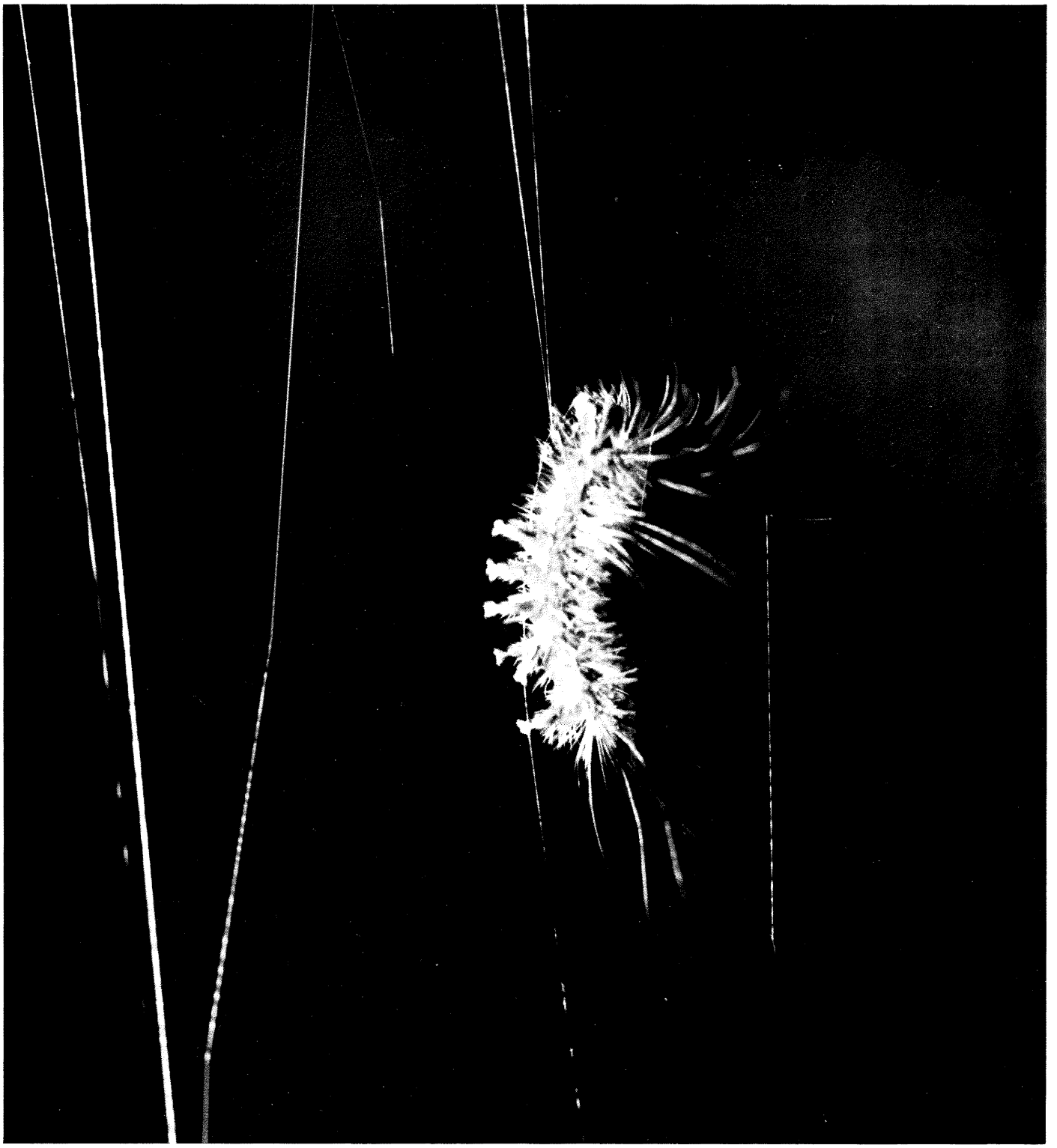
# THE HARVARD FOREST, 1980-81

Harvard University



*Frontispiece: Newly hatched larva of the Gypsy Moth. It is about 2 mm (less than 1/10") long at this stage. Dangling on their threads, they are easily blown over considerable distances by the wind. Gypsy Moth infestation was bad in 1980 and worse in 1981 in Petersham as well as at the Black Rock Forest. By mid-June 1981 all oaks, as well as some other species, were completely defoliated so the woods looked almost like early spring. At the time of this writing, (July 1981) the trees are producing new leaves.*

