THE HARVARD FOREST, 1981-82

Harvard University

Frontispiece: The shelterwood cutting in Prospect Hill Tract IX, looking west. From left to right: Ernie Gould, Martin Zimmermann, Pete Hannah. *(Photographs in this report taken by Regula Zimmermann)*

ANNUAL REPORT OF HARVARD UNIVERSITY ACTIVITIES

AT THE HARVARD FOREST 1981-82

STAFF

Karen Balzano, Laboratory Aide (September 1, 1981 - June 18, 1982)
Alison M. Berry, Research Assistant
Elizabeth J. Burkhardt, Laboratory Technician (until September 5, 1981)
Robert J. Cartica, Research Assistant (until December 31, 1981)
Catherine M. Danahar, Business Secretary and Librarian
Wayne E. Elliott, Custodian
Frank W. Ewers, Cabot Research Fellow (from January 15, 1982)
Mark Fontaine, Research Assistant (from March 22, 1982)
Ernest M. Gould, Jr., Forest Economist, Senior Lecturer in Biology
Peter R. Hannah, Bullard Fellow (from October 12, 1981)
Edward H. Hyde, Woods Crew
Jack J. Karnig, Forest Manager
Susan Lancelle, Research Assistant
Shirley LaPointe, Greenhouse Assistant
Susan Lindgren, Research Assistant (from January 1, 1982)
Ralph L. Lundquist, Research Assistant
Monica R. Mattmuller, Research Assistant
Donald C. Mitchell, Assistant to the Manager of the Black Rock Forest
Gordon B. Mitchell, Woods Crew Superintendent
Marcia A. Murry, Post-doctoral Fellow (NIH) (from April 1, 1982)
Dennis Newbanks, Cabot Research Fellow (until July 31, 1981)
Frances E. O'Brien, Secretary
Frances N. Phillips, Secretary
Hugh M. Raup, Charles Bullard Professor of Forestry, *Emeritus*
Dibyendu N. Roy, Bullard Fellow (until July 31, 1981)
Christa R. Schwintzer, Cabot Research Associate
Dorothy R. Smith, Secretary
Charles C. Spooner, Woods Crew
John D. Tjepkema, Associate Professor of (Soil) Biology
P. Barry Tomlinson, Professor of Botany
John G. Torrey, Professor of Botany
Jeffrey R. Vincent, Research Assistant (from August 1, 1981)
George J. Wilder, Visiting Scholar (Cabot Foundation)
Lawrence J. Winship, Research Assistant
Patricia H. Young, Laboratory Aide
Stefan Zajaczkowski, Bullard Fellow (until November 10, 1981)
Martin H. Zimmermann, Charles Bullard Professor of Forestry and
Director of the Harvard Forest

In the spring of 1981 the Fairchild Tropical Garden awarded Barry Tomlinson the Robert H. Montgomery Founders Medal "For Distinguished Achievement in the World of Palms and Cycads." Barry was the first person to carry on a scientific research program at the Fairchild Garden during the years 1959 - 1971 until he became a professor at Harvard.

Dennis Newbanks left us on July 31, 1981 and established his own consulting firm for tree care in Maine. He was replaced in January 1982 by Frank Ewers, a plant anatomist who obtained his PhD degree with Rudi Schmid at the University of California at Berkeley. With him came Marcia Murry, his wife. She is working on nitrogen fixation in John Torrey's laboratory on an NIH grant.

John Tjepkema and Christa Schwintzer will leave us at the end of July 1982. John has accepted the position of Assistant Professor at the University of Maine in Orono, and Christa (his wife) has obtained a faculty position there as well. -- Larry Winship will also leave us; he has accepted the position of Assistant Professor of Botany at Hampshire College in Amherst, beginning fall 1982.

STUDENTS

The following courses were taught in Cambridge by our staff members. During the fall term John Torrey gave *Plant Growth and Development* (Biol. 165), Ernie Gould and Martin Zimmermann gave *Trees, Forests and Man* (Biol. 101). Martin Zimmermann participated in *Diversity in the Plant Kingdom* (Biol. 18). In the spring, John Tjepkema offered *Soil Biology and Ecology* (Biol. 108) and John Torrey gave the *Freshman Seminar on Plant Propagation* with Conrad Smith. The latter course has been given for the eighth year and the class always makes one or two field trips to the Harvard Forest.

The *Harvard Forest Freshman Seminar*, a joint effort of Ernie Gould, Christa Schwintzer, John Tjepkema and Martin Zimmermann, was given again on four weekends at the Harvard Forest. For this purpose, we pick up the students on Friday afternoon and bring them back to Cambridge on Sunday afternoon.

