A HISTORY
OF THE
UNIVERSITY OF CALIFORNIA
STATEWIDE IPM PROGRAM

James M. Lyons

In collaboration with

Mary Louise Flint
Peter B. Goodell
Patrick O'Connor-Marer
Joyce F. Strand

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PROLOGUE

The University of California (UC) Statewide Integrated Pest Management (IPM) Program, established by legislative action in 1979, did not just happen because a few scientists thought it would be a good thing to do. Rather, it evolved out of a series of scientific advances, a receptive political climate, and changes at UC that coalesced at a particular time.

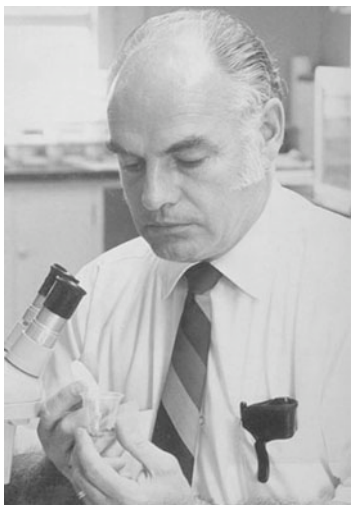
The Science

Shortly after World War II, the spectacularly successful application of the pesticide DDT to agricultural pest problems stimulated development in the field of chlorinated hydrocarbon chemistry and hence many other organic pesticides. However, it wasn't very long before a number of scientists working in pest management began to recognize these new pesticides were not to be the panacea first envisioned. For example, Michelbacher and Middlekauff, in their 1950 studies on the control of melon aphids, were among the first to describe increased pest population densities flaring up when heavy dosages of the new pesticides destroyed natural enemies. Additionally, they were able to show that if low-dosage pesticide treatments were carefully chosen, timed, and "integrated" with wind conditions and certain agronomic practices, increased populations of natural enemies resulted and good control could be achieved without seriously disrupting the environmental balance.

Vedalia beetle attacks cottony cushion scale.

Early successes with the use of biological control, starting with the introduction of the vedalia beetle into southern California citrus orchards in the 1880s to control the cottony cushion scale, led to establishment of insectaries and biological control facilities on the UC Berkeley and UC Riverside campuses. In the 1950s and 1960s, researchers began to develop the ecological foundations for the effective use of introduced biological control agents (as well as natural agents) in ecosystems with reduced use of broad-spectrum pesticides. At the same time, agronomists, horticulturalists, plant breeders, plant pathologists, nematologists, and weed scientists were also involved in the development of tactics and management practices for crop pests including plant diseases, nematodes, and weeds.

Out of these efforts, it soon became clear that there were a number of pest control "tactics," e.g., chemical, biological, cultural, physical, genetic, and even regulatory procedures, that could be employed to manage pests, but increased research was needed to focus on how these could be "integrated" into an effective, ecologically based program. In 1959, Vernon Stern, Ray Smith, Robert van den Bosch, and Kenneth Hagen published their seminal article in *Hilgardia,* "The Integrated Control Concept." This publication not only presented the definitions and explanation of terms useful in discussing IPM, but also developed the conceptual framework for successful IPM programs. They clearly pointed out that biological control and chemical control were not necessarily alternative methods, but rather "they may be complementary, and, with adequate understanding, can be made to augment one another. One reason for the apparent incompatibility of



Kenneth Hagen (left) and Robert van den Bosch, early leaders of the UC Berkeley Division of Biological Control.

biological control and chemical control is our failure to recognize that the control of arthropod populations is a complex ecological problem. This leads to the error of imposing insecticides *on* the ecosystem, rather than *fitting them into it*."

During the 1960s an increasing number of researchers were exploring integrated pest management in various cropping systems, and by the early 1970s many articles had been written and several definitions appeared in the literature. In 1972, the Council on Environmental Quality provided the following definition:

> Integrated pest management is an approach that employs a combination of techniques to control the wide variety of potential pests that may threaten crops. It involves maximum reliance on natural pest population controls, along with a combination of techniques that may contribute to suppression cultural methods, pest-specific diseases, resistant crop varieties, sterile insects, attractants, augmentation of parasites or predators, or chemical pesticides as needed. A pest management system is not simply biological control or the use of any single technique. Rather, it is an integrated and comprehensive approach to the use of various control methods that takes into account the role of all kinds of pests in their environment, possible interrelationships among the pests, and other factors.

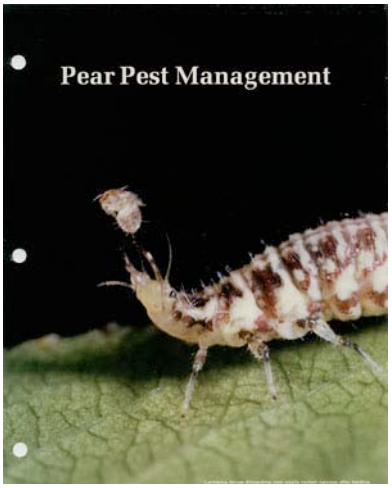
They further added that an integrated pest management program should contain at least the following three elements:

- Diagnosis of the pest problem by scouting, also referred to as "field checking," pest trapping, and/or other methods;
- Determination if and when intervention, i.e., pest suppression, is required, mostly based on damage thresholds; and
- Suppression of the pests(s) by the most appropriate tools(s) available.


Carl Huffaker, a leader of the Division of Biological Control, UC Berkeley.