# ANNUAL REPORT OF HARVARD UNIVERSITY ACTIVITIES

# AT THE HARVARD FOREST 1980-81

## STAFF

Alison M. Berry, Research Assistant
Elizabeth L. Burkhardt, Laboratory Technician (from October 1, 1980)
Robert J. Cartica, Research Assistant
Catherine M. Danahar, Business Secretary and Librarian
Lynn D. Disney, Research Assistant (until July 31, 1980)
Wayne E. Elliott, Custodian
Abraham Fahn, Bullard Fellow (from January 1, 1981)
Ernest M. Gould, Jr., Forest Economist, Senior Lecturer in Biology
David E. Hibbs, Research Fellow in Silviculture (until May 31, 1981)
Vibeke L. Holm, Assistant to the Librarian
Edward H. Hyde, Woods Crew
Ayodeji A. Jeje, Visiting Scholar (until August 31, 1980)
Jack J. Karnig, Forest Manager
Susan Lancelle, Research Assistant (from August 15, 1980)
Shirley LaPointe, Greenhouse Assistant
K. Alan Longman, Bullard Fellow (until September 30, 1980)
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
Dennis Newbanks, Cabot Research Fellow
Frances E. O'Brien, Secretary
William S. Ormerod, Research Assistant (until December 31, 1980)
Frances N. Phillips, Secretary
Hugh M. Raup, Charles Bullard Professor of Forestry, *Emeritus*
Dibyendu N. Roy, Bullard Fellow
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
Lawrence J. Winship, Research Assistant
Yong-Chi Yang, Bullard Fellow (from September 15, 1980)
Patricia H. Young, Laboratory Aide
Stefan Zajączkowski, Bullard Fellow (from November 12, 1980)
Martin H. Zimmermann, Charles Bullard Professor of Forestry and
Director of the Harvard Forest

Ernie Gould continued to serve on the National Forest System Advisory Committee for the Secretary of Agriculture. He became Chairman of the Massachusetts Forest Resource Planning Committee which is developing a state forest plan.

John Torrey was among 60 new members of the National Academy of Sciences who were elected on April 28, 1981 in recognition of their distinguished and continuing achievements in original research. Membership in the Academy, which reached 1,352 after the last election, is considered one of the highest honors that can be accorded an American scientist or engineer.

David Hibbs left us on June 1, to take up a position at the University of Connecticut where he will develop management guidelines for small woodlands in Connecticut.

