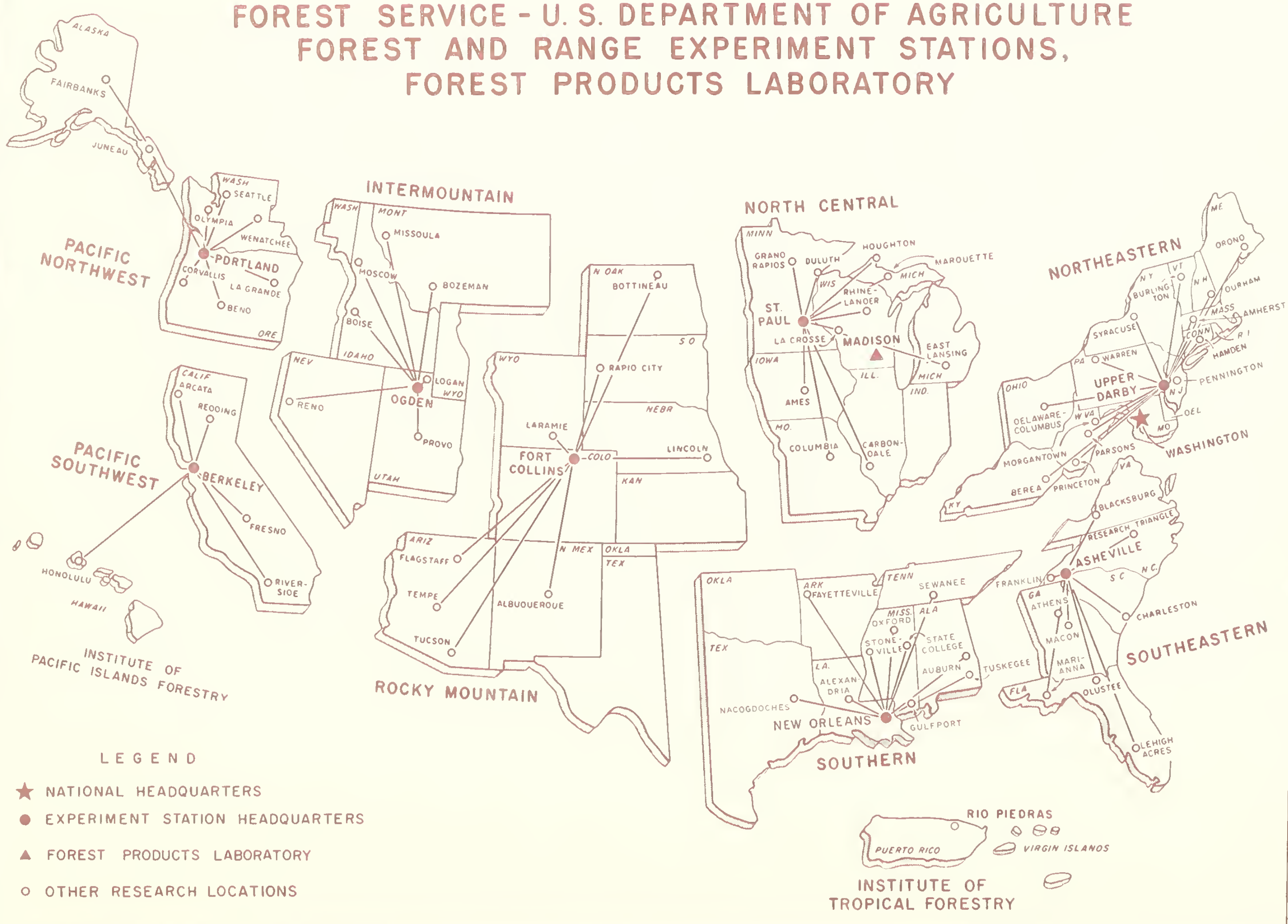
Forest Service Research Accomplishments/1973

UNITED STATES DEPARTMENT OF AGRICULTURE · FOREST SERVICE

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE
FOREST AND RANGE EXPERIMENT STATIONS, FOREST PRODUCTS LABORATORY



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

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Mr. Robert W. Long
Assistant Secretary
U.S. Department of Agriculture
Washington, D. C. 20250

Dear Secretary Long:

I am pleased to send you this report of Forest Service Research accomplishments for 1973.

The report presents a broad overview of the Forest Service research program--a program aimed at solving the critical problems faced by public and private resource managers. Major steps in our continuing quest for knowledge to improve management of America's natural resources are highlighted.

A unique feature of this year's report is that it has been produced directly from computer output, without going through the usual steps of type composition. All of the references are now stored in a computerized data bank. Future accomplishment reports will be produced from field inputs to the computer system.

Sincerely,

John R. McGuire

JOHN R. McGUIRE
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 Assistant Secretary for Conservation, Research and Education with research in other USDA agencies, with that conducted under the Hatch Act at land grant institutions, and with that conducted 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 as a convenience to the reader. Each accomplishment is summarized in a single, short paragraph. Throughout this report an abbreviation signifies the Forest Service research unit best able to supply detailed information and copies of the publications listed. Abbreviations and addresses of the research units are given on the following page.

Issued June 1974

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
Rio Piedras, Puerto Rico 00928

WO - Deputy Chief for Research
Forest Service
U.S. Department of Agriculture
Washington, D.C. 20250

PUBLICATION LIST WITH AUTHOR INDEX

I. IMPROVING ENVIRONMENTAL QUALITY, PRODUCTIVITY, AND USEFULNESS

A. Reducing Pollution

1. Controlling soil erosion

1. Grooming a ski area development will result in destruction of plant cover and soil disturbance. Revegetating these areas promptly to prevent erosion and restore soil-plant nutrient cycles is desirable. Field trials show that satisfactory vegetative cover could be obtained by fall seeding and applying fertilizers. Results also showed that covering the fertilizer and seed was at least as important as the choice of species to seed. PNW(5).

2. Basic stratification of landforms followed by careful analysis of factors contributing to unstable conditions can be used to classify unstable areas. Use of this method has resulted in a system to rate slopes as to whether they are in low, medium, or high hazard class. Management alternatives and developmental activities can then be designed to fit each stability situation encountered. PNW(11).

3. Added emphasis has been placed on development of improved logging systems which minimize soil disturbance, especially by road construction. Balloon logging caused substantially less soil disturbance than previous studies had shown for tractor, high-lead, and skyline logging methods. Deeply disturbed and compacted soil areas occupied 4.3 percent of the total area, and 15.8 percent of the area was classed as slightly disturbed. PNW(4).

4. Soil movement may decrease site productivity significantly either by removing the more productive surface soil or by covering the surface with less productive material. Clearcut logging and slash burning in a steep watershed resulted in increased rates of soil movement, especially on slopes unprotected by organic debris. The first growing season after burning, erosion occurred as dry ravel. Rapid invasion by vegetation during second year essentially halted soil movement on all slopes except extremely stony talus areas. PNW(9).

5. Wildfires induce numerous physical, chemical, and biological changes in soils. A water repellent soil is formed when a fire burns over a wildland area. The degree of water repellency that is developed depends upon soil physical properties, biological factors, and the soil temperatures during a wildfire. Chemical remedial treatments have only been partially successful in reducing water repellency and subsequent erosion on brushland. PSW(3).

6. Soil losses under simulated rainfall were used to test erodibility indices of soils from the Koolau and Waianae ranges on Oahu, Hawaii. Gross splash was related to soil erodibility index, bulk density, infiltration, and saturation moisture content; in contrast, maximum splash erosion variation was related to organic matter content as well as to an erodibility index and bulk density of the soil. Ash and basalt colluvium soils require more careful management than do basalt soils because of their higher splash rates. PSW(15).

7. The degree of weathering, fracturing density, and mineral grain size are important factors to assess in predicting slope stability. A key has been developed that provides a practical tool for classifying these factors for granitic rocks of the Idaho Batholith. This information is particularly helpful in evaluating the potential impact from road construction and for devising the most efficient and economical stabilization measures. INT(1).

8. Sediments deposited in reservoirs are important because they occupy usable water storage space. Volume weights collected in small sediment retention reservoirs in a number of forested watersheds are related to the organic content of the sediment. The relationship is a reliable basis for estimating sediment volume weight; better than the more conventional approach of relating volume weight to sediment particle size. The organic sediments are surprisingly high from the forested watersheds. These data have important implications to the functioning of the aquatic ecosystems found on forested watersheds. INT(6).

9. Temporary subsurface water tables are built up during periods of rapid water inflow due to a zone of lower permeability beneath the soil surface. Road construction incises subsurface flow. The water which previously ran through the soil is collected on the road surface. This can and often does create severe erosion and downstream sedimentation problems. Two years of data suggest that up to 8 area-inches of water can be intercepted by roads in steep mountainous areas, or about 40 percent of the total water yield. INT(7).

10. An analysis of sediment yields following road construction suggests that the largest proportion of sediment is produced the first year following construction. Sediment yields decrease rapidly with time to a minimum level within 3 or 4 years, which indicates that stabilization measures must be installed immediately after construction. Revegetation measures should be coupled with some procedure for providing mechanical stabilization during the period that vegetation is becoming established. INT(8).

2. Chemicals in the forest environment

11. Small quantities of DDT were leached through columns of DDT-treated forest floor material. Leaching of DDT was increased thirtyfold by the addition of urea fertilizer. In field tests, no detectable levels of DDT were in leachate from tension plate lysimeters installed 2 centimeters below the mineral soil surface. Lack of DDT recovery is attributed to extensive absorption on immobile material below the organic layer. These experiments indicate that humic substances may be important carriers of DDT in the organic layer of a forest soil, but they may be relatively ineffective in the mineral soil profile. PNW(16).

12. One month after aerial application of DDT (12 oz/acre) to an eastern Oregon forest, 3 oz/acre of DDT residues were detected in the forest floor; 3 years later, the DDT content had decreased by more than 50 percent, and had not leached into the surface mineral soil. No effect of the spraying was noted on soil microbial populations, nitrification rate, or amount of nitrate nitrogen in the soil. Approximately one-

third of the sprayed chemical reached the forest floor. PNW(26).

13. Herbicide applications are hazardous to fish when there is a probability fish will be exposed to herbicide concentrations which are toxic. General weed and brush control using herbicides becomes important to fish habitat when they are applied to lands adjacent to waterways. Ninety-eight herbicides were grouped into four classes based on median tolerance limits for fish. These classes may be used as an aid in selecting herbicides and formulations of least hazard to fish considering the toxicity of the herbicide and the potential for its entry into the water. PNW(21).

14. Prescribed fire is used as a tool for disposing of logging debris and for preparing the sites for planting. Logging and burning may temporarily impair watershed protection and increase overland flow and erosion of soils derived from Belt series rocks. Small nutrient losses occuring in the sediment and the overland flow during the denuded periods represent only a fraction of the available nutrients on these sites. Damage to soil and water resources and to the nutrient reservoir on forest sites as a result of clearcut logging and burning is not serious from the standpoint of future site stability and productivity. INT(19).

15. Surface mining exposes rock strata to weathering and erosion, and as a result some chemicals may reach streams and adversely affect water resources. Chemical quality of water in six small watersheds in Kentucky indicated surface mining for coal may result in chemical pollution of streams even in areas where acid is no problem. Greatest increases were in sulfate, calcium, and magnesium. Some elements continue to increase at least 2 years after mining; others peak quickly after land disturbance and soon return to premining levels. NE(18).

16. Insect mortality and aerial spray deposit often cannot be correlated when cards are used to collect droplets. Controlled experiments in a spray chamber with known emission rates and air movement indicated that under some conditions conventional spray cards may give an unrealistic picture of the spray deposit spectrum and prevent a precise correlation between deposit and insect kill. PSW(298).

17. The use of synergists can reduce the amount of insecticides needed to control and provide some understanding of the mode of pesticide detoxification. Screening of 40 compounds for synergism with one to five insecticides on western spruce budworm revealed that Zectran, pyrethrins, and SD-9077 were not synergized by any of the commonly known synergists. Because of larger losses of fluid from the insect body following poisoning with these insecticides, their primary mode of action may be exercised through increased secretions in this insect. PSW(299).

18. Previous methods for obtaining pure, acylated amitrole for use in studies of systemic pesticides have been unsatisfactory. Pacific Southwest Station chemists have now determined that N-acetylimidazole acylates amitrole to 2-acetyl-3-amino-1, 2, 4-triazole without the formation of other isomers. By using 3-amino-1, 2, 4-triazole-5-^{14}C, radiopurity was maintained. PSW(297).

3. Air pollution

19. Continuing chronic sources of phytotoxicants threaten trees over much of the country. Ozone, sulfur dioxide, and fluorides are currently the primary offenders, but others such as oxides of nitrogen, hydrogen chloride, and ammonia may become more destructive if they become more prevalent as predicted in long-range forecasts. A realistic appraisal of the magnitude of the impact of air pollution to forest trees can help in setting air quality standards. NE(450).

20. Photochemical smog from the Central Valley of California was shown to move to the Mineral King Valley in the Sierra Nevada. Measurements made at ground stations and by instrumented aircraft suggest that nitrogen oxides and hydrocarbons move upslope with afternoon winds and produce ozone in high mountain sites during following sunny days. It is suspected that the mixed conifer forest of the Sierra Nevada could be jeopardized by an increasing supply of smog in the Central Valley. PSW(456).

21. In the San Bernardino Mountains of California, oxidant air pollution damage to conifers decreases downwind from the Los Angeles-San Bernardino air basin. Over a 5-year period, the average durations of oxidant concentrations above 0.08 ppm ranged from 12.6 hours in the west to 5.7 hours 28 miles to the east. Nearly one-tenth of the ponderosa and Jeffrey pines in the western area died during this period and all portions of the coniferous forest in the 5,000- to 7,000-foot elevational zone suffered from significant exposure to pollutants. PSW(455,458).

22. An experimental chamber has been developed for identifying oxidant air pollution damage to vegetation in forest locations. Natural ventilation exhausts warm air through a stack and draws fresh air through activated carbon filters. Comparing plants in chambers with and without filters will improve the ability to identify acute and chronic oxidant air pollution damage to native vegetation. PSW(459).

23. Anatomical factors in pine needles indicate that sensitivity to ozone increases with an increasing capacity for gas exchange. Injury in the more tolerant pines is limited to cells in the near vicinity of stomates, whereas, generalized injury occurs in sensitive species. Understanding the mechanism of pollution tolerance and sensitivity is useful for predicting pollution impact and for developing new lines of tolerant trees. PSW(454).

24. Trees were shown to reduce the amount of particulate pollution in the air space beneath their canopies. Evaluation of suspended particulates and dust fall indicated that conifers were slightly more effective at removing particles than were hardwoods, but both significantly improved air quality as compared to open terrain. An improved understanding of the interplay of trees and air pollutants can lead to a more harmonious balance between man and his environment. NE(451).

25. Aircraft monotoring of photochemical smog in southern California has identified multilayers of pollution in the atmosphere with penetrations as far inland as Mineral King Valley from the Central Valley and up to 80 miles from the South Coast Basin. Severe damage to coniferous species has been documented. PSW(619-621).

B. Improving Wildland Animal Habitats

1. Evaluating and improving animal habitat resources

26. Considerable progress has been made on the application of camera-film systems to inventory and analyze the multiresources on rangelands. Scientists of Fort Collins, Colorado, are using 70-mm photographs to sample strips of landscape photographed at a small scale. They can determine the aerial extent of complex plant communities, density, cover and distribution of various plant species, or amount of bare soil; herbage yield; and animal populations (especially effective to estimate overwinter death losses of mule deer). RM(157,158).

27. Mice to accomodate the biological control of sagebrush? A possibility. Long-tailed voles kill and damage sagebrush and other shrubs over large areas during cyclic population peaks in Utah. Damage is greatest when a dense ungrazed herbaceous understory is present and when the snowpack persists throughout the winter. Population peaks are spaced 4 or 5 years apart which would fit a grazing cycle for livestock that rests a given unit of range from grazing every 4 or 5 years. A carefully coordinated management plan would promote sagebrush control as well as maintain and improve rangeland conditions. Sheep will also control big sagebrush if allowed to graze the bush in late fall. INT(162,163).

28. Livestock grazing capacities, needed yearly adjustments in stocking, and range readiness can be predicted for mountain grasslands in Montana. These predictions are made through the use of May precipitation and the air and soil temperature data during the month of June. Results indicate that range readiness can vary from year to year by as much as 26 days and readiness lags 12 days per every 1,000-foot rise in elevation. Readiness on northeastern exposures is one week later than on the southwest exposures. This information is essential to the perfection of guides for resource managers. INT(170).

29. Deer mice and pocket mice in Utah greatly increase the first 2 years following pinyon-juniper type conversion to herbaceous species. This was especially true for all small mammals taken collectively where slash was windrowed versus slash dispersed throughout open areas. Complete slash removal—burning or physical removal--resulted in a lower small mammal population. Numbers declined sharply after 2 years but still remained higher than before treatment. INT(152).

30. Saw-palmetto, the major shrub on 18 million acres of land in Florida, reduces the availability of forage and makes handling of cattle difficult. It also contributes to fire hazards. Crosschopping and root plowing treatments have now been developed by the Southeastern Forest Experiment Station to eliminate or greatly reduce the difficulties associated with saw-palmetto. The end result is a greatly increased forage yield, and also a reduction of fire hazard to pine stands. SE(169).

31. "Wildlife in your backyard" is the desire of many residents of the eastern megalopolis. Scientists at the Pinchot Institute of the Northeastern Forest Experiment Station, Amherst, Massachusetts, have devised schemes to produce wildlife in suburban yards. Alternative planing schemes were developed for various areas of the United States. This effort also explains the increased wildlife diversity as the plantings mature. NE(183).

32. Deer populations remain low over much of the forested parts of the Ozarks compared to most eastern forest. Research data by the Southern Forest Experiment Station indicates that the scarcity of high-quality winter browse, especially the more nutritious evergreen species, is probably one of the most important factors responsible for the low populations. Japanese honeysuckle, one of several shrubs studied, appears to be the almost ideal plant to provide increased production of a highly nutritious winter food. SO(179,206).

33. Time-lapse photography is a valuable technique to replace observers in evaluating animal uses of wildlife habitat. The research staff of the Rocky Mountain Forest and Range Experiment Station at Tempe, Arizona, developed a time-lapse camera for use in biological research. The apparatus was constructed from a super 8-mm movie camera activated through a solenoid controlled by an electronic timer and a photo cell for daylight operation. Timing intervals can be varied from 1/2 second to 60 minutes. Film lasts 25 days when operated at a 5-minute interval and 12 hours of daylight. Cost of the apparatus is approximately $165. RM(171).

34. Livestock ponds provide water for livestock and also provide waterfowl habitat which greatly supplements the diminishing wetlands of the Northern Great Plains. Over a 5-year period, 53 species of waterfowl and shorebirds and 47 other species of birds were found to have used 12 ponds in western South Dakota. The average pond produced 35 young puddle ducks. Extending the sample data to the 90,000 ponds in western South Dakota, a potential production of over 300,000 puddle ducks a year can be projected from this area alone. RM(160).

35. Three-fourths of a shrub plant in the cold desert of western Utah is below ground the remaining fourth is above ground. However, the ratio of below ground to above ground annual production is considerably different in that nine-tenths is below ground and one-tenth is above ground. Consequently, grazing practices that result in a reduction of below ground parts has an exponentially reductive effect on above ground parts. INT(166).

36. Dense pole stands of northern hardwoods do not produce much food and cover for wildlife, particularly game animals. Small clearcut openings throughout these pole stands will provide abundance and variety of herbs, grasses, and shrubs that supply vital nutrition for game animals and desirable niches for nesting and brood-rearing sites of ruffed grouse and woodcock. Careful location of openings on shallow soils, in frost pockets, and in areas of poor or excessive drainage, can delay their return to tree cover for 20 to 30 years. NC(699).

2. Characteristics and forage and browse values of plants

37. Fertilizer, according to laboratory tests at Ft. Collins, Colorado, not only increases the amount of Sherman big bluegrass foliage, but also develops the plants resistance to being pulled up by grazing livestock. This increased anchorage is due to increased root development when fertilizer is applied to the plants. Livestock commonly pull up the entire Sherman big bluegrass plant when grazing and reduce subsequent forage yields and grazing values. RM(194).

38. Herbaceous plants that grow profusely when moisture is available and provide low-quality roughage when needed for emergencies are highly desired in the Southwest to reduce gully erosion and also provide emergency feed. Tanglehead (*Heteropogon contortus*), according to the scientists at Tucson, Arizona, is a warm-season perennial bunchgrass native to the warm arid Southwest proven to be such a dual purpose plant. RM(210).

39. Carpetgrass, common to the pine forests in central Louisiana, is highly preferred for cover in firebreaks to help prevent the spread of wildfire. Carpetgrass tends to form pure stands with increased utilization; forage yields decrease, however, when utilization exceeds that known as moderate use. Research results indicate that carpetgrass stands must be utilized or they become weakened allowing other plants to invade and reduce the effectiveness of the firebreak. Consequently, cattle grazing can be used to protect the pine stand. SO(211).

40. The International Shrub Symposium, an interagency effort largely financed and administered by USDA, Forest Service Intermountain Forest and Range Experiment Station, Ogden, Utah, was the first endeavor to confer on genetic improvement of shrubs. Shrubs offer tremendous potentials for man's benefit in the arid and semiarid lands. The symposium

focused on the use and biology of shrubs. The 500-page proceedings of the symposium, published by the Forest Service, covers the "Continental Aspects of Shrub Distribution, Present Utilization and Potential for the Future" with special emphasis on "Genetics" as probably one of the most neglected areas in the biology of shrubs. INT(202).

41. Topping of shrubs on three deer winter ranges in Utah increased twig growth over a 4-year period providing increased browse for deer. The results of the Intermountain Forest and Range Experiment Station indicate there were no detrimental effects on shrub longevity or increases in damage from insect attack or disease. Shrub topping can be done at costs varying from $9 to $21 per acre depending on density of the shrub stand. INT(190).

3. Livestock and grazing management

42. Sheep in southwestern Montana trample from 50 to 60 percent of the herbage used while grazing. Resource managers must allow for that destruction when determining sheep grazing capacities or overutilization will occur. The degree of trampling varies with season and plant species. Consequently, management can alleviate losses due to trampling by grazing the various plants when the plants are least susceptible to trampling damage. INT(222).

43. Mule deer, common to the open woodlands, do well on a year-round diet made up almost exclusively of woody material. Scientists at Tempe, Arizona, also learned that the diet dominated by browse species was highly related to the availability of the various woody plants. The selection was dominated by birchleaf mountain mahogany and oaks which were adequate nutritionally to sustain deer during all seasons. Hence, habitat management should strive to maintain these two important shrub species and to prevent their overutilization. RM(215).

44. Beef production was considerably higher under a continuous yearlong grazing management system than under rotated-seasonal grazing management in the annual-plant type rangelands of California. The addition of sulfur-fertilizer only slightly improved livestock performance but considerably increased grazing capacity. Beef calf and cow weight performance on the perennial bunchgrass rangelands of California were slightly better under rest-rotation grazing management compared to yearlong grazing management systems. This rotated-seasonal grazing management required shifting of use to various times during a year. PSW(218,234).

45. Cost reductions can be achieved by thrice-weekly rather than the more common daily feeding of a protein supplement for cow-calf operations on slash pine-bluestem ranges in Louisiana between November 1 and May 31. This is the conclusion from research on cattle running yearlong from 1964 to 1970 on the Palustris Experimental Forest in central Louisiana. SO(231).

4. Integrating other uses and wildlife

46. Rock-raked windrows, commonly associated with land manipulation in northern Minnesota, are inviting to black bears as winter den sites but are conducive to almost twice the heat loss compared to earthen dens. The heat loss could jeopardize winter survival. Overwinter survival is dependent upon (1) the food supply available in summer habitats, and (2) the degree to which the bear must reduce its metabolic rate and weight loss. The insulating effect of the den greatly influences the latter. NC(246).

47. Sportsmen must realize that good wildlife management will be practiced on private lands only if the landowner develops an interest in wildlife and cooperates in wildlife habitat management. Landowners must expect an income from the use of their wildlife habitat before they will be willing to consider that resource in their ranch management plans. But hunter-landowner interests and attitudes differ, as was detected in comparing the problems connected to "commercial" hunting in South Dakota to those in Texas. Public hunting areas, that is, National Forests, greatly decrease the demand for commercial hunting as associated with private land unless the private landowner provides extra services. However, the implementation of a federal land use fee would greatly favor "commercial" hunting in South Dakota. RM(249).

C. Improving Social and Amenity Values

1. Environmental amenities—landscapes and open space

48. Attractive and pleasing landscapes are an important amenity resource. Americans are more interested than ever before in protecting and managing their visual resources. However, there are not good methods for inventorying, analyzing, or communicating about landscape resources. Research in landscape design is producing some answers. Six factors of recognition and six compositional types have been identified. A method for inventorying landscapes has been developed, and it has been tried out in the Lake Tahoe area. An approach to evaluating landscapes, including three esthetic criteria, also has been proposed. These developments will help resource managers do a better job of considering impacts on the visual resource of various land management alternatives. PSW(257).

49. An aid to landscape resource analysis and management is the use of computerized drawings of ground forms and vegetation. Two computer programs have been developed for this use. They generate perspective views of landscapes that can be used to predict effects that proposed changes would have on the visual resource. PNW(256).

50. Preference for urban scenery versus nature scenery has been tested in carefully controlled laboratory tests. University students were tested with selected color photo-slides. Scenes of nature were greatly preferred over urban scenes. The research also showed that people generally prefer scenery that includes variety and visual complexity. NC(255).

51. Related laboratory studies showed that, in addition to complexity, mystery and coherence contribute to people's preference for a scene. Coherent scenery "makes sense" to people. A landscape has a quality of mystery if it promises to reveal something new or interesting further on, over a hill or around a bend for example. NC(253).

52. Cemeteries can be valuable open space environmental resources—especially in urban areas where open spaces are scarce. A study of cemeteries in the Boston area showed that they are being used for bird study, squirrel feeding, picnicking, ball playing, kite and model plane flying, driving, bicycling, walking, jogging, photography, and other recreational pursuits. With planning and careful management these areas can be used as open space areas for the living without losing sight of the original purpose, respectful interment of the dead. NE(258).

2. Environmental amenities—wilderness

53. Wilderness provides unspoiled natural environments and opportunities for a unique kind of primitive recreational ex-

perience. Visits to wilderness areas are growing rapidly and, in certain places, threaten the integrity of some wilderness areas. Data collected from visitors to four areas have been used to identify important elements of wilderness management. Visitor satisfaction is related to (1) intensity of use, (2) types of encounters with other visitors, (3) how visitors are spread over space and time, and (4) destructive behavior by visitors. Solitude is important; "crowding" reduces visitor satisfaction. Large groups cause loss of satisfaction for others. Privacy at campsites also is important. Littering is very objectionable. There are conflicts among those using different means of travel (hikers versus horsemen for example). This research provides a basis for defining wilderness carrying capacities and for developing wilderness management techniques. INT(265).

54. Research has led to a proposal that special mathematical models be developed to predict the travels of individuals and groups in wilderness areas. These models, operated in computers, will be used to test alternative approaches to wilderness management. NC(261).

55. In some cases the Forest Service and The National Park Service require that visitors obtain permits before entering wilderness areas. Data on visitors and visits, obtained from the permits, are useful in producing a factual record of visitation. These data can help improve wilderness management. A computerized system is available for analyzing the data. PSW(260).

56. Fire always has been an important ecological factor in many wilderness areas. Considerable meticulous ecological research has revealed the history of natural fires in the Boundary Waters Canoe Area of Minnesota. Current studies are tracing the course of natural plant succession after the Little Sioux fire of 1972. In the second year after the fire, hardwood trees were regenerating very well and the area also had a large crop of blueberries and abundant populations of small mammals such as voles, mice, and chipmunks. NC(259,266).

57. Research on visitors to the Boundary Waters Canoe Area (BWCA), a unique part of the National Wilderness Preservation System, has shown that large groups of visitors have significant impacts on the wilderness. Large groups accounted for much of the total use in the BWCA. The impact of the large groups on the environment and on the experience and satisfaction of other visitors is greater than that of an equal number of people traveling in small groups. Based on the results of this research the Superior National Forest recently changed the regulation on maximum party size down from 15 to 10 persons. NC(263).

3. Managing recreational opportunities

58. Camping is one popular form of outdoor recreation. In recent years there have been great increases in family camping and in investments in campgrounds. Better information on the family camping market benefits private campground businesses and governments that operate public facilities. A nationwide survey has shown that there are 12.6 million active camping families in the U.S.A. and 9 million inactive. The inactive ones include 3 million who have temporarily dropped out of camping and 6 million former campers who are permanently out of the market. There are 10 million families who do not camp but are potential campers. Most of the families who are potential are in the Northeast and North Central regions of the country and earn $7,000 to $10,000 a year. NE(280,281).

59. Privately owned commercial campgrounds have become a major supplier of family camping opportunities in recent years. Research is helping to identify criteria for successful development and operation of commercial campgrounds. Much has been learned from an analysis of 182 campgrounds in New Hampshire between 1964 and 1971. Detailed cost and return records were available for 46 of the businesses. Only 78 of the 182 campgrounds were financially successful. The successful businesses were larger than the average, had over two-thirds of their sites with utility connections for travel trailers, had higher average operating costs per site, had been in business for several years, had customers who stayed more days per visit, served about four times as many customers as the unsuccessful campgrounds, and generally had more businesslike management. NE(283).

60. Skiing is an important and rapidly growing recreation industry. In the 11 Western States, for example, skiing grew from 1.4 to 4.3 million visits between 1956 and 1964. Pressure for additional ski developments is felt by both public resource agencies and private investors. A statistical study of skiing in California and western Nevada provides some clues to decisionmakers. Use of individual ski areas decreased as the price of day tickets was increased. Use increased as lift capacity increased. Nearby ski areas tend to complement one another. That is, all of them have more business because there is more than one development within a reasonable area. The statistical model used in this study is one tool for analyzing the market opportunities for proposed new ski areas. PSW(279).

61. Many Western areas that offer recreational opportunities, such as fishing, boating, and hunting, do not have enough trees and shrubs to provide shade, screening, windbreaks, traffic barriers, or pleasing landscapes for visitors. Research in California is finding better ways of establishing and growing trees and shrubs in difficult areas, such as at reservoir sites. Methods include irrigation, fertilization, mulching, selection of adapted species, and horticultural care of trees and shrubs. PSW(286).

62. In the southern Appalachian forests of the Southeast, tests have been made of visitors' preferences for features of developed campsites. The location of the comfort station was the most important factor people considered in selecting a campsite. Shading was next most important with moderate shade preferred over either full shade or little shade. Accessibility of drinking water also is important. Most campers want to be 50 to 100 feet away from community hydrants. Research findings also provide clues about management of grass and shrubs, arrangement of facilities, and the importance of fairly level but well-drained campsites. SE(272).

