatographic patterns of over 100 detected phenolic compounds in foliage of Sitka, white, and Engelmann spruce indicate that several are specific to a single species. Two of the distinctive phenolics provide a basis for determining the direction and possible degree of natural hybridization occurring between Sitka and white spruce. NE (14).

Choosing the proper seed source can be just as important as choosing the proper species. The proper jack pine seed source can produce trees nearly 30 percent taller than a local source at 10 years. Projected to a 40-year rotation this could result in an increase of $28 per acre and the difference between profit and loss of the planting venture. Recommendations on the best sources of the 7 major species used in planting programs in the Lake States have been provided by 30 years of seed source research. Seed labeling and certification procedures used for forest tree seed are explained and the type of planning to assure adequate seed procurement from recommended sources is discussed. Until and unless new information from maturing seed source trials necessitates revisions in this guide, it will be a useful tool for land managers engaged in tree planting activities. NC (15).

Northern red oak seedlings grown from acorns collected at low elevations broke dormancy and began to grow several weeks sooner than seedlings from high-elevation seed when both were planted on the same site. On exposed sites the seedlings from low-elevation seed were subjected to frost damage that reduced their growth and survival. Since the difference in time of growth initiation may well be inherent, it will limit the area where seed from a particular source may be planted and must be taken into account in tree-breeding programs. SE (16).

Knowledge that the well-known hybrid poplars from the Northeast and Europe would not perform well in the Midsouth prompted a selection program within well-adapted natural populations of cottonwood. It was determined that the use of genetically improved planting stock could increase productivity in the lower Mississippi Valley by at least 20 percent. Fourteen clones selected for their rapid growth to pulpwood size are now being propagated for use in forestry. SO (17, 20).

Estimates of genetic variance, which indicate the gains that can be expected by selection, have traditionally been obtained from long-term progeny tests. This laborious and time-consuming process may be circumvented by using Shrikhande's method for separating genetic and environmental variation through study of performance of trees in existing plantations on relatively uniform sites. Data on variability in growth rate and oleoresin yield from a 19-year-old slash pine stand in Florida indicate that this method is satisfactory if a number of statistical requirements are satisfied. SE (21).

Evidence of intraspecific DNA variation has been noted in white spruce and this study indicates similar results with Sitka spruce. Northern sources possess more DNA per cell than southern provenances which lends support to the concept of DNA plasticity. DNA levels in other studies have been altered experimentally by fluctuating environmental conditions and levels of nitrogen and phosphorus. Seeds from provenance trials will be examined to determine the degree to which quantitative changes in nuclear DNA levels and related heritable traits can be modified by environmental stress. Research of this nature could lead to manipulation of desired traits by regulating the environment. NC (18).

Past information on flowering age, which is a controlling factor in the breeding rotation of forest trees, is often based on natural stands. Flowering in sweetgum is reported to begin when trees reach ages of 20 to 30 years, but observation on plantations in Mississippi indicate that flowering may occur as early as the fourth year. Differences among geographic sources and among families within sources were observed. Selection for early flowering, providing other traits are acceptable, can reduce the time from initial selection to production of improved seed. SO (19).

Animal damage may be a limiting factor in reforestation programs in certain areas unless resistant geographic sources are available for planting. Black-tailed jack rabbits in a young ponderosa pine plantation of 79 provenances in central Nebraska preferred sources from west of the Continental Divide. When planting ponderosa pine in areas where rabbit browsing is expected to be serious, other factors being equal, the eastern sources should be favored. RM (22).

In the absence of other information, local seed souces are usually recommended for planting programs. Observations of variation found in natural stands of ponderosa pine and data from 25- to 55-year-old seed source studies indicate that local seed is the best adapted. Under severe test conditions only races adapted to severe conditions survive but under less severe conditions the local source may take as long as 50 years to exhibit superiority in survival and plot volume. The risk is related to the length of the rotation and the chance of experiencing an adverse period during the rotation. For ponderosa pine, selection of well-adapted parents within local stands appears to offer the best chance of improvement. PNW (23).

Wood specific gravity in yellow-poplar was estimated by sampling 500 trees in 50 plots in natural populations growing in the southern Appalachian region. Environmental factors (particularly available moisture) regulate earlywood-latewood transition and consequently specific gravity. If allowances are made for this relationship, then selection would be an effective tool to improve wood specific gravity in this species. The sample average of 0.41 can be used to set selection limits in the southern Appalachian Mountain area. SE (24).