## STUDENTS

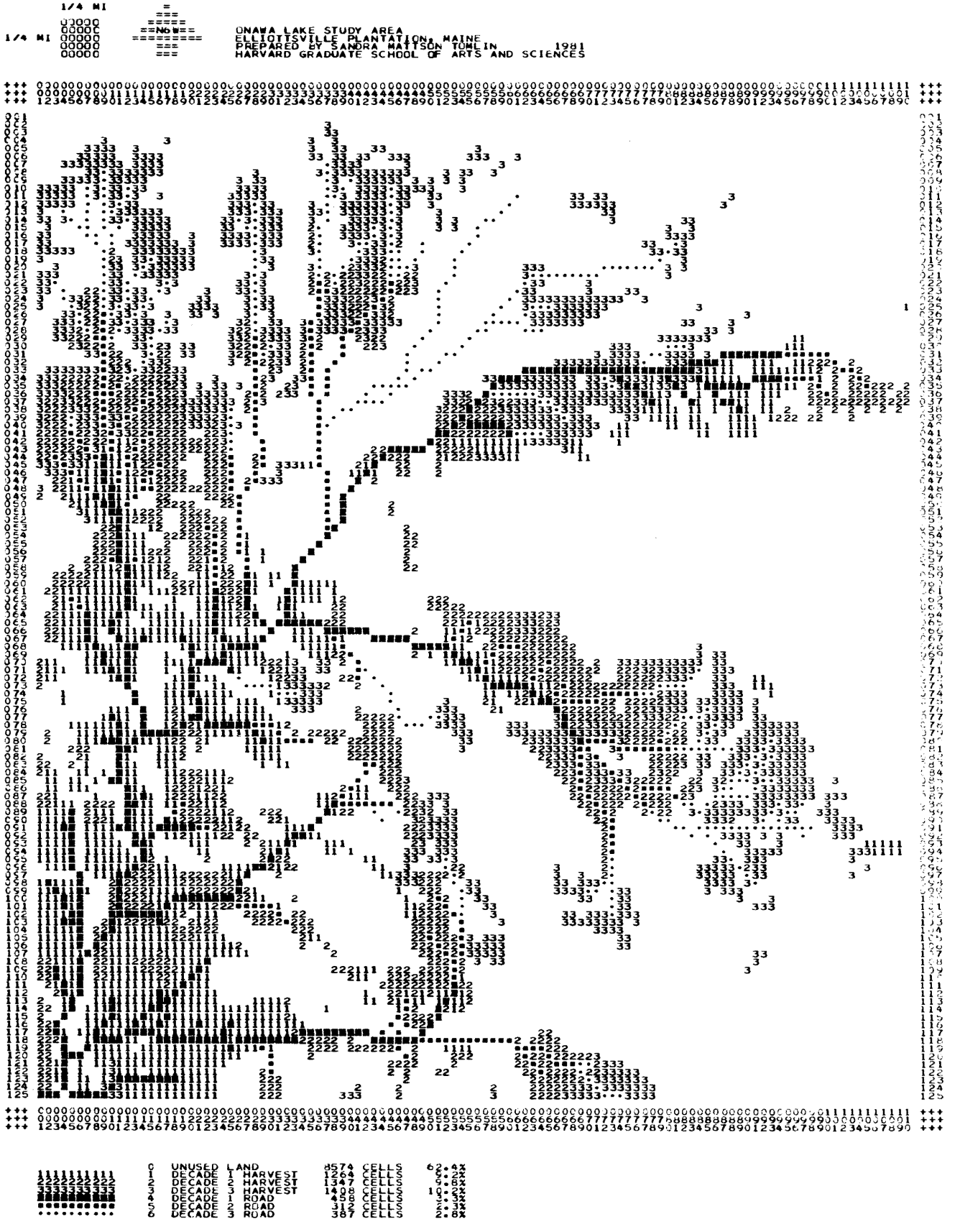
The following courses were taught in Cambridge by our staff members. During the fall term Barry Tomlinson gave *Biology of Gymnosperms* (Biol. 102). In collaboration with other faculty members, he offered *Diversity in the Plant Kingdom* (Biol. 18). Martin Zimmermann gave *Structure and Physiology of Trees* (Biol. 111). In the spring, John Tjepkema gave *Soil Biology and Ecology* (Biol. 108), John Torrey *Roots and Rhizosphere* (Biol. 215) and, with Conrad Smith, the Freshman Seminar *Plant Propagation.* Barry Tomlinson gave *Plant Form and Structure* (Biol. 168).

Two courses, one in the fall, the other in the spring, were taught at the Harvard Forest on four weekends. We picked up Cambridge students on Friday afternoons and brought them back on Sunday afternoons. They were, in the fall, *Soil, Land and Human Environment* (Biol. 298), given by Ernie Gould, John Tjepkema and Christa Schwintzer and, in the spring, the *Harvard Forest Freshman Seminar,* a joint effort of us all.

Barry Tomlinson, in collaboration with Peter Stevens of the Arnold Arboretum, taught *Plants of the Tropics* (Biol. S-105) under the auspices of the Harvard Summer School at the Fairchild Tropical Garden in Miami (June 16 - July 13, 1981). In addition he participated in a February course of the Organization for Tropical Studies in Costa Rica.

The following students took independent study courses during the past year. Jeff Vincent worked on *Long-term Forest Planning utilizing the computer* (Biol. 299r) with Ernie Gould. Kent McCue took two units of Biology 90r (fall and spring) with Martin Zimmermann and wrote a senior thesis entitled *Xylem-Vessel Connections and Water Conduction; the Physiological Significance of the Vascular Constriction at the Leaf Insertion.* Ann Bublitz took *Soil Biology* (Biol. 337, John Tjepkema); Deborah Marvel, Calvin Sperling and John Sperry enrolled in *Plant Morphogenesis and Physiology* (Biol. 308, John Torrey); John Sperry took *Tree Structure and Physiology* (Biol. 311, Martin Zimmermann).