Barry Tomlinson, in collaboration with Jack Fisher of the Fairchild Garden, taught *Plants of the Tropics* (Biol. S-105). This course is offered under the auspices of the Harvard Summer School at the Fairchild Tropical Garden in Miami June - July 1982.

The following students took independent study courses during the past year. Daniel Potter took Biol. 90r with Martin Zimmermann, working on his undergraduate thesis entitled *Distribution of Vessel-Length in Acer rubrum L. : Variations within One Tree*. The research was done during the summer of 1981 and is described in last year's report. Jeff Vincent worked on *The Impact of the White Mountain National Forest Timber* (Biol. 299r) with Ernie Gould. Ann Bublitz took *Soil Biology* (Biol. 337) with John Tjepkema; John Sperry took *Tree Structure and Physiology* (Biol. 311) with Martin Zimmermann, and Deborah Marvel took *Plant Morphogenesis and Physiology* (Biol. 308) with John Torrey.

The Freshman Seminar Class of Spring 1982. *From left to right, back row:* John Klingensmith, Ernie Gould; *center row:* Jacqueline Courteau, Jane Licciardello, Gregory Sprick, Richard Frank; *front row:* Helene Guerin, Martin Zimmermann, John Tjepkema; *bottom:* Joan Cunningham.

Ann Lewis

Jeff Vincent

Ann Lewis completed her Master of Forest Science thesis entitled *Vascular Connections Between Roots and Shoots of Acer rubrum Coppice Growth and Implications for Management*. Dye applications in 45-year-old red maple stump sprouts showed that a sprout remaining after all other sprouts were removed from the stump could use all or almost all of the root system, whereas, a sprout growing in association with other sprouts on a stump generally used a smaller portion of the root system. The results indicate that the xylem sap flow followed the presumed gradients of decreasing pressures caused by transpiration, and that cambial reorientation after injury may be controlled by factors other than auxin alone.

Two (PhD) graduate students do their work primarily in Cambridge. Deborah Marvel is based in the Biological Laboratories, courtesy of Fred Ausubel, although John Torrey is her thesis sponsor. Ann Bublitz, graduate student whose work was jointly sponsored by John Tjepkema and Robert Cook, finishes her degree work in the summer of 1982. Her thesis title is *Ecological Physiology of Lathyrus japonicus: Nitrogen Fixation, Growth and Water Relations*.

John Sperry moved to the Forest at the end of the fall semester. His thesis work concerns the hydraulic architecture of tropical trees; it is jointly sponsored by Barry Tomlinson and Martin Zimmermann. -- Jim LaFrankie arrived at the Harvard Forest in May to begin a summer's research on the comparative ecology of the genus *Smilacina* under the direction of Otto Solbrig. He is also studying the comparative morphology of that same genus with Barry Tomlinson.

Three students seeking PhD degrees in the Botany Department of the University of Massachusetts in Amherst are working full time in the laboratories at the Harvard Forest under the supervision of John Torrey. Alison Berry plans to finish her thesis research on symbiotic nitrogen fixation and nodulation in *Alnus rubra*, during the summer of 1982. Kathryn VandenBosch is studying host-microorganism incompatibilities, using *Comptonia* and *Myrica* infected by different strains of *Frankia*. Mary Lopez is concerned with the identification and localization of the lipid components in cultured *Frankia* in relation to the physiological function of the actinomycete and perhaps its identify.

In his association with Hampshire College as Faculty Associate, John Torrey served as advisor to Carol Whaling on her undergraduate Division III thesis entitled *Studies of the Lipids of Frankia, a Genus of Nitrogen-fixing Bacteria*", work done collaboratively with Mary Lopez. Carol was in residence in Shaler Hall for the fall term 1981. Dr. Torrey served as a member of Michael Blayney's Division III thesis committee. His research was on *Morphological Studies of the Endorhizal Actinomycete Frankia in Defined Medium Culture*. Arthur Simmons and Michael Blayney cooperated in a summer project at the Harvard Forest on the effect of moisture gradients on the growth of *Alnus incana* spp. *rugosa*.

MEETINGS AND VISITORS

Clark Binkley again brought his class from Yale for a weekend at Harvard Forest. The Landscape Architecture Department from the School of Design also spent the better part of a week in Petersham, using our facilities for short courses and orientation to the region. Many classes from other colleges visited the museum and used the Forest as an example of well-documented land use history.