Adequate variation in specific characters must be documented for a given species before a selection program can be justified. Fiber length and specific gravity of outerwood of loblolly and spruce pine were compared. Specific gravity in spruce pine was slightly lower than that of loblolly and fiber length in spruce pine was fairly uniform. The small fiber variation among spruce pine trees indicates difficulty in selecting for genetic fiber-length differences in this species. SO (25).

Selections of superior trees for tree improvement programs are usually made with little knowledge of the frequency with which the desired characteristics or combination of characteristics occurs. A method has been developed in West Virginia whereby selection of plus trees may be based on the distribution of measurable features like growth rate and clear stem length within the natural population. The method required determinations of site quality and measurements of sample trees throughout the selection area, but it permits selection criteria to be set with any desired degree of rigor based on the frequency with which the characteristic appears. Use of this method, for those characteristics for which it is suitable, will increase objectivity in plus tree selection and should often reduce selection costs. NE (26).

Recent interest in planting sweetgum has promoted research in genetic improvement of this valuable and widely distributed species. The research indicates that much of the observed variation in growth and form of juvenile sweetgum is under strong genetic control. Considerable improvement through mass selection appears possible from the results of a progeny test of selected open-pollinated trees in south Mississippi. SO (27).

The performance of trees in provenance trials is often used to answer questions about genotype-environment interactions. Another method is to examine various chemical constituents of plant tissues. Monoterpene composition of cortical oleoresin samples was determined for 16 populations of white spruce growing in lower Michigan. A cluster analysis of the data suggests that white spruce consists of two distinct clines or gradients extending from the Lake States northwest to Alaska and northeast to Labrador. NE (28).

Moving plant populations from one region to another within the natural range of the species may result in additional growth but experience with many species has shown that local sources usually perform best. Provenances of sweetgum, a species with a wide latitudinal range, were studied in growth chambers in Texas and the reaction to varied photo- and thermoperiods was observed. The reported differences among populations reflect the effects of natural selection upon sweetgum populations forming several races (ecotypes) with limited tolerances for environmental changes. While the recommendations are rather broad they do indicate that seed should not be moved too far north or south of the source. WO (29).

Growth rate and foliage characteristics, especially color, are important factors in selecting Christmas trees. Nine-year studies in Michigan and Nebraska of 50 sources of Mexican white and limber pines and of 128 sources of Douglas-fir indicate that Arizona and New Mexico sources of all species tested were fastest growing and have the "bluish" foliage preferred by most growers. Where winters are particularly severe growers may find some lack of frost hardiness with the southern sources of Douglas-fir, but otherwise the Arizona and New Mexico sources should provide highly desirable Christmas trees for use in the north central region. RM (30, 31).

3. INSECT-DISEASE RESISTANCE

A fast-growing, frost and drought resistant knobcone x Monterey pine hybrid has been found susceptible to red band needle blight on California redwood sites. However, one plantation so far shows no infection, but the planting site is four times higher in elevation and farther inland than other plantations, suggesting that small differences in climate may be a key factor in limiting needle blight infection. PSW (32).

The most serious deterrent to growing quality white pine in the Northeast is stem deformity caused by the white-pine weevil. Species and hybrid trials now underway indicate that some form of resistance may exist in western white pine and in a few individual trees of eastern white pine. Leader damage in the eastern white pine x Himilayan blue pine hybrid was severe. These results will give direction to new selection and breeding programs involving the white-pine weevil. NE (33).

A study of several species and hybrid combinations of pine in Connecticut indicates a variety of responses to sawfly damage. Only small numbers of eggs and larvae were observed on a number of trees in this study. This suggests that a program to produce resistant stock should include trees unattractive to adults and unsuitable for larvae survival as a promising means to reduce insect attack in plantations of improved species. WO (34).

A study of jack pine seed sources in the Lake States indicated that this species is susceptible to at least 15 pests but also contains sufficient heritable variation in these characteristics to make breeding for resistance worthwhile. Resistance to one pest does not imply resistance to another and breeders must know host-pathogen relationships thoroughly or selection for resistance to one pest may increase susceptibility to other pests. If a pest resistance breeding program attempts to include the full spectrum of insects and diseases it may be diluted to the point where no progress is made with any pest. Pests that do not have an important economic impact on forest productivity should be ignored. NC (35).