The National Science Foundation (NSF) recognized the potential significance of integrated control programs and established a national prototype research program in 1972 under NSF grant GB-34718, funded by NSF, the U.S. Environmental Protection Agency (EPA), and the U.S. Department of Agriculture (USDA). This program was administered through the UC International Center for Biological Control on the Berkeley campus and became known as the "Huffaker Project." Grants funded under this program made significant

advancements in establishing the systems analysis approach to understanding and solving agricultural pest problems. Research results from this effort were utilized in the USDA extension IPM pilot projects for cotton, apple, citrus, alfalfa, and soybean. In California, pilot projects for cotton and later for pears demonstrated to growers the value of monitoring by crop consultants in reducing pesticide use and production costs, while maintaining quality and yields. The pear pilot project resulted in the UC manual for pear pest management that was well received in the agricultural community. This manual, prepared by Dick Bethell, CE horticultural advisor in El Dorado County, and many cooperating UC authors, became a prototype for other such books to follow. Pat Weddle, one of those who worked on these IPM pilot projects, went on to found a private consulting business that continues to serve growers.



Cover page of the Pear Pest Management manual, 1978.

The Consortium for Integrated Pest Management (CIPM), a 17-university, interdisciplinary research project on four major crops (alfalfa, apple, cotton, and soybean) was initiated in 1979. CIPM was a new way for organizing and managing agricultural research. It provided a mechanism for overcoming political, disciplinary, and administrative barriers for scientists of 17 state agricultural experiment stations, land-grant universities, and USDA Agricultural Research Service (ARS) and Economic Research Service (ERS) to work collectively on a very large problem of national concern. CIPM brought together the talents of a large group of the nation's best agricultural scientists in a centrally managed and directed effort that underwent an annual peer review.

Simultaneous with these advances by pest management researchers in examining problems on an ecosystem basis, rapid advances were being made in the computer sciences. To implement an effective integrated pest management program on an ecosystem basis requires analysis of large quantities of detailed and accurate data from repeated field monitoring. Computerized data management had the ability to reduce, store, retrieve, and perform the necessary calculations to make relationships among biological and abiotic factors useful to those who have to predict the need for and supervise the treatment strategies. These advances, in terms of computer capabilities and availability to individual researchers, allowed the application of systems analysis science to complex pest management problems.

The Political Landscape

Responsiveness of faculty to the California Legislature has been an expectation since early days of UC's history. It was no accident that men like Eugene Hilgard, one of the nation's great geologists and soil scientists, and John LeConte, a world-renowned physicist, were among the first faculty hired in the 1870s. These scientists were expected to discover new things of value for the state, and they were required to appear before the legislature and give reports each year to justify the state's investment. That university–legislature relationship has continued through the years and was no different in the 1960s and 1970s as the debate over pest management strategies and the use of pesticides was developing. As the scientific community learned more and more about the environmental and human health problems associated with heavy use of DDT and other pesticides,

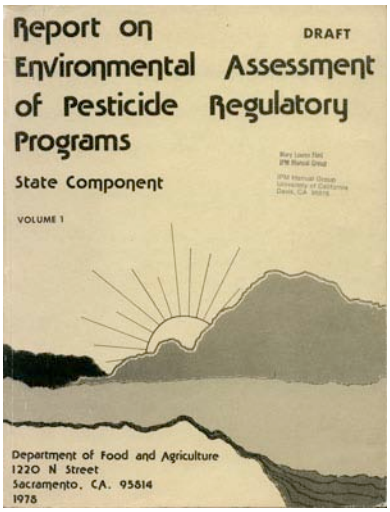
they lobbied state agencies and legislative staff to fund research on an integrated approach to pest management. However, the general public was not particularly provoked by the topic, and hence there was little incentive to place a priority on funding a new program. The faculty was lobbying on "new things of value for the state" but their voices were falling on deaf ears. Even after Rachel Carson published *Silent Spring* in 1962, the public thought of the problem more in terms of fringe issues such as eggshell thickness of peregrine falcons and western grebes. It wasn't until it was shown that workers in plants manufacturing DBCP had been made infertile that many began to pay serious attention. Finding DBCP in groundwater and drinking wells in 1978 finally captured the public's attention, and they demanded action.

In 1972, the California Department of Food and Agriculture (CDFA) began to license pest control advisers (PCAs) to advise growers on pest control methods. To use a commercial pesticide applicator to apply a pesticide or to use a restricted pesticide in California, growers were required to obtain a written recommendation from a state-licensed PCA. A copy of that recommendation had to be submitted to the county agricultural commissioner who provided a certain amount of oversight of their activities. At that time the vast majority of those who became licensed PCAs were also sales representatives associated with pesticide supply companies. This created the challenge of not only providing these individuals with suitable tools for monitoring pest populations and with reliable, science-based information on IPM, but also having to convince them to shift their traditional mode of operation. In many cases the use of a pesticide had become a form of insurance. The cost of material and application was relatively inexpensive and guaranteed a marketable crop. An additional impediment to the integrated approach was that in some cases the banking industry was reluctant to provide operating loans to growers without an assurance that they would use the tried-and-true pesticide program. Relative to the cost of labor for scouting fields or analyzing samples, pesticides were cheap. To really practice an IPM approach, the PCA could no longer simply write a prescription for some chemical based on a general calendar of possible pest problems, but would have to go into the field to actually identify the pest and the problem correctly, and spend time in monitoring and evaluating various approaches. Use of the wrong pesticide at the wrong time would jeopardize reliance on the biological control component of IPM and perhaps cause additional pest problems. It is not easy to change habits, particularly when you are paid by the amount of pesticides you sell. The licensing program contributed to more professional use of pesticides, but made only minimal inroads in the adoption of IPM.