We again had visitors from all over the world, too numerous to list. Many groups held their regular meetings at the Harvard Forest as they did in previous years.

BULLARD FELLOWS

Peter R. Hannah, Professor of Forestry at the University of Vermont, prepared a comprehensive narrative review of most of the literature on use of the shelterwood method throughout the United States and eastern Canada. Following this review, he visited with many researchers studying the effectiveness of shelterwoods in a variety of forest types and observed their field studies.

The shelterwood method has been a recognized silvicultural practice to regenerate forest stands for over a century but it has not been widely used in the United States. In management of small woodland parcels common in the eastern United States, it affords esthetic benefits in addition to the silvicultural advantages of more continuous seed supply and possible control of competing vegetation with overhead shade.

It is possible that the shelterwood method will be useful in obtaining seedling regeneration of red oak. Red oak is an important species at the Harvard Forest but many mature oak stands have little oak regeneration underneath and may be replaced by red maple. During the spring of '82, Peter Hannah installed two small shelterwood cuts in PH IX in a red oak-mixed hardwood stand with about 100 ft^2 of basal area. One portion was reduced to 45 ft^2 of basal area and another to 75 ft^2. Regeneration on permanent plots will be compared with the uncut area. In another stand, mostly of oak, red maple and white birch, with many small oak seedlings already present in the understory, the oaks will be retained in the overwood to produce more seed and increase their growth and value while the response of existing regeneration will be studied. Browsing by deer and rabbits may be part of the regeneration problem and these impacts will be observed by erecting small animal exclosures.

RESEARCH

Ernie Gould had a busy year with the Massachusetts Forest Resources Advisory Committee. The major outlines of a state plan have been completed and the first draft should appear this fall, ready for public comment. -- Although the National Forest System Advisory Committee has been discontinued, Ernie has kept in touch with USFS planning people and progress on the White Mountain National Forest. This is a fine chance to study how micro computer capabilities can be used to help the District Forester improve his day-to-day use of resources through more effective planning. Dispersed computer capacity gives us a new chance to help grass roots managers explore opportunities.

Barry Tomlinson, on study leave during the fall semester, did some field work in Queensland and New Caledonia, with emphasis on mangroves and monocotyledons. On return to Petersham two major writing projects were initiated. First was a survey of the botany of mangroves which is designed to prepare a reliable background for the ecological work which is being carried out in this economically important vegetation type. Here the herbarium and library resources in Cambridge proved enormously beneficial. The second project is a book on the developmental morphology and anatomy of palms, again a group of considerable economic importance. Knowledge of the structure and development of palms is incomplete, scattered and often inaccessible to the research worker. The survey will attempt to condense and analyze available information, much of it derived from comparative studies which have been a continuous activity for the past twenty-five years in collaboration with several investigators, most continuously with Martin Zimmermann.

Attempts are also being made to integrate structural, developmental and functional studies of the palm crown. Jeff Vincent completed a three-dimensional analysis of the distribution of the developing conducting tissues in the crown of *Rhapis*, using serial sections prepared as the result of earlier studies. From this it became clear that significant information was to be obtained only in the somewhat older but still extending regions. A start was made in Petersham, using greenhouse-grown plants, but continued in Miami in

June where abundant material was at hand. This was done in close collaboration with John Sperry whose graduate research is concentrated on hydraulic aspects of shoot development, expressed in the changing ability of a leaf to demand water from the available stem supply.

Barry Tomlinson confirmed an earlier observation that in monocotyledons with secondary growth, tracheids occur in both secondary and primary tissues; the reason for this correlation is not clear. The vascular anatomy of the monocotyledonous treelet *Lomandra insularis* was deciphered, using material collected in New Caledonia. A survey of the vascular architecture of the tropical family Araceae being conducted with James French at Mississippi State University was completed with the preparation of the final paper in the series, cited in the Bibliography.

George Wilder is undertaking a study of systematic anatomy of the monocotyledonous family Cyclanthaceae. This work is intended not only to provide further knowledge of this subject per se, but also to help better understand the relationships of the different cyclanthaceous genera with one another. In collaboration with Rolf Dahlgren and Gunnar Harling he is preparing a review of the family Cyclanthaceae for a book entitled *The Families and Genera of Flowering Plants*.