FIGURE 38: HARVEST PLAN Overlay



Sandra M. Tomlin completed a M.F.S. thesis entitled *Timber Harvest Scheduling and Spatial Allocation.* Timber harvesting schedules and a haul road transportation plan were designed to economize returns over time from a 22,000 acre parcel of forest land in central Maine. Methods involved the use of a mathematical model to represent timber production and harvesting dynamics, a numerical optimization technique to generate harvesting schedules, and a computer-based geographic information system to spatially allocate harvesting activities. The illustration on page 5 shows the final overlay of "Sam's" thesis which summarizes her management plan. She received her degree in June 1981.

For a number of years, Alison Berry has been working toward a Ph.D. at the Botany Department of the University of Massachusetts, with her research done here at the Forest in John Torrey's laboratory. This year two new University of Massachusetts students have joined the group to work on actinorhizal plants with John Torrey. They are Mary Lopez and Kate VandenBosch.

Two forestry students from Europe spent the summer of 1981 at the Harvard Forest participating in various phases of our work. Arjen Bosch, a student of Roelof Oldeman of Wageningen, Netherlands, arrived on May 4, 1981. Martin Winkler, a student of the Swiss Federal Institute of Technology, arrived on July 7, 1981. Daniel Potter (Harvard 1982) is helping with the work in the laboratory of Martin Zimmermann during the summer.

## YALE - HARVARD JOINT PROGRAM

Professor Binkley again brought his Yale class in forest management decision making to the Forest for a visit. The Harvard Forest and the Yale School of Forestry and Environmental Studies agreed to exchange library catalogs and information on new acquisitions. This is possible because both of the libraries are using the same computer program to create listings of their library contents.

## MEETINGS AND VISITORS

The Forest is well equipped as a place to hold small meetings. With a limited number of comfortable dormitory accomodations in peaceful and pleasant surroundings, it makes an ideal place for a few days of serious discussion and the exchange of ideas. We had the usual number of people use these facilities including visitors from all over the world, too numerous to list.

During the first half of 1981, Brayton Wilson, Professor at the Department of Forestry and Wildlife Management of the University of Massachusetts, spent much of his time here while on sabbatical leave. He prepared papers and lectures on apical control and on root growth, mapped the distribution of mountain laurel, and set up experiments on the movement of branches in white ash, black cherry and red maple. He was on the Cabot Foundation staff here at the Forest during 1961-67.

## BULLARD FELLOWS

K. Alan Longman, Principal Scientific Officer at the Institute of Terrestrial Ecology's Research Station near Edinburgh, Scotland, continued his research on flower induction during the summer of 1980. (see last year's report). During the spring of 1981 he returned for a month to the Arnold Arboretum as a Mercer Fellow and visited the Forest for a number of days to record the results of last year's experiments. Ringing induced profuse flowering in yellow birch (*Betula alleghaniensis*) and elm (*Ulmus americana*). Additional experiments were set up with 20 other species at the Arnold Arboretum, the National Arboretum in Washington, D. C. and the Harvard Forest. Experiments with conifers were also successfully continued.

Abraham Fahn, Professor of Botany at the Hebrew University in Jerusalem, Israel, used his time here to study the stems of *Atriplex halimus* L. (Chenopodiaceae), a plant with anamolous secondary thickening. The secondary body of this plant consists of a ground tissue with scattered vascular bundles in it. The development of secondary growth was studied with our methods of cinematographic analysis. The first extra-fascicular cambial strands are initiated in continuation of the still active intrafascicular cambia of the primary vascular bundles by extensions that overarch neighboring bundles. Additional successive cambia appear similarly in continuation of preceding still-active cambia. All "vascular bundles" form a continuous network originating from primary bundles of the leaf bases.

Professor D. N. Roy, an organic chemist and Professor of Forestry at the University of Toronto, is primarily interested in synthesizing therapeutic chemicals to be used to control the Dutch elm disease. He spent his time here studying the distribution of chemicals applied to trees. Inadequate distribution often results from improper injection. Firstly, elm is a ring-porous species which conducts water in the most recently formed, wide, earlywood vessels. In order to understand the distribution of chemicals in trees, the occurrence and mechanism of xylem dysfunction with regard to both injection and fungal colonization were studied. Experiments were made with healthy and diseased elm branches and seedlings using dye ascent (an oxydizing agent followed by the leucobase of acid fuchsin) and cinematographic analysis. (See also the description of the work by Dennis Newbanks under *Research*).