Species introduction using the proper geographic ecotypes can be a valuable tool in reforestation programs. In eastern Nebraska trees of European black pine from 21 sources were evaluated for resistance to a needle blight fungus, *Dothistroma pini*. Individual trees in 16 sources appeared to be resistant but only one source (Yugoslavia) showed universally high resistance. Trees from the resistant source were also superior in height growth suggesting that seed collection be restricted to this source if these two characteristics are of primary concern. These trees would be suitable for both shelterbelts and Christmas tree plantings. RM (36).

(For an additional item relating to III B 3 see paragraph under II B 12a).

A hybrid combining the fast growth and good quality of loblolly pine and the cold hardiness and adaptability of pitch pine has been superior to the parent species in other countries. Plantings to compare the hybrid to the parent species were made in four midwestern States and early results indicate that loblolly is the preferred species below the 39th parallel but the hybrid outgrows both parent species north of the 39th parallel. NC (37).

Hybridization between species may result in progeny that are in some way superior to their parents, but plant species by definition are reproductively isolated. How readily hybridization occurs naturally varies by species and may not be a reliable guide to how readily the species can be crossed artificially. Hybridization studies with 12 species of birch did not reveal the actual barriers to interspecific hybridization in this genera but did indicate that incompatibility reactions require close contact between pollen tube and female flower tissue and probably involve enzyme systems in both organs. Understanding the reasons for incompatibility and developing the ability to overcome this phenomenon would greatly benefit tree improvement programs. NC (38).

Seed orchard managers must try to anticipate the years and months in which graft survival will be too low to justify production costs. A field study of 1,300 Douglas-fir grafts in Oregon indicated that 90 percent survival was possible when grafting was confined to the March-May period. Summer grafting was not successful and fall grafting in September-October was especially unfavorable. Factors producing water stress conditions after mid-May probably had a detrimental effect on graft survival. PNW (39).

The results of a survey of Douglas-fir seed orchards in Oregon and Washington revealed that 46 percent of the grafts were dead and more were listed as unlikely to survive. This problem is so severe that the practicality of establishing additional grafted Douglas-fir seed orchards is questionable. Investigations of plant tissue revealed a correlation between width of a cork suberin layer in the inner bark and incompatibility. Cultural practices that facilitate additional cambium growth, such as summer irrigation, might retard suberin development and reduce graft losses. Grafting techniques resulting in better union between stock and scion of incompatible grafts will result in longer survival of the graft but temporary survival is not a real solution. PNW (40).

A revised system for classifying stages of female strobilus development in southern pine is based on a 3-year reproductive cycle (bud-year, flower-year, seed-year) instead of the usual 2-year cycle. This system better emphasizes the important bud formation period. Once bud primordia have formed, subsequent events can only diminish, not increase, the size of the future seed crop; therefore, cultural treatments to increase seed production must be completed before primordia have formed. Use of this classification will eliminate many of the present communication problems among tree breeders. SO (41).

One problem in seed orchard management is contamination by "inferior" pollen from surrounding stands. In a study in Wisconsin, high concentrations (500 ppm) of abscisic acid delayed bud break and subsequent flower development on white spruce seedlings up to 8 days; the fuel oil carrier alone, apparently acting as antitranspirant, delayed bud break as much as 5 days. Initial trials in Oregon indicate that cold water sprinkler systems may be used to delay floral bud opening in Douglas-fir seed orchards until after the peak of local pollen release. Such treatments may make it feasible to achieve selection pollination and enhance production of genetically superior seed, while at the same time reducing the isolation zone now required around many seed orchards. NC, PNW (42, 48).

The effect of self-pollination could be of particular importance in seed orchards containing a number of trees of a single clone if the amount of selfing is directly proportional to the quantity of self-pollen available. Controlled crosses of white spruce in Wisconsin indicate a reduction in seed set, chlorophyll deficiency, and growth reduction approaching 50 percent when selfing occurs. The amount of selfed seed in this study was in proportion to that amount of available self-pollen which suggests that care should be taken when establishing clonal seed orchards. Guides are presented on the number of clones, clone arrangement, and spacing to minimize selfing. NC (43).

Obtaining sufficient sound seed from controlled pollinations is one of the problems in tree breeding. The use of stored pollen has been associated with poor yields, but results of a study in Georgia indicate that good results can be obtained with stored pollen if more attention is given to collecting male strobili at the proper stage of pollen maturity. Criteria are described which are useful in determining when to collect male strobili. SE (44).