Martin Zimmermann, in collaboration with Monica Mattmuller, continued the work on the hydraulic architecture of the palm *Rhapis excelsa*. Our attention is now concentrated on the xylem connection between leaves and the stem. The palm is constructed in such a way that xylem pressures are always much lower in the leaves than in the stem when water moves. This means that under extreme stress conditions, the palm may lose the leaves, but would probably not lose the stem. The stem xylem (water conducting system) is made only once in a palm and has to remain functional throughout the life of the plant. (In contrast to this, our temperate trees continuously produce new wood, thereby growing thicker.) This work is being continued by John Sperry who spent the early part of the summer at the Fairchild Tropical Garden where he had ample material for these investigations.

The two films which explain the vascular structure and developmental pattern of the palm stem have finally been published and are now available throughout the world (see the Bibliography).

The work on xylem dysfunction due to infection, started by Dennis Newbanks last year, continues. We are now trying to see if the fungal hyphae of *Verticillium* are able to penetrate vessels of sugar maple stems without causing cavitation. A similar question is investigated in collaboration with Robert Goodman of the University of Missouri by studying a disease caused by the bacterium *Erwinia amylovora* in apple trees.

Martin Zimmermann has spent a good part of his time writing a book entitled *Xylem Structure and the Ascent of Sap*. This will appear in the Springer Series in Wood Science, hopefully next year.

Frank Ewers is working with Martin Zimmermann on problems of functional xylem anatomy. His work has so far centered on xylem dysfunction and resistance to dysfunction in relation to winter freezing. It is known that large vessels, which occur in ring-porous species such as oaks and ashes, are more

John Sperry

Frank Ewers

susceptible to xylem dysfunction via vapor blockage than are the shorter and narrower elements of diffuse porous dicotyledons and (nonporous) conifers. To learn why this is the case we froze and thawed water in different size capillary tubes to observe the formation and dissolution of air bubbles (air is not soluble in ice, which is the reason for air bubbles in ice cubes). In long and wide tubes (e.g. 400 μm x 12 cm) large bubbles are formed upon thawing which can take several days to dissolve. The large bubbles (e.g. greater than 400 μm) result from the condensation of tiny, microscopic bubbles. In small tubes (e.g. 30 μm x 7 mm) the tiny bubbles can dissolve in a matter of minutes; they do not coalesce to the extent they do in the larger tubes. Therefore vapor blockage (embolization) is less likely to occur following freezing in short and narrow elements than in long and wide tubes. This is due merely to the size of the "container". Other wood anatomical features, such as scalariform perforation plates, warty layers, or helical thickenings, each of which act to keep the tiny bubbles separated while they quickly dissolve, can also help prevent vapor blockage in certain species. In ring-porous species the long and wide vessels which are extremely efficient for water conduction, are "sacrificed" each winter. Thus, a new growth ring of large vessels must be produced in the early spring, before the leaves open. A better understanding of the mechanisms of "freezing tolerance" may have practical applications in forestry, agronomy and horticulture.

Research activities of the workers associated with John Torrey have been diverse, unified by a central interest in the actinomycete *Frankia* and its symbiotic association with the roots of a diverse group of woody dicots. They continued to explore the process whereby the filamentous soil bacterium becomes associated with root hairs of the susceptible host, modifies the cell

wall, penetrates the cell and then invades root cortical cells. Another aspect of this association under study is the degree of success of the endophyte-host plant association. As in *Rhizobium*-legume associations, there are *Frankia* strains which cause root nodulation but fail to fix dinitrogen (ineffective); other strains produce effective root nodules (infective) on the host from which they were isolated but also on other host genera or even members of other families. Host susceptibility to such cross-inoculation remains a puzzle and a prime target for further research. Cultivation of *Frankia in vitro* occupied much energy with serious efforts being devoted to growing the organism on synthetic, defined media, to accelerating the rate of growth of the filamentous cultures, and to inducing differentiation of morphologically and physiologically distinct forms. Of particular interest was the induction of terminal vesicles, structures formed *in vitro* within which the enzyme nitrogenase forms. Research on the structure of vesicles led to a study of the lipid constitution of *Frankia* grown under different conditions. Still another subject was pursued in Cambridge by Deborah Marvel, using techniques developed in Fred Ausubel's laboratory for use with *Rhizobium*. Plasmids have been found to occur in *Frankia*, differing from strain to strain. Efforts are directed toward discovering whether genetic information which might be conveyed by these small pieces of DNA within the bacteria are involved in the nitrogen-fixing capacity of the organism.