63. Canoeing has become an important recreational use of many rivers. Eroding streambanks on Michigan's Pine River, being considered for stabilization to reduce silting and improve fish habitat, generally were considered a natural part of the scenery by canoeists. Canoeists, saw a need for preserving the river in a nonresidential and noncommercial natural state and for providing more well-planned facilities, such as picnic and camping areas and toilets. Delicate ecological sites probably will have to be protected from canoeists. Present users of the river objected to litter and to the feeling of "crowding" on the popular river. NC(292).

64. Data on forest visitors' preferences, opinions, and attitudes can improve planning and management of recreational opportunities. When collected and analyzed according to scientifically developed procedures, this information can help managers do a better job of serving the public as well as protecting the resources. Factual data can be substituted for inaccurate preconceived notions. For example, analysis of users of campgrounds on the Superior National Forest showed that some campgrounds were used six times as much as others. Campers strongly prefer sites near water and with a scenic

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view. Other preferences revealed by the research were: Fishing opportunities nearby, uncrowded conditions, being away from main roads and towns, and small campgrounds (fewer than 15 campsites). NC(284).

65. Nearly a thousand references have been brought together in an annotated bibliography of articles on the human aspects of fish and wildlife conservation. PNW(289).

66. Interviews with fisherman in New York State showed that the most important factors of successful fishing trips were: Water quality, natural beauty, and privacy or solitude while fishing. Number and size of fish caught were less important. Facilities were not important at all. Fisheries management should include attention to the total environment and not to fish stocking only. NE(287).

67. Litter is a major environmental problem. Litter cleanup costs are high and are a burden on the public. Scientific study has led to development of an approach to litter control that (1) capitalizes on normal forest visitor behavior, (2) reduces litter levels greatly, and (3) cuts costs dramatically. The research showed that the traditional approaches, such as appeals and litterbags or threats are not very effective. The new system uses the voluntary help of children and givens them small rewards, such as Smokey Bear symbols, as incentives. It is a very effective, low cost, cleanup method. Indications are that it helps teach the children antilitter attitudes that continue after leaving that forest site. PNW(269-271).

68. Recreational use of forests is not easy to measure or to sample. Yet managers need accurate counts or estimates of use so that they can plan and manage more effectively to serve the public. Prior research has made substantial contributions to scientific methods of estimating various kinds of recreational use in the forests. Recent studies have developed an easy and inexpensive way of collecting and analyzing data on the home or origin of visitors. This method uses self-registration, ZIP codes, and computer data processing. SE(278).

69. Recreation research scientists have evaluated an electric eye counter for sampling traffic on a wilderness trail. These counters show promise for cutting costs of sampling trail use, but the equipment needs to be refined and tested further before being widely used. SE(277).

70. Estimating use of waysides and observation sites is difficult because of the short time spent by most visitors. Methods useful for other kinds of sites, such as campgrounds, don't work. A pilot study on the Pike National Forest resulted in a technique for solving this difficult problem by using an observer for sampling the visits and correlating that sample with automatically recorded road traffic data. SE(276).

71. Results of some years of research on methods of sampling and estimating recreational use have been made more readily available to users in a manual that provides four computer programs in Fortran IV language. SE(294).

72. Scientific study of forest visitors' preferences, attitudes, and opinions usually requires the use of questionnaires. These tools of social science research must be carefully constructed and used. Forest Service scientists have developed an annotated bibliography of nearly 200 references on the design and use of questionnaires. PNW(290).

73. Recreation planners feel the need for estimates and projections of demands for recreational opportunities. Twelve demand surveys, made in connection with state recreation plans, have been analyzed. Ten guidelines for strengthening demand estimates were formulated and outlined. There is a need for establishing uniform methods and sharing data among States. PNW(268).

74. Some current recreation policy issues have been analyzed. The results show that there is an urgent need for development of wide variety of recreational opportunities along the full continuum from concentrated to dispersed typed of activities. Too little attention is being paid to the many needs in the middle of the continuum—such as for semideveloped hiking and camping trails or off-road vehicle trails. The two ends of the continuum, pure wilderness and car camping, have received most of the attention. There is an urgent need for more, and a wider variety of, dispersed recreation opportunities outside formally designated wilderness areas. WO(285).

75. The huckleberry fields that provide economic and recreation benefits to thousands of residents of Oregon and Washington are dwindling in size and productivity, and effective management techniques for conserving and developing the huckleberry resource are urgently needed. A summary of available information has been prepared that includes descriptions and an identification key for the 12 northwestern huckleberry species. It also reviews current knowledge on blueberry management in eastern North America. This information is useful for planning research and developing management practices for the protection, culture, and use of the wild huckleberry resource in the Pacific Northwest. PNW(700,701).

D. Trees to Enhance the Environment

76. One of today's serious environmental problems is how to deal with excessive noise created by more and larger vehicles on highways and city streets. Studies in the past 5 years conducted by the University of Nebraska and the Forest Service have demonstrated that 20- to 50-foot-wide belts of trees and shrubs, with the edge of the belt from 20 to 50 feet from the center of the nearest traffic lane, can reduce the noise level by one-half. It is best to use shrubs 6 to 8 feet tall next to the traffic lane with backup rows of trees 15 to 30 feet tall. RM(702,703).

77. Trees and shrubs when properly placed in relation to the source of the noise can be effective in reducing outdoor noise level. Recent studies jointly conducted by the University of Nebraska and the Forest Service have shown that tree covered land-forms are considerably more effective than are land-forms alone or trees alone. To reduce noise from high speed car and truck traffic, the land-form should screen the noise source from view at the location to be protected. Trees, shrubs, and grass should be planted on and around the land-form to extend the range of protection and further reduce the noise level. RM(704,707).

78. The climatic and edaphic extremes characteristic of the Great Plains severely restrict the kinds of trees that can be used for environmental protection purposes in this region. Seven different seed sources of Japanese larch were grown at 13 locations in 8 States including eastern Nebraska. After 13 years Japanese larch of high elevation origins grew the best in the Great Plains. This finding is important because it adds a new species to the rather limited list of adapted conifers for environmental plantings in the Great Plains. RM(705).

79. Many older shelterbelts in the Great Plains have serious management problems resulting from mistakes in spacing and arrangement of the trees when they were planted. To avoid these problems, a proposed check list for planning windbreaks and shelterbelts was developed which includes consideration of the purpose of the planting, the best designs, and how to select the species to be planted. RM(706).

80. There is an increasing interest in the proper utilization of medicinal plants in West Pakistan since drugs of plant origin represent an important export to the United States. Over 635 flowering plants of pharmacological value have been identified recently in the Dir and Chitral forest ranges of West Pakistan by a PL-480 supported research program. A concurrent quantitative survey of the availability of medicinal plants suggests that for certain plants it is now feasible to make commercial collections for export to the United States, as well as to other nations. WO(708-712).

E. Improving Environmental Quality Through Fire Management

1. Fire prevention, hazard reduction, and prescribed burning

81. A specially designed series of fire prevention lessons were prepared for preschool children in the Headstart Project in Riverside County, California. The effects of this effort were most successful in meeting cognitive goals but positive changes in curiosity about fire and attitudes about fire were less apparent. It is important that children learn to cope with and avoid dangerous fire situations as well as to learn the prevention of wildfires. PSW(632,634).

82. Efforts are being made to involve other social scientists with the problem of man-caused forest fires. The intricate interrelationships with man, fire, and man's natural and social environments need to be studied in more detail. These efforts should increase the opportunity for involving competent scientists in the solution of man-caused fires. PSW(633).

83. Differences in organizational structure and approaches to community relationships effect management success. Basic principles must be followed in planning and executing forest fire prevention programs or the processes themselves become barriers. Six guidelines may assist the communicator to overcome some of the barriers. They are: (1) audience analysis, (2) selection of objectives, (3) message design, (4) media selection, (5) selection of communicator, and (6) evaluation. Strategies of organization and work accomplishment must be identified if we are to achieve forest fire reduction goals. SO(644), PNW(631).

84. The Southwest Interagency Fire Council has emphasized the importance of considering forest fuels and fire planning in the early stages of land-use and multiple-use planning. Such specialized operations as smoke management must also be a part of the early land-use decisions if they are to be effective because there are tradeoffs between the smoke of planned fires and wildfires. INT(622,624).

85. The weight of shrub fuel varies from a few hundred pounds to 50 tons per acre, but living material larger than 1/2 inch in diameter is seldom consumed in wildfires. Dead fuels vary from below 25 percent of the total volume to nearly 50 percent. Fuel arrangement is more important than fuel weight in determining fire behavior characteristics such as rate of spread, burning time, and intensity. Fuel moisture is rated heavily for fire-danger rating because it controls the current flammabilities of fuel. Ash content of shrub species also has effects on the pyrolysis process and affects the way a shrub stand will burn. INT(641).

86. Ten of 18 National Forests in the Intermountain Region have applied a fuel break concept recently developed on the Wasatch front. Atrazine and simazine are used to control the flammability of cheatgrass. Up to 50 percent reductions in rate of fire spread are achieved. PSW(635).

87. Fire spreads nearly 5 times as rapidly through dry annual grasses and forbes than on plots where these same plants are growing in combination with creeping sage stands. Because of its low stature, fuel volume, low fire spread, low resistance to fire control, and adaptability to site, creeping sage appears to be a good candidate for planning in areas where hazard reduction is a goal. PSW(642).

88. Perennial shrubs survive adverse conditions by maintaining a reservoir of dormant meristems or buds. The origin, development, dormancies, and photoperiodism of these buds are important in the management and maintenance of fuel breaks or other shrub treatments for grazing or watershed purposes. INT(623).

89. Fenuron, tandex, and picloram are herbicides used to maintain control over scrub oak regrowth. Fenuron and tandex are nonselective sterilants which eliminate most plants while picloram has little apparent effect on grass cover. After a 30-month test, good stands of grass developed. This is important in the maintenance of fuel breaks or in range management considerations. INT(643).

90. A random orientation line intersect sample line is best for measuring residue in cutover areas where topography and logging create orientation patterns. Areas where terrain is more gentle can be sampled by a unidirectional pattern. Estimates of volume within plus or minus 15 to 20 percent are possible. Higher intensities can improve precision. PNW(638).

91. Five fuel types in the Lake States Region have been described and displayed in graphical ADP generated form. Crown weights and crown volumes are shown. This method will help managers describe changes in fuel complexes. NC(647).

92. A set of alignment charts developed for the Lake States estimates fuel loading of downed dead wood using a planer intersect technique. Fuel inventories can be improved. NC(645).

93. A preattack area planning guide developed for the Pacific Northwest tells how to assemble, store, retrieve, and update preattack data within the total resource inventory system. PNW(630).

94. Surveys in 13 southern States indicate that over 2 million acres were prescribe burned annually during the past 8 years. Prescribed burning is a vital forest management tool in the South. It plays many roles such as, fuel hazard reduction, seedbed and site preparation, control of undesirable species, wildlife habitat and grazing improvement, and certain disease control. SE(628,636,640,646).

95. A new device for safely, electrically firing prescribed fires has been developed. Design, operation cost, and diagrams are available. Reliability improves efficiency and safety. NC(639).

96. Smoke from wildfires in the Florida Everglades restricted visability 68 percent of the time for 17 days of April 1971. Aircraft operations were reduced by 12 percent. However, maximum concentrations of particulate were well below national standards for air quality. This indicates that smoke from large fires has less effect on air quality than it does on certain of man's activities such as aircraft operations. SE(648).

97. The formation and diffusion of particulate matter from prescribed fire are being thoroughly investigated, but to date, there is no evidence to indicate that air quality has deteriorated more in areas where prescribed fire is used extensively than it has where prescribed fire is rarely used. Smoke from prescribed fire can be traded against the consequence of wildfires and large smoke plumes. SE(625-627,629,637).

2. Fire management methods and systems

98. Rigorous testing of the CL-215 airplane, the first aircraft built specifically for air tanker work, revealed that (1) the efficiency (feet of adequate fire line built per gallon of retardant delivered) of the CL-215 is approximately the same as that of other air tankers tested, (2) the capacity of the CL-215 is intermediate in the range of sizes available, (3) the CL-215 is less flexible than air tankers having multiple gating or trail gating, and (4) the CL-215 has the advantage of a water scooping mode and can use an onboard water thickening system. Gum thickened retardants show a 17 percent superiority in drop characteristics over water. The onboard mixing system using gelgard can increase the drop characteristics by approximately 10 percent. Thickened retardants allow drops from higher altitudes, thereby increasing safety. The test of the CL-215 could set precedence for testing new candidate air tankers. WO(661).

99. Florida Division of Forestry achieved successful drops with the DeHaviland beaver aircraft used as a water tanker in Canada. Forest Service studies showed that drops had good conformation comparable to aircraft such as the TBM. These small aircraft provide specific capabilities for unique situations. SE(656).

100. Increasing the amount of either ammonium sulphate or ammonium phosphate fire retardant on ponderosa pine needles or aspen excelsior fuel beds causes a reduction in rate of spread and rate of weight loss and an increased amount of residue. At all treatment levels ammonium phosphate is more effective in decreasing the rate of weight loss and increasing residue than ammonium sulphate which has little effect on residue. Weight loss and especially residue quantify glowing combustion. These relationships serve as standards for comparing the effects of other chemicals or proposed forest fire retardant additives. INT(655).

101. A commercially available hydraulic seeder used regularly by the Oregon State Highway Department for roadside maintenance gave satisfactory results for mixing and spreading powdered and liquid retardants. A two-man crew was able to apply large volumes of retardant quickly to aerial and ground fuel in "hard to reach" locations. This development makes it more efficient to apply retardant with ground tankers for fire control or for treating hazardous areas and borders of prescribed fires. PNW(662).

102. Helicopters and helibuckets are proving useful, additional tools to the Alaska fire program. Tactical and logistical problems of controlling remote fires in Alaska are tied to the vastness of the country. Consequently, fixed-wing aircraft have traditionally played an important role. Now helicopters are adding to their capability particularly since there are readily available sources of water in many of the fire fighting areas. PNW(659,660).

103. A computer program (FIRDAT), written in Fortran-4 developed for use in Regional data processing offices, will compute components and indexes of the National Fire-Danger Rating System for each day of weather. This permits the examination of historical weather records and an analysis of fire danger. RM(654,657).

104. A computer method of displaying information in the form of a 3-dimensional histogram was developed. This method can be used for a variety of data and provides the user sufficient information to examine three related variables. PSW(658).

105. A theoretical study of precipitation effects on dead cylindrical fuels indicates that rainfall rate and amount have little effect on changes in fuel moisture but duration of precipitation is very important. This information, when confirmed by field tests, will aid development and refinement of national fire-danger rating. RM(653).

106. A revised Fire Weather Observers Handbook was issued and distributed nationally. The handbook gives instructions for location layout of fire weather measuring stations. It is important that all fire weather stations have acceptable observations stations and some degree of uniformity. INT(652).

107. Moisture content of tobosa grass can be predicted using wind speed, relative humidity, and air temperature. Accurate predictions of moisture content are necessary for judging fire danger and predicting expected fire behavior. PSW(651).

108. An inexpensive 31-day battery-operated weather station has been developed to use in lieu of more expensive presently available commercial models. Inexpensive radiation shields for thermisters and thermocouples were also developed. These are helpful devices for recording weather in remote stations where frequent observations are difficult and for instrumenting many biological research and management activities. PNW(649,650).

3. Forest fire science

109. Minimum temperatures for pilot ignition were established as 340°C with a pilot flame using ponderosa pine needle samples. Other practical tests using lighted matches dropped into southern slash pine litter identified ignition probability for southern fuels. Ignition delay times and temperatures are necessary inputs for fire modeling. SE(663), INT(678), PSW(664).

110. Central temperature history and mass loss curves are correlated with initial diameter and are practically independent of environmental conditions. Temperature histories of fuel elements are important in the understanding of ignition and fire spread. SE(665).

111. A newly discovered dehydration product of levoglucosan has been shown to be important in the tar formation process when both the basic and acidic fire retardants are used. Both types drastically lower the levoglucosan yield but basic retardants have a much greater effect on the tar yield and on the flammability of cellulose. With acid retardants, the decrease in levoglucosan yield is accompanied by an increase in the dehydration product identified. PSW(670).

112. Progress is being made in new technology for studying the chemical breakdown of hemicellulose, a major plant material. Identification of products produced in the presence of different flame retardants allows scientists to describe the mechanism of fire suppressants. INT(676).

113. Through new computer techniques it is now possible to simulate the combustion of cellulose and other C-H-N-O fuels. The technique will compute combustion products for arbitrary fuels for specified combustion conditions. PSW(677).

114. The intensity of a combustion wave moving through a forest homogenous fuel array is an important but poorly defined concept of fire behavior. A concept of reaction intensity, which is related to the rate of fuel consumption per unit of basal area within the combustion zone has been developed. This knowledge is necessary for the characterization of fire intensity in terms that are useful for predicting the behavior of a spreading fire. INT(668), SE(673).

115. The National Fire-Danger Rating System uses a new fire spread model developed specifically for a wide range of wildland fuels. This model is persented from conceptual stage through evaluation and demonstration and applied to hypothetical fuel models. INT(674).

116. None of five experimental and theoretical fire spread models tested in Arizona oak chaparral gave adequate, absolute predictions. However, a statistical model using essentially the same inputs, but weighted with chemical coefficients, accounted for 81 percent of the variation in rate of spread. The revised model provides useable guides for predicting absolute values of fire spread in Arizona oak chaparral. RM(672).

117. Fireline supervisors and firefighters have been given new aids to help understand the concept of fire environment and the specific processes that influence the formation of fire whirls. Fire whirls are dangerous to firefighters and make fire control difficult. PSW(666,667).

118. Fire managers have gained additional useful information from the analysis of wildfires. A study of the Air Force Bomb Range Fire in North Carolina indicated that 14 miles of fire spread in 7 hours was a direct result from gusty winds, adverse wind profile, and passage of a cold front, along with heavy uniform loading of fine fuels. Byram's equation for predicting fire blowup was useful in the analysis. The importance of fast initial attack was demonstrated by a study of the 1971 northern Minnesota fire which burned almost 15,000 acres in a 3-day period. The fire reached 60 percent of its final size in the first 6 hours. The studies made on two state protection districts on the Clark Forest in Missouri identified factors that contribute to fires, particularly on multiple fire days. SE(671,679), NC(669,675).

F. Improving Insect and Disease Control

1. Detection and evaluation

119. Aerial color and infrared photography are becoming increasingly valuable for detecting and evaluating forest diseases. Recent studies have identified "signatures" that distinguish trees affected by air pollution, Dutch elm disease, oak wilt, ash dieback, white pine basal canker disease, annosus root rot, and *Poria* root rot. Combined with comfirmation by direct ground sampling, aerial photography promises to be a powerful tool for disease survey and a useful aid in research on disease epidemiology. NE(462,463), PSW(461).

120. Aerial photography provides a reliable means of monitoring the trend and spread of bark beetle infestations. Analysis of large- and small-scale photography now permits choice of the optimal photoscale to minimize interpretation error for damage surveys. A scale of 1:32,000, for example, is generally best for assessing tree mortality due to the mountain pine beetle in the Black Hills. PSW(312).

121. A number of remote sensing techniques are available for use in forestry. Some are presently too costly or do not provide satisfactory resource data. Applications include side-looking airborne radar (SLAR), multispectral scanning, and color and color infrared photography. The latter techniques have been most used by forest managers and protection specialists during the past 5 years. PSW(304).

122. The effect of gypsy moth defoliation on tree condition and mortality has not been fully evaluated. A series of preliminary predictive tables have been prepared by the Northeastern Station following a comprehensive analysis of a large mass of historical data. These give both annual and cumulative tree mortality rates and the condition classes of surviving trees for particular tree species according to the intensity and duration of defoliation. These tables require confirmation in current outbreaks, but they will provide initial means for predicting the potential impacts of gypsy moth defoliation in northeastern forests. NE(301).

123. Through the years, the airborne dispersal of insects such as the gypsy moth and beech scale has been regarded as a natural phenomenon which is beyond our control. It is not a purely random process, however. Recently developed atmospheric dispersion models for air pollutants can be integrated with a gypsy moth larval dispersal model to increase the accuracy of predictions of rate of spread, insect numbers, and resultant defoliation. A predictive model for larval dispersal is an essential tool in population assessment. NE(306,307).

124. A fast procedure was needed to permit individual examinations of large numbers of diseased Douglas-fir tussock moth larvae infected with either or both of two types of nucleopolyhedral viruses. A method was developed which utilizes an alkali solution containing nonionic hydrocolloid, hydroxyethel cellulose. This procedure permits counting of inclusion bodies in mixed samples and the determination of the density and ratios of the two viruses. PNW(308).

125. A description of distinguishing features of important needle diseases of Scotch pine Christmas trees has been developed. Christmas tree growers now will be able to detect these troublesome diseases early, thereby allowing effective control measures. NC(468,469).

126. A new technique for the direct isolation from soil of the black root rot fungus was developed. A combination of wet sieving and culturing on a selective medium allows estimation of the propagule population of the casual fungus. This technique can be used in forest nurseries to determine the need for control prior to seeding. PSW(466).

127. Fruiting bodies of the endotrophic mycorrhizal fungus, *Endogone*, were described and a technique permitting detection of this fungus in the soil was developed. Sporocarps can be identified in soil samples by their form and bright red color after soaking and washing in an acidified acid fuchsin solution. This procedure worked well with *Endogone* associated with sugar maple and can aid in future biological studies of these beneficial symbionts. NC(464).

128. Improved survey methods are needed for predicting defoliation of Douglas-fir by the western spruce budworm in Oregon. Optimum size and allocation of egg and larval samples have been determined. Ranges of egg mass and larval densities have been related to categories of defoliation. These guidelines will improve the precision and reliability of budworm evaluation in the West. PNW(302).

129. Spruce-fir stands defoliated by eastern spruce budworm were compared for 10 years with stands protected by insecticides to determine the effect of defoliation on growth and mortality of balsam fir. Defoliation reduced growing stock by an average of more than 1,000 cu. ft. per acre. Most mortality and growth reduction occurred during the fourth and fifth years of heavy infestation. Suppression decisions should therefore be made prior to this point. An index has been developed to assist the manager in assessing the stage of damage in individual stands and the need for action. NC(300).

130. Outbreaks of the western spruce budworm in the central and southern Rocky Mountains are eventually terminated by natural causes. Analyses of life tables compiled for two generations at three locations revealed that considerable mortality occurred during fall and spring dispersal periods and during the winter months. To improve the accuracy of biological evaluations, eggmass surveys in late summer or fall should be followed by spring surveys when most of the larvae are in the fourth instar. This will permit determination of overwinter survival and improve suppression decisions. RM(305).

131. Determination of parasitism of western budworm can be a tedious task when it involves dissection or rearing. Newly developed radiographic techniques will permit rapid differentiation of normal and parasitized budworm pupae. INT(310).

132. Research is leading to the application of nondestructive techniques for detecting internal defects in trees and wood products. A mobile X-ray unit developed for field use looks promising for determining wood quality prior to harvest, for evaluating tree hazard in municipal and recreational areas, and for inspecting utility poles, pilings, and other wood products. Cooperative research with the University of New Hampshire indicates that wood decay can also be detected by measuring changes in resistance to a pulsed electric current. These techniques promise to be inexpensive and safe alternatives for nondestructive detection of defect. NE(460,470-472).

133. Light traps may be used to determine the seasonal occurrence, relative abundance, and flight activity of insects affecting cones and seeds. By this means, the flight habits of two species of pine-feeding loopers, *Nepyta semiclusaria*, and *Lambdina pellucidaria*, in the Georgia Piedmont region have been determined. This information will aid in the timing of control of these pests. SE(313).

2. **Biology and understanding**

134. *Ips grandicollis* aggregation behavior is influenced by volatiles produced by the host and the insect. The combination of host terpenes and frass from male beetles is one of the primary sources of attraction involved in mass attack and aggregation. Various environmental and physiological factors influence the response of male and female beetles to the attractant complex, however. These findings will aid in developing attractants for surveys and suppression of this insect. SE(383, 384).

135. Response to natural attractants varies among *Ips pini* populations occurring in different geographic regions. Tests conducted in California, Idaho, and New York revealed differences both in pheromone production and behavioral responses. These results dramatize the necessity for considering pheromonal variability in survey and control programs involving the use of attractants of widely distributed pests. INT(351).

136. The pathogenicity of entomogenous fungi varies with temperature and relative humidity. Laboratory tests with adult southern pine beetles indicated that *Beauveria bassiana*, *Aspergillus flavus*, and *Fusarium solani* were most pathogenic at temperatures of 15-25° C and relative humidities of 55-94 percent. SE(360).

137. Tests of 10 strains of naturally occurring bacteria against southern pine beetle larvae revealed that *Bacillus cereus*, *B. thuringiensis* var. *thuringiensis*, *B. thuringiensis* var. *kenyae*, *Pseudomonas aeruginosa*, *P. fluorescens*, and *Serratia marcescens* were all pathogenic to the insect. Virulence differed between strains of *S. marcescens*. SE(359).

138. Fungal symbionts in a glandular structure (mycangium) in female adult southern pine beetles are thought to aid nutrition of larvae developing in the phloem tissue. An undescribed *Sporothrix* and a basidiomycete are the predominant fungi, although other microorganisms occasionally occur in the mycangium, also. SO(321).

139. Concentrations of inorganic constituents, water, and ash in the inner bark of loblolly pine vary seasonably and on different soil types. In North Carolina, ash, water, calcium, aluminum, manganese, and iron differed significantly among trees on three soil types. Most elements reached maximum concentrations in the fall, minimum in the spring. These findings may provide a partial explanation for the late season buildup of such pests as the southern pine beetle in the southern Piedmont-Appalachian Mountain region. SE(385).

140. Prey consumption and rate of development of the predator *Thanasimus undatulus* vary with the size and availability of mountain pine beetle brood. The larval period lasts from 56 to 68 days. In laboratory studies, 18 to 43 host larvae were consumed during this period, depending upon their size and numbers. This information will be useful in evaluating and predicting the effectiveness of known numbers of this predator under natural conditions. INT(316).

141. A model has been developed to predict the effects of three species of woodpeckers on endemic, epidemic, and panepidemic populations of spruce beetle larvae. Resultant predictions compared favorably with estimates made by measuring relative survival of larvae inside and outside of woodpecker exclosures. The combined predatory impact of the woodpeckers was least effective on epidemic populations of spruce beetles. RM(349).

142. Xylem resin of pines is closely linked with their resistance to tree-killing bark beetles. Three resistance mechanisms—preference through attraction, repellency, and synergism; antibiosis by both chemical and physical properties; and tolerance by healing and secondary resinosis--are active in this relationship. The level of resistance to bark beetle attacks can be increased through tree selection or breeding. PSW(374).

143. An epidemic of the spruce beetle in north central Colorado declined after 2 years. Reduced fecundity, resin flow, interspecific and intraspecific competition for food, predation, parasitism, dry inner bark conditions following woodpecker drilling, and subzero temperatures all contributed to the decline. RM(354).

144. Detailed investigations have been completed on the mating, egg-laying behavior, and brood development of *Ips pini* under controlled laboratory conditions. This information will be used in field and laboratory studies of the population dynamics and control of this pest. INT(373).

145. *Ips cribricollis* and *I. calligraphus* infestations are currently limited to felled trees in young Caribbean pine stands in northeastern Nicaragua. When these stands become older and more dense, it is anticipated that *Ips* and southern pine beetles may cause significant tree mortality. Managers should be able to identify these pests and be alert to the need for direct control if the problem arises. SE (391,392).

146. The identification of economic insect species and their life histories and behavior are important to understanding the structure and functioning of forest ecosystems in interior Alaska. A key has been developed and flight periods determined for major bark beetles associated with white spruce stands. This information will aid studies of insect populations and development of stand management techniques. PNW(323, 324).

147. Dwarf mistletoes reduce root growth as well as stem and crown growth of ponderosa pine. Roots of seedlings were considerably shorter with only about one-half the mass of roots of paired healthy seedlings when measured 2 years after experimental inoculation. Young pines infected with dwarf mistletoes apparently suffer a competitive disadvantage for soil moisture and nutrients which helps explain why infected pines grow so poorly. PNW(501,502).

148. Dwarf mistletoe in a single, isolated, overstory of ponderosa or Jeffrey pine can infest about an acre of pine

reproduction. The maximum distance of spread from isolated trees averaged 120 feet and was generally greatest in the direction of prevailing winds. Prompt removal of infected residual trees, left after fire or logging, is advised to avoid losses in the succeeding generation. PSW(520).

149. Light stimulates infection of dwarf mistletoe in Digger pine. Radicles of germinating dwarf mistletoe seeds failed to penetrate and become established in pine tissues when light was excluded. Light and photosynthesis of the young mistletoe plant appear to condition normal trophic responses of the expanding radicle. This is another step toward understanding the physiology of infection which ultimately will lead to new techniques for managing these destructive parasitic plants. PSW(538).

150. Basic biological experimentation clarified the requirements for infection of junipers by *Phomopsis* blight. In controlled environments, infection was limited to new foliage and occurred when wet, mild conditions prevailed. These findings will be useful in investigations of the epidemiology of this blight which is recognized as the most damaging nursery disease of conifers used for Great Plains' shelterbelts. RM(522).

151. New evidence indicates that the beech bark disease, caused by fungi infecting feeding wounds of scale insects, is well established and threatening most of the beech resource in the eastern United States. Beech is an important component of our forests for wood, recreation, and wildlife habitat. Research is needed to better understand and, eventually, control this disease. NE(548).

152. Brown spot needle cast is causing major defoliation of Scotch pine Christmas trees in north central United States. Control studies following epidemiological research show that one properly timed application of Bordeaux fungicide will protect most conifers from infection for an entire season. Red pine also was discovered to be susceptible to this disease. Research now underway will determine how best to prevent serious outbreaks in this important pulp and timber species. NC(516,517,550).

153. Differences between northern and southern isolates of the brown spot needle cast fungus have been found. Isolates from Scotch pine in the Lake States have different physiological requirements for growth in culture than isolates from longleaf pine in Mississippi. Furthermore, the northern isolates are most pathogenic to Scotch pine while the southern isolates are more pathogenic to southern pines. These indications of separate races of the fungus have important implications in tree improvement programs and on the development of control strategies. SO(497).

154. The cause of an aggressive pine needle cast of the Pacific Coast, *Lophodermella morbida*, has been identified and described. Evidence suggests that this fungus is endemic and limited to moist, moderate climates. It is particularly damaging in ponderosa pine planted in the westside Douglas-fir zone of Oregon. RM(556).

155. Information on anthracnose disease of eastern hardwood trees, especially American sycamore, black walnut, and white oak, was summarized in a new pest leaflet. This foliage disease is enhanced by moist situations. Use of resistant species or varieties is recommended. Removal of infected foliage and spring applications of Ferbam or Bordeaux fungicides are used for nurseries and ornamental trees. NE(481).