Hybridization is one important method used by forest tree breeders to produce superior genotypes. Unfortunately, many potentially advantageous crosses yield few if any sound seed. Nonviable embryos have been found in several western hard pine crosses, but the most critical period for both hard and soft pines occurs before fertilization. Inability of pollen tubes to maintain a normal growth rate could account for at least 50 percent of eventual ovule abortions in some species crosses. In most pine crosses more than one incompatibility barrier is involved however, and defining these barriers will be important in developing physiological and biochemical explanations for failures that occur in pine hybridization. PSW (45).

One objective of tree improvement programs is mass production of genetically superior seed usually collected in grafted or seedling seed orchards from selected trees. White spruce in untreated plantations in northern Wisconsin produced few seed at age 21, and good seed crops are expected only every 2 to 6 years in producing stands. However, grafted trees grown at normal seed orchard spacings, weeded and fertilized, will produce large numbers of cones at age 9, although controlled pollination may be required to increase yield of filled seed per cone in the first seed years when pollen supply is low. Good seed years in managed orchards might occur as frequently as every second or third season. NC (46).

Programs for genetic improvement of southern hardwoods must be preceded by investigations of natural variation within a species, geographic variation, and progeny testing and other related breeding studies. A thorough review of previous investigations revealed three important requirements for a breeding program: (1) restrict the number of species in a program; (2) establish well-designed geographic variation studies; and (3) place greatest emphasis on second-generation selections where gains will be far greater than those obtained from initial mass selection in wild stands. Available information indicates that valuable genetic gains can be achieved in southern hardwoods if such a program is followed. SO (47).

Plant breeders are interested in interspecific hybridization to combine favorable traits of species. After 18 growing seasons, an F_1 shortleaf x loblolly pine hybrid backcrossed to loblolly pine had better survival and had produced more volume per acre than local loblolly pine in a Georgia study. Local loblolly had fusiform rust cankers on 61 percent of the stems while the hybrids were completely free of rust cankers. Shortleaf x loblolly pine hybrids have good potential for preventing severe losses to fusiform rust and increasing timber yields in plantations in central Georgia. SE (49).

One method of increasing yields of crop plants has been the development of inbred lines followed by hybridization. The use of similar techniques in forestry has received relatively little attention because of incompatibility in many species and the long intervals between each selfed generation. Experiments with ponderosa pine indicate that self-fertility will be high enough to permit easy production of selfed seedlings. The development of inbred lines for future hybridization studies may be feasible with this species. PNW (50).

Hybrids made by crossing tulip poplar from Mississippi with trees from New York produced progeny that were 40-percent taller than progeny from open-pollinated controls. These results must be considered tentative because the open-pollinated controls may have exhibited inbreeding depression. However, the results lend encouragement that superior yellow-poplar growth may be achieved through use of intraspecific hybrids and that rangewide pollen shipment and short-term pollen storage is feasible for this purpose. SO (51).

Branch pruning to increase seed production in tree seed orchards would be more efficient if some method were available to distinguish in advance between cone-bearing and non-cone-bearing branches. Growth of secondary branches in the season of cone initiation was found to be positively correlated with cone production for both slash and longleaf pine. There was no correlation between primary branch size and cone production, and heavy production in one year tended to reduce production the following year on the same branch regardless of size. These relationships will be useful in helping differentiate between cone-bearing branches and those that may be pruned. SE (52, 53).

(For additional items relating to III B see paragraphs under II B 9a and III A 2.)

Distribution and classification of forest trees

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C. Improving Use of Wood

1. WOOD AND TIMBER QUALITY

An entirely new concept was employed to develop a system for grading sawtimber. Only five tree characteristics are measured to provide estimates of timber value and lumber yield through the use of estimating equations. This improved system promises a significant reduction in the cost of appraising quality in some 6 billion board feet of inland Douglas-fir sawtimber annually and also more accurate estimates of value and volume. PNW (19).

Studies over the range of several minor species of southern pine have provided new information on their suitability for products. Increment core specific gravity was determined for each species. Equations were developed for predicting tree specific gravity from increment cores. Estimated average tree specific gravities were: Virginia pine - .447, pitch pine - .471, pond pine - .474, and South Florida slash pine - .580. No geographic variation was detected for Virginia pine and pond pine. SE (6, 7, 28, 36).

Techniques were explored for improving relationships of increment core specific gravity to merchantable tree specific gravity. In a Virginia pine study, the outer half of the breast height core (representative of approximately 88 percent of the merchantable volume) provided a better estimate of average tree gravity than the entire full-radius core. Application of this knowledge in practice will reduce greatly the effort required in obtaining core samples. FPL (30).