John Tjepkema, with the aid of Bob Cartica and Susan Lindgren, continued his studies of the input of nitrogen to forests by the deposition of aerosols on leaf surfaces. The most abundant forms of nitrogen in these aerosols are probably ammonium nitrate and ammonium sulfate which arise from both air pollution and natural sources. The aerosols impact on leaf surfaces and are then washed into the soil by rainfall. The rates of deposition are being estimated by exposing washed leaves and simulated leaves of plastic to the atmosphere for various intervals, and then washing the accumulated aerosols from the surface. The measured nitrogen input to pine forests from this dry deposition of ammonia and nitrate is about equal to the input of nitrogen in precipitation and may be important in maintaining forest fertility.

Lawrence Winship, in collaboration with John Tjepkema, continued to study nitrogen fixation and root nodule respiration by actinorhizal plants, in particular, *Alnus rubra*. Using a root nodule gas exchange system developed here at Harvard Forest, he has been able to continuously monitor the function of intact, attached root nodules as they convert acetylene to ethylene, release hydrogen, and exchange oxygen and carbon dioxide during respiration. Since the nodules remain connected to fully functioning plants, long-term experiments have been possible, allowing a detailed examination of the effects of temperature, oxygen concentration and substrate availability on nodule function. He found that the energy cost of nitrogen fixation by nodules of *Alnus rubra* remains relatively constant over a wide range of temperature and oxygen conditions.

Christa Schwintzer continued her studies of the ecology of *Myrica gale* (sweet gale) in Tom Swamp with the help of Susan Lancelle. They found out that *Myrica gale* stems were shortlived, reaching a maximum age of 8 years. Most of the annual aboveground growth was due to stems (56%) and leaves (41%) with only 3% devoted to reproduction. The root nodules fixed about 30% of the plants' annual nitrogen requirement. The remainder of the nitrogen came

Left: Larry Winship and "Harvey", our computer. Larry spent a great deal of time selecting and assembling the best combination of hardware to serve our purposes. He was also indispensable in getting the right software and then making the whole ensemble work. "Harvey" is a real intellectual achievement.

Opposite: Putting firewood into the basement of Shaler Hall: Buzz Mitchell on the right, Bud Hyde on the left.

from the soil. The cost of nitrogen fixation was substantial with nitrogen fixation consuming about 8% as much carbon as was contained in the annual production. In a separate study of seedlings growing in moisture gradient boxes with controlled water tables, they found that nodule initiation and growth was highly dependent on soil moisture. Interestingly, the seedlings allocated 6-7% of their total biomass to nodules in the wettest soils but only 1% in the driest.

FOREST OPERATIONS

During the last year the woods crew cut about 37 cords of firewood, but spent only about ten percent of their time doing such operations. Most of their time was spent maintaining roads, trails, buildings, grounds, tools and equipment. We have started plans that will increase the time devoted to experimental cuttings next year, hoping to have considerably more wood to burn which will further reduce our oil bill for Shaler Hall.

The Tom Swamp I thinning continued into the fall, but is not finished yet. In the spring we started on a hardwood shelterwood cut that was laid out by Peter Hannah to explore the problems of getting red oak regeneration (see Bullard Fellows, pages 7-8). He also marked several other experimental cuttings that we will start next year.

HARVARD BLACK ROCK FOREST

As of June 25, 1982, Donald C. Mitchell retired from his position as assistant to the manager of the Forest. He was replaced by John Brady, who for the last two years, served as a contractor involved with thinning portions of our woods. Damian King, a college student, was hired on a temporary basis to assist John Brady. Both of these men will take care of maintenance work in the forest.

Remeasurements of silvicultural plots which we have monitored for almost fifty years continue. New tallies are made at five-year intervals; all living trees are kept painted with identifying numbers. A record is kept of any ingrowth and such trees are also numbered for addition to our tally.

Preparations have been made for an experimental harvest of mature overstory timber in Compartment IV at the upper Hulse Road. One ten acre block within a larger area which was heavily thinned in 1957-58 is to be treated, leaving an adjoining tract as control. All existing reproduction was carefully sampled prior to logging. A post-logging reproduction count will be made to accurately account for young trees destroyed during the process of log extraction. Short and long term impacts of this management technique will be of interest to silviculturists.

BIBLIOGRAPHY

The following articles have appeared in print during the fiscal year 1981-82.

Berry, A. M. and J. G. Torrey. 1981. Early stages in root hair infection of the actinorhizal plant, *Alnus rubra* Bong. Bot. Soc. Amer., Misc. Ser., Publ. 160: 3.

Callaham, D. A. and J. G. Torrey. 1981. The structural basis for infection of root hairs of *Trifolium repens* by *Rhizobium*. Can. J. Bot. 59: 1647-1664.