Yong-Chi Yang, Professor of Forest Mensuration and Forest Biometry of the Department of Forestry, National Taiwan University, worked on models to describe the growth and density of even-aged forest stands. He used data from remeasured permanent point sample plots that had been established throughout red pine plantations in the Harvard Forest. He also completed a paper on forest management planning and resource inventory methods for IUFRO (International Union of Forestry Research Organizations). Other research included a plan for the management of bamboo forests to obtain sustained yield. The optimum management path was achieved by linear programming on the Harvard Forest's computer. -- He also translated *Timber Management Plans*, published by the United States Forest Service, into Chinese, for the Taiwan Forestry Bureau.

Stefan Zajączkowski, Docent (Associate Professor) at the Agricultural University in Warsaw, Poland, is interested in the regulatory systems responsible for morphogenetic control in plants, primarily trees. A dominant role in the proposed control system is ascribed to oscillatory phenomena involved in the polar transport of auxin that result in supracellular auxin waves. In Poland he studied in collaboration with Professor Tomasz Wodzicki (Bullard Fellow 1966-67) auxin waves experimentally; here he approached the problem from a more theoretical angle. The paths of vessels, as shown by cinematographic analysis, are subjected to Fourier analysis. Apical control in trees and configuration of morphogenetic fields in the main stem and branches were studied by computer analysis.

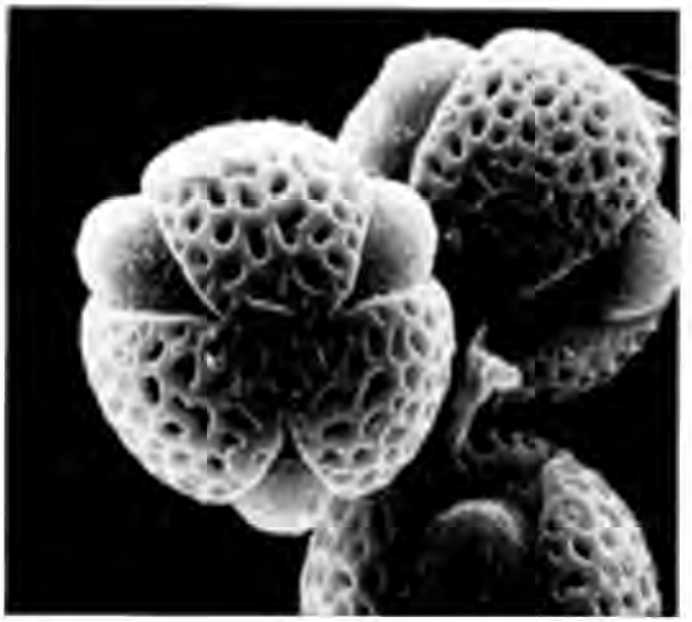
## RESEARCH

Ernie Gould continued his research on forest land planning. Now that the Forest has a mini-computer it is possible to write programs that considerably speed up some of our commonly used analyses and develop wholly new programs in other fields. One of the first efforts has been to develop programs for solving IRAM forest planning models. These make it possible to generate forest production profile estimates for 10 or more decades into the future. Linear programming and other rules such as "cut the heaviest stocked stands first" can be used. This work will not only aid research, but also will enrich our teaching.

David Hibbs completed his study of the growth of isolated white pines in the hardwood forest. Following a large disturbance that regenerates both pine and hardwoods, most pine seedlings are soon suppressed under the faster growing hardwoods. However, occasional pines do manage to avoid this early suppression for a variety of reasons. These compete successfully with the hardwoods. In the long run they become emergents, towering over the surrounding hardwood forest. -- During a brief trip to the Fairchild Tropical Garden in mid-winter, David completed a manuscript with Jack Fisher on the architectural plasticity of *Terminalia* and made some light studies within the canopy of *Terminalia*.

Barry Tomlinson's work has turned towards a detailed investigation of the vascular anatomy of stems in the tropical family Araceae (the Jack-in-the-pulpit family), in collaboration with James C. French (now of the Mississippi State University). The results have been written up in a series of publications. The survey is being extended to a study of the developmental aspects of shoot morphology, in part using local representatives of the family (e.g. *Calla, Symplocarpus*). Additional work has been concerned with the range of those anatomical characters which reflect biochemical diversity in the family.