Wood property changes in red pine resulting from effluent irrigation were determined in a Pennsylvania study during four growing seasons. Ring width of trees irrigated with effluent at spreads of one-inch per week increased by 30 percent, but specific gravity dropped 9 percent. Two-inches per week resulted in only 11 percent increase in ring width with an 11 percent decrease in specific gravity. Although stem wood was generally affected less than crown wood, this research indicates that red pine cannot withstand large quantities of effluent. NE (21).

Overestimated tree defect partly explains large differences between timber sale bid offers and appraised values of northern hardwood timber. Cull volume in sugar maple estimated by the current method was compared with actual cull volume measured from flitch photographs, and by log scaling. The estimated volume from the current method was about four times as large as from the other methods. Use of this information will result in more accurate timber appraisals. NC (32).

The relationship between site quality and specific gravity of quaking aspen has not been known. Regression analyses of data from a Wisconsin study showed no consistent relationship. Based on these data, forest managers apparently can concentrate on volume production of aspen without concern that variation in specific gravity associated with site quality will influence the yield of fiber. FPL (24).

In the manufacture of Douglas-fir plywood about 16 percent of the veneer volume is lost between the drying operation and trimming of the finished plywood panel. Information developed on losses due to edge-jointing, reclipping, trimming, patching, gluing, and panel layup, will enable more accurate estimation of veneer log values and production cost. Study techniques developed also will be useful to management in evaluating production methods. PNW (16).

Because of keen competition for raw material some southern pine plywood mills have been forced to peel turnpentined timber. A study to determine the effect of turpentining on grade-yield recovery showed that turpentined blocks yielded 28 percent less total veneer, with 24 percent less B veneer and 20 percent more D veneer than nonturpentined blocks. Regression equations developed--involving only block diameter, kind and number of grade-reducing defects, and turpentined face dimensions--give good estimates of volume of veneer by grade. SE (4, 5).

A study of 20 white fir trees in California indicated that "wetwood" has little detrimental effect on most wood properties but has a serious impact on the degrade experienced and time required in the kiln drying process. Wetwood was found to be concentrated in the lower portion of the tree stem. The information will enable industry to accomplish more efficient drying of true fir. PNW (38).

Pecan and hickory lumber are often in commercial practice mixed and sold under one or the other group name. Distinction is not easily made, but may be advantageous at times because the true hickories are superior to the pecans in toughness, shock resistance, and hardness. A means of separating these two groups of wood, using only low magnification, was developed. SE (35).

Detailed information is often needed on the size, grade, and identification of individual pieces of lumber produced in a sawmill. A photographic technique was developed for accurately recording such information on the production line. The method is particularly useful to researchers and industry in studying timber quality, lumber-grade yields, and key elements in the production process. PNW (23).

Much low-quality hardwood timber, particularly oak, has limited utility--even for pallets. A completely new system has been devised to use very low-grade timber for pallets and still provide a superior product. It incorporates knife cutting (rather than sawing), drying in a press (rather than in a kiln), and laminating several pieces with an adhesive together to form pallet parts. The yield from the logs is increased by elimination of the saw kerf, greater strength results from dispersion of defects, and overall pallet performance was improved. Production of laminated lumber in as little as 15 minutes from log to finished product is possible. The system will extend timber supply both by increasing yield from each log and by permitting the use of low-grade logs. This concept shows promise for production of other products such as framing lumber for housing. FPL (76).

The SHOLO (from SHOrt LOg) concept was developed to enable the profitable conversion of very low-grade hardwood logs directly into products. Lumber is not produced. This concept is a significant breakthrough in utilization of the vast supplies of poor-quality trees that hinder rural area development and sound forest management in the eastern United States. NE (108, 109).

Some western species (Engelmann spruce, lodgepole pine, and inland Doublas-fir, for example) almost defy preservative treatment by conventional methods. As a result, their utility for uses such as poles and posts is greatly impaired. A new modification of the double-diffusion treatment gave satisfactory penetrations and retentions for the species mentioned. This development will greatly extend the utility of these species and augment the timber supply by opening up new sources of material for applications requiring preservative treatment. RM (94).

The FPL natural finish, developed some years ago, is a widely used, nonfilm forming finish of good durability and appearance. Under conditions prevailing in the southern States, however, there has been a tendency for the finish to become darkened by mold growth. Reduction of the amount of linseed oil and an increase in the amount of preservative solved the problem. The modified formulation provides an improved, durable natural finish for use in hot, humid environment. FPL (67).