In 1976, California Attorney General Evelle Younger issued a formal opinion that a strict interpretation of the California Environmental Quality Act (CEQA) required that an environmental impact report be prepared before any application of an environmentally hazardous pesticide. Strict adherence to that position would require the preparation of an estimated 100,000 environmental impact reports annually. With pressure from the agricultural lobby, the State Legislature rushed to exempt pesticide regulation from the impact report requirement, but only for a period. In the interim, the CDFA, the pesticide regulatory agency at the time, was required to develop both a comprehensive assessment of pesticide use in California and a plan for reducing whatever serious problems the department might find associated with that use. This plan was to be completed by 1978.

The State Agriculture Code placed a burden upon the CDFA to explore, develop, and foster alternatives to environmentally harmful chemical pest control strategies, and IPM was the common

term given to alternative strategies developed explicitly to reduce the use of harmful chemicals. By this time, IPM was a well-known concept to California's agriculture community, which, together with the University of California, had done more to advance IPM technology than any other community in the world. Unfortunately, the concept of IPM was not well known to government officials, state legislators, educators, and the general public. In December 1977, the conference "New Frontiers in Pest Management: A Comprehensive Evaluation of Integrated Pest Management," was held in Sacramento for the express purpose of expanding public awareness of the value of integrated pest management. To demonstrate how the political field was shifting by this time, it is noteworthy to list the educational institutions and agencies that sponsored this event. They included: University of California, California Department of Education, California State Legislature, U.S. Office of Education, California Resources Agency, California Community Colleges, State Water Resources Control Board, California Engineering Foundation, and California Department of Food and Agriculture. This conference had a robust agenda, including discussion of many aspects of integrated pest management as a concept and outlining how to proceed in implementation. Dr. Mary Louise Flint, Assistant Director, Pesticide Impact Report, CDFA (later to be hired by the UC IPM Project as director of the IPM manuals group) gave a presentation, "Educational Needs for Integrated Pest Management." In this presentation she effectively outlined the educational and publication needs for an effective IPM program, which served as a roadmap for subsequent proposals.



CDFA released the Environmental Assessment of Pesticide Regulatory Programs report in 1978.

In October 1978, in response to the Attorney General's 1976 opinion, CDFA issued a draft "Report on Environmental Assessment of Pesticide Regulatory Programs." This four-volume report was highly critical of pesticide use and regulation in California and suggested that pesticides were overused in the state because alternatives and integrated pest management were not being considered in pest control decisions. The release of the report generated front page headlines in newspapers across the state, and the California Legislature jumped into action to see what could be done to address the problem and calm both environmentalists, concerned with potential hazards, and growers, who feared loss of potential chemical tools.

The report included 68 recommendations to overcome the many problems identified in the report as associated with pesticide use in California. Most of the recommendations related to state regulatory programs to bring them into compliance with the CEQA. However, a few recommendations suggested ways that UC could assist in reducing the problems through development and promotion of IPM programs. Specifically,

> 19. The CDFA (including agricultural commissioners' staff) and University of California, should cooperate in preparing pest management information sheets for crop-specific pest management reevaluations which cover the following subjects: a) identification of the crop, pests, and pesticides which it covers; b) description of the pest management system, including pest monitoring techniques, economic thresholds, application rates and methods, and any other necessary information; c) description of

> the relative advantages and disadvantages of the pesticides included in the system; d) description of all regulations and special restrictions on the use of pesticides.
>
> 59. The University of California should be encouraged to expand its research into alternative pest control strategies, specifically integrated pest management and mitigation measures. Research and funding agencies should be encouraged to use the PUR (Pesticide Use Reporting) system in establishing pest management research priorities.

The dialog and hoopla generated by the report lingered well into 1979, with legislators holding hearings and considering the report's recommendations and various legislative approaches to the problem. This set the stage well for the introduction of the University's proposal for a special IPM program in spring 1979. As stated in an April 9, 1979, Sacramento Bee editorial,

> The University of California is proposing to establish a five-year, $9.4 million program to reduce pesticide use in California and to increase use of integrated pest management (IPM). … If ever a budget request is welcome, this is it….
>
> …Late last year, an Environmental Assessment Team in the Department of Food and Agriculture concluded, as have other study groups in the past, that what has stood in the way of broader use of IPM techniques has often been nothing more than inertia or ignorance about the method and its possibilities. …The UC effort is therefore welcome not only because it will almost surely develop more sophisticated means of IPM, but because it will give new visibility and legitimacy to an underused technique that may well make things easier not only for the environment and public health, but for the grower who uses it.

The University of California

The historical practice in university funding and governance make it difficult for research and extension outreach activities to adjust to rapidly changing times. Early in the history of the Agricultural Experiment Station and Cooperative Extension Service in California, essentially all of the support came from two sources: formula funding from the federal government, and a block grant for research from the California Legislature. State funding for agricultural research became constrained in the early 1960s as many demands of an increasing population with a variety of special needs were placed in competition for tax revenue. Up until about 1961, the state block grant had been increasing annually, allowing new resources to be used to employ researchers and provide technical support as new problems arose in agriculture.