A survey of pollen morphology in mangrove plants, using the scanning electron microscope, was begun. Particular emphasis was given to *Avicennia*, which is a somewhat problematical genus because of its abundance and wide distribution. Species do seem to differ appreciably in pollen wall sculpturing. A map of the distribution of *Rhizophora* species, based largely on herbarium records, was completed.



Pollen grains of
*Avicennia eucalyptifolia*.
Magnified 2000 times.

The survey of vessel-length distribution in some of our common woody species has been completed in Martin Zimmermann's laboratory. In our ring-porous tree species, where vessels are very wide, they are also very long; the longest ones almost as long as the stem itself. In trees with narrow vessels like our diffuse-porous species, the vessels are less than a meter long. There appears to be a strong correlation between vessel length and width. This is true even within the growth rings of diffuse-porous trees where the very slightly wider earlywood vessels are longer than the narrower latewood vessels. But the most significant finding was that there are always many more short than long vessels. During the summer of 1981, the study is concentrating on a single species, red maple. This work, done mostly by Daniel Potter, has shown that vessel length increases from twigs to branches and downwards along the stem; the longest vessels are in the rope-like roots.

We are also studying the vessel structure of palms in order to learn more about sap transport in these plants. Using existing films of *Rhapis*, a palm whose vascular structure we investigated in much detail years ago, we analyzed the vessel network. This was done by Martin Zimmermann, Monica Mattmuller and Kent McCue. For the latter, the work was part of an undergraduate thesis.

Dennis Newbanks is interested in wilt disease physiology. The question he is trying to answer is whether embolism plays a role in xylem dysfunction in Dutch elm diseased American elms and Verticillium-wilt diseased sugar maples. This is important to know if one wishes to understand disease progression and to apply successful therapeutic treatment (see the report about D. N. Roy's work under *Bullard Fellows*). Dennis has the plants take up dye solution from vacuum; the dye track is then followed by cinematographic analysis, and embolized vessels become visible. Conductivity experiments with pathologically affected stems have traditionally been made with cut pieces, but this technique releases the normal negative pressure of the xylem and gives false results due to capillarity. Dye uptake experiments from vacuum can avoid this problem.

*Above: Dennis Newbanks with his appartus which permits plants to take up dye solution from vacuum.*

*Above: Christa Schwintzer and Susan Lancelle taking soil samples from the moisture gradient box. Below: Elizabeth Burkhardt mounting microtome sections.*

Christa Schwintzer completed two field studies of the ecology of *Myrica gale* (sweet gale) in Tom Swamp with the help of Susan Lancelle. Together with John Tjepkema they examined the seasonal pattern of the energy cost of nitrogen fixation by root nodules. The energy required for nitrogen fixation is supplied by the plant to the root nodules in the form of carbon compounds derived from photosynthesis. Consequently, the nodules compete with other plant processes for carbon compounds. The consumption of carbon compounds by nodules ($CO_2$ evolved) and nitrogen fixation (acetylene reduced) were measured from mid-May through late October. As expected, the energy cost was high at the onset and cessation of nitrogen fixation but was much lower during the rest of the growing season. The overall seasonal value was 5.1 $CO_2/C_2H_4$. This is relatively low and compares favorably with energy costs measured in other actinorhizal and legume nodules. -- The effect of water table depth on the growth of *Myrica gale* seedlings was examined in moisture gradient boxes with controlled water tables located out-of-doors but sheltered from rain. The seedlings did not tolerate permanently waterlogged conditions but grew best in very wet soils just above the water table. They also grew surprisingly well on the driest end of the gradients.

Christa Schwintzer and John Tjepkema attended the Fourth International Symposium on Nitrogen Fixation in Canberra, Australia, where they presented aspects of their work (abstracts in *Bibliography*). John Tjepkema's recent studies have been on *Parasponia* which is a tropical member of the elm family which occurs only in Indonesia and Papua New Guinea. It is of interest because it is the only nonlegume nodulated by rhizobia and because the root nodules differ from legume nodules in structure and in the lack of leghemoglobin, a protein involved in oxygen transport. Surprisingly, studies of gas transport and respiration show that these processes are very similar in *Parasponia* and legume nodules, in spite of the lack of leghemoglobin. Furthermore, the lack of leghemoglobin does not substantially increase energy usage in *Parasponia* nodules. Thus the association between legumes and rhizobia is less specific than previously thought and it may be possible to create new nitrogen fixing associations between rhizobia and nonlegume crop plants.