Feasibility tests of using overlays to mask defects and improve paintability of low-grade ponderosa pine boards were conducted satisfactorily at speeds up to 180 feet per minute. Knotholes and torn grain were the most troublesome defects to mask. Corrective repair methods were studied to increase the proportion of lumber in the low Common grades that could be overlayed. Severe types of defects were corrected by first patching voids with urethane foam. This research will facilitate development of a commercial process for upgrading large quantities of low-grade softwood lumber. RM (105).

Methods of increasing permeability are important to the improvement of processes such as wood drying and wood preservation. A recent study showed that when the mold Trichoderma viride increases the longitudinal permeability of wood, it acts by modifying the internal structure, especially the pits, and thus opens pathways for preservative solutions. It was found also that a newly discovered coccus bacterium (as yet unidentified) was even more effective than was the mold organism. The rapidity of action (three days vs. weeks) enhances the possibility of practical microbiological pretreatment to increase permeability. FPL (83).

A simple wood wafer assay technique was developed that permits rapid evaluation of liquid permeability. Such assays can be used to measure effect of solvents, drying rates, temperature, anatomical structure, and other factors influencing treatability of wood. ITF (50).

The manufacture of plywood today requires veneer having specific characteristics that depend on the ultimate utilization of the plywood. In turn, most effective production of veneer depends on the characteristics of the log from which it is cut. Data on both aspects are available, but in widely scattered sources. For the first time, such information has been gathered together in a single publication, along with a discussion of the importance of the characteristics. This will be invaluable to the veneer manufacturer in choosing the logs to be cut into veneer, and in choosing new species to be used for particular products. Both aspects will have an important effect in extending the timber supply and in providing better plywood to the consumer. FPL (92).

Comparison of knife and abrasive planing on production type machines showed that abrasive planing required 6 times more power and knife planing generally produced a higher quality surface. With knife planing, however, machining defects extend deeper than abrasive scratches and surface quality decreases as feed rate increases. These results will help production managers decide when to apply abrasive or knife planing. NC (120).

Cross-grain knife planing offers important advantages over parallel-to-grain planing. High-quality flakes for particleboard manufacture are produced simultaneously with a high-quality planed surface. This reduces waste disposal problems while increasing volume recovery from short-length raw material. Maximum surface roughness also was less with cross-grain planing. NC (121).

During manufacture, the moisture content of the wood in laminated structural components (beams, columns, arches) must be close to the equilibrium moisture content encountered in service. This is desirable to minimize checking, excessive stress on glue joints, and dimension changes. Moisture content levels have now been obtained for a variety of laminated structures and conditions of use in various areas. These data provide for the first time a guide to the manufacturer for establishing the proper moisture content of materials in order to provide users with troublefree structures. FPL (77).

Use of operations research can provide precise information on lumber production alternatives and thus benefit the sawmilling industry. While large firms already utilize many operations research techniques, information being developed can also be used by smaller, medium-size firms. SE (55, 125).

Failure to assess accurately the relationships between log costs, yields, and in-plant processing costs has led to the failure of many small hardwood sawmills. A computer program called SOLVE was developed that computes the maximum dollar value that can be paid for delivered logs of different hardwood species, grades, diameters, and lengths. A SOLVE-use packet has been prepared for foresters to use in helping interested mill owners set up this system. NE (39).

A common problem of sawmill operators is how to obtain the maximum dollar value from lower grade hardwood logs. A study of Appalachian hardwoods showed that the hearts of many factory grade logs could be more profitably sawed into ties and timber than into lumber. NE (54).

Since air-drying of hardwood lumber is a slow and costly process, a method of low-temperature drying of 4/4 Appalachian red oak was tested and evaluated. Low-temperature drying can permit hardwood lumber producers to respond more rapidly to changes in market conditions, and to more accurately schedule lumber deliveries on a year-round basis. NE (64).

West Virginia is one of the Nation's prominent producers of hardwood lumber and timber products. A 1967 comprehensive study of West Virginia's sawmill industry disclosed that the State's 300 sawmills produced over 400 million board feet of lumber and provided employment to over 5,000 individuals. NE (74)

Plywood can be manufactured from grade 3 mixed oak logs using the same machinery and plant process used for making southern pine plywood, according to studies conducted in West Virginia. Preliminary tests indicate that this hardwood plywood can be used for sheathing, subflooring, and pallet decks. If commercially feasible, production of this product could bring new employment opportunities to Appalachia. NE (62, 63).