In 1966, partly because of increasing demands on state tax dollars, but also because many in the public and legislature were unhappy with the UC administration for its handling of the "free-speech" movement on the Berkeley campus, an 8% cut in the block grant for research occurred, and another 8% was cut in 1970. As a result of these reductions, UC departments and county Cooperative Extension offices were stretched to carry out their research and extension programs with less money, and there was little interest in redirecting existing funds that would cut across disciplinary and county boundaries to address new problems.

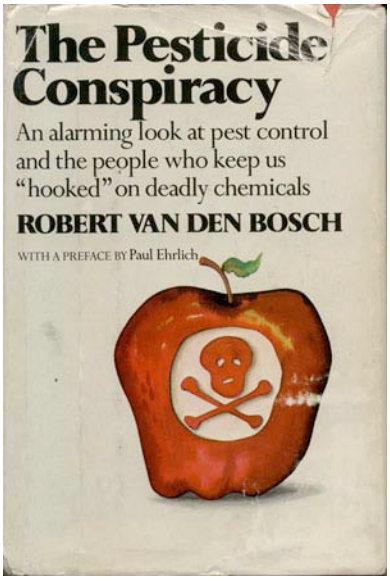
As growers perceived new threats and problems, the University convinced them that they would, by some mechanism, have to obtain new funds for research, as it was virtually impossible to redirect existing resources away from the long-established priorities. And the growers heeded this call. First, they began proposing a series of budget initiatives directed at meeting high priority problems, and these resulted in the establishment of statewide special programs and projects such as Mosquito Research, Pear Decline Funds, Mechanization Research, Control of Starlings, each reporting to the UC Vice President—Agriculture. Secondly, they began to establish industry-based research programs under provisions of the Marketing Act authority of CDFA. Under this act, commodity groups could tax themselves for a variety of activities, including funding research. As a result, a number of commodities established advisory boards that raised funds from their industry to support research. However, neither of these mechanisms for raising new funds identified research on an integrated approach to pest management as a high priority. The bulk of these monies were directed either towards solving a particular pest problem for a given commodity or for genetic modification and plant breeding.

Another force in play during these years was the federal government's large investments in strengthening the country’s science structure following the end of World War II. NSF, National Institutes of Health (NIH), and USDA were offering grant programs that attracted scientists from agriculture, particularly the younger appointees, as well as the rest of the scientific community. Ability to obtain grants from such sources had a large impact on an individual's merit-and-promotion progress. A self-sustaining, circular process evolved whereby the route for peer acceptance as a scientist was through peer-reviewed journal publications, particularly as a senior or sole author; the route to those publications was to seek funds to purchase instruments and supplies and to hire graduate students, postdoctoral scholars, and technical support; and the route to those funds was to become successful in obtaining extramural grants from NSF, NIH, USDA, grower organizations, and yes, from the pesticide industry. Since university departmental budgets could provide only the infrastructure: laboratories, greenhouses, field operations, and some secretarial and technical support, the focus of the research became that of the particular funding agency involved. As this process evolved during the 1960s and 1970s, administrators in the UC Division of Agricultural Sciences (“the Division,” later Division of Agriculture and Natural Resources), colleges and departments, and Cooperative Extension had less and less impact on the direction of the research. And these grant sources were not sympathetic toward long-term, interdisciplinary, team projects focused on specific crops.

In 1974, Ivan Thomason and Jim Lyons were asked to present a white paper on research funding at the Division's annual statewide conference at Asilomar. In this white paper, the team proposed that the Vice President—Agriculture set aside some funds, on the order of $500,000, to be used to fund targeted research addressing priority problems in the Division. This proposal was met with complete disdain by all in attendance.

During the 1960s and 1970s, grower organizations, commodity groups, Farm Bureau, and others, had close alliances with the agrichemical industry and were susceptible to the lobbying efforts of that industry to counter any discussion about the possibility of alternatives to pesticides. Besides the fact that a number of pest management researchers were being heavily funded by pesticide companies, UC's administration was also caught up in the agrichemical lobby. As articulated in

Robert van den Bosch's 1978 book *The Pesticide Conspiracy*, an organization, the California Education Foundation on Agriculture and Food Production (CEFAFP), was formed in 1970, "to begin, and continue, a vigorous educational program on the role of chemicals in modern agriculture and on their relationship to the environment and the demands of the public for attractive, safe, and wholesome food." The primary mover of CEFAFP was Allen Grant, Ronald Reagan's appointee as president of the California Board of Agriculture (and hence an *ex officio* member of UC's Board of Regents), and a staunch proponent of the agrichemical business. The general tone of CEFAFP philosophy was to imply that those environmentalists who suggested there might be some alternative to unrestricted use of pesticides were " largely a cover for leftist and radical groups to further their objective of destroying the country's political and economic system." To gain respectability for this organization, CEFAFP appointed UC Vice President Kendrick and Emil Mrak, ex-chancellor at UC Davis, to its board of directors.