156. Identification of the orange-spored needle rusts of true firs in the Rocky Mountains by morphological means is now possible. The fir-huckleberry rust occurs on both current and previous season's needles and has rougher spores than the fir-fireweed rust. Proper identification is a necessary prerequisite to understanding these diseases. INT(507).

157. A *Coleosporium* needle rust known previously only on limber pine in New Mexico and on pinyon pines throughout the Southwest was found in epidemic proportions in high-elevation forests of Mexican white pine in Oaxaca, Mexico. This and other new information on the geographic and host range will aid in evaluating the potential hazard of this rust to pine forests. INT(523).

158. In sparse gypsy moth populations, the resting place of larvae greatly affects their survival. It was found that late instar larvae follow silk trails down the trees at dawn and relocate in protective niches at or near the base of the trees. They then ascend the same trees at night and resume feeding. This behavior protects them from several natural predators. NE(357).

159. Eighty-six aerobic bacterial pathogens have been isolated, characterized, and identified from gypsy moth larvae collected in sparse and dense populations. The most common pathogens were *Streptoccoccus faecalis*, *Bacillus cereus*, *B. thuringiensis*, Group C. *Enterobacter* types, and *Pseudomonas* spp. Only the first two were found to cause appreciable mortality in dense populations. Continuing studies will determine the significance of the bacterial complex in regulating gypsy moth population. NE(370).

160. The western spruce budworm normally passes through an obligate diapause, or dormant period. Pacific Southwest Station entomologists have been able to prevent diapause by altering the physical conditions in which first-stage larvae are reared. This will greatly increase the number of generations in a year and permit higher production of the insect for research purposes. PSW(353).

161. Fatty acids and oils affect the glucose metabolism and survival of western spruce budworm. In laboratory tests, oleic and linoleic acids and sweet almond oil prevented glucose metabolism in pupae but not in larvae. These acids were 15 and 3 times more toxic to larvae and pupae, respectively, than almond oil or mineral oil. This knowledge of biochemical changes induced by fatty acids may lead to new, selective methods of insect control. PSW(318).

162. Many parasitic wasps are highly selective in their choice of host insects. Specially designed experiments have shown that *Monodontomerus dentipes*, for example, differentiates between larch and red-headed pine sawfly cocoons. This confirms previous observations on the host specificity of this parasite. SE(331).

163. The lodgepole needle miner, *Coleotechnites milleri*, attacks and kills lodgepole pines in the western United States and Canada. Results of studies in Yosemite National Park on the biology and ecology of this insect, its natural enemies, environmental influences that affect population fluctuations, and field tests of insecticides have been summarized in a USDA Technical Bulletin. PSW(379).

164. Stands heavily defoliated in 1936-37 by the Douglas-fir tussock moth at Mammoth Lake, California, were studied to determine the incidence and extent of subsequent decay in top-damaged trees. Few decay organisms were isolated. However, old-top damage and wetwood were common. It was concluded that in eastside Sierra Nevada white fir stands defect is not economically serious where larger trees will be logged within 35-40 years after heavy defoliation and top damage. PNW(386).

165. Insects influence the flow of energy in aspen forests through their activities in defoliating, boring, girdling, gall making, and sucking plant juices. Their net impact is not well understood but in some cases may be beneficial. Greater knowledge of the role of insects in the energetics of an aspen stand will improve management decisions aimed at increasing productivity and other resource values. NC(322).

166. Outbreak populations of the lodgepole needle miner in central Oregon occur primarily in topographic basins where lodgepole pine grows in pure stands and is the "climax" species. The insect is virtually absent in sites with high seasonal water tables, deeply developed soil profiles, and dense tree stocking. Similarly, populations usually decline abruptly in stands on well-drained slopes where lodgepole pine is seral or is growing with ponderosa pine. Degree of infestation thus appears to be influenced by a combination of environmental and tree physiological factors that vary significantly with different forest-site conditions. PNW(358).

167. The life history, behavior, and recent outbreaks of an oak leafroller, *Archips semiferanus*, have been described. This insect defoliates red oaks in northeastern Lower Michigan and Pennsylvania. The killing of scrub oak in Michigan favors the release of underplanted red pines. However, in urban, scenic, wildlife, and oak timber-producing areas, defoliation and mortality cause serious economic, social, and ecological losses. NC(387).

168. At least 40 species of weevils feed on trees and shrubs in North Dakota windbreaks. Of these, the red elm bark weevil, white pine weevil, poplar- and willow-borer, an ash seed weevil, the strawberry rooot weevil, and an acorn weevil are the most important. Knowledge of the life histories and behavior of these pests has been summarized in a Station Research Note. RM(356).

169. In the laboratory, elm spanworm eggs do not hatch at temperatures lower than 5° C. Optimum hatch apparently occurs at 19-20° C and 95-100 percent relative humidity. Mathematical models have been developed to predict the time of hatch of the spanworm in the field. SE(332).

170. Field and laboratory tests in Washington and Oregon revealed that high evaporative conditions reduced egg numbers and survival of the European pine shoot moth. This factor could limit the distribution of the insect in the semiarid western pine region. PNW(330).

171. Hybrid poplars planted on Ohio spoilbanks in 1951 are suffering decline and mortality from *Fusarium* canker. Isolation and inoculation trials confirmed the pathogenic nature of the fungus on 16 hybrid combinations. Adverse soils and too close spacing seemingly predispose the trees to *Fusarium* attack. *Fusarium* canker must be overcome if poplars are to be used extensively in reclamation projects. NE(484).

172. The *Sirococcus* pine tip blight was discovered on Coulter pines in forest nurseries in coastal northern California. This disease, found last year on Jeffrey pine, is a new problem in western United States. It has proved to be periodically troublesome to spruce and pines in Europe and eastern United States. Studies in California indicate that this fungus is inactive during winter, but development of fungicide treatments for warmer season application in nurseries is warranted. PSW(553).

173. To reduce the harmful impact of *Scleroderris* canker disease to red pine plantations in the Lake States, planting stock must be disease-free and not planted near residual infected trees. Research on inoculum production and dissemination emphasized the hazard of local intensification within plantations. Prescribed burning appears to be a promising tool to remove infected trees before problem sites are replanted. Development of effective controls for this damaging canker disease is requisite to large-scale reforestation with red pine. NC(549,551).

174. Research at the North Central Experiment Station shows that shade favors growth of *Hypoxylon* cankers on aspen. Cankers receiving the smallest amount of available light in controlled experiments developed the most rapidly while those receiving full light grew the least. Variations in canker growth rate must be considered when evaluating impact from disease incidence surveys. NC(474).

175. An outbreak of *Diaporthe* canker in 1958 killed many yellow birch seedlings in the Upper Peninsula of Michigan. Infection and mortality were most severe on poorly drained sites and among the less vigorous seedlings. Although the mortality is a part of the natural thinning process, any mechanical thinning should favor disease-free dominants. NC(498).

176. Research on spore dissemination of the western gall rust fungus showed that dispersal of inoculum is limited to springtime in the Bessey forest nursery of Nebraska. Control of this pine disease in the nursery could be achieved with protective fungicides applied only in May and June. RM(521).

177. Tissue cultures of slash pine when subjected to attack by fusiform rust provide an ideal test system for study of host-parasite relations. Physiological, cytological, and biochemical studies now permit precise control over pathogenic interactions. The tissue culture technique could lead to more efficient and economical screening of potential chemical, biological, and genetical controls damaging diseases of southern pines. SO(488,510,511,560).

178. Evidence now implicates the existence of genetic variation within geographically distinct populations of the fusiform rust fungus. Differential responses were found among several pine progenies exposed to different geographic sources of the causal fungus. This information will aid in developing resistance to fusiform rust in pines for use in particular regions of the South. SO(554), SE(525).

179. Limb rust was observed on several pine species in northern Mexico. This rust appears to be caused by a fungus also endemic in ponderosa pine forests of our Southwest. Consequently, our research on silvicultural control should be directly applicable to forests in northern Mexico. INT(524).

180. Teliospore induction by the white pine blister rust fungus was determined to be regulated by host factors that can be indexed by winter bud formation in *Ribes*, the alternate host. Prevailing cool temperatures are required, but temperature controls induction less than previously suspected. These findings permit greater temporal flexibility when experimenting with the short-lived teliospores. Identification of the specific physiological changes responsible for sporulation could serve as targets for artificial control of the parasite. INT(489).

181. PL-480 research in India identified a common stem rust of Chir pine to be the cause of mortality to plantings of Canary Island pine in the western Himalayas. The alternate host, *Swertia*, is not known within the Canary Islands, but the rust should be considered as a potential threat to the culture of Canary Islan(pine on the continents where *Swertia* occurs. WO(476).

182. New evidence suggests that black locust witches'-broom might be caused by a mycoplasma. Electron microscope studies of ultrastructure showed mycoplasmalike bodies in phloem cells of broomed locust. Such bodies were not found in healthy tissues. This provides new hope that the disease might be susceptible to treatment with systemic antibiotics. NE(542).

183. Techniques for mass-rearing *Dendrosoter protuberans* and improved methods for studying its biology are needed before the effect of this parasite on elm bark beetle populations can be ascertained. Recent studies showed that *D. protuberans*

can oviposit and develop on smaller European elm bark beetle larvae developing in artificial media. This permits continuous rearing and detailed studies under controlled conditions. NE(348).

184. Two diets have been developed that permit completion of larval development of the smaller European elm bark beetle in the laboratory. Though unsuitable for oviposition, the two diets represent an advance in developing artificial means for rearing elm bark beetles. NE(342).

185. A mite, *Pyemotes scolyti*, is an important predator of the smaller European elm bark beetle. Cross-breeding with a mite which preys upon the fir engraver beetle (*Scolytus ventralis*) revealed that the mites are the same species. Thus, the mite strain from either beetle species may have control potential for both insects. SO(362).

186. Cooperative research with Yale University clarified the effect of temperature on growth of several *Ceratocystis* fungus species. A constant temperature of 25° C was optimum for most species and temperature fluctuations generally reduced growth. An understanding of physiological responses to environmental conditions will aid further research on these fungi which include the causal organism of Dutch elm disease. NE(528).

187. A polysaccharide isolated from filtrate of oak wilt fungus cultures induces wilt symptoms in oak cuttings. The compound was chemically described as a mannan. This phytotoxin explains part of the oak wilt disease syndrome. NE(515).

188. Control of the insect vectors of oak wilt disease requires knowledge of the biology and behavior of the oak bark beetles, *Pseudopityophthorus minutissimus* and *P. pruinosis* . The overwintering stages and period of adult emergence of these species have been determined. This information will be of value in determining the timing of control actions. NE(371).

189. An outbreak of sapstreak disease of sugar maple was discovered in Wisconsin. The disease was traced to root and trunk scars created by previous logging activity. To prevent further disease intensification, harvesting should cease for a few years in areas contiguous to diseased trees. NC(499,500).

190. Prevention of insect damage to seed crops requires an intimate knowledge of insect-plant interactions. The interrelationships between insects and seed production have been described in a reference book on seed biology. This publication will be a valuable reference to seed producers. PSW(326).

191. Various investigators have sought to establish and prove that certain glands produce sex pheromones in insects. It has been determined that such a gland is located in the intersegmental membrane between abdominal segments 8 and 9 in female *Dioryctria abietella* adults. The function of the gland has been confirmed by bioassays with male moths. SE(334).

192. *Eucosma cocana* has been found to cause destruction of second-year cones of loblolly and shortleaf pines in Georgia. New information has been obtained on the larval biology, parasites, and predators of this pest. SE(333).

193. The pathogenic nature of several nematodes to southern pine seedlings has been clarified. The lance nematode proved damaging to sand pine, while lance, lesion, stunt, and pine cystoid nematodes had deleterious effects on longleaf pine. SE(536,537).

194. The influence of nematodes on forest trees was summarized as part of a new book "Economic Nematology." Some nematodes such as those parasitizing destructive forest insects are beneficial, but many others directly harm tree roots and increase their susceptibility to pathogenic fungi. Although estimates of impact are lacking, nematodes are known to cause serious problems in forest nurseries and are suspected to cause widescale growth loss in plantations and natural woodlands. SE (535).

195. Favorable responses of Douglas-fir to nitrate fertilization were attributed to mycorrhizal fungi. Nitrate reductase provided by symbiotic fungi allows reduction of nitrate to forms that can be assimilated and used in tree growth. PNW(512).

196. Several mycorrhizal and other root-associated fungi were identified as new species of *Endogone*, *Elaphomyces*, and *Phaeocollybia*. Proper recognition of mycorrhizal fungi is a necessary prerequisite for developing an understanding of natural biological systems for root disease control. PNW(552,558,559).

197. Root numbers and their distribution and condition differ significantly for loblolly pines growing on flat sites and on low, pimple mounds in central Louisiana. A 2-year study revealed that trees growing on the wet, flat sites were deficient in fine and mycorrhizal roots compared with their neighbors on the mounds. Response of flat site trees to intermittent, severe moisture stress probably contributed to premature tree decline and susceptibility to bark beetle attack. SO(352).

198. Sand pine was shown to be susceptible to the root disease fungus, *Phytophthora cinnamomi*. High mortality occurred in groups of experimental seedlings within 2 weeks following planting in infested soil. It is suspected that *P. cinnamomi* alone, or in combination with the root fungus *Clitocybe tabescens*, limits successful establishment of sand pine in poorly drained sites outside its natural range. SE(533).

199. The black root rot pathogen which is a common pest in forest nurseries in warm areas might also be a potential hazard in cooler situations. Cooperative research with Yale University indicates that the pathogen may vary in temperature response and that natural selection processes could allow adaptation to lower temperatures. NE(529).

200. *Armillaria* root rot of sugar maple is an especially serious problem to trees under stress. Stress such as that following premature defoliation by gypsy moth was found to increase susceptibility of sugar maples to severe root rot damage. Artificial defoliation reduced starch reserves and increased levels of simple sugars and amino acids. These and other chemical changes in roots favor the development of the root rot fungus. Artificial regulation of biochemical changes resulting from stress could reduce harmful effects. NE(562-564).

201. A highly virulent root disease of forest plantations was identified in Brazil. The causal fungus, described as a new species, *Cylindrocladium clavatum*, is lethal to both native *Araucaria* and exotic pines. Although currently known in only a few locations, this disease poses a serious potential threat to reforestation of cleared tropical hardwood sites. SE(494).

202. A root rot fungus, *Phellinus torulosus*, known previously to occur only in Europe and Asia, has been found in two locations in southeastern Arizona. It occurs at elevations of above 8,000 feet, mostly on southwestern white pine in which it causes a white pocket root rot. The fungus probably is not a new introduction but rather an overlooked problem common in high elevation southwestern white pine stands. FPL(485).

203. The complex chemical-microbiological system of wood decay in living trees in being elucidated. Early responses of stems to wounding include a decrease in enzyme activity, reduction of starch, occlusion of vascular elements, and an accompanying succession of microorganisms. Some bacteria that occur in decaying wood have a nitrogen-fixing ability that probably aids in the nutrition and activity of wood-destroying fungi. Complete understanding of the decay processes can lead to improved means of preventing defect and to management of forest residues. NE(531,543,545,547), PNW(541).

204. White-rotting wood decay fungi produce unique forms of peroxidase which might be of commercial value. Four isozymes were detected from a *Poria* fungus, and three were distinct from those commercially extracted from horseradish. Because of their unique composition, fungus peroxidase could find use in industrial synthesis of lignin-related compounds. SE(504).

205. Extensive losses of usable wood in oaks due to decay occurs in eastern United States. Decay generally increases with age and is especially prominent in the black (red) oak group. Fire scars, large dead branches, and various wounds are common entrance points for the numerous fungi involved in the decay process. The incidence of decay can be reduced by better fire control and by silvicultural procedures such as controlling density to reduce branch size and damage by wind and ice, by reducing harvest rotation ages, and by minimizing injuries during logging or thinning operations. NE(480,491), SO(513).

206. Decay causes little economic loss to hickory in the Central States although individual trees do suffer severely. Fire scars and other wounds are entrance points for several fungi. Estimates based on destructive sampling indicate that overall losses account for only 1.6 percent of the gross volume. Consequently, decay will not limit utilization of the hickory resource. NE(479).

207. Ring and ray shakes greatly reduce the value of wood for many products. Dissections of numerous trees showed conclusively that shakes were associated with wounds. These findings clarify the basic understanding of shake formation and promise for eventual reduction in losses caused by shakes. NE(546).

208. Female carpenterworm moths produce a potent sex pheromone that lures the male for mating. Bioassays indicate an acetate of an unsaturated alcohol with 14-16 carbon atoms is the active component. SO(376).

209. Field studies in Mississippi hardwood forests revealed that emergence of carpenterworm moths begins in April, peaks in late May-early June, and ends in late June-early July. Timing of female and male emergence differs as do daily emergence patterns. These findings will help pest managers to predict seasonal and daily occurrence and patterns of attack in the South. SO(377).

210. Tree age influences trunk borer infestations in cottonwood plantations. Studies of plantations representing 8 age classes and two sites revealed that the cottonwood clearwing borer is a problem during the first 3 years following establishment. The poplar borer is a problem thereafter. Site quality has no descernible effect on the level of borer infestation. SO(315).

211. The living beech borer, *Goes pulverulentus*, severely injures individual hardwoods in the United States and southern Canada. Its biology and habits in red oak and American beech were studied in Arkansas and Mississippi. Though not a major pest, this borer does cause significant damage, particularly in trees that are small and occupy subordinate positions in the stand. SO(375).

212. PL-480-sponsored studies in India indicate that gummosis of eucalyptus is caused by wounding. Gummosis is a natural reaction in trunks wounded by animal chewing, attack by insects or fungi, and various physical disturbances such as result from fire, frost, and wind. It is essential, especially in eucalyptus with smooth bark, to reduce trunk wounding in order to produce high-quality wood. WO(475).

213. Very few natural enemies are known to affect wood borers. In a 3-year study of woodpecker predation in central Ohio, it was determined that first-year red oak borer larval populations in the inner bark were reduced by as much as 33 percent. Thus, woodpeckers may have a significant effect in regulating borer populations and their damage. NE(345).

214. The cerambycids *Saperda inornata* and *Oberea schaumii* infest and damage the stems of small trembling aspens and the root suckers and twigs of large trees. Their distribution within the crowns of larger trees, the importance of their galleries as infection courts for *Hypoxylon* cankers, and the relationship of infestation to site quality has been determined for Michigan aspen stands. This information contributes to a better understanding of these insects in the Lake States. SE(365-368).

215. The black twig borer, *Xylosandrus compactus*, has spread to many host plants in the Hawaiian Islands since its first discovery in Hawaii in 1961. Beetle infestations have caused heavy tree damage, and recent attacks have been associated with the death of apparently health forest trees. To date, mortality has occurred in five tree species growing in plantations on the island of Oahu. PSW(363).

216. Hawaiian forests of native ohia and koa are suffering from an acute decline disease. Recent aerial and ground surveys indicate a steadily deteriorating condition, especially on the slopes of Mauna Kea. Studies were initiated to determine the cause and ecological consequences of this severe disorder. PSW(509).

217. Physiobiochemical research on cellular protoplasm is providing new explanations of the mechanisms by which plants resist extremes of heat, cold, and drought. Changes in amounts and kinds of protoplasmic chemicals, such as amino acids and sugars, affect protoplasmic viscosity, membrane plasticicity and permeability, and water-ice relations. These are associated with seasonal and species variations in resistance to stress. An adequate understanding of stress resistance could lead to amelioration through plant breeding and chemical regulation. NE(518,519).

218. A widespread decline of ponderosa pine in the Denver area, previously thought to be due to air pollution, was found instead to be caused by excessive soil salinity. In cooperative studies with Colorado State University, typical tipburn symptoms were induced by experimental applications of salts. Total salts and chloride levels in soils with injured pines exceeded levels around healthy pines. Improving soil drainage shows promise for ameliorating this problem in ornamental trees. RM(555).

219. An information retrieval system (SOLAR), designed cooperatively with Washington State University, to facilitate searches of plant pathological literature is operational. The present data base of 10,000 abstracts was prepared primarily for white pine blister rust. It is expected to grow to 40,000 abstracts by 1975, with rather complete coverage of the physiology and biochemistry of plant diseases. A compatible remote terminal and telephone can provide worldwide access to SOLAR, thereby improving the efficiency of pathological research. INT(492,530).

220. The status of aspen in the Lake States has been reviewed. Aspen is subject to several debilitating diseases. Some stands are too decadent for economical harvest and will

eventually deteriorate and be replaced by other species. Unless the rate of harvest is increased or the pathological rotation age is raised by reducing the impact of disease, large acreages of aspen will be lost. NC(473).

221. Aspen on the Gros Ventre elk winter range in Wyoming are dying because of a combination of "barking" by big game, injurious insects, and diseases. The outlook for aspen regeneration is especially critical because of the heavy impact of browsing, pests, and competition on aspen sprouts. If the trend continues, about a two-thirds reduction in overstory aspen stems is predicted by the year 2000. The Forest Service is now studying the possibility of using fire to regenerate the deteriorating aspen type. INT(506).

222. A monograph on forest diseases in India climaxes 5 years of intensive forest disease research carried out under the PL-480 program. The treatment contains a comprehensive guide to the numerous parasitic organisms that attack over 100 species of forest trees. Silvicultural measures to reduce damage are suggested for each of the more serious diseases. This monograph is a major step toward the growing of healthy, highly productive stands of forest trees in India. WO(477).

223. Scientists sponsored by PL-480 carried out quantitative forest disease surveys in West Pakistan. Prominent diseases included diebacks of mulberry and *Dalbergia*, leaf rust of *Acacia*, blights of juniper and deodar cedar, and heart rots of various conifers and hardwoods. This marks a major step in forest pathological research in West Pakistan where healthy forests are in great demand because of an inadequate supply of high-quality wood. WO(527,569).

224. A recent analysis suggests that the adverse impact of diseases and insects to wildland shrubs is comparable to that experienced with forest trees. Numerous diseases and pests are especially troublesome to important browse shrubs on big game winter ranges in western United States. Increased emphasis on pathology and entomology is necessary to insure the success of programs to improve wildlife habitat and produce genetically superior shrubs. INT(341).

225. Damaging forest diseases and insects may increase in significance as intensively cultured forests are created to meet the growing demand for wood for an exploding world population. The trend toward highly mechanized operations results in a biotic simplification that could easily lead to catastrophic forest damage from diseases and insects. To prevent such losses, broadly based research programs need to accompany the development of intensive forest culture. WO(544).

226. A key to adult bark beetles commonly associated with white spruce damage in interior Alaska is available for scientists and managers. PNW (680,681).

227. The mahogany shoot borer (*Hypsipyla grandella*), a serious pest of the Meliaceae (mahoganies and related species) in the Western Hemisphere, has made it almost impossible to raise plantations of these valuable tropical hardwoods. Results of field and laboratory studies in Puerto Rico indicate that the various Meliaceae species produce chemical substances poisonous to *Hypsipyla* species, but the specific shoot borer which has evolved with each particular tree species has adapted to these substances and uses them as an attractant. This information will be helpful in devising methods for controlling the borer or reducing its damage. ITF(714).

3. Pest control techniques

228. Biological control of dwarf mistletoes appears possible but costs are uncertain. An analysis of current knowledge suggests that the best approaches lie in the introduction of foreign insects that attack only dwarf mistletoes and in the encouragement of certain fungal diseases, such as resin disease, which destroy the mistletoe root systems along with foliar shoots. RM(575).

229. Dwarf mistletoe causes extensive damage to hemlock in west coastal North America. In just Washington and Oregon, annual timber losses are estimated at over 40 million cubic feet. In addition, associated witches'-brooms and decay increase danger from falling trees in recreation areas. Effective control is possible by complete harvest of infested stands, or in recreation sites by pruning of brooms and removal of hazardous trees. PNW(596).

230. Silvicultural control practices have reduced the level of dwarf mistletoe and protected the ponderosa pine recreation forest on the South Rim of Grand Canyon. Plots studied for 20 years document that periodic sanitation is an effective control for dwarf mistletoe in high-use recreational sites. Sanitation has forestalled mortality and associated vegetative changes along the South Rim, thereby sustaining scenic and esthetic values provided by ponderosa pine. RM(582).

231. Combinations of three synthetic attractants, host monoterpenes, and infested bark were tested in sticky traps and on live trees to determine their effectiveness in inducing attack or disrupting aggregation of Douglas-fir beetles. Frontalin-treated trees were attacked but most of these and adjacent attacked trees survived. Methylcyclohexenone (MCH) disrupted or blocked attraction to frontalin-treated trees or traps and the associated "spillover" into adjacent trees. Trans-verbenol had no conclusive effect on beetle aggregation behavior. It is concluded that MCH offers a viable alternative for regulating beetle populations and protecting susceptible trees. INT(403,415).

232. Reduced concentrations of pesticides or the use of an oil carrier alone promise to reduce costs and environmental contamination in western bark beetle control programs. Field tests in Wyoming using 0.25 pound of ethylene dibromide in 5 gallons of fuel oil or fuel oil alone killed at least 90 percent of the spruce beetle larvae and pupae in downed trees. Large-scale tests are now needed to determine the feasibility of altering current operational control recommendations for this and other bark beetle species. RM(416).

233. Better guidelines are needed for determining treatment height on mountain pine beetle-infested ponderosa pines in Colorado. Systematic analyses of brood development in relation to height of attack, presence of pitch tubes, and blue stain have shown that trees need to be treated only to within 5 feet of the highest beetle pitch tubes. This will prevent overtreatment, reduce costs, and reduce effects of the pesticides on natural control organisms occupying the upper trunk. RM(408).

234. Small-diameter lodgepole pines were baited with the attractant trans-verbenol and the host terpene, alpha pinene, to determine if mountain pine beetles could be attracted to such trees and away from nearby, larger trees. Although baited trees less than 8.5 inches in diameter were generally attacked, a greater number of nearby, unbaited, larger-diameter trees were also killed. thus, further refinements are needed before we can effectively regulate mountain pine beetle populations with attractants. INT(410).

235. The fungicide benomyl shows great promise for control of Dutch elm disease and oak wilt. A water-soluble derivative, MBC-HCl, was synthesized and is being extensivly tested for efficacy. This form of benomyl is soluble even in high concentrations, it has a low viscosity which favors uptake and vascular distribution, it is chemically stable, and it retains fungitox-

icity for longer periods with no phytotoxicity at working concentrations. Preliminary results from field trials, using pressure injection, suggest that it is a promising candidate for disease prevention and therapy. NE(574,585).

236. Tests were conducted to determine if the smaller European elm bark beetle—the principal insect vector--would be affected adversely by feeding on twigs containing benomyl. The disease was suppressed, but beetle feeding, longevity, and reproduction were unaffected by the fungicide. NE(404).

237. Bioassays of elm bark beetle feeding must be correlated with assays of insecticide residues by gas liquid chromatography to provide a basis for predicting beetle feeding on treated, living elms. Twig crotches collected from trees sprayed by helicopter and by mist blower revealed low and variable correlations for helicopter-sprayed trees. Correlations were high and uniform for mistblower-sprayed trees. Thus, mistblower applications provide more reliable protection from elm bark beetle attacks than do helicopter applications. NE(393).

238. Forest tree seedlings can now be protected during storage. Benomyl fungicide, applied either as a prelifting field spray in the nursery or as a seedling dip, reduced losses of 50 percent in giant Sequoia nursery stock to a negligible amount. With benomyl treatment, gray mold should no longer be a detriment to successful cold storage. PSW(600).

239. The proceedings of an international meeting on resistance of forest trees to rust diseases held in 1969 in Moscow, Idaho, was published. More than 140 specialists from all over the world discussed white pine blister rust and new research developments in hard pine and cereal rusts. Considerable progress toward production of rust-resistant white pines has been made, along with new ways of increasing the efficiency of tree breeding programs. INT(571).

240. Resistance to western white pine to blister rust is a composite of independent mechanisms inherited in a simple Mendelian manner. These mechanisms include exclusion or abortion of needle infections and walling-off of stem cankers. It now appears feasible to develop a balanced system of resistance in western white pines. Such resistance would maintain a gene pool within forest populations that could guard against changes in virulence by the blister rust pathogen. INT(576,577,584).

241. Methods for large-scale inoculation of western white pine progeny used in developing resistance to white pine blister rust were evaluated. Inoculations are made in covered nursery beds with inoculum from *Ribes* leaves. The technique results in heavy but spotty infection. Lack of uniformity continues to be a costly problem that is overcome by computerized statistical analysis. INT(570,583).

242. A method was developed for uniform inoculation of large numbers of pines or oaks with fusiform rust. Water suspensions of basidiospores or aeciospores are applied in an aerosol spray on greenhouse-grown slash and loblolly pine or oak seedlings. This method was increase efficiency and accuracy of an operational program for selecting rust-resistant southern pines. SE(573,589).

243. Microscopic examination revealed an apparent anatomical mechanism in southern pines for resistance to the fusiform rust fungus. The mechanism involves the death of cells in and around the infection point in young stem tissues. Reaction areas apparently wall-off the pathogen and the new tissues develop disease-free. Knowledge of how rust resistance operates can lead to more efficient programs of genetic improvement of valuable southern pines. SO(578).

244. Intensive site preparation, including burning and plowing before planting, significantly increased the incidence of fusiform rust in slash pine plantations in southeastern Georgia. When examined 7 years later, plantations established on treated sites had more fusiform rust than did those in which planting was done without prior site preparation. However, site preparation also increased overall tree growth. Caution in site preparation should be exercised in high rust hazard sites. SE(590).

245. Ferbam, carboxin, and oxycarboxin provided better control for fusiform rust of loblolly pine in nursery seedbeds than did benomyl or chloroneb. Apparently none of the test fungicides were systemic even with the addition of DMSO. Satisfactory control of fusiform rust in southern forest nurseries still requires application of foliar sprays before, during, and after periods of wet weather. SE(594).

246. In field trials, sex pheromone perception by male European pine shoot moths was inhibited by the use of synthetic acetates. Cis-7, cis-8, and cis-9 dodecenyl acetates were particularly effective. One or more of these materials may have potential as a behavioral control agent for manipulating populations of this insect. PNW(396).

247. Case histories of five Douglas-fir tussock moth outbreaks in California and Oregon revealed that all infestations followed a 3-year cycle. Minimal defoliation occurred during the first year, severe foliage loss the second year, and minor defoliation and ultimate collapse of the populations by the end of the third year. Although other factors were involved, a virus disease appeared to be the principal natural cause of insect mortality during the collapse. To prevent serious damage, outbreaks must be detected early and controls applied selectively in high moth population centers. PNW(420).

248. Use of nucleopolyhedrosis viruses in controlling forest and agricultural insects requires that microbial preparations be essentially free of hazardous contaminants. Oak Ridge National Laboratory and Forest Service scientists have developed a procedure for purifying specific virus formulations for the Douglas-fir tussock moth, European pine sawfly, and the gypsy moth in quantities sufficient for operational use. NE(395).