A simple, inexpensive, and effective method for describing characteristics of forest resources which influence transportation costs has been developed through studies in Northern Michigan. The methodology developed will be helpful in evaluating rural development opportunities based on timber resources. NC (131).

A study to develop a basis for investment decisions by wood products companies provides information on site location factors. Site selection techniques are evaluated and sources of relevant data on location factors and how they may be used are discussed. NE (129, 130).

The sodium, calcium, magnesium, and ammonia based pulping and recovery processes for the NSSC pulping (currently approximately 10 percent of U.S. total pulp production) of wood all have certain disadvantages with regard to cost, pollution, chemical recovery, or product quality aspects. A new combination of magnesium and ammonia base for use by NSSC mills results in a pulping system that is satisfactory with regard to all of these factors. FPL (153).

Warping, cupping, and bowing of construction-type hardboard sometimes occurs when it is exposed to wide changes in moisture. Increasing the temperature during pressing was found to reduce the linear movement of hardboards. This process modification can minimize stability problems, reduce press cycle time (speed production), and lower the rate of water absorption without affecting mechanical or structural properties significantly. FPL (163).

Machine-made papers seldom have strength properties comparable to laboratory-made handsheets. Properties closer to those of handsheets can be achieved by decreasing the consistency or "thickness" of the pulp-water slurry fed to the paper machine. Added suction boxes are effective in removing the additional water on the screen without the need for slowing down the machine speed. This permits the production of lighter weight papers without a corresponding loss in strength or production efficiency. FPL (136).

A cattle feed formulation incorporating 20 percent mixed hardwood sawdust to provide a major part of the roughage component has been field tested commercially. Sixty-two steers were satisfactorily finish-fed at a large feedlot in the Northeast. The study corroborated research results and demonstrated a profitable alternative practice in waste wood utilization and beef production. Waste processing residues such as sawdust, bark, and branches provide good roughage for dairy cattle as well as beef cattle. Feeding a pelleted concentrate containing 32 percent aspen sawdust had no adverse effect on milk production or percent milk protein. FPL (154).

The orientation of fibers making up a paper sheet, and the amount of stretch applied to a forming paper sheet during drying, profoundly effect sheet properties but are largely a chance phenomenon. Controlled measurements show that changing the stretch (restraint) applied to the sheet during drying varies tensile strength 30-40 percent and changing the degree of fiber orientation can cause a 300 percent variation in tensile strength. Optimizing the stretch and fiber orientation of a sheet is therefore of primary importance. A new method for measuring shrinkage in handsheets was developed in order to more accurately evaluate experimental variables. FPL (157).

4. WOOD ENGINEERING

Sandwich panel house construction is strong and utilitarian. It uses about 60 percent less wood than is required in conventional construction, and is being advocated by several companies in their houses designed for "Operation Breakthrough." Design criteria for structural performance are well established, but long-time durability was not known. The performance of selected sandwich panels from a 21-year old experimental building was evaluated and the results indicate excellent potential for this type of construction. FPL (190).

Effective engineering utilization of wood and wood-base materials depends on accurate assessment of clear wood strength properties on a fully representative sample. A newly devised random sampling procedure offers substantial improvement over previous methods by providing (1) an objective method for setting sample size, and (2) a method for attaining randomness in the sample collection. By eliminating bias in sample selection, this procedure gives wood scientists information that will enable them to obtain, at a minimum cost, estimates of timber properties to which they can assign confidence statements. FPL (168).

Possible condensation in the walls of conventionally framed and insulated air conditioned wood structures has caused some concern. Studies on an air-conditioned test house in Georgia showed no significant moisture buildup in the wall cavities. No environmental conditions developed that might cause decay, paint peeling, or other hazards. SE (172).

When subjected to fire, wood structural members surface-char and reach high interior temperatures. The effect of such high temperatures in reducing strength must be considered in original designs. Few data at temperatures approaching those attained in fire have been available. In recent studies, compressive and tensile strength, stiffness, and creep characteristics were evaluated for Douglas-fir at temperatures up to 288° C. These data provide the basis for more efficient utilization and greater fire safety of wood structural members. FPL (114).

Consideration of consumer protection has increased demands for use of fire-retardant-treated wood in construction. To ensure safe, effective structural utilization of this building material, strength values were accurately established, enabling designers to build fire safety and performance satisfaction into wood structures. FPL (175).