Dahlgren, R., G. Harling and G. J. Wilder. 1982. Cyclanthaceae. Monocot Newsletter, April 1982: 7-32.

French, J. C. and P. B. Tomlinson. 1981. Cinematographic analysis of the stem vasculature of the Araceae - subfamilies Calloideae and Lasioideae. Bot. Soc. Amer., Misc. Ser., Publ. 160: 10.

French, J. C. and P. B. Tomlinson. 1981. Cinematographic analysis of the stem vasculature of the Araceae - subfamilies Philodendroideae, Colocasioideae and Aroideae. Bot. Soc. Amer., Misc. Ser., Publ. 160: 10.

French, J. C. and P. B. Tomlinson. 1981. Vascular patterns in stems of Araceae: subfamily Monsteroideae. Amer. J. Bot. 68: 1115-1129.

French, J. C. and P. B. Tomlinson. 1981. Vascular patterns in stems of Araceae: subfamilies Calloideae and Lasioideae. Bot. Gaz. 142: 366-381.

French, J. C. and P. B. Tomlinson. 1982. Vascular patterns in stems of Araceae: subfamily Philodendroideae. Bot. Gaz. 142: 550-563.

Hirsch, A, M., W. L. Pengelly and J. G. Torrey. 1982. Endogenous IAA levels in boron-deficient and control root tips of sunflower. Bot. Gaz. 143: 15-19.

Honda, H., P. B. Tomlinson and J. B. Fisher. 1982. Two geometrical models of branching of botanical trees. Ann. Bot. 49: 1-11.

Lorimer, C. G. 1981. Survival and growth of understory trees in oak forests of the Hudson Highlands, New York. Can. J. For. Res. 11: 689-695.

Newbanks, D., D. N. Roy and M. H. Zimmermann. 1982. Dutch elm disease: what an arborist should know. Arnoldia 42: 60-69.

Raup, H. M. 1981. A collection of writings. See B. B. Stout (Ed.).

Sovonick-Dunford, S., D. R. Lee and M. H. Zimmermann. 1981. Direct and indirect measurements of phloem turgor pressure in white ash. Plant Physiol. 68: 121-126.

Stout, B. B. (Ed.). 1981. Forests in the here and now. A collection of writings of Hugh Miller Raup, Bullard Professor of Forestry, *Emeritus*, Harvard University. (131 pp.) School of Forestry, University of Montana.

Tjepkema, J. D. and R. J. Cartica. 1982. Diffusion limitation of oxygen uptake and nitrogenase activity in the root nodules of *Parasponia rigida* Merr. & Perry. Plant. Physiol. 64: 728-733.

Tjepkema, J. D., R. J. Cartica and H. F. Hemond. 1981. Atmospheric concentration of ammonia and ammonium in Massachusetts and deposition on vegetation. Nature (London) 294: 445-446.

Tjepkema, J. D., W. Ormerod and J. G. Torrey. 1981. Factors affecting vesicle formation and acetylene reduction (nitrogenase activity) in *Frankia* sp. CpIl. Can. J. Microbiol. 27: 815-823.

Tomlinson, P. B. 1982. Anatomy of the Monocotyledons. Vol. VII. Helobiae (Alismatidae). Clarendon Press, Oxford.

Torrey, J. G., J. D. Tjepkema, G. L. Turner, F. J. Bergersen and A. H. Gibson. 1981. Dinitrogen fixation by cultures of *Frankia* sp. CpIl demonstrated by $^{15}N_2$ incorporation. Plant Physiol. 68: 983-984.

Wilder, G. J. 1982. Inflorescence. Pages 130-132 in: McGraw-Hill Encyclopedia of Science and Technology. McGraw-Hill Book Co.

Wilder, G. J. and D. H. Harris. 1982. Laticifers in *Cyclanthus bipartitus* Poit. (Cyclanthaceae). Bot. Gaz. 143: 84-93.

Yang, Y. C. 1981. Forest resource inventory method in Taiwan. Pages 291-297 in: Proceedings of the 17th IUFRO World Congress, Tokyo, Japan, September 6 - 12, 1981.

Yang, Y. C. 1981. Forest management planning in Taiwan. Pages 383-389 in: Proceedings of the 17th IUFRO World Congress, Tokyo, Japan, September 6 - 12, 1981.

Yang, Y. C. and Feng, P. L. 1981. Bertalanffy's generalized growth function applied to stands of varying CCF. J. Jap. For. Soc. 63: 294-297.