During this same period, Dr. Guy McCloud was a special assistant to Vice President Kendrick. Dr. McCloud was a retired executive of an agricultural chemical company and had strong connections to the pesticide industry. About this same time, the U.S. Congress established a pesticide coordinator position at each land-grant institution to respond to criticisms that the government was not doing enough to protect public health from the overuse of pesticides. Dr. Ed Swift, an extension entomologist and strong supporter of pesticide use, became the statewide pesticide coordinator for the Division. Ed Swift and Guy McCloud had offices adjacent to Vice President Kendrick's and they had great influence in the direction of the Division's research and extension programs in pest management. When Ivan Thomason, Professor of Nematology, UC Riverside, was appointed as Assistant Director of Cooperative Extension for Pest Management Programs by Kendrick, he suggested that these two individuals with strong ties to the pesticide industry sitting in the Vice President's office posed a serious problem—both in perception and in fact. Shortly after McCloud retired, Ed Swift was relocated to an office at the USDA ARS Western Regional Laboratory in Albany, and he too, soon retired. Dr. Mike Stimmann, employed as the pesticide training coordinator at the time, was recruited and hired as the statewide pesticide coordinator to replace Ed Swift. Mike focused his efforts on making sure that Division personnel working with pesticides followed state and federal pesticide rules and regulations. He also continued to provide pesticide safety training.

While CEFAFP never accomplished much, its activities were taken over in 1974 by the Council of California Growers, an agribusiness lobbying and public relations organization whose very existence reflected the pervasive desire to hold on to the notion that any pest problem could be controlled by spraying the appropriate chemical.

However, also during the mid-1970s, the USDA–UC CE pilot projects on integrated approaches to pest management began to demonstrate clearly the value of such a program in reducing pesticide use, while at the same time lowering production costs. As a result, growers' interest in supporting these alternatives to heavy pesticide use began to increase. The growers also recognized that they would likely face increased regulatory constraints on the use of pesticides if they didn't change their

practices, so they began to express some interest in a larger research project to support development of IPM. At the same time, pressure from the UC scientists leading the IPM crusade within the pest management departments began to have an impact on administrators in the Division of Agricultural Sciences. In February 1975, Robert van den Bosch and Carl Huffaker, Division of Biological Control, UC Berkeley, forwarded a draft, "A Research Proposal: An Integrated Control Program at Kearney Field Station" (appendix I), to P. S. Messenger, chair of Entomology, UC Berkeley. This document stated in part:

> University of California researchers have made striking advances in integrated control. For example, in the San Joaquin Valley important headway has already been made under the NSF-EPA project (above), and in various other Experiment Station efforts in cotton, grape, alfalfa, walnut, citrus, olive, and stone fruits.
>
> It is proposed, therefore, that an Integrated Pest Management effort to exploit these advances be centered on research conducted by University personnel at, or associated with, the Kearney Field Station operation.
>
> The crux of the proposed Kearney Field Station program would be to develop around a central modeling and systems analysis specialist, a team of scientists and technologists to pool their efforts in problem solving research to expand upon the existing integrated control base. In this connection, the proposed program would involve as main principals the disciplines of entomology, plant pathology and weed science.
>
> Optimal pest control requires, among other things, a thorough understanding of the biology and ecology of each pest, of weather, soil, and cultural conditions, and the consequences of each contemplated action on other parts of the system. Thus, the work of scientists in different disciplines must be closely integrated; the modern use of modeling and systems analysis has afforded the most effective tool we know for doing this. It has served to crystallize and effectively bring together the expertise and data from various disciplines. From this base, analytical pest management decision making can be developed to help the California farmer make his major pest control decisions with minimum guesswork, thereby limiting his use of chemicals to times of essential need. This in turn will minimize the very expensive and often self-defeating prophylactic use of pesticides.

This document articulated the integrative philosophy, concept, and structure of such a program, and was the first step towards UC organizing a formal IPM program.

The next activity to surface was in April 1977 when chairmen of four UC Berkeley departments (E. Schlinger, Department of Entomological Sciences, E. Sylvester, Division of Entomology and Parasitology, R. van den Bosch, Division of Biological Control, and A. Weinhold, Department of Plant Pathology) sent the following proposal to establish a university-wide IPM program to Vice President Kendrick.

Proposal to Develop a University-wide Program in Integrated Pest Management

WHEREAS pests (e.g., pathogens, insects, mites, nematodes, weeds, vertebrates) deprive us of nearly one-half of our crops in cultivation and storage, attack or compete with desired resources in our forests, pasturelands, parklands and urban areas, attack our structures and other possessions, transmit some of our most serious diseases, and bite, sting, harass and revolt us, and

WHEREAS crop and livestock pests alone cost the California agro-economy at least one billion dollars a year, and

WHEREAS the prevailing pest management strategy, strongly oriented to chemical control, has not only failed to bring satisfactory relief from many major pest problems but has in fact aggravated certain old problems and engendered new ones with the extensively used chemical pesticides frequently causing serious ecological, economic and sociological harm, resulting in increasing societal concern over these impacts and a rising demand for their reduction through the alternative strategy of integrated pest management (IPM), and

WHEREAS the major agency to undertake the IPM responsibility in the state is the University of California, but recognizing that despite the existence of considerable relevant intellectual, logistical, and physical resources, no clearly established philosophical and operational framework now exists within the University to address and undertake the holistic, truly interdisciplinary thrust required by a meaningful integrated pest management program, and further recognizing that a funding base must be developed to support a meaningful University IPM program, we respectfully recommend that the committee cited below, composed of knowledgeable IPM specialists, be formed at the earliest possible date to be charged with the development of a prototype University of California master plan for IPM research and implementation. Specific aspects of the committee's charge are herewith outlined.