249. A hymenopterous parasite, *Agathis pumila*, was released at five locations near St. Maries, Idaho, in 1960, to control the larch casebearer. Although the parasite became established in three of the areas and caused up to 68 percent mortality, its inability to spread has limited its usefulness. Consequently, the casebearer has spread through more than 90 percent of the range of western larch. Researchers have therefore altered their approach to include introductions of multiple native and/or introduced parasite species and other means of control. INT(398).

250. Alternative, environmentally acceptable toxicants are needed for control of many forest defoliators. Several insecticides have shown promise in controlling *Malacosoma disstria*, *Hemerocampa vetusta*, *Symmerista canicosta*, and *Acleris gloverana*. Field tests are needed to establish minimum effective dosage rates and optimal timing of applications. PSW(407,409,413,414).

251. Juvenile hormone analogs effect the fecundity, development, and survival of insects. Several chemicals were tested on 6th instar larvae of the western spruce budworm. Low dosages tended to decrease egg production and hatch. Higher dosages increased the degree of deformity, disrupted growth and development, and increased mortality. More potent compounds caused additional moulting. PSW(412).

252. Preparations of Thuricide HPC were applied with a mistblower at rates of $16x10^9$ and $8x10^9$ International Units per acre, or 1 gallon and 0.5 gallon per acre, respectively, for gypsy moth control. These treatments, applied at 10-day intervals, provided partial protection of foliage and significant larval mortality. Unsprayed areas were nearly completely defoliated. Further study is needed to determine optimal dosage rate, number of applications, and timing of treatments. NE(421).

253. The construction details, costs, and calibration data for a microbial insecticide spray tower have been described. This device permits precise dosage and formulation evaluations at low cost prior to actual aerial field testing. NE(406).

254. The gypsy moth is currently spreading southwestward into new environments where its natural enemies are sparse or lacking. Rearing techniques and biologies are being determined for five promising parasites by the USDA for possible mass release and colonization in these new areas. NE(411).

255. Mistblower applications of malathion are registered for use in suppressing populations of the red-headed pine sawfly. Further tests with aerial and mistblower applications of this pesticide applied at the rate of 10 ounces per acre and 2 gallons per acre, respectively, provided 84-100 percent control. These data would support the registration of aerial application of malathion for control of this sawfly. NE(401).

256. The major volatile trail-marking pheromone of the Texas leaf-cutting ant, *Atta texana*, has been isolated, identified as methyl-4-methylpyrrole-2-carboxylate, and synthesized. The synthesized pheromone and several of its analogs elicited strong trail-following responses from worker ants in the laboratory and the field. The synthetic pheromone offers potential in trapping ants or in leading them away from food sources. SO(417,419).

257. A defoliating weevil, *Magdalis gentilis*, is attracted to thinned stands of lodgepole where it may destroy up to 100 percent of the foliage on crop trees. Though damage to forests has been limited to date, activity of this insect can be minimized by delaying thinning until late July. INT(400).

258. A pictorial guide has been prepared for the insects and diseases affecting southern seed orchards. Hosts, distribution, damage symptoms, biology, and cultural control treatments are presented for each species or species group. This publication will be used by orchard managers and others interested in seed production. SE(405).

259. Soil applications of 1 lb. of the systemic insecticide phorate per tree in Alabama, Georgia, and Florida seed orchards reduced infestation or damage by *Dioryctria* spp., *Laspeyresia* spp., thrips, and seed bugs by more than 80 percent. The treatment also increased the percentage of sound seed harvested. Lower dosages were less effective, suggesting that the 1 lb. rate was the most efficacious. SE(397).

260. Twenty-two different species of predators were introduced from Europe, Asia, and Australia during the period 1959 through 1966 to control the balsam woolly aphid on Fraser fir in the Mt. Mitchell area of North Carolina. From observations in 1968, *Larcobius erichsonii* is the only species established. Three species of native, predatory mites were found to be abundant and, possibly, more important as natural enemies. However, there is no tangible evidence as yet that the native or foreign predators have significantly altered the course of this outbreak. SE(399).

261. Damping-off, nematodes, root rots, diebacks, and several leaf diseases periodically reduce nursery production. Sanitation, soil amelioration and fumigation, and protective foliar fungicides are recommended to meet production demands for disease-free planting stock. SE, SO(595).

262. Basic copper sulfate fungicide can partially control needle blight of Arizona cypress in southeastern nurseries. Tests were made of 30 materials in search of a replacement for restricted mercury compounds. Basic copper sulfate provides reasonable control except during severe disease epidemics. SE(593).

263. Control of the *Poria* root rot fungus by biological means is being evaluated in the Pacific Northwest. Nitrogen and organic compounds of red alder influence soil chemistry and prevailing microflora in ways that inhibit *Poria*. On *Poria*-diseased sites, short, merchantable rotations of pure alder or mixtures of alder with *Poria*-susceptible conifers are promising for control of the disease. PNW(601-603).

264. Reasons were found for reduced colonization of pine stumps by the annosus root rot fungus during late spring and summer in the Southeast. The explanation lies in a complex combination of reduced inoculum, high temperatures, and competing organisms such as *Peniophora gigantea*. This confirms an earlier suggestion that plantations in southeastern United States south of approximately 34° N. latitude can be thinned in late spring and summer with little danger of increasing annosus root rot in residual trees. SE(592).

265. Progeny of loblolly pines used in a southeastern cooperative tree improvement program were shown to be susceptible to annosus root rot. Mortality was uniformly high in inoculation tests among the more than 10,000 seedlings from controlled crosses of 151 "superior" parents. This nullifies an earlier first-year report of suspected resistance. If resistance is needed to combat this disease, it probably will be necessary to select specifically for this trait. SE(579).

266. Research has verified the importance of mycorrhizae as agents for biological control of rootlet pathogens. The mechanisms whereby mycorrhizae induce resistance include the creation of physical barriers to invasion by pathogens, production of antibiotics that inhibit pathogens, and chemical stimulation of favorable rhizosphere microorganisms that successfully compete with pathogens. Research now underway will assess the potential of several mycorrhizal fungi for inoculation into forest nursery soils. SE(586,587).

267. Mycorrhizae protect slash pine from dehabilitating attack by *Phytophthora* root rot. Controlled experiments indicated that slash pine seedlings bearing ectomycorrhizae formed by *Pisolithus tinctorius* or *Cenococcum graniforme* can grow well in soil infested with *P. cinnamomi*, whereas nonmycorrhizal seedlings in similar infested soil become chlorotic and stunted. This is important new evidence useful in developing strategies for protecting the rootlets of forest trees from pathogens. SE(588).

268. Standard treatments with 1 percent aldrin solutions dispensed from planting machines have provided erratic control of white grubs in the Lake States. Reevaluation of this method, as well as applications of 1 percent aldrin solutions with a backpack sprayer and granules dispersed from a planting machine revealed that all three methods properly carried out would provide adequate protection for at least two seasons. NC(402).

269. The composition of resin may have a prime role in determining succession of fungi invading pine sapwood. Variation in the growth of several sapwood fungi occurred in laboratory trials containing pine terpene additives. Early colonizers were generally more tolerant than their successors and variation was expressed within species isolates as well. Screening of genetic variants for possible use in hastening

degradation of logging residues might be feasible by this pureculture technique. SO(572).

270. Placing paraformaldehyde pills in sugar maple tap holes to increase sap flow can lead to heart rot. Experiments in the Northeast determined that the frequency and extent of decay is significantly greater with this practice than with untreated tap holes. Losses due to decay more than offset the gains in maple sap yields. It is advised that paraformaldehyde not be used. NE(598).

271. Preliminary results suggest that dressings applied to tree wounds are ineffective in preventing invasion of microorganisms. Fresh axe wounds on sugar maple and American elm were either coated with asphalt dressing, orange shellac, polyurethane varnish, or left untreated. No differences in invasion of microorganisms and wood discoloration were noted one year later. Improved wound dressings appear necessary to prevent defect in valuable shade and ornamental trees. NE(597,599).

272. Snow movement causes severe stem defects in conifers on steep, mountainous terrain. Studies in Idaho defined six classes of deformities of which "butt sweep" is the most frequent, whereas, "dog leg" and "stem failure" are the most injurious. Deformed stems reduce mechantability and together with other economic and environmental costs make commercial forest operations on steep slopes difficult. Where harvesting on steep slopes is feasible, partial cutting is recommended to minimize stem deformatives since residual trees impede snow movement. INT(581).

273. Salvage harvesting in northern Idaho of pole blight-affected western white pines had no effect on disease development in residual white pines, but it did influence associated conifers. Pole blight continued to develop in remaining white pines. Western redcedar responded well to release, but the Douglas-fir component suffered heavy mortality from *Poria* root rot. These findings will aid in predicting future consequences of silvicultural practices on similar sites in the Inland Empire. INT(580).

4. Pest management strategies

274. A new cost-optimizing procedure allows managers to formulate goals and safety standards for control of hazardous trees in recreational sites. A selected goal and a uniform hazard-rating procedure can be established and a balance between hazard, control costs, and attractiveness of the forest site attained. PSW(604).

275. Common diseases of shade forest trees in urban areas of the South can be reduced. Selection of disease-resistant trees, special cultural techniques, and fungicidal controls are integrated into recommendations to promote a healthier, more satisfying forestlike environment in southern cities and suburbs. SE(605).

276. The effects of mountain pine beetle, the need for control, and the effectiveness of certain suppression methods are critical questions facing managers of lodgepole pine stands. An evaluation of 10 treated and untreated areas in Wyoming and Idaho showed that chemical control treatments slowed the rate of tree mortality but did not affect the beetle outbreak period or the final number of trees surviving. Generally, harvesting of large-diameter, thick phloem pines at mid- and low-elevations in stands composed of 64 percent or more lodgepole pine was suggested for reducing the potential for severe outbreaks. INT(422).

277. *Phytophthora* root rot continues to threaten survival of the unique and highly valuable Port-Orford-cedar. The disease spreads through movement of contaminated soil and water. Exclusion of people, equipment, and animals from drainages that still harbor healthy stands is the only means of prevention. Practical ways to restrict movement of contaminated soil are advised for salvage logging of infected stands. Losses can be minimized, but there appears no hope of raising another merchantable rotation of Port-Orford-cedar under existing conditions of disease and land use. PNW(606).

G. Accelerating Forest Resource Surveys

1. Forest inventory

In a continuing effort to provide current information for future timber supply analysis, field work was conducted in Louisiana, Alabama, Vermont, New Hampshire, Wyoming, Utah, South Dakota, New Mexico, Missouri, Tennessee, Georgia, Oregon, and California. Reports appraising the forest resource condition were issued for five States or parts of States.

278. Wisconsin's growing stock volume increased over 30 percent between 1956 and 1968 to a level of 11.0 billion cubic feet, and sawtimber volume increased from 13.8 to 21.8 billion board feet. These gains were made despite a small loss of commercial forest area—from 14.9 million acres in 1956 to 14.5 million acres in 1968. The aspen-birch type (4.2 million acres) and the maple-beech-birch type (3.5 million acres) led other types in area. Growing stock growth in Wisconsin in 1967 exceeded removals by over 100 percent, 500 million cubic feet to 233 million cubic feet. NC(1053).

279. Preliminary statistics on Delaware's forest resources indicate that forest area has remained about the same but inventory volume has increased. Growth exceeded removals for hardwoods but growth only equalled half of removals for softwoods. Thus, the softwood proportion of inventory volume has dropped sharply. NE(1039).

280. Tennessee's commercial forest area declined 5 percent between 1961 and 1971, with a diversion to pasture dominating the loss. Softwood timber volume increased 26 percent and hardwoods gained 11 percent in spite of this area loss because of the net growth excess over removals. Most of the volume increase accrued to trees less than 18 inches in diameter. The same pattern of constant or declining commercial forest area but increasing timber inventory was also observed in the 1972 reinventory of Alabama. SO(1049,1050), SE(1043-1045).

281. The first complete inventory of timber resources in Mendocino and Sonoma Counties, California, indicates that there is 19.1 billion board feet of sawtimber on 1.56 million acres of unreserved forest area. Almost half the area is stocked with low-quality hardwoods and scattered conifers resulting from logging, wildfires, or unsuccessful attempts to convert timberland to grazing land. In recent years forest industries of the counties have been utilizing predominantly old growth from their own lands. In the next 10 to 15 years they will have to rely increasingly upon young growth redwood sawtimber, much of it from farm and miscellaneous private lands. PNW(1052).

282. Because of the rapidly changing nature of the Southern forest resource and industrial structure, more detailed and up-to-date information than is available in published reports is often requested. In response to this, both the Southern and Southeastern survey units have developed custom data retrieval capacities. For example, data on more than 100 specified areas were compiled in the Southeast in FY 1973. SO(1042).

283. A broader scope of forest inventory data is needed to enable land managers to evaluate the feasibility of meeting in-

creasing demands for nontimber uses of the forest. A transitional sampling design was developed that permits comparisons between stands for size, accessibility, productivity, and restrictions imposed by competing uses. Trial use of this design in Montana and Idaho in 1970 was the first step in establishing complete timberland records. INT(717).

2. Timber utilization and production

284. The trend of similar sawmills dropping from production and larger or medium sized mills replacing them has continued into the mid and late 1960's in four Eastern States. Pennsylvania, Kentucky, Missouri, and Alabama all experienced a 30-45 percent decline since the early 1960's in the number of active sawmills according to recent industry surveys. The same States, however, had constant or increasing saw-log production levels. NC(1065), NE(1067, 1068), SO(1062).

285. Pulpwood production increased roughly 85 percent in Alabama from 1962 to 1971 and the pulp industry recently entered Kentucky with three mills. Pulpwood production dropped slightly in the Lake States and the South from 1970 to 1971, however. NC(1064), SE(1058).

286. Southern pulpwood prices rose slightly in 1971. Softwood pulpwood price was $21.15 per cord in the Southeast, $19.49 per cord in the Midsouth east of the Mississippi, and $18.73 per cord in the Midsouth west of the Mississippi. SE(1072), SO(1063).

287. Midsouth pulpwood hauling distances from the stump to the mill are about what they were in 1960. Forests within 50 airline miles of pulpmills have consistently supplied about half of the wood requirements. SO(1059).

288. The percentage of primary plant residues used for other products varies greatly by State. Roughly 85 percent of the residue was used in Alabama in 1971 but only 40 percent was used in Missouri in 1969. Pennsylvnia (1969) and Kentucky (1969) fell between these States. the dominant residue market is for pulping material. Alabama's excess residue was mostly fine particles which generally have too short fibers for pulping, however. Most of the unused Missouri residue was hardwood and the State only has two pulpmills. A 1968 survey of mill residue flows in Washington, Oregon, and California showed that 88 percent went to domestic plants and 12 percent was exported. Eight-three percent of the domestic residue shipments was used by pulpmills. NC(1065), NE(1067,1068), SO(1062), PNW(1069).

289. The 1971 Oregon log harvest was up 12 percent from its 1970 level but Washington harvest was unchanged. Log harvest levels in Western Oregon have been steady since the early 1950's with the increase in public harvests offsetting the decline in private harvests. Western Washington harvests have been increasing on both public and private lands, reflecting to some extent the increased availability of second-growth stands. Eastern Washington and Eastern Oregon harvests have increased since the early 1950's. Pacfic Northwest log production has been counter cyclical with reference to the business cycle since World War II. Housing starts lagged one year, and National Forest stumpage prices were significantly related to log production. PNW(1074-1077).

290. Estimates of logging residue in western South Dakota, Wyoming, Utah, and Colorado for 1969 ranged from 4.72 percent of the cubic volume to 10.43 percent of total growing stock. Most of the residue is the result of damage from tree felling and is wood from trees from which saw logs are harvested. Knowledge of residue volumes is especially important where there is an active wood chip market since the residue volume is usually too small or low quality for sawn products. An on-site chipping study in Wyoming of logging residues in lodgepole pine stands was found to increase fiber yields by 35 percent. INT(1070,1073).

3. Survey techniques

291. Analysis of two-stage 3P sampling, indicates that this approach may be an efficient means of obtaining intermediate volume estimates between full scale forest surveys. A simulated 3P sample predicted the total cubic volume for five counties in southern Alabama to within 0.7 percent of that predicted by the latest forest survey. The 3P sample only required measurement of 4 percent of the trees measured in the full survey. SO (1093,1094).

292. Evaluation of photo inventory plot location has demonstrated that not only do irregularities of ground elevation cause problems but a plot bias may also exist on flat areas under some conditions. It is essential that the photo plots are uniformly distributed over the earth's surface if a bias is to be avoided. Analysis of inventory data in the 12 Pacific Northwest counties revealed that double sampling for stratification, using a combination of photo plots and field plots, is about twice as efficient as simple field plot sampling for timber volume estimation. PNW(1090,1095).

293. The possible use of high altitude and satellite imagery for land resource classification and measurement has induced considerable research work. High altitude color infrared photographs of a 1:120,000 scale covering eight 41-square-kilometer study areas over a period of 20 months were used to identify 13 forest and nonforest land classes. Over 97 percent of the forest points were interpreted correctly regardless of season. The study also revealed the likelihood of specification error for particular land use classes. Computerized techniques for land use classification on 1:120,000 scale color infrared photographs were also analyzed using an automatic scanning micro-densitometer with a red, a blue, a green, and a clear filter. Results were compared with a map derived from 1:32,000 scale color infrared film and ground checks. PSW(1078,1091).

294. Analysis of medium scale (1:32,000) color infrared photographs successfullly monitored the spread of mountain pine beetle infestations in the Black Hills of South Dakota from May to September of 1972. New research permits the optimization of the choice of photoscale against interpretation error. Airborne multispectral scanner equipment was also used for detection of forest stress in the ponderosa pine ecosystem in the Black Hills. Preliminary results indicate the best channel ratios for stress detection. PSW(1096,1097).

295. Normal color and color infrared photos are becoming increasingly valuable tools for detecting symptoms of forest diseases by remote sensing. Recent studies show these films can distinguish between healthy and disease-stressed vegetation in air pollution injury, Dutch elm disease, oak wilt, dwarf mistletoe, ash die-back, *Fomes annosus*, and other diseases. PSW(1085).

296. The field of geographic information systems is a rapidly evolving one in which there has been no commonly accepted vocabulary. To meet this need, a partial glossary of 225 terms has been assembled and is now available as a guide to standard usage. PSW(718).

H. Economics of Forest Management

1. Methods of financial evaluation and planning

297. An improved timber inventory projection model uses exogenous estimates of (1) supply and demand to determine annual cut, (2) changes in acreage which reflect changes in forest investment, and (3) net growth, including changes in investment in cultural practices. This model has several advantages over many other available methods. First, it estimates market equilibrium quantities each time period rather than postulating their intersection at some point far in the future. Second, it focuses attention on an increasingly important forest management problem—changes in land use. Third, it can be adapted to a variety of inventory and supply problems. NC(1098).

298. A method for projecting value growth of hardwood timber stands uses tree-development (changes in diameter, height, and quality) probabilities based on continuous forest inventory (CFI) data. This is the first step in building a more precise tool for forest land managers desiring to recognize the value production potential in their stands and forests. NE(1100).

299. A zero-one integer programming procedure has been developed for systematic planning of commercial thinning operations in young-growth Douglas-fir. This new approach is demonstrated, tested, and compared to existing rule-of-thumb methods of a case study area in western Oregon. PNW(1101).

300. The allowable cut effect, which may be a factor in investment analyses where harvest volumes are dependent upon the physical rate of growth of a forest, is described and illustrated. Some of the physical and economic ramifications of the concept may be important determinants in developing management plans. PNW(1102).

2. Timber growing economics

301. Projections of aspen inventory and cut in the Lake States indicate that today's apparent surplus of aspen cannot continue indefinitely. The analyses assumed three sets of assumptions and historical trends of cut, growth, and utilization. The projections indicate that Minnesota may be able to support more than the projected cut. Forest industries drawing their wood from traditional sources in Michigan and Wisconsin must plan to procure their wood elsewhere within these States, substitute other species of wood for aspen, or cut less than the projected amount during the next 15 to 25 years. NC(1110-1112).

302. The fourth in a series of determinations of financial maturity for the important timber species in the northeast, establishes the rates at which sugar maple trees increase in value due to diameter and height growth and improvement in quality over a 10-year period. Detailed rates of value increase to be expected over a 10-year period are exhibited. The effects of different conversion costs and changing costs and prices over a 10-year period are analyzed. NE(1115).

303. An analysis of the economic desirability of accelerated roadbuilding for access to old-growth timber on a unit of the Umpqua National Forest in Oregon found four accelerated roadbuilding alternatives inferior to the current rate of construction. Only in the case of substantial, continuing inflation were projected rates of return on investment for accelerated roadbuilding above 6 percent. The inclusion of nontimber benefits and costs, changes in price and cost levels since 1966, and recent improvements in logging technology do not appear to alter results appreciably. PNW(1117).

304. The behavior patterns of small woodlot owners revealed by a study in Pennsylvania suggest that we should provide information about the management and marketing of forest products to more owners of large wooded tracts (50 acres or more). Owners who have sold forest products and practiced some form of forest management on their woodlands in the recent past should prove most receptive to sales promotion. NE(1109).

305. Life insurance companies have accepted forest land and timber as loan security since 1950; six firms now have timber loans in 25 States, chiefly in the South and Pacific Northwest. Lending policies vary, but all firms require that the woodland be managed soundly. Two-thirds of the borrowers are individuals. SO(1122).

3. Multiple-use economics

306. A comprehensive model of the U.S. range resource evaluated potential programs of range land development. The system uses linear programming to analyze alternative plans for the management and protection of range land in 36 ecosystems. It shows how each proposed plan affects the output and nine physical products including annual unit months and water yield and 13 environmental values such as soil stability and rare and endangered species. WO(1126).

307. A typical dense chaparral area on the Tonto National Forest was analyzed to explore the economics of chaparral management. Costs and benefits were developed for 12 alternative management plans, ranging from complete conversion of chaparral to grass to leaving the chaparral untouched. Labor, equipment, materials, and transportation costs were identified for each alternative over a 50-year period. Products considered for each alternative include water, sediment, range, recreation, wildlife habitat, esthetics, and fire protection. Primary emphasis was on the development of values for the products affected. This study showed that the method can give adequate information to the land manager for management planning. RM(1130).

308. Economic returns from planting forage in a shelterwood management regime in ponderosa pine-grass areas of eastern Washington are summarized for various assumed planting costs, forage values, and growth data. The approach allows a forest manager to rank forage-planting alternatives according to their rates of return, when better forage yield for domestic grazing is the primary objective or when noneconomic benefits appear equally desirable. PNW(1132).

4. Impacts on forest industry and regional economies

309. An analysis of the economics of producing both timber and pulp chips showed that if pulp and paper firms installed chipping headrigs at pulpwood yards, they could earn greater profits, timber growers could receive higher prices, and society could benefit from improved utilization of the timber resource. SO(1139).

310. Competition in the timber harvesting industry and legal obstacles have thwarted recent collective bargaining efforts by pulpwood producers' associations. A study indicated that cooperatives appear to offer the best prospects for producers to legally bargain collectively with wood buyers. SO(1135).

311. A national forest economy input-output model describes the flows of values in this major economic sector dealing only with industries that process logs and bolts or utilize the wood products immediately after this stage. The model was successfully implemented with data from the Bureau of the Census and other standard sources. SO(1138).

I. Improving Engineering Systems

312. One of the most pressing problems facing forest managers is finding suitable means for utilizing forest residues. The engineering component of this gross problem includes the development and testing of creative handling and on-site processing of these residues. Preliminary trials of on-site chipping of lodgepole pine residues suggests a potential for adding as much as 35 percent greater total wood yield from clearcut areas where whole unmerchantable trees or residue portions of merchantable trees are yarded and chipped *in situ*. INT(1206).

313. Logging residues, chipped in their entirety in the field, contain whole-tree material, including bark. An essential engineering component for residue utilization in paper-making or for most reconstituted wood products necessitates a practical, economic bark-chip separation and segregation technology. Such a technology is now ready for pilot testing. NC(1194-1196, 1202-1205, 1217, 1218).

314. A basic requirement for designing suitably engineered logging systems is a precise means of determining log or tree weights and centers of gravity. Recently completed studies report on estimated log or tree weights for typical northwestern species and for weights and centers of gravity for typical Lake States species. PNW(1212), NC(1216).

315. Proper design and construction of logging road systems is an important engineering element for successful logging, especially where critical environmental stewardship issues are at stake. One critical analysis of a road in sensitive Idaho batholith soils indicates that with proper attention to design and construction, suitable and environmentally secure logging roads can be built. 0For Pacific Northwest conditions, recent studies show how yarding distances for aerial logging systems can be predicted from map data and how road and landing criteria can be subsequently engineered into the logging plan. PNW(1200, 1213), INT(1201).

316. Advanced logging concepts are moving from the laboratory to operational situations. Recent trials of balloon logging in Idaho provide the initial data for substantial modification and improvement to suit conditions heretofore untried. 0Running skyline systems developed through research over the last 5 years are now operational and are proving themselves under a variety of field conditions. These initial systems suggest a need for an even broader "family" of skylines that would be useful in locations other than the Northwest. INT(1207), PNW(1211).

317. Simulation and other computer-based modelling systems provide an excellent means for examining numerous possible ways for solving complex logging problems. Recently completed studies, under a wide variety of assumptions and conditions, focuses attention on the potential for bringing about substantial cost reductions for commercial loggers. NE(1198, 1209), NC(1199), INT(1208).

J. Improving Water Quality and Yield

1. Improving water yields

318. It is estimated that 2,000,000 acre-feet of water is lost annually to evaporation from snow in the Sierra Nevada of California. Suppression of evaporation from snow may be achieved with use of long-chain-fatty alcohol monolayers. Twelve pounds per acre are sufficient to achieve maximum evaporation reduction. The chemical is not a pollutant and does not cause increased snowmelt at this rate of application. It does not migrate from point of application. The treatment is recommended for reduction of evaporation from high loss sites. PSW(42).

319. Information on the flow of water and dissolved solutes in trees provides valuable insights into tree growth processes under changing environmental conditions. Flow of radioactive tracers in 6-year-old lodgepole pines and red firs ranged fro 12 to 84 cm per hour. No water moved in lodgepole pine during the winter, whereas red fir transpired a small amount during that period. The procedures permit precise determination of conditions favoring tree growth, and provide a new means of estimating water use per acre. PSW(36).

320. Seasonal water depletion from a 1.5 m soil mantle averaged 188 mm on uneven-aged plots, 87 mm on clearcut plots, and 57 mm on plots without vegetation in a Wisconsin hardwood forest. Total amount of depletion increased with mantle depth; thus cutting had a greater water-saving effect on deeper soils. NC(38).

321. Sublimation from blowing snow is estimated from the balance of heat and mass transfer on a volume of air and nonuniform in particles. The effect of turbulence on convection around the particle appears unimportant in view of the small particle size. Turbulent transfer determines the snow concentration profile, and the gradients of heat and water vapor necessary to balance the sublimation process. RM(41).

322. A mathematical model for the sublimation of wind-blown snow was developed which predicts the distance a particle of given size will travel before completely sublimating; critical variables are particle speed, relative humidity and temperature of the air, and total insolation. Measurements of these conditions during all drifting events over the 1970-71 winter, indicate average transport distances of 460 and 900 m for particle diameters of 0.010 and 0.015 cm. respectively. RM(46).

323. A dynamic model has produced tentative results regarding the probable effects of timber harvesting on snowmelt in a central Colorado watershed. Snowmelt rates in mature lodgepole pine and Engelmann spruce forest were compared against a hypothetical pattern of 5 tree-height diameter openings, cut into the watershed so that trees on 40 percent of the area were removed. The estimated effect showed increased melt rates early in the melt season and lower snowmelt later. Although harvest cutting affected timing by causing the bulk of the snowmelt to occur earlier, the duration of the snowmelt season was apparently not significantly changed. Early-season snowmelt was accelerated in the small openings, but in both natural forest and cut-over areas, the last snow melted at about the same time. RM(33).

324. The efficiency of loblolly pine in eliminating sediment production from severely eroded and gullied waste lands is shown by an analysis of hydrologic measurements from experimental watersheds. Sediment yields 25 years after planting loblolly have been reduced to 0.03 ton per acre per year. The yields are a direct function of stormflow volumes. While loblolly reduces sediment to amounts approaching the geologic norm, the effect of reforestation on stormflows is largely a function of soil characteristics. Stormflows can be completely eliminated from small catchments of well-drained soils. SO(47).

2. Managing, rehabilitating, and improving watersheds

325. An open ditch hastened the drainage of water from surface or near surface horizons of peat on a typical lake-filled organic soil. The ditch had little influence on the water table beyond 5 m from the ditch when the water table was in

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deeper horizons of moderately decomposed peat. A similar treatment influenced the water table to a distance of 50 m laterally in an organic soil consisting of less decomposed peat. NC(57).

326. Little is known about quantitative relationships of surface form and water behavior of small forested watersheds. Three small contiguous Black Hills watersheds were analyzed in terms of elementary length dimensions, nondimensional elements, and similitude concepts. Maximum length of watershed and average length of first order basins scale most nearly the same as volume yield and stormflow peaks. It is theorized that these parameters are (1) primary controls over volume yield and peak flows and (2) better indicators of watershed behavior than watershed area. Refinements of this type improve the basis for small watershed systems analysis and simulation. RM(125).

327. Water yield increase following a wildfire in north central Washington averaged about 3.5 inches. The increase came mainly during the spring snowmelt and during summer months. Since the protective canopy was destroyed, maximum daily stream temperature was increased as much as 10° F. The temperature increases were well within limits prescribed for trout, however. PNW(80).

328. Mesquite not only redistributes nutrient elements within desert grassland ecosystems, but also provides a microenvironment that enhances availability of nitrogen and phosphorus. Pot tests disclosed differential availability of N, S, and P for three native perennial grasses in soil from under mesquite trees compared with soil from adjacent open areas. These measured differences in physical and chemical properties between areas appears to be the reason for greater abundance and improved perennial grasses observed under mesquite. PNW(120).

329. Trembling aspen root suckers originate from newly initiated meristems, preexisting primordia, or suppressed short shoots, but the first two are probably the most important. Evidence was found of suppressed short shoots in aspen roots but not of suppressed buds buried in the periderm. Vascular trace shows that the developing sucker responds to polarity in the root; it grows distally as it extends inward and basipetally to the root cambium. INT(110).

330. Streams require an additional number of gravel bars to adjust to slope. Average step length between logs and gravel bars are strongly related to channel gradient and median bed material size. More bars formed when fewer numbers of logs were available. Implications for forest management are that sanitation cuttings (removal of dead and dying trees) would not be permissible where dynamic stream equilibrium exists and bed material movement should be minimized. RM(79).