Yang, Y. C. and Ying, T. H. 1981. Management and distribution of the main commercial bamboo species in the Chu-Shan area of Taiwan. Pages 111-119 in: Bamboo Production and Utilization. T. Higuchi (Ed.). Proceedings of the Congress Group 5.3A, Production and Utilization of Bamboo and Related Species, 17th IUFRO World Congress, Kyoto, Japan, September 6 - 12, 1981.

Zamski, E. 1981. Does successive cambia differentiation in *Avicennia* depend on leaf and branch initiation? Israel J. Bot. 30: 57-64.

Zamski, E. and A. Azenkot. 1981. Sugarbeet vasculature. I. Cambial development and the three-dimensional structure of the vascular system. Bot. Gaz. 142: 334-343.

Zimmermann, M. H. 1982. Functional anatomy of angiosperm trees. Pages 59-70 in: New Perspectives in Wood Anatomy. P. Baas (Ed.)., Nijhoff & Junk, The Hague, The Netherlands.

Zimmermann, M. H. 1982. Piping water to the treetops. Natural History 91 (7): 6-13.

Zimmermann, M. H. and A. A. Jeje. 1981. Vessel-length distribution in stems of some American woody plants. Can. J. Bot. 59: 1882-1892.

Zimmermann, M. H. and M. R. Mattmuller. 1982. The vascular pattern in the stem of the palm *Rhapis excelsa*. I. The mature stem. Film C 1404. (Film data and summary available as a reprint). Institut für den wissenschaftlichen Film, Nonnenstieg 72, 34 Göttingen, Germany.

Zimmermann, M. H. and M. R. Mattmuller. 1982. The vascular pattern in the stem of the palm *Rhapis excelsa*. II. The growing tip. Film D 1418. (Film data and summary available as a reprint). Institut für den wissenschaftlichen Film, Nonnenstieg 72, 34 Göttingen, Germany.

Zimmermann, M. H., K. F. McCue and J. S. Sperry. 1982. Anatomy of the palm *Rhapis excelsa*. VIII. Vessel network and vessel-length distribution in the stem. J. Arnold Arboretum 63: 83-95.

This is a list of publications which have appeared in print between July 1, 1981 and June 30, 1982. Publication lags one or more years behind the description of research in this report. Many of these publications are available as reprints. If you are interested in receiving any of these, please write to the Harvard Forest, Petersham, MA 01366, or where the address is given, directly to the authors.

Petersham, Massachusetts
August 1982

Martin H. Zimmermann
Director

HARVARD FOREST

To the Dean of the Faculty of Arts and Sciences:

Sir,--The following is a report on the Harvard Forest and the Harvard Black Rock Forest for the year ending June 30, 1982.

STAFF

In the spring of 1981 the Fairchild Tropical Garden awarded Barry Tomlinson the Robert H. Montgomery Founders Medal "For Distinguished Achievement in the World of Palms and Cycads". Barry was the first person to carry on a scientific research program at the Fairchild Garden during the years 1959 - 1971 until he became a professor at Harvard.

A number of courses were taught by members of the Harvard Forest staff, both in Cambridge and in Petersham, and students did independent work at the Forest.

STUDENTS

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Peter R. Hannah, Professor of Forestry at the University of Vermont, prepared a comprehensive narrative review of most of the literature on use of the shelterwood method throughout the United States and eastern Canada. Following this review, he visited with many researchers studying the effectiveness of shelterwoods in a variety of forest types and observed their field studies.

The shelterwood method has been a recognized silvicultural practice to regenerate forest stands for over a century but it has not been widely used in the United States. In management of small woodland parcels common in the eastern United States, it affords esthetic benefits in addition to the silvicultural advantages of more continuous seed supply and possible control of competing vegetation with overhead shade.

It is possible that the shelterwood method will be useful in obtaining seedling regeneration of red oak. Red oak is an important species at the Harvard Forest but many mature oak stands have little oak regeneration underneath and may be replaced by red maple. During the spring of '82, Peter Hannah installed two small shelterwood cuts in PH IX in a red oak-mixed hardwood stand with about 100 ft^2 of basal area. One portion was reduced to 45 ft^2 of basal area and another to 75 ft^2. Regeneration on permanent plots will be compared with the uncut area. In another stand, mostly of oak, red maple and white birch, with many small oak seedlings already present in the understory, the oaks will be retained in the overwood to produce more seed and increase their growth and value while the response of existing regeneration will be studied. Browsing by deer and rabbits may be part of the regeneration problem and these impacts will be observed by erecting small animal exclosures.