We request this ad hoc committee to respond to the following charges for development and for implementing this Integrated Pest Management program:

Define the role of integrated pest management in the University of California in relation to the agricultural resources of the State;
Define the existing state of the art of Integrated Pest Management in California, the nation and the world;
Present a model research program for one of the major crops in California, e.g., cotton;
Develop programmatic schemes for multidisciplinary, multi-crop research, using crop combinations such as alfalfa, cotton and tomatoes, or grapes, citrus, and stone-pome fruits;
Identify the available University of California resources, itemize new resources needed, and develop the estimated budget needs for this program on a yearly basis for the first five years;

> Develop an organizational structure for the program including administrative, research and extension functions; and
> Develop a program plan for implementing the proposal for Integrated Pest Management—Statewide.
>
> To implement this charge, we recommend that the ad hoc planning committee be composed of the following University of California faculty members with field experience in systems-oriented pest management:
>
> Ferris, Howard, Asst. Nematologist (UC Riverside)
> Gilchrist, David, G., Asst. Plant Pathologist (UC Davis)
> Gutierrez, Andrew, Assoc. Entomologist (UC Berkeley), Chairman
> Luck, Robert L., Entomologist (UC Riverside)
> Shoemaker, Christine, Visiting Asst. Res. Systems Ecologist (UC Berkeley)
> Thomason, Ivan J., Asst. Director, Coop. Ext. (UC Riverside)
> Thomson, Sherman, Asst. Plant Pathologist (UC Berkeley)
>
> In addition, we recommend that this committee consult with other University of California faculty and staff members, as well as outside consultants involved with integrated pest management as the need arises.
>
> The resulting program, subject to such review and modification deemed necessary to improve its feasibility and viability, shall be presented by the statewide administration of the Division of Agricultural Sciences to those administrative, legislative, and public bodies for their consideration, review, and support.

On May 31, 1977, Vice President Kendrick issued a memo charging the above committee with the responsibilities outlined and stated he was "not giving the committee a deadline for completing the proposal, but an early report would be appreciated for planning purposes." In July of 1977, Andrew Gutierrez, chair of the advisory committee, forwarded a draft document from the committee to the vice president. During the remainder of 1977 and early 1978, the draft document was circulated widely to deans and appropriate department chairs for review and comment. The advisory committee produced a report on the "development and implementation of a statewide integrated pest management program in California" (appendix II), and in response, Vice President Kendrick wrote the following to the committee:

> I am pleased with the report and am impressed with the amount of work you have put into it. I have perused it and I can state that I am in general agreement with your recommendations, but I expect there will be need for modification of some of the details of the administration of the project. However, I firmly support the principles from which you have drawn up the recommendations.
>
> I want to have my Council of Directors review and fully understand the program before I initiate its implementation. I hope we will be under way by summer.

> By this letter I want each of you to know of my sincere gratitude for your good contributions to this endeavor. I want to especially thank Andy Gutierrez for chairing this project.
>
> With this letter I am discharging the Committee. I know each of you will be expecting something to happen, and I can assure you that it will. I ask for patience, however, because my past experience reminds me that very few things of this nature progress as rapidly as we all would like.

The "Gutierrez Committee" report was widely circulated to deans, department chairs, and Cooperative Extension personnel for their review, comments, and suggestions. Following this review, Vice President Kendrick appointed a small committee (Ivan Thomason, Assistant Director Coop Ext. for Pest Management, UC Riverside; Charles Hess, Dean, College of Agricultural and Environmental Sciences, UC Davis; James Lyons, Associate Dean for Plant Sciences and Pest and Disease Management, UC Davis; and Roy Rauschkalb, Regional Director, Cooperative Extension, UC Davis) asking for a document to be presented to the Legislature to seek funding for the project.

This document was circulated within the vice president's Council of Directors and they all agreed that the time had arrived. With CDFA's draft "Report on Environmental Assessment of Pesticide Regulatory Programs" in hand, and its strong recommendation that "the University of California should be encouraged to expand its research into alternative pest control strategies, specifically integrated pest management," it was clear that the science and the public policy had merged into uniform support for IPM and that the time was ripe to put forward the University's plan. However, much to everyone's dismay, Vice President Kendrick did not believe this was the right time. He said that the UC president's office was already negotiating the University's budget and he did not believe the president would be willing to forward any new initiative for the current year's budget.

Those involved in developing the initiative did not agree with this assessment and took the proposal "to the street." Dean Hess discussed the proposal with the Farm Bureau, several other grower's organizations, and with Richard Rominger, Director of CDFA, and Dan Dooley the Deputy Director. Jim Lyons and Ivan Thomason discussed the document with various commodity groups. There was strong support for the proposal, even from the Environmental Defense Fund, the Sierra Club, and the United Farm Workers, although these latter groups were still not sure they could trust the University to follow through on the project and worked to add a public policy committee into the proposal to provide some oversight. The most significant part of this process was that Rominger and Dooley had the ear of Governor Jerry Brown, who also became enthusiastic about the proposal. When word got back to the UC president that the governor would like to see this proposal included in the University's budget request, he agreed that indeed it was the right time, and hence, as if by magic, Jim Kendrick decided it was the right time, too. The proposal was formally placed in the legislative process on April 9, 1979 (appendix III).

The project was approved by the Legislature with a July 1, 1979 budget allocation of $1.125 million. The "Integrated Pest Management" language as finally approved by the Legislature and the Governor (appendix IV) states in the last paragraph, "it is legislative intent that UC attempt to reallocate internal resources in order to increase support for integrated Pest Management in 1980-81 to a total of $2 million."