331. Soil ripping in 1963 effectively reduced runoff on the San 0Luis watershed of the Rio Puerco, New Mexico, and caused a favorable shift in forage production from galleta to alkali sacaton. Ripping effects on runoff are shortlived but forage production patterns may persist for 10 years. RM(50).

332. Preliminary production functions are identified for alternative land treatments in northern Arizona. These treatments are designed to increase water yield within a multiple use framework. Even without price information, a range of "best" input combinations can be identified. Product-product functions were developed for water, timber, and herbage for five strip cutting alternatives. These functions indicate the supplementary, complementary, and competitive outputs obtained from a given expenditure. Outputs and costs were evaluated over a 90-year period to account for the dynamic nature of production. RM(97).

333. Worldwide experience indicates that alder contributes significantly to the supply of nitrogen in the ecosystem0 A definite potential exists for employing alder in forest management in much the same way that legumes are utilized in agriculture. Current research indicates also that *Alnus rubra* may play a significant role in controlling *Poria weirii*, a virulent root pathogen which causes extensive losses of commercial timber tree species in western North America and Japan. PNW(117).

334. Overlapping, vertical aerial photos provide sufficient information for determining extent of snow cover in a small open area of mountainous terrain where accurate ground control is not available. Index measurements can be extrapolated to a much larger drainage. RM(76).

335. Snowmelt floods cannot be reduced by forest management practices in the Northeast. Snowmelt floods are regional in nature so management would have to be applied over very large areas to have any effect. Management of snow to produce more summer streamflow is also not feasible in the Northeast, since snowmelt runoff cannot be prolonged beyond spring. However, removal of conifers from a watershed will increase spring streamflow by up to 2 or 3 inches due to elimination of the interception loss. NE(72).

336. It is desirable to establish herbaceous and woody species in combination to stabilize spoil banks. However, herbaceous vegetation competes with tree species for light, moisture, and nutrients. Herbaceous vegetation planted on coal-mine spoil did not significantly affect the survival of trees but greatly suppressed their growth. By the fifth growing season, tree growth was suppressed by grass alone and was greatest in plots dominated by legumes. Competition from herbaceous vegetation can be lessened by encouraging legumes and avoiding strongly competitive grasses. NE(14).

337. The high wall is the dominant physical feature of most surface mining in mountainous terrain. High walls represent only 15 percent of the horizontal area disturbed and can be reduced by blasting or covering with spoil, but these measures may be necessary only in areas of high esthetic value. However, certain grading practices and placement of trees can reduce the visual impact of high walls by partially screening them from view. NE(101).

338. Black locust is one of the more commonly planted species on surface-mine spoils with a pH of 4.5 or less. Seedlings fertilized with nitrogen and phosphate, and triple-superphosphate in combination with ammonium nitrate are equally effective. Black locust should be fertilized with nitrogen and phosphorus to achieve rapid site protection on acid surface-mine sites. NE(102).

339. Relationships between forest and floods are complex, and often not properly identified. Forests provide the maximum opportunity for controlling runoff from flood-producing rainfalls, but forests cannot prevent floods. The principal source of flood runoff from forests is subsurface flow that moves rapidly d wnslope through the forest floor and topsoil. Forests provide the best possible natural cover for minimizing overland flow, runoff, and erosion. NE(93).

340. Interception loss was measured in loblolly pine stands and in a mature hardwood-pine forest in South Carolina. Annual interception loss from the hardwood-pine stand was similar to that of the pine stands. Where extensive conversions of hardwood to loblolly pine occur, significant reductions in the amount of water available for streamflow or ground water may be expected. SE(113).

341. Soil freezing did not change the infiltration rate sharply on natural oak-hickory forest and abandoned field

plots near LaCrosse, Wisconsin, until late winter. However in a 25year-old conifer plantation, the infiltration rate was reduced to near zero by early winter due to an impermeable snow-ice layer on the ground caused by snowmelt drip. Thus, conifer plantation may contribute more surface runoff than either deciduous forest or fields during snowmelt and winter rain. NC(77).

342. Contour trenches have been used for emergency protection of denuded mountain watersheds. Six years of soil water measurements on and adjacent to a contour-trenched area shows that some redistribution of soil water occurs following trenching. Trenching did not alter soil water conditions enough to significantly change water yields from the watershed. A reduction in water use from trench bottoms was offset by an increased loss from the cut-bank and trench fills. No change in soil water was apparent between trenches. INT(66).

343. Water quality management relates to problems of ultimate social importance. The technology is available to control large-scale changes in sediment, temperature, and chemical and bacteriological quality of water from forest land. In many cases, water quality considerations are also economic in terms of maintaining site quality, minimizing road mileage and maintenance, and reducing treatment cost. PNW(107).

3. Preventing watershed damage

344. Erosion by mass-wasting processes is often underestimated because some processes, such as soil creep and dry creep, are unspectacular and landslides occur infrequently. These forms of erosion make up a large proportion of the total erosion process. Mass movements are especially sensitive to disturbances by man such as during road building, logging, and vegetative manipulation. Terrain features can indicate the likelihood of slope failure. Using these features, the costs of repair can be estimated fairly well in advance. PSW(137).

345. A linear array of detonating cord was used to simulate a sonic boom. The boom was directed toward the fracture zone of a small avalanche path where the snow was unstable, as indicated by natural avalanches in the area. In three of four tests, avalanches were released by a boom of 12 pounds per square foot overpressure after withstanding lesser booms. One of the avalanches had a fracture face 8 feet 11 inches deep. RM(131).

346. Net radiation measured over a black spruce stand and a clearcut strip in a bog showed little difference in daytime values the first summer after logging. The second summer net radiation was lower in the clearcut strip than over the black spruce stand by 14 percent in June and 20 percent in September. While more energy was potentially available for evapotranspiration in the black spruce stand more energy was converted into sensible heat than in the clearcut strip. NC(127).

347. Some of the techniques which have proven most useful in management of wildland resources are multivariate and factor analysis. These techniques can help identify the complex physical, social, and economic variables which make up the management system by characterizing the management process as discrete treatment-response phenomena. PSW(133).

4. Water quality

348. Annual loss of nitrogen, phosphorus, silica, and the cations sodium, potassium, calcium, and magnesium followed the same pattern as annual runoff. Water passing through this Douglas-fir ecosystem conserved nitrogen effectively as indicated by an average annual dissolved nitrogen outflow of 0.5 kg/ha from an annual average input of 1.0 kg/ha in precipitation. Loss of nutrients by soil erosion may become of major importance over a longer time scale due to widely spaced unsampled catastrophic erosion. PNW(142).

349. Insecticides, herbicides, and fertilizers are important chemical tools in intensive management. Aerial application of these chemicals will result in their initial distribution among the air, vegetation, forest floor, and surface water compartments of the forest environment. Evaluation of the toxicity characteristics of forest chemicals indicates carefully controlled forest chemical applications will not significantly impact on stream organisms. PNW(145).

K. Bettering Silvicultural Systems

1. Natural regeneration

350. Basic knowledge on the growth and maturation of fruits and seeds of southern hardwoods is inadequate to support improvements on seed technology and use. Recent studies at the Forest Tree Seed Laboratory in central Mississippi have shown that sweetgum and sycamore fruits reach full size by late June and are physiologically mature by mid-August and early September respectively. Chemical changes in the two species were similar except that the major food reserves were carbohydrates in sycamore and fats in sweetgum. These results expand our knowledge on seed maturity and confirm the value of present seed maturity indices. SO(719).

351. There are several methods available for the determination of seed moisture content, but most have not been calibrated against a standard reference method. A recent study at the Forest Tree Seed Laboratory in Mississippi has shown that oven drying methods give moisture contents within 0.5 to 1.0 percent of the standard toluene distillation method for sycamore, sweetgum, and green ash. An electronic meter was also found to be suitable for sycamore and sweetgum. These results will make determination of seed moisture content simpler and more reliable. SO(720).

352. Information on factors affecting germination of swamp tupelo seeds is needed to develop methods of regenerating this species after a harvest. Tests under controlled conditions in the laboratory revealed that germination was rapid in moist, drained soil at 21 ° C, but did not occur in flooded soil. Thus, seedling establishment requires rapid germination and growth during the brief periods when conditions are favorable. SE(723).

353. Because of very limited timber cutting in the past, little is known about the natural reforestation of Sitka spruce on Afognak Island in Alaska. Observations made in one 25-year cutover area indicate that much of it is dominated by grass and herbaceous vegetation; growth of Sitka spruce seedlings is slow as a result of this competition. If these conditions are typical, special measures will be necessary to ensure adequate regeneration after logging on this unique Alaskan island. PNW(724).

354. Increasing use of shelterwood cutting in forests of coastal Oregon provides seedbeds that contain much more organic material and receive more shade than previously thought desirable for regeneration. Recent studies with seven coastal species show that organic seedbeds in the Sitka spruce—hemlock type, although desirable when exposed to full sunlight, are suitable seedbeds under the partial shade of a shelterwood cutting. The duff provides extra nutrients for the short-rooted seedlings that develop under these low light conditions. PNW(727).

355. If viable seeds of the desired species accumulate in the forest floor, they may ensure an adequate quantity of reproduction when favorable germination conditions are created by harvest cuttings. In a West Virginia study, black cherry seeds stored in the forest floor retained their viability over 3 years. Fewer than 10 percent germinated after the first winter, 50 percent germinated after two winters, and 25 percent germinated after three winters. Forest managers need not rely on current seed crops in scheduling harvests in black cherry. NE(732).

356. Little is known about seed production of paper birch in interior Alaska. A 5-year study near Fairbanks revealed that total seed crops during the period 1958-63 varied between 542 and 72,805 seeds per square meter; viable seed per square meter varied between 42 and 27,520. Seed crops adequate for natural regeneration of 100-foot-wide clearcuts occur in at least 1 out of 4 years in this portion of the taiga. PNW(733).

357. Forest managers in Alaska have available to them new information for managing white spruce. Results of research and experience in western Canada and Alaska were brought together to suggest a number of silvicultural treatments known to provide adequate conditions for natural regeneration. Similar summaries have been prepared for Alaska paper birch, quaking aspen, balsam poplar, and black cottonwood. PNW(683-685).

2. Silvicultural methods

358. Forest managers in the central Rocky Mountains are faced with the problem of modifying established timber harvesting practices to meet the increased use of forests for many purposes. Guidelines are now available to aid the manager in developing alternatives to clearcutting old-growth lodgepole pine forests. Alternative partial cutting practices provide for maintenance of forest cover in recreation areas, travel zones, and scenic view areas; other patterns of cutting give options for increasing water yields, improving wildlife habitat, or integrating timber production with other key uses. RM(734, 735).

359. Foresters have been challenged to harvest wood more efficiently while maintain a forested landscape while seedlings planted on the cleared strips are growing up. Several variations of this harvesting method are suitable for areas where natural scenic beauty must be maintained. NC(736-739).

360. Control of competing herbaceous vegetation is essential for successful planting of hardwoods on upland sites in the mid-South. A preemergence spraying with 2.5 pounds per acre of simazine reduced both herbaceous and grass competition by more than 80 percent in a trial in Louisiana without damage to the hardwood seedlings. This treatment was also effective in weeding pines, and appears to be worth testing in bottomland planting as well. SO(740).

361. A comprehensive review of current knowledge about the effect of clearcutting eastern forests on various ecological factors has revealed that much of the concern about clearcutting is largely unfounded. Clearcuttings do produce a temporary unsightly appearance that make them unsuitable for use in some locations. However, the complex environmental changes that occur after clearcutting favor the establishment of certain tree species; improve habitats for certain types of wildlife; produce a small increase in water yield; and, if properly applied, incur little risk of long-term environmental damage. NE(745).

362. Past harvesting of aspen has not always resulted in satisfactory regeneration because competition from residual trees and shrubs in many areas has inhibited the development of aspen suckers. Consequently the areas of merchantable aspen in the Lake States have been reduced. Competition on some of these areas has been minimized by mechanical harvesting, prescribed burning, felling residual trees, or by applying herbicides. The resulting stocking was much greater than on areas where competition was not reduced. Hence, clearcutting is essential for satisfactory regeneration of aspen. Production of merchantable aspen was increased further by thinning to about 800 trees per acre at 10 to 15 years and to 200-400 trees per acre at 20 years. NC(746, 747).

363. In response to the surge of national interest in forest management, a handbook has been prepared synthesizing present knowledge regarding biologically feasible systems of forest culture for harvesting, renewing, and maintaining 37 major forest types in the Nation. The handbook, entitled "Silvicultural Systems for the Major Forest Types of the United States," recognizes the importance of forests for wildlife, recreation, water, and timber and discusses the various systems of forest culture that can help meet these needs. Some of the systems are most appropriate for application on lands best suited to meet the Nation's need for forest products. 0The book also covers limitations in the use of certain systems imposed by species requirements, natural hazards, and the makeup of existing stands. It should help dispel uncertainties about silvicultural options and their consequences in the major forest types of the United States. WO(748).

3. Ecological relationships

364. A guide to the use of Research Natural Areas (natural scientific preserves) on Federal lands in Oregon and Washington has been compiled which describes the physical and biological features for each of 45 reserved tracts. Maps and photographs are included. Capsule summaries for each area include establishment data; size; administering agency; location; availability of special maps; environmental, biological, historical features; and history of research. The guide will be a key reference for scientists and educators who wish to study the biota and ecological processes of selected natural environments. PNW(751).

365. Recent concern about endangered species of plants has prompted a reevaluation of the principle of competitive exclusion—the theory that two or more competing species cannot coexist indefinitely. In a New Hampshire study of simulated forest stand development, yellow birch steadily replaced paper birch, a phenomena that was confirmed by actual species representation in a virgin stand of northern hardwoods. The real possibility of extinction of paper birch in undisturbed stands illustrates the need for intensive management to assure a future supply of this highly valuable and aesthetically desirable species. NE(752).

366. Fine roots are often neglected in studies of forest biomass because of the difficulty of separating finely divided, widely dispersed roots from soil samples. In a white spruce plantation in Maine, the biomass of roots 3 mm in diameter and smaller represented as much as 20 percent of the total root biomass. This fact must be taken into account by ecologists when estimating total tree biomass or standing crop. NE(755).

367. Knowledge of differences in drought resistance among the oaks is needed to fully understand where the different species should be grown. Recent studies in Missouri show that leaf and root cells of post oak are better able to survive dehydration than those of black, white, or red oak. Red oak

was least successful at surviving dehydration, and it was not able to postpone dehydration as well as the other species. Thus, post oak is the most drought resistant, and red oak the least resistant of the species studied here. NC(756).

368. Environmentalists are concerned about the possible changes in productivity and composition of the earth's forests that could be brought about by the ever-increasing amounts of carbon dioxide, particulates, and gaseous pollutants in the atmosphere. Although the direct effect of a higher carbon dioxide concentration is an increase in vegetative productivity, this increase would be partially offset by reductions in sunlight intensity and air temperature associated with increasing particulates. Drift of particulates could change the amount and distribution of precipitation but the effect of changes in this factor on overall productivity cannot be predicted. In general, any climatic changes that might occur are likely to be deleterious because tree species are adapted to a specific climate. NC(757).

369. Knowledge about structure and functioning of natural ecosystems in the taiga of Alaska is meager. The distribution of selected nutrient elements in portions of 5-, 15-, and 20-year-old alder ecosystems developing on the Tanana River have been studied and described. Changes in nutrient distribution with time between soil and plant materials are essential items of information for understanding the function of an ecosystem. PNW(686).

L. Remote Sensing Methods

370. The linking of remote sensing data for wildland resources with appropriate computer programs will permit data analysis, storage, updating, and rapid retrieval by planners, policy-makers, and managers in many resource fields. Many information systems and automated procedures for land use classification are in early stages of development and should be more fully utilized in research and in practice. PSW(428-431).

371. New methods have been developed for handling the digital calibration data and sensitometric analysis of color films. This will permit computer analysis and improved classification and pattern recognition. PSW(425,427).

372. Spectral signature measurements using multiband camera systems require precise calibration of camera shutters. A technique has been developed for measuring the exposure times of focal plane shutters with special emphasis on aerial cameras. Any user of aerial cameras can now adjust or calibrate the exposure times without removing the camera lens. PSW(426).

373. There is increasing interest in forest and nonforest land classification for using imagery taken from high altitude aircraft and from space. Photographs taken over a 20-month period and covering eight 16-square-mile areas near Atlanta, Georgia, were correctly classified in more than 75 percent of the cases. Use of smaller scale, high-altitude color infrared photography significantly increased area coverage without sacrificing accuracy. Substantial savings in operational costs were also obtained. PSW(423).

374. A low-cost projection-viewer has been developed to enlarge parts of microscale aerial photographs. These can be used for assessment of insect- and disease-caused damage, type mapping, monitoring environmental changes, or other purposes. PSW(424).

M. Weather Modification and Weather Effects

375. Forest Service scientists are cooperating with the BLM and are evaluating their Alaskan lightning abatement program. This work will influence future USDA lightning modification efforts. INT(687).

376. Continued research strongly supports the hypothesis that forest fires are caused by a specific type of discharge. This work provides a sound physical basis for predicting the potential of fire ignition and is a major step in developing a natural risk index for the National Fire-Danger Rating System. INT(691).

377. Lightning fire statistics for southeastern Georgia indicate that while some thunderstorm days produce lightning-strike fires others do not. It was found that thunderstorm days with lightning-strike fires were characterized by higher values of buildup index and spread index than fire-free days. SE(694).

378. Studies of large outdoor propane fires have resulted in a spin off. Halon flame extinguishers can be used to suppress explosion hazards. This suggests a safety action that could be taken when spraying LP gas for fog seeding. PSW(693).

379. New mathematical and statistical techniques have been developed for generating families of probability distributions for analyzing weather patterns and for explaining and predicting wind flows. SE(688,695,696), RM(690).

380. Observations in the meso scale of the Cascade Mountains identified strong gale force winds, instability lines, and squalls that were not identified by routine synoptic analyses. These are important weather influences which effect ignition and spread of forest fires. More attention needs to be placed on meso scale systems for identifying and warning fire control officers. PNW(689).

381. Scientists from the Macon Laboratory report that passage of a cold front and the dynamic action of the high-level jet stream were responsible for most of the large fires that occurred in North Carolina on a major fire day, December 4, 1970. Eight southeastern States had 1167 fires which burned 43,294 acres. SE(697).

382. The effects of weather on seed production of loblolly pine were shown by a study from 1947-1968 on the Hitchiti Experimental Forest. Temperature and evaporation shortly after pollination in May were dominant critical variables. Rainfall in July appeared to be a significant factor. Cool moist weather in March hindered fertilization while warm, dry April weather favored it. SE(692).

II. IMPROVING UTILIZATION AND EXTENDING WOOD SUPPLIES

A. Intensive Culture Methods

1. Site evaluation and soil improvement

383. The reliability of plant analysis as a technique for predicting fertilizer needs of forest crops depends upon careful standardization of sampling procedures to control the many variables that affect nutrient composition. A study of 60-year-old even-aged oaks in West Virginia showed that easy-to-reach foliage from the lower crown is suitable for foliar nutrient composition and dry weight determinations. Application of these findings should reduce the high cost of leaf sampling and promote the effective use of foliar analysis for diagnosing the fertilizer requirements of forest stands. NE(758).

384. To achieve the maximum growth increase at minimum cost from fertilizer applications, it is essential that plant responses to various nutrient combinations be known. A recent study in West Virginia has shown that red oak seedlings will not respond to phosphorus applications unless nitrogen requirements are also satisfied. Likewise, potassium produces a small additional response only in the presence of high levels of both nitrogen and phosphorus. Red oak fertilization on soils similar to those studied here should always include nitrogen and phosphorus but additional potassium is often unnecessary. NE(759).

385. The growth of Ocala sand pine in some of the sandhill plantations in Florida is limited by deficient amounts of available soil phosphorus. A greenhouse test revealed that seedling growth was greatest in soil containing 1.0 to 1.5 ppm of available phosphorus. Phosphate fertilization, therefore, will increase the growth of planted Ocala sand pine only on soils containing less than 1 ppm of available phosphorus. SE(760).

386. Evaluation of fertilizer needs in forest trees requires a background of knowledge on nutrient requirements of the species involved. Several studies in Maine have shown that paper birch seedling growth is much more sensitive to nitrogen supply than to supply of phosphorus or potassium. Foliar nitrogen levels of 3 to 4 percent indicated adequate supplies of this nutrient. NE(761,762).

387. Silty old-field soils on the Mississippi River flood plain are often depleted of nutrients and are marginal for the production of cottonwood fiber. However, growth of a 6-year-old cottonwood plantation was increased by as much as 200 percent with nitrogen fertilization (168 kg/ha) in a recent study. Thus, fertilization should permit utilization of some of these marginal sites. SO(763).

388. Because rhododendrons generally thrive on acid soils, the application of lime may be detrimental to this plant. However, application of as much as 35,866 kg of agricultural limestone per hectare caused no visible reaction in a rosebay rhododendron stand in the southern Appalachians of North Carolina, even though pH in the surface 2.5 cm was increased to as much as 7.1. Thus, liming of soil for other purposes probably will not harm rhododendron, nor does it offer promise as a means of eradicating rhododendron in places where it is not wanted. SE(765).

389. Regeneration and growth of water tupelo and baldcypress in the swamp forests of the southeastern States have not been satisfactory after harvest cutting. In a greenhouse study of potted seedlings, growth was better in saturated soil than in unsaturated soil, but only when water in the unsaturated soil decreased substantially below field capacity between waterings. Growth was increased further by fertilization with solutions of urea. These results can be used in prescribing drainage and fertilizer practices to improve growth of trees planted in these swamps. NC(766, 767).

390. Land managers in the Ozark Highlands of Arkansas and Missouri need techniques to evaluate potential pine growth on sites where there are now no pines for growth measurements. A study of soil and site relationships showed that, in this area, site index for shortleaf pine can be predicted from slope convexity, aspect, elevation, and degree of oak and hickory competition. SO(768,769).

391. Yellow birch trees growing on acid, podzol soils in New England contain very high concentrations of manganese. A recent New Hampshire study shows that these concentrations, which range up to 4500 ppm, are much higher than those required to produce toxicity in seedlings grown in nutrient solutions. Although other elements present in forest-grown birch may alleviate the effects of high manganese to some extent, the possibility of toxicity must be considered in any future research on birch nutrition. NE(771).

392. Black walnut can be expected to survive well and grow rapidly only if planted on suitable soils. A recently published compilation of the soil series occuring in Illinois, with classification of the suitability of each, will assist in selecting the better sites for planting this valuable hardwood. NC(773).

393. Extensive flooding in the Mississippi Valley has raised concern over effects of flooding on forests. After floods deposited 2600 tons of silt on 2.8 acres of a black walnut plantation in north central Missouri, extensive mortality and growth reduction resulted. Damage was closely related to the thickness of the silt deposits and was more harmful after spring than fall deposition. This episode demonstrates the need for erosion control practices and for more careful site selection. NC(774).

394. Site index for young ponderosa pine stands in California cannot be estimated accurately from existing curves. But recent studies have shown that estimates can be improved either by adjusting the existing curves or by estimating site index based on total length of the first four internodes above breast height. These methods materially improve estimates of site index in young stands and improve forecasts of forest productivity. PSW(775,777).

395. Guidelines on when to fertilize black walnut plantings have been inadequate to ensure that maximum growth or nut production will be obtained. Research has now shown that foliage symptoms and foliage nutrient concentrations can serve as quick guides to nutrient status of black walnut. These guides and suggested procedures for using them have recently been published for use by walnut growers. NC(776).

396. Site index curves for California black oak, previously unavailable, have now been developed. The curves have been related to slope aspect and to site index of a close associate—ponderosa pine. For the first time, these curves provide a means of estimating the growth potential of California black oak in even-aged stands on the Sierra Nevada and southern Cascade Ranges. PSW(778).

397. Prediction of site quality would be greatly facilitated if it could be determined from soil types. However, analyses of soil-site plots in the Missouri Ozarks failed to reveal any relationship between soil types and oak site index. Furthermore, site index was not related to the presence or absence of a fragipan. The variability in site quality found here is apparently due to factors not delineated in current soil classifications. NC(779).

398. Information on nutrient cycling is essential for effective soil management. In the Piedmont area of North Carolina, total litterfall was 25 percent greater in a mixed hardwood stand than in a loblolly pine stand with a hardwood understory. Hardwood litter contained about twice as much K, Mg, Mn, and Cu as pine litter. Results indicate that the hardwood understory of the pine was quantitatively important in nutrient cycling. SE(780).

2. Artificial regeneration

399. Previous studies in India have shown that silver fir seedlings do not readily regenerate naturally in deep raw humus unless the roots reach mineral soil and mycorrhizae develop. To avoid these problems associated with natural regeneration, artificial regeneration methods are now being tried. Seedlings with mycorrhizae are first grown at low-elevation nurseries and then planted in the mountains. Although growth rate was not increased, the method of growing planting stock at low elevation in India is still of some benefit since survival was much better. WO(781).

400. Seed dormancy is a problem in both direct seeding and nursery culture of southern pines. Research in Louisiana has shown that in loblolly pine that seedcoat seems to delay germination more by mechanical constraint than by limiting water or gaseous exchange. Stratification acts to increase the capability of the embryo to rupture the seedcoat. This information helps to clarify the basic causes of dormancy, and will be useful in finding ways to improve the germination efficiency of pine seeds. SO(782).

401. Can loblolly pine seed that has been stratified to overcome dormancy be successfully returned to storage if it is not all used? An experiment in Louisiana showed that viability of vigorous seed lots remains high, but they gradually regain their dormancy, whereas lots of lower vigor store poorly and become more dormant than untreated seed. This information will be helpful in deciding on disposal of left-over stratified seed. SO(783).

402. A knowledge of pollen phenology and dispersal pattern is important for seed production management. In a natural stand of shortleaf pine, pollen collected on celluloid tape traps indicated significant differences in density of pollen for years, location, elevation, and trap orientation. Annual variation was extremely large and could be a major factor reducing seed yields in some years. SE(789).

403. Strobilus development in shortleaf pine was studied in detail to determine the cause for low seed set in the Virginia Piedmont. During a 6-year period strobilus survival ranged from 3 to 65 percent with an average of only 29 percent. The major factors causing strobilus mortality were found to be spring frosts, insects, and physiological abortion. These factors must be controlled in seed orchards in this region if high yields of seed are to be produced. SE(790).

404. A quantitative estimate of annual seed efficiency in shortleaf pine cones was needed to evaluate the low seed production of this species. An analysis of mature cones for 6 years indicated that seed losses are of three major types: (1) small first-year aborted ovules, (2) sunken and resin-filled second-year aborted ovules, and (3) unsound (empty) seed. Based on the potential number of seed per cone the seed efficiency was only 14 percent. There is an obvious need to reduce these various forms of ovule abortion if seed production for this species is to be greatly increased. SE(791).

405. When planting pines in the Piedmont—for timber production, Christmas trees, or highway beautification--land managers must choose among the many species available. In a South Carolina study, loblolly pine grew faster than five other species tested, while slash pine grew nearly as well and can probably be substituted for loblolly with little growth loss. Shortleaf pine may also be suitable for timber production but had slightly poorer growth and survival than the other two speices. Virginia, longleaf, and eastern white pine performed so poorly that they would be uneconomical for timber production but should be suitable for other purposes. SE(792).

406. Unmerchantable scrub oaks and wiregrass dominate millions of acres of sandhills in the Southeast. Conversion to pine, however, probably will be profitable. A new USDA Handbook brings together the results of 45 years of research on methods of reducing competition for soil moisture and nutrients that will enable planted pines to survive and grow under the severe stress of the sandhill environment. Practical site preparation methods, both mechanical and chemical, are described. Loblolly pine and slash pine have proven suitable for planting on the more moist sites, but Choctawhatchee sand pine grew better on the drier, more infertile sites. SE(793).

407. Nursery production of the large stock required for successful reforestation of difficult Douglas-fir sites is expensive. A recent study in Washington has shown that 3-year-old seedlings are cheaper to produce than the usual transplants of the same age, even though the seedlings require more bed space. For optimum results, production of 3-year seedlings at a density of 8 to 10 seedlings per square foot is recommended. PNW(795).

408. Cutover jack pine stands on sandy soils (Grayling Sands) in the northern half of lower Michigan have not regenerated satisfactorily. In trials of various site preparation methods, best stocking was obtained on plots that were scarified with an Athens disk 2 weeks after burning and then seeded at the rate of 20,000 jack pine seeds per acre. NC(796).

409. A natural hybrid between West Indian (*Swietenia mohogani*) and Honduras (*S. macrophylla*) mahoganies in the United States Virgin Islands reputedly combines the drought resistance and excellent wood quality of West Indiana mohogany with the faster growth of the Honduras species. Ten years after planting, in a replicated trial on three sites in St. Croix, the hybrid had survived better and grown faster than either parent species. The hybrid mahogany is therefore recommended for plantations of this valuable hardwood species in the Virgin Islands, except on very dry sites. ITF(800).

410. Valuable tropical timber trees from other countries have great potential for supplementing the native flora of Puerto Rico and similar areas. Extensive adaptability trials in the sandy well-drained uplands show that the following introduced species have the most promise: Honduras pine for most landowners; mahoe (*Hibiscus elatus*) for a cabinet wood;

kadam for a general utility wood or for areas with severe weed problems; and eucalpytus or casuarina for post or pole crops. ITF(797).

411. Reliable methods are needed to reforest Allegheny hardwood areas that fail to restock naturally after cutting. Studies of direct seeding of black cherry in northwestern Pennsylvania show that fall sowing of fresh seed (before October 1) and spring sowing of stratified seed are equally effective. Seedbed cultivation is unnecessary, but proper seed handling and covering, control of weeds and grasses, and protection from browsing in areas of high deer populations are critical. NE(803).

412. Less expensive techniques of establishing stands are always desirable, and will be especially important for short-rotation cultural schemes where very dense stands are needed. Recent studies in Georgia with sycamore and in Mississippi with green ash have shown that cuttings will sprout when planted horizontally in furrows, providing a technique of establishing new stands that should be economical because it can easily be mechanized and requires a minimum of plant material. SE(808), SO(805)0.

413. Knowledge of the meteorological conditions that favor the development of loblolly pine seed is needed for predicting seed crop size. In Georgia, seed production was favored by a low mean temperature and a low evaporation rate during the month of May when pollination occurred; and by higher than average rainfall in July when flower primordia were differentiated. Hence seed production in loblolly pine orchards could be increased during drought years by irrigation in May and July. SE(806).

414. Forest landowners are concerned about slow diameter and volume growth in dense even-aged stands resulting from direct seeding. In an 11-year loblolly pine stand in central Louisiana, strip thinnings at 3 years of age were as effective as selective thinnings in increasing diameter growth of the residual trees. Power equipment can be used to do precommercial strip thinning quickly and at low cost. SO(807).