RESEARCH

Ernest Gould had a busy year with the Massachusetts Forest Resources Advisory Committee. The major outlines of a state plan have been completed and the first draft should appear this fall, ready for public comment. -- Although the National Forest System Advisory Committee has been discontinued, he has kept in touch with USFS planning people and progress on the White Mountain National Forest. This is a fine chance to study how micro

computing capabilities can be used to help the District Forester improve his day-to-day use of resources through more effective planning. Dispersed computer capacity gives us a new chance to help grass root managers explore opportunities.

John Tjepkema, with the aid of Robert Cartica and Susan Lindgren, continued his studies of the input of nitrogen to forests by the deposition of aerosols on leaf surfaces. The most abundant forms of nitrogen in these aerosols are probably ammonium nitrate and ammonium sulfate which arise from both air pollution and natural sources. The aerosols impact on leaf surfaces and are then washed into the soil by rainfall. The rates of deposition are being estimated by exposing washed leaves and simulated leaves of plastic to the atmosphere for various intervals, and then washing the accumulated aerosols from the surface. The measured nitrogen inputs to pine forests from this dry deposition of ammonia and nitrate is about equal to the input of nitrogen in precipitation and may be important in maintaining forest fertility.

Lawrence Winship, in collaboration with John Tjepkema, continued to study nitrogen fixation and root nodule respiration by actinorhizal plants, in particular, *Alnus rubra*. Using a root nodule gas exchange system developed here at Harvard Forest, he has been able to continuously monitor the function of intact, attached root nodules as they convert acetylene to ethylene, release hydrogen, and exchange oxygen and carbon dioxide during respiration. Since the nodules remain connected to fully functioning plants, long-term experiments have been possible, allowing a detailed examination of the effects of temperature, oxygen concentration and substrate availability on nodule function. He found that the energy cost of nitrogen fixation by nodules of *Alnus rubra* remains relatively constant over a wide range of temperature and oxygen conditions.

Christa Schwintzer continued her studies of the ecology of *Myrica gale* (sweet gale) in Tom Swamp with the help of Susan Lancelle. They found out that *Myrica gale* stems were shortlived, reaching a maximum age of 8 years. Most of the annual aboveground growth was due to stems (56%) and leaves (41%) with only 3% devoted to reproduction. The root nodules fixed about 30% of the plants' annual nitrogen requirement. The remainder of the nitrogen came from the soil. The cost of nitrogen fixation was substantial with nitrogen fixation consuming about 8% as much carbon as was contained in the annual production. In a separate study of seedlings growing in moisture gradient boxes with controlled water tables, they found that nodule initiation and

growth was highly dependent on soil moisture. Interestingly, the seedlings allocated 6-7% of their total biomass to nodules in the wettest soils but only 1% in the driest.

Many other research activities, including my own, have been supported by the Cabot and Atkins Foundations. These activities are described in those reports.

FOREST OPERATIONS

During the last year the woods crew cut about 37 cords of firewood, but spent only about ten percent of their time doing such operations. Most of their time was spent maintaining roads, trails, buildings, grounds, tools and equipment. We have started plans that will increase the time devoted to experimental cuttings next year, hoping to have considerably more wood to burn which will further reduce our oil bill for Shaler Hall.

The Tom Swamp I thinning continued into the fall, but is not yet finished. In the spring we started on a hardwood shelterwood cut that was laid out by Peter Hannah to explore the problems of getting red oak regeneration (see Bullard Fellows). He also marked several other experimental cuttings that we will start next year.

HARVARD BLACK ROCK FOREST

As of June 25, 1982, Donald C. Mitchell retired from his position as assistant to the manager of the Forest. He was replaced by John Brady, who for the last two years, served as a contractor involved with thinning portions of our woods. Damian King, a college student, was hired on a temporary basis to assist John Brady. Both of these men will take care of maintenance work in the forest.

Remeasurements of silvicultural plots which we have monitored for almost fifty years continue. New tallies are made at five-year-intervals; all living trees are kept painted with identifying numbers. A record is kept of any ingrowth and such trees are also numbered for addition to our tally.

Preparations have been made for an experimental harvest of mature overstory timber in Compartment IV at the upper Hulse Road. One ten acre block within a larger area which was heavily thinned in 1957-58 is to be treated, leaving an adjoining tract as control. All existing reproduction was carefully sampled prior to logging. A post-logging reproduction count will be made to accurately account for young trees destroyed during the process of log extraction. Short and long term impacts of this management technique will be of interest to silviculturists.

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Director