I. THE BEGINNING:

July 1, 1979 to June 30, 1980

With $1.125 million in hand, the UC Division of Agricultural Sciences embarked on the daunting task of establishing the legislatively mandated program. The broad goals were to

- increase the predictability and thereby the effectiveness of pest control techniques;
- develop pest control programs that are economically, environmentally, and socially acceptable;
- marshal agencies and disciplines into integrated pest management programs;
- increase the utilization of natural pest controls;
- prolong the useful life of acceptable pesticides by minimizing development of pesticide resistance; and
- reduce the pesticide load in the environment.

These goals were to be accomplished by establishing four key elements described in the funded proposal:

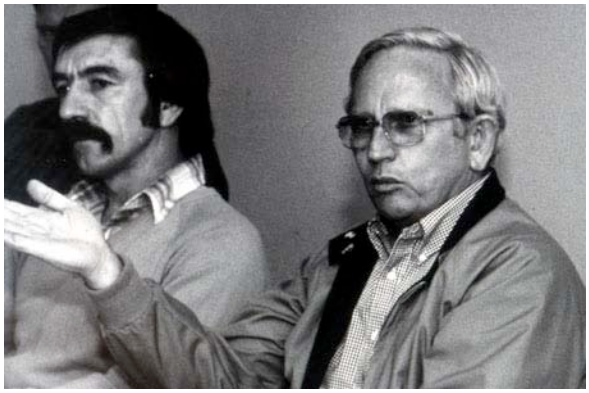
- A grants program;
- A field implementation program;
- A computer network; and
- A program for publication of pest management manuals.

A contemporary philosopher once said, "the only thing more difficult to move than an academic faculty is a cemetery," and each of the four areas of endeavor of the approved new program i.e., the grants program, the field implementation program, the computer network, and the pest management manuals, were about to challenge long-standing institutional and academic paradigms. The process that unfolded provides essentially a case study of institutional change. So, by its very existence, the Statewide IPM Project (later “Statewide IPM Program”) immediately antagonized and caused resentment by county directors, farm advisors, campus-based department chairs, AES faculty, and CE specialists. The only reason the process went forward and ultimately succeeded in its mandate, was that Vice President Kendrick, the deans at Berkeley, Davis, and Riverside, the director of AES, and the director of CE were all vested in the program and wholeheartedly supported the IPM Project director and actions that were about to be undertaken.

Organization and Administration

The first issue to be resolved in establishing the program was that of the director. It was not stated, but clearly understood through the process of preparing the proposal and defending it in legislative hearings, that Ivan Thomason, Associate Director of CE for Pest Management, UC Riverside, would become the director. However, Ivan had made plans for and accepted the opportunity to take a sabbatical leave at Michigan State University starting July 1, 1979, the same date the new program was to begin! After some discussion with his Council of Directors, Vice President Kendrick decided to have the three associate deans from UC Berkeley, UC Davis, and UC Riverside initiate the program and manage it jointly until Ivan completed his sabbatical. The first meeting of the joint committee focused on how best to divide up the $1.125 million between the three

campuses. Upon hearing this result, Dean Hess at UC Davis, one of the authors of the proposal, convinced Vice President Kendrick to change his plan, as it was clear the committee approach was not going to achieve the expected results. He offered to relieve Jim Lyons from his associate dean duties and ask him to serve as director until the return of Ivan Thomason. Kendrick agreed and Lyons was appointed as interim director of the Statewide IPM Project. Lyons' first decision was to ask Andrew Gutierrez, Biological Control, UC Berkeley, to serve as associate director of the program; when Andy agreed, the two of them charged off into unknown waters.



Jim Lyons, right, interim director of the Statewide IPM Project, 1979-80.

Policy Advisory Committee. Because of the history of the Division's close ties to the pesticide industry as cited in the Prologue above, many individuals in environmental groups and some in state agencies were not sure they could trust UC to follow through on its commitment to an integrated approach to pest management. A policy advisory committee (PAC) was mandated in the approved proposal to provide a mechanism for oversight of the funds. The PAC, with broad representation from the agricultural community, government, and consumer and environmental organizations was invited to participate in this effort, discuss general direction of the program, and provide liaison and consultation with a broad segment of the state and private organizations with interests related to IPM. Thirty individuals (listed in appendix V) attended a PAC meeting in Davis on December 11, 1979.

Program Location. As the project was getting organized, Charles Hess, Dean of the College of Agricultural and Environmental Sciences at UC Davis, and one of the individuals involved in preparing the proposal for the Legislature, provided space for the program on the Davis campus. Space for the computer network was made in Wickson Hall in the center of the campus, where an empty laboratory room was remodeled. This remodeling involved walling off a small room to be dedicated to the central computer, and installing a raised floor, additional air conditioning, and a special fire safety system. The remainder of the room was outfitted with desks and cubicles for staff. The manuals group was located in space in a duplex (designated as HD-2) located near the UC Davis airport and several miles from the campus center.

Field Implementation

The primary goal of the IPM program was to have integrated pest management practices implemented in the field. To facilitate that process, the legislatively mandated program called for employment of one IPM specialist/coordinator and six area IPM farm advisors. The notion of having area IPM advisors located in counties, with cross-county assignments to implement IPM practices at the local level by working with other farm advisors, growers, and pest control advisers, immediately challenged the established tradition of advisors not crossing county lines. Crossing county lines made their responsibility somewhat akin to the role of a CE specialist, and that in turn, threatened the turf of existing pest management CE specialists.