415. Seeds of white ash require exposure to a cold, moist environment for 60 days before they will germinate. This cold period was reduced to 30 days by presoaking the seeds for 12 hours in a solution containing 1 ppm of gibberellic acid. This reduction can speed up seed germination tests which are necessary to determine sowing rates in nursery beds. NC(809).

416. Seed yields of the southern pines are usually calculated in terms of pounds of seed per bushel of cones. The number of seeds per cone can be determined by slicing, but the number of cones per bushel varies greatly both within and between species. A study in Louisiana showed that the average cubic volume actually occupied by the cones in one bushel is relatively constant regardless of cone size. Using these averages—10,068 cubic centimeters per bushel for longleaf, slash, and shortleaf cones, and 18,162 cubic centimeters for loblolly cones--the number of cones per bushel can be estimated quite accurately by measuring the average volume of a few sample cones. SO(810).

417. The feasibility of planting needs to be evaluated as a means of regenerating northern red oak in young natural stands where it is now scarce. Seedlings planted in the Southern Appalachians of North Carolina survived well but their height growth has been unacceptable in spite of annual removal of competition. These results suggest that successful plantings will require much more intensive culture if planted oaks are to outgrow their competitors. SE(811).

418. Although container planting should provide better survival and subsequent growth than conventional methods, the amount of improvement must be determined before the method can be fully evaluated. Containerized Douglas-fir and noble fir planted in the Oregon Cascades averaged 2 1/2 times taller and had significantly higher survival than bare-rooted stock after one year. Widespread field trials underway will provide additional data over the next few years, but the method appears to have great potential. PNW(812).

419. Early attempts to plant and culture cottonwood in the Upper Mississippi Valley have not been very successful. Recent studies show that planting large seedlings to a depth of 24 to 30 inches will result in better survival and growth than use of cuttings or conventional planting of nursery-run seedlings. Site preparation and weed control are also essential. NC(813).

420. The relatively short growing season in northern latitudes causes difficulties in nursery production of seedlings that are large enought to plant when 2 years old. First-year survival of outplanted 2-year-old seedlings of white spruce and jack pine grown in the more favorable environment of an unheated plastic greenhouse was 60 to 100 percent greater than those grown in an outdoor nursery in Michigan. These results indicate the need for testing the effects of a plastic greenhouse enviornment on other northern species. NC(814).

421. Many failures of Engelmann spruce plantations in clearcut openings in the central Rocky Mountains have resulted from careless handling of nursery seedlings as well as from adverse environmental conditions after planting. Guidelines are now available that will provide the forest manager with the techniques needed to successfully plant spruce. Included are the kind of stock to plant, time of planting, transportation and storage, selection of planting spots, site preparation, planting methods, and plantation protection. RM(815,816).

422. The amount of animal depredation of direct-sown seed must be known so that adequate protection can be provided where needed. In a study of spot-seeded yellow-poplar in central Tennessee, it was found that screen-protected seedspots had three times as many seedlings as unprotected seedspots, but a sufficient number of the exposed seed escaped damage to provide fair stocking. Thus, unprotected seed can provide acceptable yellow-poplar stocking if a large number of seedspots are used. SO(818).

423. To improve chances for successful conifer regeneration in the Southwest, a provisional tree seed-zone and cone-crop rating scheme was developed. The forested areas of Arizona and New Mexico are divided into 10 physiographic-climatic regions, each with a number of 50-mile-wide seed collection zones. The system includes a 10-unit scheme for rating cone crop production. Collection zones will be used to define limits for segregating seed collected thus avoiding costly off-site planting errors; the cone-crop rating scheme will assist in planning regeneration cuts. RM(821).

424. A comprehensive summary of technical information on reforestation practices in California has been compiled which includes virtually all of the significant findings related to this subject during the past 60 years. It includes specific and detailed information on cone and seed handling practices, nursery practices, site preparation, planting and seeding. For the resource manager and timber grower in California this is a reference of inestimable value for planning and managing reforestation programs. RM(820).

425. To satisfy the demand for genetically improved seed, efforts are being made to stimulate cone production in seed orchards while trees are young. In a slash pine orchard in northern Florida, 168 kg of N per hectare was applied at 6

years and again at 9 years of age. This fertilization schedule doubled the cone crop at 8 years of age and tripled it at 11 years to an average of 66 cones per tree. SE(823).

426. It is frequently assumed that sufficient mycorrhizae will develop naturally to enhance the survival and growth of pines planted on soils containing the requisite fungi. However, in an experiment in Louisiana seedlings grown in inoculated soil had four times as many bifurcate roots (e.g. visible mycorrhizae) as did those grown in uninoculated soil, and 1/3 more of the inoculated seedlings survived when outplanted. Initial field survival was closely correlated with both the number of bifurcate roots at lifting and nitrogen and phosphorus levels in the plants. The results indicate that mycorrhizal development in the nursery can be increased by growing seedlings at uniform spacing in low-density beds that are fertilized at a moderate rate. SO(824).

427. Comparative performance data are needed to guide the selection of species for planting on various sites on the Cumberland Plateau. In a comparative test in Jefferson County, Alabama, loblolly pine outgrew Virginia pine at all topographic positions, and Virginia pine in turn outgrew yellow-poplar at all positions except in the bottoms. The study suggests that loblolly is the preferred species on most sites, with alternatives for Viginia pine on warm slopes and shallow soils, or yellow-poplar on lower slopes and bottoms. SO(825).

428. Douglas-fir regeneration is often unsatisfactory on hot, dry south-facing slopes in northwestern California. A recent study has shown that shade will improve germination and survival if direct seeding is used, but shading did not affect survival of planted seedlings. Thus, some means of providing partial shade—such as a nurse crop--should be used if these sites are to be direct seeded. PSW(827).

429. Kadam (*Anthocephalus chinesis*), an extermely fast-growing broadleaf species, appears very promising for industrial wood plantations in the tropics. Two simple methods of extracting the seeds have been developed in Puerto Rico, by macerating either dry or wet fruits. The seeds, separated by sieving, are 98 percent pure, and more than 90 percent germinate. ITF(828).

430. Black walnut seed is difficult to store. However, recent seed storage studies in Indiana show that walnut can be stored for at least 2 years in either deep outside pits or in cold rooms, if proper attention is given to seed moisture content. These results will help reduce annual fluctuations in walnut nursery production by reducing dependence on current seed crops. NC(834).

431. The search for nursery techniques that might improve subsequent growth and survival of black walnut seedlings has led to the suggestion that fibrous-rooted seedlings might perform better than normal tap-rooted seedlings. Root pruning was found effective in developing fibrous roots, but field plantings in Illinois and Indiana have not shown the expected advantages of fibrous roots. Instand, stem diameter appears to be a more important indicator of early height growth. NC(835).

3. Stand improvement

432. Response of trees to particular stocking levels often depends upon the condition of the trees or stand prior to thinning. Studies in Oregon show that 30-year-old ponderosa pine plantations containing trees with well-formed and full crowns can be reduced to as few as 140 trees per acre and still produce the same volume as stands containing four times as many trees. But small-crowned trees do not respond if thinned heavily, and stands containing dense understories may also fail to respond to heavy thinning because of competition. Thus, heavy thinnings in ponderosa pine should be limited to stands of large-crowned trees where understory vegetation is sparse. PNW(838).

433. Herbicidal sprays applied in drops large enough to assure effective placement on target species and prevent drift to nearby susceptible plants are usually less effective than when applied in fine mists. Research in Louisiana with radioactively labelled 2,4,5-T showed that the amount of chemical absorbed by the leaves of six hardwood brush species is proportional to the logarithm of the drop volume. This information should allow savings of 1 to 4 gallons of spray per acre with thickened sprays when compared to the old "rule of thumb" of 72 drops per square inch. SO(842).

434. Natural reproduction on moist sites at intermediate elevations in northern Idaho usually is a dense mixture of 4 to 8 coniferous species in which control of species composition has been difficult to attain. Recent observations on experimental plots installed 35 years ago, however, revealed that the best control of species composition was obtained by harvesting the overstory and cleaning out unwanted species before the young stand attained an age of 30 years. With this information, land managers can change the composition of the stand to favor development of species suitable for the planned use of such sites. INT(843).

435. The possibility that epicormic sprouting will degrade butt logs is an important deterrent to thinning in even-aged yellow-poplar stands in the southern Appalachians. In a North Carolina study, there was much individual tree variation in the production of epicormic sprouts, but the incidence was low and could not be correlated with thinning intensity, number of residual trees, age, or site index. Thus, thinnings can be made without incurring serious degrade due to epicormic sprouting. SE(844).

436. Research on tree development after thinning, fertilization, and other silvicultural treatments have shown that growth rate can be increased by release and often enhanced by the addition of nutrients. Using a new X-ray method for the rapid determination of wood density distribution, a study in California in a thinned 46-year-old ponderosa pine seed production stand indicated that unthinned trees decreased in growth rate and had a slight increase in wood density. In contrast, thinned and fertilized trees increased by 33 percent in growth rate and 3 percent in wood density. Although thinning with fertilization did not necessarily contribute to wood uniformity, these commonly applied cultural practices were beneficial by increasing growth. PSW(845).

437. How much should an individual tree be released to benefit from thinning, and for how many years will the effect last? In a 70-year-old white spruce stand in Maine, trees released on three or four sides grew twice as fast in diameter as the controls or those released on only one or two sides, and the effect was still evident 10 years after thinning. These results will help in prescribing silvicultural treatments for the many acres of pole-sized overstocked stands of even-aged spruce in the Northeast. NE(846).

438. Many different techniques have been developed in attempts to control unwanted drift of pesticide sprays from target areas. A recent summary of aerial spray additives for control of herbicide drift has just been published to assist foresters in choosing an appropriate technique. Materials covered include invert emulsions, particulating agents, thickening agents, and foam sprays, of which the latter two show special promise for forest use. PNW(847).

439. Injection with herbicides is a common method of removing undesirable hardwood trees from southern forests, but there is a continuing need for more effective and economical chemicals. Research in Louisiana showed that undiluted 2,4-D amine is effective and economical on many species, and that on those resistant to this chemical alone the addition of picloram or picloram and 2,4,5-T will give satisfactory results. Detailed recommendations have been developed for various species in terms of chemical mixture, dosage, and spacing of injections for best results. SO(849-851).

440. Selection of hardwood crop trees in young stands is often limited because many of these trees have sweep or crook in the lower stem. But a recent study of green ash saplings in Illinois has shown that considerable natural straightening of the stem will occur after release as a result of faster diameter growth on the inside of the crook. Thus sapling stems with a considerable amount of sweep and crook are acceptable as crop trees. NC(852).

441. Firetree, an agressive plant pest in Hawaii, can be controlled by herbicides but the falling limbs and stems of the dead trees reduce the form and quality of planted replacement species. Cutting the damaged trees and removing all but the dominant sprouts on each stump replaced the cull trees with valuable growing stock. Australian toon and tropical ash, because of their strong tendency to produce vigorous sprouts, gave the best response to treatment. Use of this method can maintain the volume and quality yield potential of plantations without costly replanting. PSW(854).

4. Animal damage

442. Although the protective coating generally recommended for Douglas-fir seed in the Pacific Northwest includes no Arasan, many foresters have begun including it in recent years. A reevaluation of the various components of the seed coating substantiates earlier findings that the addition of Arasan reduces germination without providing improved protection from deer mice. Since birds are not serious predators in the Pacific Northwest—as they are in the South where Arasan is used extensively--there appears to be no justification for adding Arasan to Douglas-fir seed coatings. PNW(855).

443. Feeding by various animals, expecially deer and hare, can seriously damage Douglas-fir regeneration. Chemical analysis and fermentation studies of foliage from clones and progenies with known and unknown susceptibility ratings to browsing revealed genotypic differences in tissue digestibility, in effects of essential oils on cellulose fermentation, and in chemical composition. Some of these resistance characteristics are transmittable through breeding. Breeding for resistance to browsing is of special importance now because of present objections to the use of synthetic chemicals and the high cost of mechanical protection. PNW(857).

444. Chlorogenic acid—a phenolic compound that may affect seed production and susceptibility to animal damage--has been isolated for the first time in the foliage of a north-temperate conifer, Douglas-fir. Concentrations of the compound varied among genotypes, suggesting the chlorogenic acid content may be a useful variable in tree breeding programs. PNW(858).

5. Growth requirements

445. Reasons for the distinct type lines which often occur between lodgepole and ponderosa pine stands in south-central Oregon are not clearly understood. Soil water levels close to saturation favored germination of lodgepole over ponderosa pine but had no differential effect on survival and growth of the two species during the early seedling stage. Exclusive occupancy of "wet sites" by lodgepole is thus not the result of differential species tolerance to mineral soils with high water contents as earlier suspected, unless such tolerance in ponderosa pine changes with age. PNW(862).

446. Early growth response to temperature differentials and soil fertility levels is not known for lodgepole and ponderosa pine in south-central Oregon. Fertilization at four levels increased growth of both species under nine different temperature regimes studied. Lodgepole pine growth was not as sensitive to night temperature changes of 8° to 16° C as was ponderosa pine growth. The number of daily degree hours necessary for maximum growth increased with increasing soil fertility level for night temperatures of 16° C. These findings demonstrate the importance of the fertility of the rooting medium when studying temperature effects on seedling growth of these two species. PNW(861).

447. It would be useful if selected cells which make up wood could be controlled or at least modified as wood is developed. Studies to determine if this is feasible are now under way by Israeli scientists supported by the United States PL-480 program. They are attempting to determine how selected cells originate and differentiate into wood. For example, they recently found in tree-of-heaven that the differentiation of the vascular rays is not controlled by the cambium but by associated tissues producing or consuming selected stimulating substances. Thus it may be possible to control the vascular ray development and perhaps other cells by externally controlling hormone production. WO(863,872).

448. Several species of the widely occurring fungus genus *Hebeloma* are thought to be ectomycorrhiza-formers. Recent joint studies between the Forest Service and the Claude Bernard University in France demonstrated that 16 different European species of the genus *Hebeloma* were able to form a mycorrhizal relationship with Virginia pine of the United States, while five species could not. These results suggest that marked physiological differences do exist between the different fungal species and that this type of data can be used to further the taxonomic characterization of this fungus genus. NE(865).

449. Mycorrhizae are symbiotic associations in which the smallest secondary roots of higher plants are invaded by specific fungi, and the roots retain their vital characteristics without pathological symptoms. Mycorrhizal fungi improve uptake of nutrients for host plants, protect roots against pathogens and move carbohydrates from one plant to another. Forest trees could not survive in their natural soil habitat without mycorrhizae. The little-known role of mycorrhizae in life cycles of the associated fungi and their hosts have now been summarized with data from the world's literature. NE(864).

450. Mature woody stems are hard and often dry or resinous and contain few living cells per unit volume. Enzyme studies of such material is difficult if not impossible. A new enzyme extraction method of woody plant material involving the homogenization of milled lyophilized tissue has been developed which is both reproducible and physiologically sound. The method has wide application in both biochemical and physiological investigations of tree tissues. NC(867).

451. Our understanding of the regulation of indoleacetic acid (IAA, a growth-regulating hormone) levels in plants is hindered by lack of knowledge on the location at which IAA oxidase activity occurs. An experiment in New Hampshire reveals that IAA oxidase and peroxidase activity occur

together, indicating that both are functions of a single enzyme. NE(869).

452. Habitat classifications and descriptions are needed in the mixed conifer zone of the Southwest to delineate where various tree species are apt to grow best. Dry-season moisture stresses in wild Arizona mixed conifer seedlings less than 15 cm tall were higher than those for larger seedlings. Night time recovery was complete. Stresses did not increase through the dry season and their day-to-day variability seemed a function of day-to-day weather differences. Species differences were small but significant. Although inconclusive for classifying regeneration habitats in Southwestern mixed conifers, these findings support the avoidance of small planting stock and the selection of those species with lowest stem moistures stress that are otherwise adapted to the planting site. RM(871).

453. Many landowners who grow black walnut for nut production are overlooking the timber values that could be obtained from these same trees. Research in Illinois shows that by planting more trees per acre, pruning side branches until a 9-foot log is produced and thinning at appropriate times, landowners can produce high-value walnut logs and still obtain good nut yields. NC(873).

454. One promising lead for genetic improvement of cottonwood is to select trees that retain their leaves longer than average. Annual growth on such trees is prolonged over a longer portion of the frost-free season. These late season increments are of high quality because they consist of wood fibers with very few or no conducting vessels. Thus leaf retention provides one index of selection for wood quality in cottonwood. NC(875).

455. Leaf surface area is a very good measure of photosynthetic productivity which determines wood yield, but leaf area measurements are difficult and time consuming. On two clones of hybrid poplars, leaf length proved to be a simple, nondestructive substitute for leaf area measurements. Hence the relative ability of various poplar clones to produce wood can be estimated by measuring their aggregate leaf lengths. NC(876).

456. Young developing leaves of many broadleaved species are both importers and exporters of the plant foods formed by photosynthesis, but the pathways for such bidirectional transport are not known. Experiments on young leaves using radioactive carbon dioxide revealed that plant food is photosynthesized in the mature tips and exported to other parts of the plant with a simultaneous import from other leaves to the immature basal region of the leaf. Transport from the mature tip directly to the base does not occur. This result is a significant contribution to our knowledge of how plant foods are translocated in trees. NC(877).

457. The process of water and nutrient movement in the xylem occurs within a preformed but complex structural system. Using radioisotopes to interpretate the translocation of nutrients, recent studies in Wisconsin with cottonwood seedlings have further demonstrated that mature leaves do not import assimilates from other leaves under normal conditions but developing leaves always will. But under special conditions where the mature leaf is above an isotope-fed leaf it will import assimilates and this movement represents a cross-transfer from phloem to xylem at a node. These results demonstrate the importance of knowing the position as well as the structural and the functional relationships of the vascular system if we are to understand nutrient movement in trees. NC(874).

458. The growth of slash pine appears to be limited by shortage of available phosphorus on a number of sites in the South. A study in Louisiana revealed that 1 year-old slash pine seedlings in a growth chamber accumulated more radioactive phosphorus in their needles at a 15-20° C day-night temperature and 2500 foot-candles than at higher temperatures and reduced light. This information will be helpful in selecting the proper season for fertilizer application. SO(878).

459. The presence of mycorrhizae on tree root systems is generally considered beneficial. Investigations by Indian scientists have recently shown that mycorrhizal inocula from hardwood litter were able to form mycorrhizae in conifers and vice versa. But beneficial effects in terms of faster growth occurred only when seedlings received the mycorrhizae from their own type of litter. These results further support the proposal that benefits accrue from mycorrhizae to higher plants only with specific fungi. NE(882).

460. Overwinter depletion of food reserves in tree seedlings may trigger mortality or limit rapid development when growth resumes. Studies in Colorado revealed that lipid, protein, and hemicellulose concentrations in Engelmann spruce seedlings varied little during the period December to June; in contrast carbohydrate concentrations were lower in June, but the differences were no greater than the variability during the winter. These trends disprove the hypothesis that food reserve depletion is a major cause of overwinter mortality of spruce in Colorado plantations, and support the search for other principal causes. RM(883).

461. In view of the potential use of ionizing radiation for producing mutations, we need to know when trees are most sensitive. Two-year-old jack pine seedlings were most sensitive to gamma rays at a dosage of 900R when the exposure was made in July at the time of shoot primordia differentiation. Hence radiation applied during this period could result in the maximum number of mutations from which promising ones might be selected. NC(884).

462. *Pinus merkusii*, a tropical Asian pine which is considered to be a potential plantation species for tropical and subtropical areas, apparently is not suitable for Puerto Rico. Two years after outplanting seedlings of both the insular and continental ecotypes of this species on two sites on the island, the plants were healthy but had made less than one-fourth as much height growth as seedlings of *Pinus caribaea* var. *hondurensis*. ITF(886).

6. Growth and yield

463. Preliminary tables and yield equations indicate that growth of thinned even-aged yellow-poplar stands in the mountains of Virginia, North Carolina, and Geogia may vary from 80 to 280 cubic feet per acre per year depending on site index and residual basal area. The yield tables permit managers to evaluate yields of alternative thinning schedules on sites of varying producitivity in stands of varying ages maintained at different stand densities. SE(889).

464. Wood processors and users of Black Hills ponderosa pine have questioned whether fast-grown wood is apt to have the same technical properties as a slow-grown wood. Stemwood analyses from trees in typical thinned and unthinned second growth stands revealed no differences in average specific gravity, percent late wood, or percent extractives between thinned and unthinned trees; wood at all heights from thinned trees had significantly larger rings and shorter fibers. Height had a significant influence on all variables examined, except ring width in unthinned trees and percent extractives in both the thinned and unthinned trees. Results sug-

gest that manipulation of stocking through thinning to hasten growth of Black Hills ponderosa pine is unlikely to cause major changes in wood properties. RM(891).

465. Intensive culture in northwest Douglas-fir forests is still in its early stages because of the remaining volumes of old-growth timber. An analysis of European data shows that potential yields of Douglas-fir from intensively managed plantations in Europe considerably exceed even gross yields (net yield plus all mortality) of natural stands of the same site index in the U.S. These data aid in predicting responses from future intensive management in the Douglas-fir region. PNW(892).

466. In an experiment in Arkansas, restraint from normal wind sway of 19- to 22-year-old loblolly pines resulted in lessened bole taper, ring width, wood density, compression wood incidence, latewood tracheid diameter, and number of earlywood and latewood tracheids within immobilized portions of the boles. These results help to explain the influence of wind on the growth of trees, and indicate that shortened rotations obtained through heavy thinning may lead to increased reaction wood. SO(893).

467. Although normal yield tables have been in use in this country since about 1900, we still lack tables that allow prediction of stand development as a function of time, site, and cultural treatment. A recently published article points out the need for yield tables for intensively managed stands, and summarizes the current state of the art in yield table construction. The article provides a stepping off point for further yield table work. PNW(894).

468. Ever-increasing demands for more wood as well as nontimber commodities require more intensified timber management practices for the upland oak forests of the East. Growth and yield predictions have been developed for thinned upland oak stands by age, basal area, and site class, all in increments of 10 units from age 20 to 110 years, from 20 to 130 square feet of basal area, and from site index 55 to 85. Application of the recommended thinning practices can increase volume yields from one-fourth to one-third over those obtained from unmanaged stands. NE(897).

469. Slash pine has been extensively planted west of the Mississippi River, where it is not native, but information on its growth and yield in this region is limited. Early results from two long-term thinning experiments in southwest Louisiana indicate that in terms of total volume growth there is little to be gained by thinning on good sites up to 27 years of age. Landowners who are interested in maximum return on short rotations, as for pulpwood, therefore probably do not need to incur the costs associated with thinning. SO(898,902).

470. Much of the potential timber yield in stands of western white pine has been lost because of overstocking. The best response to various degrees of commercial thinning in an 80-year-old stand was obtained by removing about 35 percent of the volume to release the crowns of the best dominant and codominant trees. Results show that this type of thinning can provide an early monetary return from the stand and still maintain volume growth near its maximum rate. INT(899).

471. The ability of unsightly coal mine spoils in Kansas to support rapid tree growth are largely unknown. Remeasurements of plantations established 22 years ago show that some species have made good growth—averaging as much as 35 feet in height and 8.5 inches in diameter in loblolly pine. Other promising species include shortleaf pine, Virginia pine, burr oak, and sycamore. These results show that many spoils in Kansas are sutiable sites for timber production. NC(900).

472. Data on optimum stocking levels for timber production are needed to provide guides for stand density control in ponderosa and Jeffrey pine pole stands. Results of a recent study on site index 65 to 80 land in northeastern California show that thinning to about 80 square feet of basal area per acre will bring such stands to merchantable size as rapidly as possible with negligible loss of total cubic-foot volume production. PSW(904).

473. There is relatively little data on the growth and development of managed stands over long periods of time. Results of repeated thinnings over a 21-year period have recently been summarized to provide this type of information for Douglas-fir in Washington. The thinnings have resulted in improved growth of residual trees with little change in total usable yield, and show that an earlier harvest is the primary benefit of such thinnings. PNW(905).

474. Before short-rotation coppice management for sycamore can be applied on a large scale, the effects of spacing and rotation age need to be determined. In a Georgia study, it was found that the percentage of leaves in the whole tree harvest increased with wider spacing, but decreased with age, while the proportions of branches increased with both wider spacing and increased age. Of the combinations tested, plantings made at 1 by 4 feet and allowed to grow for 4 years produced the largest annual yield (8.9 tons per acre fresh weight annually) with the smallest proportion of that yield in leaves and branches. SE(907).

475. Some foresters have been reluctant to use disking for reducing competition in young stands of pine because of the destruction of roots near the soil surface. In a 12-year-old slash pine plantation on moderately deep sandy soil in northern Florida, disking 2 to 4 times annually reduced the root surface area in the upper 15 cm of soil, doubled the root surface at depths of 30 to 45 cm but did not affect either total root surface area or bolewood production. These comparisons were made with trees in a nondisked part of the area that was cover cropped during the first 5 years but had no competing vegetation afterward. These results indicate that disking can be used to reduce competition in slash pine plantations on similar soils without risk of reducing the root surface area. SE(908).

7. Forest measurements

476. Site indices are often needed on sites where the trees are too young or otherwise unsuitable for direct measurement of the site index. For red pine stands in Minnesota, reliable prediction of height at 50 years of age were made from measurements on young trees of the 5-year height growth in the internodes beginning at 8 feet above the ground. Phosphorus content of the soil also affects site index. Of four methods frequently used for determining phosphorus in agricultural soils, the one involving extraction with dilute (0.01N) hydrochloric acid of the upper 25 cm of mineral soil provided the best estimate of site index for red pine. NC(909,910).

477. Yield tables are available for estimating the volume of pulpwood and saw logs in slash pine plantations, but estimated yields for additional products are needed. Taper curves were constructed for slash pine from which the volume of veneer bolts in a plantation can be estimated. This extension of multiple-product yields is valuable for both buyer and seller when timber sales are made. SE(912).

478. Site quality of newly abandoned fields planted with slash pine under the Soil Conservation Reserve program (soil bank) is better than that on old-field plantations. A new yield table was made that provides a more accurate yield estimate

for 10- to 15-year-old trees on soil bank sites than is provided by yield tables for old-field plantations. Site index curves, however, show that the initial superiority of newly abandoned fields is lost about 20 to 25 years after planting. Hence yield tables for old-field stands are reliable on these sites after 20 years. SE(911).

479. More complete tree utilization, made necessary by critical timber supplies, is creating frequent need for estimates of merchantable stem volume calculated to various merchantable top diameters. Research has shown that transformations can be made to the Behre equation of tree form, making it possible to estimate stem volume to any merchantable limit as a percentage of basal diameter or as a fixed top diameter. The transformations also make it possible to derive taper equations from data gathered on volume to variable top diameters. PSW(913).

480. Land managers in Montana, Idaho, and Utah need growth and yield data on Rocky Mountain lodgepole pine so that they can predict its response to various degrees of thinning. To satisfy this need, an equation was developed for predicting future diameter growth of this variety. Curves plotted from this equation proved to be valid in both managed and unmanaged stands for a time span of one decade. INT(109).

481. An understanding of the theory, development, and application of stocking equations is very useful to land management specialists in making decisions when timber is a part of the resource mix. A concise guide presenting this perspective has been published using newly synthesized equations for determining stocking from point sampling inventories in cutover and virgin ponderosa pine stands in Arizona to illustrate methodology. Stocking equations can be used to help evaluate land treatment potentials, to determine treatment feasibility on a single management unit, and as a basis for setting operating priorities on a number of management units. RM(915).

482. Foresters are increasingly faced with a changeover to metric units—a task that can be extremely complicated in the case of forest inventory systems. Recent modification of STX--a large computerized forest inventory system--allows it to process either U.S. or metric input and to convert from one to the other before final output. This revised system permits immediate use of metric units while retaining the existing capability of handling U.S. units of measure. SE(916).

483. Ring counts of decayed wood are difficult because the wood crumbles away, yet decayed sections of stemwood need to be counted to determine tree age. Accurate ring counts and radial growth measurements on decayed transverse wood sections are possible when rotted wood is frozen. This technique was developed and successfully used during stem analysis studies of old-growth mixed conifers in the Oregon-Washington Cascade Range and has universal utility. PNW(918,919).

484. Presale cruises of standing trees to estimate net volume and value can be quite inaccurate in stands of defective timber. Study in western Oregon of cruising by falling, bucking, and scaling sample trees shows that the magnitude of errors resulting from standing tree measurements is high and that fall, buck, and scale cruising is particularly appropriate for sales containing high-value, defective trees. PSW(920).

485. Volume, taper, and related tables are essential tools that forest managers use in estimating standing timber. Improved tables have been developed for ponderosa pine in Arizona and New Mexico. Volumes are in total cubic feet and cubic feet to a variable top. Tree heights are in feet and numbers of logs. Standards for basic mensurational values meet the needs of both the national Forest Survey and regional forest managers. RM(921).

486. Foresters frequently need quick accurate estimates of stand volumes. Improved tables and point-sampling factors are now available for rapid reliable determination of volumes for Engelmann spruce stands in Colorado and southern Wyoming. Volumes are in total cubic feet, cubic feet to a 4.0-inch top, and board feet (Scribner and International 1/4-inch Rules) to 6-inch and 8-inch tops. Tree heights are in feet and numbers of logs. RM(923).

487. Tree crown width is a commonly used statistic in forest measurement work, and growth and yield studies often require the measurement of thousands of tree crowns at a considerable expenditure of time. Field conditions in the Rocky Mountains prompted development of a small, lightweight mirror instrument of simple design to assist in rapidly and accurately measuring tree crowns. The instrument, which has a large field of view, can be handled easily and leveled horizontally by a user standing in any direction with respect to the tree. It is also rugged enought to survive jostling in a pack or vehicle without damage, since it has no moving parts or delicate mechanism. RM(924).

8. Management planning

488. Organizations faced with the decision of how to best obtain computer services have a bewildering array of alternatives from which to choose. Some helpful guidance for this decision is now available in a recently published article that summarized information on the alternative systems available and discussed the merits of in-house versus outside processing, various methods of access, and the limitations and possible improvement in teleprocessing. SE(928).

489. A comprehensive procedure for computation of yield tables for dwarf mistletoe-infested, even-aged ponderosa pine in Arizona and New Mexico has been developed to help forest managers predict yields and evaluate and make necessary comparisons of alternative management decisions for these stands. RM(929).

9. Maple syrup production

490. Sugarbush operators are interested in the relationship between sap-sugar yields and characteristics of sugar maple trees. In general, individual tree characteristics that express live crown ratio were highly related to sap volume yield and total sugar production. There was little evidence of a relationship between tree characteristics and sap-sugar concentration. NE(934).