Consumer demands for housing, combined with concern for using our forest resources wisely, make it imperative that each component in the house make a maximum contribution to its overall performance. An experimental study and theoretical analysis were combined to establish a method of predicting engineering performance of wood-plywood members assembled with adhesives or fasteners of finite rigidity as compared to those assembled by methods assumed infinitely rigid. Use of the method can provide improved structural component design to reduce wood requirements and allow wider material choice, especially in on-site construction. FPL (185).

Most efficient use of wood resource requires that lumber grades produced are closely tailored to intended end-uses. Procedures have been developed that relate lumber requirements for strength and stiffness to specific anticipated structural uses such as floor joists. Even minimal anticipated improvements in lumber efficiency through acceptance of these grading concepts on floor framing lumber alone could result in a saving of 1 1/4 million board feet of lumber per million house starts or enough floor framing for 1000 additional houses. FPL (173).

Efficient design of corrugated fiberboard containers and maximum protection of contents will be realized only if accurate assessment of container crushing strength can be made. In addition to accurate data on the strength of the components, accurate measurement of the dimensions of the cross section of the fiberboard are necessary. Exacting techniques for these measurements have been perfected that will enable corrugated box manufacturers to design containers to afford maximum protection of contents using minimum material and at minimum cost. FPL (182).

5. MISCELLANEOUS

Economic projections indicate that wood supplies must be greatly increased by 1980 to meet anticipated demands. Increased use of logging and manufacturing residues, waste paper and fiberboard, and wood debris, together with improved efficiency in wood-based construction and manufacturing represent large potentials for extending supplies. Forest Service scientists estimated that, by the end of the 1970's, intensified harvesting and utilization research would make it technically and economically feasible to gain 4.7 billion cubic feet of wood from the above sources. This is important to both meeting demand and to pollution abatement. FPL (199, 200).

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D. Supply Demand, and Price Analysis

An analysis of the demand and price situation for forest products provides up-to-date information on timber product markets as of 1970. Information is presented on price and consumption trends for lumber, plywood, pulp and paper, and miscellaneous products, including naval stores. WO (12).

Construction of single-family houses in 1968 involved an average of 10,271 board feet of lumber, 4,158 square feet (3/8-inch basis) of plywood, 1062 square feet (1/8-inch basis) of hardboard, 742 square feet ($\frac{1}{2}$-inch basis) of insulation board, 180 square feet (3/4-inch basis) of particleboard, and 3.7 squares of shingles and shakes, according to studies of houses inspected by the Federal Housing Administration. These volumes were higher than in 1959 and 1962 for all products except lumber and insulation board. Most increases in wood use reflected growth in the average size of houses inspected. Some growth in use of plywood and particleboard was caused by the substitution of these materials for lumber. WO (19).

The United States wood-preserving industry treated over 253 million cubic feet of wood products in 1969. This was a decrease of nearly 7 percent from the volume reported in 1968 and the smallest amount reported since 1965. Poles, crossties, lumber, and timbers accounted for over 205 million cubic feet, or about four-fifths of the total volume. Of the remainder, fence posts and piling were most important. WO (11)

A preliminary study of competition between wood and nonwood framing materials in "manufactured housing" (mobile homes, modular units, and sectional housing) disclosed no definite trends in materials use. Whether steel or aluminum framing gains in this market will depend in part on future relative costs of wood and nonwood framing materials. WO (13).

Average log prices in transactions in western Washington and Oregon, as reported to the Industrial Forestry Association, rose 60.3 percent between 1963 and 1969. Prices for export were significantly higher than for the same species and grades going to domestic mills. PNW (1)

Use of millwork products almost tripled during the past two decades, although growth was not equal among all types of millwork, according to recent studies. Future demand for millwork products appear likely to be directly related to levels of residential construction. INT (6).

Building codes are frequently cited as obstacles to the use of innovative construction concepts in housing. A survey of possible building code restraints in use of wood floor-foundation systems for single-family houses revealed that many cities do not prohibit use of plenum or pole foundation systems. In cities without definite code restrictions on these flooring systems, local custom or unfamiliarity with the use and performance of this type of construction have limited use. SE (4).

Expenditures in recent years for upkeep and improvement of residential and nonresidential property have amounted to about one-fourth of all building construction expenditures. A study of wood products use in residential remodelling and upkeep in the South showed that choice of products used in this market is made primarily by the owner himself. SE (23).

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INDEX

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