For the past year, John Tjepkema and Robert Cartica have measured atmospheric concentrations of gaseous ammonia and particulate ammonium at the Harvard Forest. From these data, and from measurements of the accumulation of particulate ammonium on leaf surfaces, they have been able to estimate the rate of nitrogen input to forests from these sources. Contrary to expectation, gaseous ammonia concentration was very low and not a significant nitrogen input to forests. However, the deposition of particulate ammonium on leaf surfaces was quite significant, especially for conifers. Although further study is needed, it appears that the only significant nitrogen inputs to pine forests in Massachusetts are precipitation and the dry deposition of particulates, with both being equally important.

One of the difficulties in working on symbiotic systems in plants is the problem of successfully handling the growth and development of both the host plant and the microsymbiont separately and then associating them to achieve a natural and effective symbiotic relationship. In their continuing studies among a number of host tree species and their actinomycete symbiont, *Frankia*, John Torrey's group continues to have successes, sometimes unpredictable, and

also some failures. During the past year, through the joint efforts of John Tjepkema, William Ormerod and John Torrey, a great deal was learned about the *in vitro* cultivation of *Frankia*. *Frankia* was grown in a totally filamentous state. On transfer to defined medium lacking nitrogen, sporangium and spore production, as well as vesicle differentiation, were induced. Correlated with the formation of vesicles *in vitro* is the formation of the enzyme nitrogenase as demonstrated by acetylene reducing activity. By adding small amounts of fixed nitrogen, one can suppress vesicle formation totally as well as acetylene reduction.

Using these methods, it has been possible through the collaborative efforts of Alison Berry, Kate VandenBosch and Mary Lopez to attempt to determine what is the "infective" particle in cultures of *Frankia* sp CpI1 inoculated on aseptically grown seedlings of *Alnus rubra*. It seems clear from these studies that the morphological stage in the life cycle of the microorganism influences its infective capacity.

## FOREST OPERATIONS

The red pine thinnings in Tom Swamp VIII and IX have been completed. Most of the cutting was done last summer, but this summer, the small trees and tops were chipped. A small clearcut area in the red pine of TS VIII was planted with the nitrogen-fixing shrub autumn olive (*Elaeagnus umbellata* Thunb.).

Timber cutting in Prospect Hill VII, which began in April 1980 continued through July of the same year. Nearly all of the fuel wood burned in Shaler Hall during the past winter came from this source. The wood furnace was started up relatively late last winter; we burned about 30 cords, thus saving some heating oil. Beginning in May 1981, experimental thinning and improvement cuttings, which will produce cordwood, resumed in Tom Swamp Tract I off Sunset Lane. About 11% of the woods crew's time was spent in logging operations; 70% was used for general maintenance work.

## HARVARD BLACK ROCK FOREST

Following the relocation of the scenic trail (see last year's report), it became desirable to revise the trail map which had been last printed in 1975. The updated version appeared in November 1980. There is a continuous demand for these maps.

Miss Kelly Smith, a recent graduate of the SUNY College of Environmental Science and Forestry at Syracuse, arrived in June to begin making an inventory of timber resources of the Forest.

Since May 1981, the Forest has been hosting a study to test small skidding machines for fuel wood under various terrain conditions. Richard Lea and Donald Koten from the College of Forestry in Syracuse, and a graduate student, Tony Quadro, work together with Neil Huyler of the Forest Service Station in Bennington, Vermont. Another participant in this venture is David Strong, head of the Ulster County Wood for Fuel Project in New Paltz, New York. Tony Quadro, in residence at the Black Rock Forest with Fred Rosa, a Forest Service summer employee, is coordinating the field operations. This work will fulfill part of the requirements for his master's degree.

Donald Mitchell continued to maintain the grounds and roads of the Forest. This summer he is assisted by Eugene Conley.

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This is a list of publications which have appeared in print between July 1, 1980 and June 30, 1981. 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 1981

Martin H. Zimmermann
Director