491. The lack of an easy method of estimating relative sap volume produced between trees has long stymied efforts to make phenotypic selections of sugar maples for superior sap volume production. From a study in Vermont, a high correlation between sap-flow rate and total sap volume produced during the sugaring season was found among trees that were both single- and multi-tapped. Measurements of sap-flow rates over a short period of time in conjunction with other parameters provide a reliable measure for making plus-tree selections for super sap volumes. NE(935).

492. In northern Vermont, vacuum pumping for sap collection during the fall is not advisable even though profitable sap collection by gravity from fall tapping of sugar maple trees has been reported in certain localities. The volume yields were only 2/3 as much as in the spring. It is recommended that if favorable conditions are observed in a locale, vacuum pumping in the fall should be tried on a small scale before attempting a large operation. NE(939).

493. With the renewed interest in plastic tubing for collecting maple sap for processing into maple syrup, a how-to-do-it guide for constructing and installing the plastic tubing system has been prepared. Both aerial and ground lines are described, with details on hanging lateral lines, laying ground lines, tapping trees, and connecting spouts, droplines, and conduit lines. NE(940).

494. Bigleaf maple in California, Oregon, and Washington produces a sweet sap similar to that of eastern species of maple, but little is known about its potential for the production of syrup. In experiments in Oregon, the volumes and sugar percentages of sap from bigleaf maple were somewhat less than from sugar maple sap in the East. Color and flavor of the syrup produced were about equal to the lower grades of sugar maple syrup. Production of syrup from bigleaf maple is feasible and with the application of improved extraction, collection, and processing methods, commercial production may be possible. PNW(938).

495. The size of tubing needed for maple sap collection in a sugarbush is an important decision because of cost and its effect on sap yield. From studies in Vermont the most important factors affecting maple sap flow in plastic tubing are tubing diameter and slope percent. Estimates are given to help determine the most efficient tubing installation for a specific sugarbush situation. NE(941).

496. In general, fall tapping without vacuum of sugar maple trees for sap collection is not recommended. The sugar content of the fall collected sap is about 2/3 of the sugar content found in the spring and sap volume yields are very low, only 15 percent of the spring volume. However, it is suggested that fall sugar readings can be used to determine a tree's relative sweetness and thus serve as a guide for tree selection for sugarbush thinning. NE(942).

10. Naval stores

497. Very little is known about the factors affecting resin duct formation in pines and the mechanism of resin secretion. Studies on Aleppo pine in Israel showed that resin ducts are formed about 3 1/2 months after cambial activity is resumed and their number is determined by the temperature at the time the cambium becomes active. A resin droplet being forced through a cell wall was photographed in a resin duct fragment kept alive in an isotomic solution of mannitol. This research has advanced basic knowledge of the biology of pines. WO(946,947).

B. Breeding Improved Trees

1. Distribution and classification of forest trees

498. Data on the distribution of various trees species is usually presented in rather general terms. More specific information has recently been published for 86 forest and woodland tree taxa native to California. Maps are accompanied by descriptive notes that relate the distribution of each species to its ecological and taxonomic position. This publication provides basic information needed by foresters, ecologists, and others who work with the tree and woodland communities of California. PSW(948).

499. The true firs, one of the largest groups of coniferous forest trees in the world, are widely distributed over the Northern Hemisphere especially in the high altitudes and boreal regions. Because of their great morphological variability, the taxonomy of true firs has long been in a state of confusion. To clarify the botanical relationships among the world firs, a comprehensive investigation was conducted by members of the staff of the National Taiwan University in cooperation with the U.S. Forest Service. A fully illustrated monograph was prepared which provides detailed descriptions, keys, lists, indexes of common names, notes on habitat, and a general bibliography for 39 species, 23 varieties, and 8 hybrids, with special chapters devoted to the fossil history of the group and the geographical and altitudinal distribution. Tree scientists in the United States as well as those the world over will find this book of immediate use in the identification of the true firs, in genetic studies, and in selecting the proper species to be planted. WO(950).

500. There are six species of white pines native to western North America and Central America. These include the commercially important species of sugar pine, western white pine, Mexican white pine, and southwestern white pine. The two remaining white pine species, whitebark pine and limber pine, are not of commercial importance but have a high esthetic value. The distribution, variation, and site requirements for these six species are now summarized and evaluated for those interested in these species. INT(951).

2. Inherent variation

501. Black walnut shows great genetic diversity across its wide natural range and it is sometimes difficult to decide which seed source one should plant. Recent studies in Illinois have indicated that southern seed sources flush earlier in the spring and drop their leaves later in the fall than northern sources. In addition, southern sources also grew faster than northern sources. These early results suggest that where spring frosts are not a serious problem southern walnut seed sources should be planted. NC(953).

502. Late spring frosts will damage the tender new growth of black walnut trees and the earliest trees to break dormancy are vulnerable for the longest period. In an effort to avoid or to lessen the problems associated with frosts, the pattern of leaf flushing for walnut from various midwest geographic locations was determined. Southern seed sources were found to flush earlier than northern sources and trees that flushed early one year also flushed early the next year. In selecting the proper walnut seed source early flushing trees should be avoided in an area with a history of late spring frosts. NC(954).

503. The long generation interval in forest trees is often a hinderance to early selection and breeding programs. Thus, early flowering is a highly desirable trait but early flowering should not reduce vegetative growth. In a recent study 6-year-old Virginia pines produced sufficient numbers of both male and female strobili to allow early selections and rapid genetic gain, and the reproductive growth did not reduce height growth. SE(955).

504. Because trees with rapid juvenile height growth pass through the vulnerable seedling stage more quickly, nursery and outplanting practices which increase seedling growth are being developed but these methods are expensive. Genetic improvement of juvenile growth has been suggested as a possible alternative. A recent study with 54 Douglas-fir families planted at two sites in Washington showed that potential for genetic improvement in rapid early seedling height growth is good with an average genetic gain in seedling height growth of approximately 12 percent. PNW(956).

505. Polyembryony, more than one embryo per seed, is a rare occurrence particularly in angiosperms. Recently this unusual phenomenon has been found in sugar maple and two sets of twin seedlings were grown successfully for more than

3 years. This is the only known case of sugar maple twins actually developing into normal seedlings. Later studies will determine their genetic make up. NE(957).

506. The use of oleoresin analyses in identifying pine species and hybrids is now a well established method in many phases of genetics and tree improvement, especially those dealing with the development of pest-resistance for certain tree species. There are, however, limits to the usefulness of this technique. For example, recent oleoresin analyses throughout the range of loblolly and shortleaf pines demonstrate insignificant qualitative differences between comparable samples and no differences between samples in or out of southern pine bark beetle epidemic areas. There was, however, a decreasing percentage of the dominant terpene, a-pinene, in samples from east to west and from south to north throughout their natural range. SO(959).

507. The ability of a coniferous seedling to develop into a vigorously growing tree depends largely upon the size and rate of activity of its shoot apical meristem. By means of both anatomical and mathematical techniques the apical dome volume was found to increase 10-fold while meristematic volume growth rate declined from 20% to 12.5% per day in 20-days-old to 140-days-old spruce seedlings. Further analysis of this basic type of growth information will yield a better understanding of the problems and processes associated with the differences between slowly growing trees and genetically superior trees. NE(963, 964).

508. Wavy grain pattern is a desirable feature in selected high-quality hardwoods. It may be possible in the future to encourage the wavy grain development with a better understanding on how such patterns originated. Recent studies in Poland supported by the PL-480 program have now established how cell divisions in the cambium are preferentially oriented to the right or left and how they form a wave pattern. This is an important first step in establishing how the wavy patterns are initially developed. WO(965).

509. In order to obtain better yield estimates of genetically superior seed from young Jack pine seed orchards, cone production, cone characteristics, and seed yield per cone from different seed sources planted in Northern Wisconsin were studied. For seven of the seed sources nearly all cone characteristics and seed yields were similar, with two of the more western seed sources having the smallest seed. There was, however, considerable variation among trees within a given seed source. These results suggest that as much consideration and importance must be placed on variation between trees of the same source as has been previously placed on trees of different seed sources. NC(966).

510. A common problem in forest tree improvement research is the extrapolation of data from young progeny or provenance test plantations to predict tree performance at final rotation age. In a loblolly pine progeny test plantation measured at ages 3, 4, and 15 years, genetic correlations showed that little change in genetic control of height takes place after the 5th year, and that resistance to fusiform rust at age 15 differs little from that at ages 3 or 5. These high genetic correlations provide good evidence that families can be selected at early ages for breeding purposes. SE(968).

511. It is commonly assumed that improved trees from forest genetics programs can be evaluated only after many years. But a test of eastern cottonwood clones in Mississippi has shown that correlations between measurements made in the first three years and in the sixth year were high, suggesting that culling of clones after two growing seasons is a feasible way to reduce the time and cost of cottonwood improvement programs. The study also provides estimates of heritabilities and indicates that large increases in volume production can be obtained by selection for either height or diameter. SO(969).

512. Differences in the growth of forest trees of different seed sources are caused by unequal sensitivity to external factors, such as temperature and light. Recent studies in Poland have shown that trees of different origin also differ in their sensitivity to X-rays. Seedlings of high-elevation Scots pine of Polish origin grown from X-ray-irradiated seed were more radioresistant and recovered better from radiation effects than seedlings from low land. Low dose X-irradiation of seed was found also to stimulate dry matter production of and increased size as well as number of needles on Scots pine seedlings. WO(970,979).

513. A recent genetics study of several 53-year-old plantations of selected Douglas-fir in western Washington and northwestern Oregon indicate that genetic control of apical growth is strong in certain environments and that this control changes during a tree's lifetime. Genetic control is the strongest in the juvenile and early reproductive years but may decline under some conditions of environmental pressures. These results, support the feasibility of genetic selection for early rapid growth in Douglas-fir. PNW(971).

514. White spruce, one of the most widely distributed conifers in North America, has a considerable growth potential and is now used widely to produce a high-grade pulp for the production of quality paper. To assist the forest geneticists and tree breeders in planning future white spruce improvement programs, a review of its genetics now has been prepared. In this review white spruce evolution, migration history, distribution, phenology, heritability, and breeding behavior are summarized. NC(972).

515. Selected trees must be progeny tested but the tests are expensive and require many years to complete if decisions are delayed until the progenies are at or near rotation age. Data from 15-year-old progenies of 27 selected slash pine trees not only revealed differences among the progenies at 15 years but also showed that third-year data on height, survival, and rust infection could be used to accurately predict volume per acre at age 8 or at age 15. Data on these three traits could be used to choose among families much earlier than at rotation age. SE(974).

516. Basic information on variation of wood properties and other traits of yellow-poplar is needed. Analysis of wood samples from 500 yellow-poplar trees in the Southern Appalachians revealed that specific gravity in the species decreased with increasing site index, increasing elevation, and more northerly latitudes. Only part of the variation in specific gravity could be attributed to enviromental factors. This reliable description of the population is useful in designing future tree improvement programs for yellow-poplar in the Southern Appalachians. SE(975).

517. Spanish cedar (*Cedrela* spp.) produces a valuable tropical wood but is difficult to regenerate. The genus has a wide distribution in the Western Hemisphere which appears to be associated with considerable natural variation. A provenance trial in Puerto Rico and St. Croix has already revealed difference in survival, growth, and susceptibility to shoot borer attack in the nursery, with best and poorest overall performance by sources from Guanacaste, Costa Rica, and Misiones, Argentina, respectively. The results of field trials with these seedlings will help to identify superior provenances for use in Puerto Rico and similar areas in the American tropics. ITF(976).

518. Monoterpene compounds in the oleoresin of conifers are useful in defining genetic differentiation of populations of many tree species. None of the 9 measured monoterpenes differed significantly among geographic seed sources of red spruce in 14 populations growing in Quebec, Canada. Although the monoterpenes were not suitable for determining hybridization between red and black spruce, they may still be of value in studying hybridization of other spruce species. NE(977).

519. Trees of the same species but from different geographic areas often differ in both growth characteristics and selected wood properties. This general observation has been further supported by a recent Forest Service funded study at the University of Texas where sweetgum seedlings of different origins were grown under a series of controlled temperature and light conditions. Greater fiber tracheid length and lower specific gravity was correlated with a decrease in latitude of seed origin, while cell length varied more with environmental conditions of short day-length and cooler temperatures than seed origin. When cell length and wood density are important in sweetgum utilization both the origin and the environmental conditions under which the trees are growing should be considered. WO(978).

3. Insect-disease resistance

520. Western white pine is among the most valuable conifers native to western United States. However, because the blister rust disease limits its growth and survival, western white pine management is uneconomical over many parts of its native range. More than 20 years have been devoted to studying the inheritance of white pine blister rust disease resistance and now this information as well as features of the paleobotany, flowering, seed yield, and inbreeding of this species, have been summarized. This summary is of value to those who are interested in improving and selecting disease resistant western white pine for future planting. INT(982).

521. Blister rust disease is a major limiting factor in the successful growing of white pines in many parts of the world. Among the more than 20 species of white pines, there are possible differences in their resistance to blister rust. A re-examination of the world's literature on blister rust resistance and on field observations provided information for a tentative ranking among 14 of the different white pine species as to their disease resistance. This new ranking along with consolidated and updated information on botanical ranges as well as crossability of the white pines can be used in planning future white pine blister rust resistance breeding. INT(981).

522. Brown-spot needle blight is a major deterrent to natural regeneration of longleaf pine in the South. Recent research in Alabama shows that about 10 percent of wild seedlings remain nearly free of the disease, and most of these have superior juvenile growth. Natural regeneration following a good longleaf pine seed year often provides seedlings in such numbers that the disease-resistant fraction alone will provide a full stand. However, the land manager must recognize and exploit their existence, especially by modifying prescribed burning practices so that the superior seedlings are not injured. SO(983).

523. Methods are needed for producing varieties of tree species resistant to phytotoxic gases in the atmosphere. A selection system based on visible needle injury has been developed and tested for evaluating resistance of foliage of Scotch pine to injury by ozone and sulfur dioxide. The system is useful in evaluating breeding programs or in mass production of resistant clones or varieties, and has been shown to be successful in selecting resistant Scots pine. NE(984).

524. Improved methods are needed for the rapid identification of resistance in southern pines to the fusiform rust fungus. In recent investigations in Mississippi two artificial inoculation tests made it possible to identify resistance trees in 9 months, compared to at least 4 years required in field tests. The proportion of plants infected was a better measure of field performance than numbers of stem infections or total numbers of infections. This new artificial inoculation method has wide application in the fusiform rust resistance program now being developed in the South. SO(985).

525. The most serious pest on white pine in the Northeast is the white-pine weevil. Leader damage by the pine weevil on 27 seed sources tested in southern Maine suggests that chances of locating individual sources with acceptable levels of resistance are remote. Alternative methods of producing weevil resistant material must be explored. NE(986,987).

526. Tree rusts are the most serious of all forest diseases, and a knowledge of host-fungus resistance physiology is a prerequisite for efficient genetic gains. A recent review of the world's literature on this subject suggests that the principal resistance mechanisms against the major rust, white pine blister rust, are hypersensitivity of foliage and stem cells, and production of periderm barriers in the stem. The main rust of the southern pines, fusiform rust, appears to be more passive since resistance to it involves preformed fungus toxins. SO(988).

527. Among the most destructive pests of forest trees are members of the rust genera *Cronartium* and *Peridermium*. A recent review for forest tree breeders of the world's literature indicates that tree susceptibility to the rusts ranges from high to near immunity, with interspecies hybrids exhibiting a similar range. Heritability of resistance can be high and relatively stable to varying conditions of rust hazard. Although little is known of mechanisms of resistance, this review indicates a physiological basis, depending on the rate of response of the tree's cortical tissues to invasion by the rust. PSW(989).

528. Slow early height growth of longleaf pine is often partly due to the stunting effects of the brown-spot disease. In a test with wind-pollinated seedlings from 540 parents, infection in the seedlings of the best 10 percent of the parents average 48 percent compared to a population average of 63 percent. Inherent fast height growth was not a major resistance mechanism. In addition, the percentage of resistant, fast-growing seedlings identified varied greatly with seed source and was greatest in seedlings from southwest Alabama seed. Seeds and cuttings from the selected parents are now being used to establish a resistance breeding seed orchard. SO(990).

4. Tree breeding methodology

529. Black walnut seed orchards can provide nurserymen with easily accessible genetically improved seed of known origin. Guidelines and some useful hints have now been developed to assist those interested in establishing a walnut seed orchard. In developing a seed orchard consideration must be given to defining the seed collection area, as well as to the actual growing, planting, and maintaining of the superior seedlings. Planning for the next generation orchard is also explained. NC(991).

530. Self-pollination can be a major cause of seed loss in pine seed orcahrds. Using available data on seed development a theoretical model was developed to describe the relationship among multiple fertilizations, embryonic lethal alleles, and unsound seed following self-pollination. Tables from this model can now be used to predict the occurrence of unsound seed in

self-pollinated pines or to estimate the number of lethal alleles carried by the self-pollinated parent. SE(992).

531. In an attempt to induce genetic variation in river birch, its pollen was first irradiated by various levels of gamma radiation and then used in a series of controlled crosses. Pollen irradiation had no effect on the number of female flowers that matured nor on the number of seeds per flower. But viability of the filled seeds was reduced to 60 percent and young seedlings having an abnormal number or shape of cotyledons increased with an exposure of 8000 roetgens or greater. This increase in aberrant seedlings shows that the technique may be an effective means of inducing genetic variation, in spite of the reduced reproductive capacity resulting from use of the irradiated pollen. NC(993).

532. A 1970 evaluation to determine the scope of the artificial regeneration efforts in California by the Forest Tree Improvement Committee, Northern California Section, Society of American Foresters, indicated that approximately 34,000 acres were planted and 20,000 acres direct seeded. Fifty-four percent of the acres regenerated was with Douglas-fir and only a very small percentage of these acres were planted with genetically improved seeds. The appraisal indicates that the current tree improvement effort in the State of California falls far short of that required to improve this State's timber resources, and recommends an expanded program of silvicultural and genetic research to meet the future timber needs of California. PSW(994).

533. The identification of selected enzymes from various tissues of forest trees can serve as excellent genetic markers in tree breeding studies. Equipment and procedures employing starch gel electrophoresis for the identification of individual enzymes are fully described and illustrated for use by other scientists intersted in using this new technique. PSW(995).

534. The failure of the graft union to heal normally is a serious limitation to the development of the grafted Douglas-fir seed orchards. In a recent investigation in the Pacific Northwest where the graft compatibility of genetically related and unrelated rootstock scion combinations were compared, scion clones were 75 percent compatible when grafted on half-related rootstocks. In contrast scion clones were only 56 percent compatible when grafted on unrelated rootstocks. Grafting failures can be reduced by controlling the genetic origin of the rootstocks in future seed orchards. PNW(996).

535. Progeny testing to evaluate the genetic superiority of selected trees has the disadvantage of requiring a long period of time. In slash pine, good correlation between parents and their 3-year-old offspring was obtained for growth rate, specific gravity of wood, turpentine content of wood, and ethanol-benzine extractives. Hence, the progeny test period for these traits in slash pine may be reduced from 20 or more years to 3 years. SE(997).

536. Willow and cottonwood trees are most often propagated by rooting cuttings. Recent studies in India have demonstrated that rooting of willow stem segments is enhanced by 0.1 mg/l. IAA and 1.0% glucose while black cottonwood cuttings rooted best with 0.1 mg/l. IBA and 0.5% sucrose. Hormone effects on rooting of these species are determined partly by the nutritional status of the cutting, and the addition of a carbohydrate source such as glucose or sucrose provides a correct physiological balance. WO(999,1011).

537. To date only a few dawn redwood trees outside of China have produced both male and female cones. This had led to some misinformation concerning the origin and distribution of male cones on this rare and interesting tree. Recent observations in California have now clearly shown that the male cones are produced in lead axils on highly specialized flower branches and are not in florescences as previously reported. PSW(1000).

538. Grafting branches from selected superior walnut trees is a useful way of reproducing this species but often after a few years the grafted tree dies. In order to determine the cause or causes for this failure as well as the internal anatomical changes associated with the graft union, 22 combinations of walnut species and hybrids were grafted in Illinois. During the first 5 years, the bark grew faster on most of the black walnut stock plants than on the grafted branch of the Persian x black walnut hybrid. This is an early indication of incompatibility which must be avoided. NC(1001).

539. To better understand the fruiting process in forest trees and to aid in developing methods for reducing flower abortion, a Polish scientist has conducted a series of detailed investigations on the qualitative and quantitative levels of hormones in the reproductive organs of poplar. Immature flowers were generally high in auxins and low in inhibitors. The maximum amounts of inhibitors are found in the bursting buds, not in dormant ones as previously thought. Female flowers in the catkin stage contained more auxins that the male. WO(1002).

540. Tissue culture, the practice of growing a given plant tissue under controlled conditions, could provide a quicker and a better method of vegetatively reproducing desirable forest trees. An Indian scientist has now been able to establish tissue callus from five American pine species and two Indian species on known nutritive media. For chilgoza pine native to India he has obtained limited differentiation of root and presumptive shoot apical meristems. Although whole trees were not developed, these results do suggest that successful propagation of coniferous trees by tissue culture techniques will be possible in the near future. WO(1003).

541. Little is known about the financial returns that can be expected from hardwood tree improvement. Results of a preliminary economic analysis suggest that tree improvement with artificial regeneration is likely to be profitable for those hardwood species such as black cherry and paper birch that grow rapidly, produce large quantities of seed, and have higher than average market values. A secondary finding was that tree imporvement would pay only when combined with a program of intensive culture. These results emphasize the need for care in selection of hardwood species for tree improvement programs, and provide some guides for the selection of species on which tree improvement is likely to be profitable. NE(1006).

542. Rooted cuttings of yellow-poplar are most easily obtained from sprouts, but propagation of select trees by this method is of limited usefulness unless some means is devised to induce sprouting without cutting the entire tree. Studies in Georgia have shown that sprouting can be induced on most trees by partial girdling, or by severe pruning of various portions of the crown. These methods of forced sprouting and propagation offer a shortcut means of obtaining clonal lines for research or seed orchard uses. SE(1004,1005).

543. To further our understanding of the rooting phenomena of hardwoods the endogenous hormones of developing buds, shoots, and adventitious roots of willows were isolated and identified by a team of Polish scientists. A gibberellinlike hormone and growth inhibitor similar to abscisic acid were found in both the shoot and bud of willow cuttings. It appears that the root influences both the quantity and quality of the gibberellin in the shoot and vice versa, but the controlling factor of the inhibitor was not demonstrated.

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Later studies will deal with the actual interactions of the inhibitors and gibberellins on adventitious rooting. WO(1007,1008).

544. In the study of the dynamics associated with changes in forest tree populations, there is a recurring need to define these changes in terms of mathematical equations in order to estimate future changes. Applying existing Leslie-type matrix analyses, projections of forest tree population behavior were constructed which account for variation in both survival and reproduction due to possible sampling error as well as to variations in the environment. This model equation must still be tested as additional data becomes available. SE(1009).

545. Detailed investigations in India of the comparative rooting ability of a number of different tree species indicated that, in general, ease of rooting is associated with certain groups of trees. Furthermore, their results strongly support the widely held view that seasonal variation in the rooting ability of cuttings is related to the state of the dormancy which, in turn, governs starch and auxin levels in cuttings. Hormone induced rooting could be accelerated and increased by the addition of an energy source, such as sucrose. WO(1010).

546. One of the most important factors in determining the profitability of seedling seed orchards is amount of time required for the orchard to produce seed. Both fertilization and cultivation were found to enhance early male and female flower production in a 4- to 7-year-old loblolly seed orchard in southern Mississippi. Although increasing the level of fertilization had little effect on increasing the number of trees flowering, it did increase the number of cones on those trees which were bearing. SO(1013).

547. Before improved plant material is released for commercial use it is necessary to describe the methods and criteria used to select and reject clones, varieties, or parentages. Beginning with 13,000 hybrid poplar seedlings in 1924, 40 clones have now been selected in the Northeast on the basis of growth rate and pest resistance. These clones have been distributed to ten state nurseries and are now available for commercial plantings. NE(1014).

548. Forest tree improvement programs are now an established part of the total management of our public and industrial forests. In order to assist the natural resource manager with the terms and language employed by tree breeders and to provide a common and acceptable language for the tree breeders in different parts of the country, a revised glossary of 175 terms in genetics has been prepared. This new edition updates the 1959 edition by redefining most terms, adding some, and deleting others. SO(1015).

549. Among oak species are a number of valuable trees which are becoming more important in forest management with the increasing demand for hardwood fiber. Improved methods for the genetic improvement of oaks such as long-term pollen storage at 18°C and better methods of pollination using special bags were developed and tested in Yugoslavia under the PL-480 program. These investigations also described the basic details of flower development which will directly aid the U.S. tree breeder in applying these new methods to American species. WO(1020).

550. Walnut is a valuable forest tree in the United States, producing both a useful nut and highly valued wood for the furniture industry. PL-480 supported research in Yugoslavia has shown that superior Persian walnuts that grew faster and had fewer forks came from the higher altitudes or more northerly latitudes of Yugoslavia. By crossing the superior Persian and American black walnut additional genetic improvement can be achieved. WO(1021).

551. Seedlings of western white pine have a definite period of winter dormancy. For this species to be grown normally in a greenhouse or growth chamber for experimental purposes, a cold-conditioning method was developed. For 2-year-old seedlings to approach maximal growth without natural winter conditioning, they must receive a minimum of 14 weeks of artificial chilling at 40°F. INT(1019).

552. Polyploid races of forest trees have potential value as an intermediate stage in forest tree breeding research since such trees provide a mechanisms for controlled gene exchange. In a series of studies in Finland, germinating seeds of 10 birch species were treated with 0.06% concentration of the chemical colchicine. Colchicine induced polyploids in six of the birch species, but the polyploid seedlings were characterized by a high mortality and an initial slow growth. At age 3 to 5 trees had short trunks and bushlike branching with leaves greater than normal size, larger stomata, and larger mesh size of the venation network on the lower surface. Later studies will determine how these trees flower, and whether they will produce seeds following controlled pollination. WO(1022).

553. When different pine species are crossed, cone abortion is often high and seed-set low. Two Yugoslavian scientists have attempted to overcome these breeding barriers in the cross of Austrian and Scots pine by using pollen previously irradiated with gamma rays. Irradiated pollen permitted normal seed development for 11.5 months following pollination, while cones in the same cross treated with normal pollen aborted shortly after pollination. Although they did not get seed-set, their method will make it possible to overcome selected breeding barriers in some American pine species by preventing early cone abortion. WO(1023).

C. Improving Uses and Protection of Wood

1. Utilization potential and processing of wood

554. A reference handbook for those interested in, involved in, or contemplating utilization of the major woodland tree species of Arizona provides information on stand and stock characteristics and physical and chemical properties of the species. The occurrence, physical characteristics, and utilization potential of pinyon, juniper, and Gambel oak are reported here. RM(1220).

555. *Pinus caribaea* grown in Puerto Rican plantations were sampled to determine the amount, orientation, and effect of compression on some physical and mechanical properties of the wood. Compression wood did not affect specific gravity, modulus of rupture, or work to maximum load in beam tests. Modulus of elasticity decreased as did all shrinkages except longitudinal. Boards from thse trees were kiln dried without seasoning degrade and were easy to machine. The results indicate that plantation grown *Pinus caribaea*, although high in compression wood, can be utilized successfully. ITF(1221).

556. Newly developed standard eastern white pine logs and tree grades were tested for reliability in predicting the value of standard yard lumber products from a sample of white pine trees and logs. The tree grading system predicted a lumber value of the sample trees within 3 percent of the actual, and the log grading system predicted a lumber value of sample logs within 2 percent of the actual. The grades provide a working tool for both buyers and sellers of white pine logs. NE(1222).

557. Weight scaling, rather than log scaling, is the most common method of purchasing southern pine tree-length logs. Season of the year affects the weight loss due to drying dur-

ing storage. Woodyards in South Georgia should limit storage periods for pine tree-length logs to approximately one week in summer, but could extend storage up to 6 weeks during the winter months. SE(1225).

558. Heartwood and sapwood of black walnut (*Juglans nigra* L.) were prefrozen and then thawed prior to drying to test the effect of prefreezing on wood hygroscopicity, dimensional properties, and extractives. The tests indicated that prefreezing induced shrinkage reductions result from increased bulking of the fibers by extractives during drying and altered hygroscopicity of the wood. What is meaningful is that prefreezing favorably altered the wood-water system and therefore can provide the possibility of accelerating drying without increasing defects. NC(1227).

559. A computer program, written in FORTRAN, predicts the maximum yield of cuttings for softwood cut-up and edge- and end-gluing operations. The program calculates cutting recovery (given cutting width and length constraints and defect locations on the board) and specifies the maximum number of rips. This program will improve wood conversion efficiency through improving yields, reducing wastes, and reducing human errors. RM(1231).

560. Trees cut in thinning of Douglas-fir stands were processed into lumber by a profiled cant chipper, a square cant chipper with resaw, and a bandmill. Recovery totals by processing method are given in both lumber and chips. This information will be useful to mill operators and timber managers in predicting product yields and evaluating different production methods. PNW(1232).

561. Residual volumes of wood, bark, and needles were obtained in a lodgepole pine stand after clearcutting to a 6-inch-diameter top. A total of 4,333.1 cubic feet of residue per acre, excluding needles, remained after logging. In terms of utilization potential, 82 percent of the residue was 3 inches or larger. FPL(1233).

562. An adhesives evaluation system has been devised providing data for specific design situations that can be related to anticipated levels of stress and deflection, as well as the critical nature of each adhesive application. The system includes accelerated aging to forecast durability properties for 50 years and longer. This approach provides information needed by adhesive formulators, raw material manufacturers, and architects and design engineers to secure dependable adhesive bonding in building construction. FPL(1235).

563. A study of surface characteristics and lumber recovery information indicates that problems encountered in applying a log grading system to sugar pine trees can be alleviated by modifications in the specifications. The modifications do not appear to decrease the performance of the grading system used by foresters and cruisers in various operations requiring grading. PNW(1243).

564. Thirty-six resins formulated with varying ratios of phenol, sodium hydroxide, formaldehyde, and resin solids were used in tests of glue bond quality of southern pine. Of the three formulation variables, the NaOH/phenol ratio gave the most surprising results. The ratio of 0.4 is considerably lower than any used in industry, but resins thus catalyzed gave consistently better bonds than those with higher proportions of caustic. SO(1245).

565. Recently, interest has developed in applying the scanning electron microscope to study the stretching of cellulose fibers. A single and inexpensive fiber-stretching device was designed and fabricated using the existing standard stereostage and goniometer 360 degrees stage control. Thus, cellulose fibers can be stretched and photographed while being viewed with a scanning electron microscope. FPL(1253).

566. A two-volume handbook characterizes the 10 southern pine species as an industrial raw material and describes the processes by which it is converted to use. This handbook is the most comprehensive reference to the utilization of the southern pines available anywhere. SO(1254).

567. A public U.S. patent was issued for a process for steam straightening and kiln drying lumber, the lumber being held under total restraint with respect to warping during the process. The lumber is steam straightened and kiln dried to a moisture content of 9 percent. SO(1257).

568. About 98 percent of the Sitka spruce lumber sawn in a southeastern Alaska lumber recovery study was in cants 3 to 8 inches in thickness. Thirteen percent of the lumber volume was graded No. 2 and 3 clear by the Pacific Lumber Inspection Bureau rules and 9 percent high grade cants (Piano grade) under export rules. PNW(1259).

569. New log grades for cruising coast Douglas-fir have been developed and tested. They are for application to standing timber and provide an accurate estimate of lumber and veneer yields and timber values. PNW(1260).

570. Rate-related dimensional stability characteristics of wood-base composition board panels were found to be dependent on interparticle capillarity. Total moisture absorption was controlled by characteristics inherent to the varying types of composition board and was found to be a logarithm of time. Linear expansion and thickness swelling were found to be directly correlated with moisture absorption and, in some test, time. Methods which improved bonding or reduced the number of available absorption sites were proved to be better stabilizing methods. This research was awarded first place in the 1970 Wood Award Competition co-sponsored by the Forest Products Research Society and Wood and Wood Products Magazine. FPL(1262).

571. Gas chromatography has been found an efficient and relatively accurate method for quantitatively and qualitatively determining the major components of creosote. Results of this procedure compare favorably with the more tedious flask distillation procedures, and separation of individual components can be achieved in as short a time as half an hour. FPL(1263).

572. A prediction equation has been developed for estimating the initial moisture content of Douglas-fir based on green volume and green weight. The same two variables and elapsed drying time can also be used for efficiently estimating the percent of moisture content during drying. The same estimates can be made for ponderosa pine when hardness of green wood is considered as an additional variable. Commercial application of this predictive method is directed toward kiln-drying operations. INT(1264).

573. Properties that affect the manufacture and use of veneer and products made from veneer are described for 156 U.S. tree species. Each species is rated for use in the general categories of construction plywood, decorative face veneer, inner plies of decorative panels, or container veneer and plywood. This report serves as ready reference for all U.S. species likely to be used for veneer. FPL(1267).

574. Wood moisture content affects tool forces and thus the energy consumed in machining. Moisture also interacts with other factors in influence the process of chip formation and, hence, affects the shape and size of the separated particle. When boring holes in southern pine of varying moisture content, torque and thrust increased with increasing moisture content to a maximum of 5 to 10 percent, then decreased to a constant value at fiber-saturation point. SO(1270).

575. The Western Wood Density Survey is a long-term program to assess the wood quality via wood density for the major western timber species. Wood density data are presented for 15 commercially important western timber species, with emphasis on 6 species not previously evaluated. FPL(1271).

576. Maple logs were sawed by two grade-sawing methods and a live-sawing method into lumber. Live sawing gave the greatest yield of rough clear cuttings; however, when warp is considered, grade-sawing becomes superior. Where a remanufacturing plant has any control over the sawmilling operation, loss from warp can be reduced if the sawyer is instructed to avoid live-sawing as much as possible. FPL(1272).

577. Rootwood tracheids of southern pine average one-third longer and are one-third larger in diameter and have walls 18 percent thinner and lumens almost two-thirds larger than stemwood tracheids at stump height. Since the stump and roots left after logging contain about 25 percent as much wood as is found in the harvested stem, knowledge of root tracheid measurements is important in assessing the utilization potential. SO(1273).

578. Trees throughout the commercial range of spruce pine (*Pinus glabra* Walt.) were sampled to determine effects of tree age and growth rate on morphological, mechanical, physical, and chemical properties. The wood properties studied were those deemed of importance in the manufacture of fiber or solid products. SO(1275).

579. The feasibility of roll-laminating fiber overlays on low-quality ponderosa pine common to the Southwest U.S. was studied at the pilot plant stage. Lumber repair techniques involving abrasive planing, wood plugging, chemical repair, and selective cutup were also studied. Results indicated that a high proportion of defects cannot be successfully overlaid without repair and that repair techniques are restricted by the need for an effective automated defect repair system. RM(1279).

580. The relationships of wood specific gravity to height in tree were investigated for 28 commercially important timber species. In 17 species, specific gravity decreased with increase in height; in 5 species, specific gravity increased with increase in height; in 3 species, specific gravity initially decreased with increase in height, then increased; and in 3 species, no significant change was observed. Information bears on strength properties and pulp yields of upper logs of sticks. FPL(1282).

581. One-half-inch-thick slices of clear, flat-grained red oak and southern pine were cut with the knife and flitch inclined, relative to the cutting motion, at angles of 45, 67.5, and 90 degrees. The depth of fractures into the wood slices was least when using inclination-angle differences of 45 degrees; however, thickness uniformity was poorer, the surfaces rougher, and there was considerable twist. Best overall quality occurred when there was no angular difference between the knife edge and the grain direction of the wood. FPL(1283).

582. Slash pine has thicker bark, a higher percent of bark by weight, a lower bark moisture content, and a higher bark specific gravity than loblolly pine. Location differences within a species were large for bark moisture content and bark specific gravity. This research is directed toward the development of increasing the utilization of the bark residue resource. SE(1284).

583. A newly revised guide to hardwood log grading was prepared. The guide is to serve as a teaching aid and field reference. Basic principles and details on practical applications are given. NE(1286).

584. An apparatus to continuously and simultaneously measure the swelling and liquid uptake by cylinders of wood is described. The device measures swelling during liquid penetration into wood, and can also be used to study the effect of various chemical treatments on either swelling or shrinkage. Measurements of this kind are useful for determining the best chemical treatment conditions. NC(1288).

585. Production of a laminated structural wood product by an innovative system which markedly improves yield at reasonable cost is now technically feasible. The complete log-to-product system consists of rotary cutting veneer up to one-half inch thick, press-drying the thick veneer in less than 15 minutes, applying glue to the hot sheets, and laminating into a thick structural material. The entire processing time is 30 minutes. An economic analysis shows that the selling price for vertically laminated joists would be equivalent to the majority of sawn structural lumber used for housing. FPL(1291).

586. Nomographs have been prepared allowing accurate estimates of dimension yields from various grades of hard maple, black walnut, and red alder lumber. Upon determination of the yields, cost comparisons can be made of the various grades and grade mixes to obtain the most economical choice for the specific cutting order. Until computerized processing and decision making become commonplace, and for small manufacturers who cannot afford an elaborate system, these nomographs present a useful alternative. FPL(1293).

587. Four paint combinations applied to simulated vertical siding of four wood species have been exposed outdoors in Hawaii since 1964. A three-coat, self-primed latex application is holding up best, with oil base primed latex, three-coat oil base, and two-coat oil base combinations next best in that order. Australian toon is holding paint best, followed by redwood, robusta eucalyptus, and Douglas-fir. For good service, durability, and appearance, three coats of self-primed latex on Australian toon or redwood are recommended. PSW(1296).

588. In pilot tests, introducing an enzyme solution into round sections of Rocky Mountain Douglas-fir markedly improved the creosote treatment of this hard-to-treat species. The enzyme pretreatment increased the depth of creosote penetration to full sapwood uptake, increased the total creosote retention, and produced an essentially "dry" surface. FPL(1300).

589. In the wood density survey of the Southern forest resource, information was collected on the specific gravity of the four major southern pines over their natural growth range. In terms of geographic variability, only slash pine and longleaf pine showed a general trend of specific gravity increasing from north to south. This information contributes to the characterization of this major forest resource. FPL (1302).

590. Northern red oak (*Quercus rubra* L.) lumber from trees with heartwood infected by certain anaerobic bacteria proved more susceptible to honeycomb and ring failure during kiln drying than similar lumber from non-infected heartwood. The implication of this work is that it would be possible to speed up the drying of red oak and decrease drying degrade if boards containing bacterial infections could be sorted out and dried separately. FPL(1304).

591. Little information is available concerning the chemical composition of growth rings with ring shake present as compared with normal hardwood growth rings. Working with scarlet oak and black walnut, it was shown that concentrations of holocellulose, alpha cellulose, lignin, and wood methoxyl differed between "normal" and "shake" growth rings. Abnormal distribution of the various components may weaken the wood

structure and thus be one cause of separation. Knowledge of this type may help in identifying causes of ring shake. NE(1309).

592. Loblolly pine wood was coated with either phenolic varnish, pigmented alkyd paint, or pigmented latex paint and artificially weathered. Observations made under a scanning electron microscope showed each coating to have a different failure mode, with the latex being more durable than the other two. SO(1312).

593. Wood density distribution, or uniformity, is an important characteristic in the determination of wood quality. Studies with ponderosa pine in California have now shown that X-ray techniques can be effectively used to measure wood density distribution across large increment cores. When wood density distribution is considered along with the mean wood density, a useful index to the type of conversion processes and products most suitable for that wood can be constructed. PSW(1024).

594. Gelatinous fibers, usually found in tension wood, cause difficulties in sawing and machining. Paper made from pulpwood containing such fibers has low strength. A high proportion of water-conducting vessels to fibers in pulpwood also reduces the strength of paper made from it. Very high percentages of gelatinous fibers were found in straight-boled, dominant cottonwood trees that were growing rapidly under intensive management. In the same trees, the proportion of vessels in the wood increased with height. These results indicate that the incidence of gelatinous fibers and of xylem vessels should be a primary consideration in evaluating wood quality of trees exhibiting rapid growth. NC(1026,1027).

2. Wood chemistry and fiber products

595. In preparing pulpwood for pulping, the bark is ordinarily removed and not used in the pulp-making process. However, bark does contain fiber. Pulping the bark along with the wood increases the fiber yield from a rough cord of wood by 4 percent. This also has the benefits of eliminating the debarking operation, eliminating the loss of white-wood during de-barking, and permits the use of small tree branches, tops, and other wood wastes that are difficult to de-bark. To get the additional 4 percent fiber requires 0.2 percent more pulping chemical and 0.2 percent more chlorine bleach. FPL(1313,1326).

596. In the recycling of mixed municipal refuse, reduction of particle size and removal of pieces of plastic are necessary but difficult steps. Size reduction by hammermilling has been practiced on a large scale. Analyses of hammermilled waste show that, except for producing a large percentage of overfine material, hammermilled paper fiber undergoes no important degradation. Two methods have been developed for effectively separating thermoplastic films from wastepaper. Most of the plastics of solid waste are thermoplastic and soften on heating. The first method utilizes the principle of the thermoplastic films adhering to a heated surface. The second consists of suspending the waste mixtures in hot gas to contract or ball up the films followed by air classification or screening. Both methods are practicable and the second can be used immediately with equipment presently available on the market. FPL(1314,1332,1333,1337,1338).

597. New studies on the potential of pulps and wood wastes for ruminant feeds have shown that at high lignin contents, pulps from hardwoods are more digestible by ruminants than softwoods. Below 7 percent lignin, pulps have equal digestibility. Digestibility is inversely proportional to lignin content and is independent of the method (pulping process) of lignin removal. The same relationships were found when lignin was removed by fungi. The rate at which nine white-rot fungi removed lignin and carbohydrates from wood was measured. All fungi removed carbohydrate along with the lignin. A procedure also has been developed for determining the digestibility of cellulose and wood with cellulytic enzymes. It is useful for screening various physical and chemical treatments for improving the digestibility of wood materials. Using this enzyme test, fine grinding was found to be the most effective wood treatment. Dilute alkali and liquid ammonia increased the digestibility of aspen to 50 percent and 36 percent respectively. FPL(1315,1327,1335).

598. Paper testing methods are frequently difficult to reproduce and interpret in meaningful ways. Some advances in this field have been made. Interfiber bonding is an important factor in mechanical and optical properties of paper. Most methods for measuring this property rely on indirect measurements of exposed surface areas. A new method is described whereby surface areas are measured by small X-ray scattering techniques. In ring and flat crush tests on paper the comparability of results using different machines was also examined. Significant differences were found between the flexible and rigid types of testing machines. Suggested modifications of test procedures should include restricting the tests to one type of machine or standardizing machine parameters. FPL(1317,1328).

599. The speed at which corrugated fiberboard can be produced is in part dependent upon the runnability of the corrugated medium itself. The runnability of the corrugated medium is influenced by the web tension during corrugation. Installation of an automatically controlled tension device, electronically coupled to a magnetically operated disk brake system, resulted in accurate measurement and also control of the web tension of the corrugating medium on an experimental fiberboard machine. FPL(1322).

600. In chemical pulping processes, as much as 50 percent of the wood raw material is solubilized and lost to fiber production. Up to half of this is carbohydrate that is removed unnecessarily under the lignin-removal conditions which are usually alkaline. Additional basic information on the complex alkaline degradation reactions of cellulose and other wood carbohydrates has been developed. Oxygen, alkalinity, and higher temperatures increase the rate of cellulose degradation. Neighboring hydroxyl groups promote the breaking of chemical links in cellulose chains. Reactions leading to the formation of butyric acid derivatives and the migration of acyl groups in carbohydrate in wood or pulp have been described. The method is based on dehydrating carbohydrates to furans using sulfuric acid and measuring the resulting furans spectrophotometrically. FPL(1324,1343-1346).

601. The morphology and characteristics of individual wood fibers markedly affects the properties of papers made from those fibers. Paper strengths increase with fiber cell wall thickness to a critical point and then there is an adverse effect. The ratio of fiber length to cell wall thickness appears to be a good indicator for the paper making potential of a pulp. Earlywood papers show consistently higher tensile strengths than latewood papers. Cell wall densities of the two kinds of fibers are the same. Earlywood fibers have more uniform fiber-to-fiber conformability than latewood fibers. The amount of bonding developed in latewood is insufficient to fully utilize greater fiber strength. FPL(1325,1348,1349,1351).

602. Fast-growing, short-rotation crops of poplar and sycamore trees can produce as much as 4 tons per acre per year of biomass useful for pulpwood. This is more than four times the average dry wood weight produced in conventional pulpwood growth. Satisfactory pulps were made from whole

rapid-grown poplar trees and the presence of bark presented no special problems in either pulping or bleaching. Eleven-year-old trees gave the highest yields and stronger papers than younger trees. With sycamore, 4-year-old seedlings gave maximum production. Good quality pulps were made from all of the short-rotation sycamore trees studied. The pulps were found suitable for making acceptable bleached kraft papers and dry-formed hardboards. FPL(1329-1331).

603. The chemical extractives of elm and Eastern white pine were examined further. A symptom of Dutch elm disease is the formation of a brown discoloration in the last one or two annual growth rings. Phenolic substances identical to those extracted from heartwood but not found in sapwood were found in the "brown ring" area. These substances may be related to natural disease resistance factors. Information on the phenolic constituents of various elms can be used to distinquish between anatomically closely related species. The major chemical constituents of extracts of Eastern white pine cortex tissue and a needle polyprenol were characterized. The diterpenes, strobol, strobal, and manoyl oxide were present. FPL(1342,1352).

604. Wax-treated corrugated containers account for 6 to 7 percent of the corrugated containers presently used. This is expected to increase to 10 percent or one million tons in the near future. virtually all of this good-quality, wax-treated material is burned or buried after use rather than recycled since the specialized, solvent extraction equipment necessary for wax removal is not available at most recycling mills. A practical, more generally applicable method for wax removal has been developed that uses conventional mill equipment. Wood fiber reclaimed from such material shows promise as a significant source of fiber for use in corrugating medium either as 100 percent reclaimed fiber or blended with virgin fiber stock to improve properties. FPL(1334).

3. **Wood engineering**

605. Condensation because of excessive moisture is an aggravating problem for many building owners. A summary report suggests several design alternatives, including vapor barriers, insulation, ventilation, and other construction details to alleviate this problem. FPL(1353).

606. New clear wood mechanical properties were established for five western softwoods. Properties for white and sugar pine, western redcedar, and Port-Orford-cedar were not greatly different than those obtained in 1915. For a fifth, however, subalpine fir, new estimates are significantly higher; 22 percent in modulus of elasticity and 10-14 percent in other properties. Results will ultimately lead to more efficient and reliable structural design with these species. FPL(1355,1356).

607. Paper sacks are an important container for shipping many materials. When sacks fail, valuable contents are lost or damaged. If too much paper is used in constructing sacks, valuable paper resources are wasted. A theoretical design formula has been developed to predict failure of sacks subjected to certain drop heights. This is important to designers, manufacturers, and users. FPL(1365).

608. About 80 percent of the observed variation in tensile strength of dimension lumber can be explained by nondestructive measurements. These include a variety of stiffness measurements, several strength ratio estimators, slope or grain, and, to a small degree, specific gravity. FPL(1371).

609. Lumberlike products can be successfully built from laminated veneers. Strength properties can be maintained if butt joints are properly engineered and fabricated. Tensile strengths can exceed those of solid lumber of equal log grades. FPL(1381).

610. Observations and measurements of moisture contents in wood framing members used in natatoriums reveals that when design standards for occupancy are met, there is no hazard to wood framing or roof. Guidelines are provided to assure proper insulation and ventilation to avoid problems. This information is important to designers, developers, and builders of swimming pools and other wood structures where like humidity and moisture conditions exist. FPL(1383).

611. Hardboard can be used in many engineered structures. Recent studies provide the means for calculating the design characteristics of hardboard used as the webbing for I-beam construction. FPL(1384).

612. Experimental evidence shows that creep deformation of wood is accelerated by both increasing and decreasing moisture exposures, a factor that may be of considerable importance in design of wood structures. The research proposes a kinetic model for creep response of wood which attributes accelerated creep with a changing moisture environment to the diffusion of moisture within loaded specimens. Material basic to development of predictive models for creep of wood in uncontrolled environments is presented. FPL(1385).

613. A limited survey was made of users of the FPL low-cost house designs. Of the 225 homes constructed based on FPL plans, 93 percent reported costs less than $12,000. Ninety-two percent of the homeowners had annual incomes less than $7,000. Conclusions reached indicate that structurally sound houses can be built to meet the needs of most people at prices they can afford. FPL(1387).

614. Timber bridges offer an important alternative to steel or concrete for many sites. Recent research results provide a simplified method for designing wood bridge decks and connector systems using charts, rather than computers. RPL(1390).

615. Nail popping is a frequent, unsightly, and costly defect in resilient tile flooring used in houses. Techniques have been developed which significantly reduce such problems through use of short screws or nails used to fasten underlayment to subflooring. This practice eliminates nail popping resulting from penetration of longer nails into floor joists subject to large dimensional changes, and should be of particular interest to home builders, flooring contractors, and the like. SE(1391-1393).

4. **Biological degradation**

616. The function of protozoans occurring in the hindgut of the Formosan termite (*Coptotermes formosanus*) is not well understood. Tests were conducted to determine the ability of these termites to break down cellulose and to synthesize lipids with and without the normal gut fauna. Results suggested that the protozoan, *Pseudotrichonympha grassii*, is essential to normal cellulose breakdown, lipid synthesis, and survival of worker Formosan termites. Controlling this protozoan could control the termite. SO(436).

617. Recent studies have provided more information on the importance of protozoan symbionts in the feeding, soldier differentiation, and survival of the Formosan termite workers. Workers with protozoa fed more and survived better than did termites lacking all or some of their protozoan associates. SO(438).

618. Temperature affects the feeding and survival of native and Formosan subterranean termites. Workers lacking normal intestinal protozoa ate less and survived for shorter periods

than did colonies having these organisms. Formosan termites and their associated protozoans were able to survive higher temperature than *Reticulitermes flavipes.* These findings contribute to understanding the distribution, survival, and potential destructiveness of the respective termite species. SO(437,439).

619. The synthesis and subsequent breakdown of lipid materials form an important aspect of termite metabolism. The fatty acids in the body fat of *Reticulitermes flavipes* were determined after feeding on sound wood and wood rotted by the fungus *Lenzites trabea* in the field and laboratory. The major components were palmitic, palmitoleic, stearic, oleic, and linoleic acids. Differences in composition occurred between termite colonies and among termites fed on sound versus rotted wood. This information helps clarify the biochemical relationship between termites and their associated microorganisms. SO(433-435).

620. The psocid *Liposcelis bostrychophilus* is usually associated with anobiid-infested wood, but its role has not been clearly established. Laboratory tests revealed that as psocid numbers increase consumption of beetle eggs also increases. Under natural conditions, psocids apparently contribute in a limited way to the natural regulationg of anobiid infestations SO(442).

621. New, environmentally safe ways for extending the life of wood in use are being sought at the Southern Forest Experiment Station. Trials on malt agar showed that a *Streptomyces* sp. could strongly inhibit growth of decay fungi, but in pine sapwood the antagonist tended to hasten decay rates. This illustrates the need to completely understand systems when formulating biological control technology. SO(608).

622. Several previously undiscovered wood decay fungi have been described and identified by scientists at the Center for Forest Mycology. Identification of the numerous and diverse fungi involved in decay will allow more efficient research on clarifying the complex systems involved in decay processes. FPL(607,611,612).

623. Lignin was found to be selectively removed from wood by certain white-rot fungi. As a result, these woods were more digestible by rumen fluid and a mixture of polysaccharidases. This finding could lead to new uses for unused wood. FPL(610).

5. Prevention and control of wood-destroying organisms

624. Research on preventing decay in wooden structures has been summarized for technical use. Lumber cut from second-growth timber contains mostly sapwood, which is susceptible to decay. Such lumber can be protected by building designs which keep untreated wood dry and by pressure-treating wood with preservatives whenever contact with soil or other sources of moisture cannot be avoided. Increasing the service life of wood is an important step in conserving our valuable natural resources. SO(614,615).

625. Standard ground-board and stake tests to evaluate various soil treatments for protecting wooden structures from subterranean termites have been underway at Gulfport, Mississippi, since 1944. Many chemicals have failed to provide acceptable, long-term protection. Chlordane, aldrin, dieldrin, and heptachlor applied at various concentrations and rates continue to be fully effective after 18-22 years. SO(446).

626. Alternatives for the chlorinated hydrocarbons aldrin, chlordane, dieldrin, and heptachlor are needed for subterranean termite control. Carbamate and organophosphate insecticides have provided full protection for more than 4 years in southern Mississippi tests. Continuing standard slab and ground-board tests will determine the full potential of these materials and provide the necessary efficacy data for registration. SO(443).

627. Destruction of polymeric insulating materials, used on communication lines and in electronic equipment, by termites is of considerable concern in south temperate and tropical environments. Cooperative tests with the U.S. Naval Research Laboratory in Panama and Mississippi showed that polymeric formulations plasticized with tricresyl phosphate fortified with ortho isomer were least damaged by termites after 75 months of exposure, either with or without lindane, dieldrin, and aldrin. Formulations plasticized with tri-p-cresyl phosphate were nearly as good. This information will be utilized in fabricating termite-resistant insulating materials. SO(444).

628. The use of toxic inhibitors to protect cables sheathed or insulated with flexible polyvinyl chloride plastics against termite damage is hazardous in many situations. A cooperative study was undertaken with the Naval Research Laboratory to determine the effectiveness of nontoxic, termite-proof polymers in Panama, Mississippi, and Louisiana. Best results were obtained with ethylene propylene rubber and chlorosulfonated polyethylene formulations, which were highly resistant to termites, innocuous to man, and promised long service life without loss of effectiveness. SO(447).

629. Long-term stockpiling of pulp chips outdoors is facilitated by a newly patented technique which controls chip deterioration. Pulp chips are treated with an aqueous mixture of sodium sulfide and sodium carbonate, both of which are readily available and inexpensive at pulpmill sites. The treatment reduces natural heat evolving processes and wood rot, and reduces losses in stored chips by two-thirds. FPL(618).

630. Increased decay resistance of ammonia- and sodium hydroxide-treated wood was attributed to increased pH and to abnormally high levels of ammonical nitrogen rather than destruction of thiamine. These treatments were effective only against brown-rot fungi under low decay-promoting conditions. Refinements in wood preservation will become more feasible when mechanisms such as these are understood. FPL(616,617).

631. A number of wood-destroying beetles, commonly referred to as powder-post beetles, cause damage to seasoned wood in buildings. A new bulletin answers questions about the appearance, habits, damage, and control of these pests. SO(448).

6. Miscellaneous

632. Lobeline, an alkaloid used in antismoking preparations, usually is extracted from wild plants of *Lobelia inflata.* But harvesting of wild plants is not very profitable because much labor is required to find suitable plants in the widely scattered population. Cultivated lobelia plants in central Kentucky were larger and had a higher lobeline content than wild plants in the same area. Yield estimates indicate that cultivation of lobelia probably will be economically profitable at the current selling price of dried plant material. Analyses showed that *L. cardinalis* and *L. puberula* contain at least as much lobeline as *L. inflata.* Small groups of plants of each of the three species are scattered over the southeastern United States. A potential grower, therefore, can select the species best suited to his local conditions. SE(1034,1035).

D. Marketing Under-Used Species and Residues

633. The conversion of logs into lumber often results in the creation of fine wood residues equivalent to about one-third of total log weight. Profitable markets for fine wood residues are not available in all areas because of the variable character of these materials and economic constraints of handling and transportation. However, there are many potential uses for such residues and managers should carefully evaluate these opportunities within the context of their individual plant circumstances. SE(1140).

634. Prices paid by mills in the northwestern United States for "fiberwood" (chips, sawdust, shavings, and logs) varied widely during 1971 and 1972. Chip prices ranged from $7.75, to $21.25 per bone dry ton (BDT) during 1970-1971. Prices vary by location and species group. Sawdust prices have remained stable within a range of $3 to $7.50 per BDT over the past 10 years. Shavings prices averaged from $5 to $7.25 per BDT in 1970-1971, very close to the price range prevailing over the past decade. PNW(1142).

635. A detailed evaluation of a new hardwood sawmill system which includes a debarker, automatic carriage and circular headrig, chipper, and a sawyer-controlled vertical edger, showed that low-grade hardwood logs (Grade 3 and below) can be processed profitably. This new sawmill system should find wide application in the Appalachian region where about 70 percent of the sawtimber consists of Grade 3 and poorer quality material. NE(1143).

636. Until recently, bark has been the most difficult wood processing residue to convert into useable, marketable products. However, bark producers now are effectively developing markets for bark as mulches and soil conditioners. This article describes these markets and discusses the ways in which bark is used effectively for mulches and soil amendments. NE(1145).

E. Supply, Demand, and Price Analysis

637. A computer model was developed for projecting long-run demand for housing by type of dwelling unit and region. The model also provides a framework for projecting future housing demand under specified assumptions relating to population and economic growth. Tabular data showing these respective projections are presented. Since residential housing is the market for more than a third of all lumber and plywood consumed annually in the United States, trends in housing construction are of major significance in assessing future demand for timber products from the nation's forest resources. NC(1169).

638. More than 42 percent of the $2.1 billion dollars of Canadian forest products shipped into the United States in 1969 entered through northcentral region Custom Districts. Three commodities—newsprint, softwood lumber, and woodpulp--accounted for 89 percent of the value of all forest products imported from Canada and 87 percent of all Canadian forest products that come imto the northcentral region. NC(1152).

639. Construction of apartments in the United States in 1969 involved an average use per apartment unit of 3,886 board feet of lumber, 1,879 square feet of plywood (3/8-inch basis), 49 square feet of hardboard (1/8-inch basis), 52 square feet of particleboard (3/4-inch basis), and 45 square feet of insulation board (1/2-inch basis). These wood-use data were derived from a sample of apartment projects for which architectural plans and specifications were completed during 1969. Comparisons with data from a similar 1962 study indicate that while plywood use per housing unit has increased slightly, lumber use has declined by about 14 percent. WO(1176).

640. An analysis of the demand and price situation for forest products provides up-to-date information on timber product markets as of 1971. Information is presented on price and consumption trends for lumber, plywood, pulp and paper, and miscellaneous products, including naval stores. WO(1158).

641. In 1972, nearly 300 secondary wood-processing firms were in operation in West Virginia. A directory classifies these forms into categories and shows their location, raw material requirements, and type of product manufactured. This information aids area lumber and other primary processors in finding markets for their products, and also assists consumers of secondary products in locating sources of supply. NE(1156).

642. An analysis of the production and shipments of mobile homes in the contiguous 48 states during the period 1966-69 disclosed a shifting pattern of geographical concentration of production. On the basis of a model which relates mobile home use to state population characteristics, projections of mobile home shipments were made for the 1971-75 period. Since mobile homes now are a significant component of housing demand, these data will be helpful to wood materials suppliers in planning production and marketing strategies. SE(1162,1164).

643. A detailed time and motion study on sample logging operations in West Virginia indicated that in the log skidding phase, cost savings can be greater from improved machine operator practices than from upgrading skidding equipment. Since skidding represents one of the major costs in logging, logging managers should consider skidder operator training or production bonuses as promising opportunities to reduce harvesting costs. NE(1170).

644. An adaptation of a method developed in Sweden was used in an analysis in the Lake States relating timber inventory volumes to transport distances to specified delivery points. The procedure developed shows promise as a useful aid in analyzing area timber resources information and making decisions on wood procurement strategies. NC(1148).

645. A quarterly marketing report on the Northwest forest industries presents current timber industry information on production; prices; employment; trade; volume and average prices of stumpage sold by public agencies; and other related items. PNW(1153,1154,1159,1160).

646. The tariff on imported maple syrup products was abolished in 1972, and domestic maple syrup producers have anticipated market changes due to its removal. However, an analysis of syrup price and tariff levels since World War II concludes that no substantial increase of shipments of maple syrup products from Canada into the United States is likely as a result of the tariff removal. NE(1173,1174).

647. The major end-product for hardwood plywood (usually birch) stock panels in 1970 was kitchen cabinets. Over one-third of the wholesalers contacted in a study of the hardwood stock panel market reported that stock panel sales have been declining because of market inroads by plastic-overlaid particleboard panels. NC(1167).

F. Marketing—General

648. Wood craftsmen in Kentucky increased their production, received higher returns from sale of their crafted wood

products, and improved their skills by belonging to a handicraft cooperative. Some of the problems identified in this study of a handicraft cooperative were the underutilization of fixed assets, the need for more business knowledge and improved training facilities for craftsmen. NC(1187).

649. A bibliography of current published information on Christmas tree production and marketing provides a means of quickly and easily locating up-to-date information on this industry. This information can assist Christmas tree producers, wholesalers, and retailers in making better decisions on production and marketing practices. NE(1189).

650. An analysis of the commercial potential of a new kiln-drying method for hardwood lumber involving presurfacing green lumber and kiln-drying on an accelerated schedule, showed several advantages. this new drying method, developed by the Forest Products Laboratory, reduces drying time by nearly one-half permits a higher kiln-capacity use, produces slightly lower lumber degrade loss, and reduces fuel and power costs. NE(1185).

651. Model building codes covering high-density, commercial sections of urban areas usually contain provisions for "fire districts," "fire limits," or "fire zones." Within such areas, construction materials and methods are closely regulated so as to minimize the danger of fire. Results from regional studies of fire zones review the purpose, use, and implications for construction methods and materials use. SE(1178-1181).

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