Carl Koehler, CE Entomologist on the Berkeley campus, was appointed as acting IPM specialist/coordinator while a committee conducted a national search for a person to fill the position permanently. This search resulted in the hiring of Dr. Frank Zalom, Assistant Professor of Entomology, Fisheries and Wildlife, at the University of Minnesota. He was chosen because of his strong teaching and research record in biology, ecology, computer science, and field entomology. The administration instructed the IPM Project to recruit area IPM farm advisors first from within the existing CE personnel. In April 1980, three qualified, internal applicants were employed by the IPM Project through internal transfer within Cooperative Extension. These were Carolyn Pickel, assigned to the central coast area, to be located in Watsonville; Bill Barnett, assigned to the Central Valley, located in Fresno; and Bud Beasley, assigned to the southern desert area, located in El Centro. An external search for additional area advisors was undertaken simultaneous with the IPM specialist/coordinator search. IPM specialist/coordinator Frank Zalom came on board in September 1980 and two additional area IPM advisors, Phil Phillips for the south coast and Craig Weakley for the Sacramento Valley, were hired in October 1980, following this external recruitment.

Frank Zalom, right, joined the IPM Project in 1980 as IPM specialist/coordinator.

When area advisors were first hired and located in county offices, the county directors were enthusiastic about having an additional advisor in their county who "will be able to handle all of our backyard and home calls." When they were finally disabused of this notion, they were less enthusiastic of having someone in their county whom they did not completely control. Another puncture in the conventional paradigm.

IPM Manuals

A key mandate in the funding of the Statewide IPM Project was to prepare pest management manuals on specific crops. The crops selected were those in which it was perceived there was the greatest amount of science-based integrated pest control strategies already in place. The strategy outlined in the proposal was to hire experienced scientific writers who would prepare these manuals. The historical paradigm was again challenged. The traditional work product for an AES researcher or CE specialist or advisor was publication of his/her works as a sole or senior author. How were the pest management experts, who most needed to participate in providing the knowledge for these publications, going to get credit towards their merits and promotions?

Facing this challenge, the Project set out to find a director for the IPM manuals group. Andy Gutierrez immediately suggested we seek out and hire Dr. Mary Louise Flint in that position. His recommendation was based on her scientific background and her having obtained her PhD with van den Bosch and the biological control group at UC Berkeley, as well as her writing and editorial experience with the CDFA environmental assessment of pesticides documents (cited earlier), as well as with U.S. Council of Environmental Quality. She readily accepted and commenced to organize the manuals group. The first step was organization of a Pest Management Manual Committee, composed of M. L. Flint as chair, and members Lynn Hawkins, CDFA; Bill Barnett, Fresno County CE; Jack Clark, Davis Campus CE; Mel Gagnon, Davis Campus CE; and Mike

Stimmann, Davis Campus CE. The Project hired two senior writers, Paul Rude and Bruni Kobbe, and the three started work on pest management manuals for alfalfa, walnuts, tomatoes, and rice. These writers were critical in formulating early formats and a structure for developing pest management manuals. Although the pear manual published by Bethel et al. in 1978, with its great color photographs and in-depth pest descriptions, was a starting point, the new IPM manuals aimed to take more of an ecosystem approach with emphasis on crop development and normal cultural practices in relationship to pest problems, and consideration of interactions between pest management practices applied for one pest on other pest populations. Working closely with the alfalfa IPM workgroup—especially Charlie Summers, Dave Gilchrist and Robert Norris—Mary Louise Flint wrote the prototype manual, IPM for alfalfa hay.

IPM Manual Group staff study book layout. From left, Paul Rude, Director Mary Louise Flint, and Bruni Kobbe.

In many areas, necessary practical information was not readily available and new monitoring guidelines, identification helpers, or monitoring forms needed to be devised in consultation with experts. Paul Rude, with a strong entomology background, began writing the manual for tomatoes, enhanced the alfalfa manual model by writing keys to lepidopterous pests, and played a critical role in beginning to build the large library of photographs that has been accumulated over the years through the IPM manual production process. Bruni Kobbe drafted the walnut manual, which featured the evolving codling moth IPM program and excellent phenology diagrams. Writers spent substantial time in the field with farm advisors, IPM area advisors, and photographer Jack Clark to obtain the necessary photographs. To develop each of these early manuals, the IPM manual staff worked very closely with the IPM commodity workgroups. Developing a consensus on the best available information and recognize regional differences in problems and efficacy of practices was essential. New research information enhanced the manuals and the manual-writing process stimulated new research projects.

Computer System

The program was mandated to purchase, install, and utilize a computer-assisted communications system for processing and disseminating information required for effective IPM programs. The system needed to be designed to serve in three different ways: for information storage and management—past history of a field, current label information, and use restrictions of certain pesticides; as a communicator of information where large amounts of information must be communicated rapidly both to and from the farm advisor, grower, or pest control adviser; and for processing crop and pest data through the use of models, mathematical simplifications of biological, physical, or chemical processes.

The contentious issue in this part of the program was the debate between purchasing a central computer with modems and terminals at host locations, or investing in personal computers that could be put in the hands of individual researchers or advisors. The program was leaning toward a

central "midi" computer system, with 200 megabytes of disk storage. However, a vocal minority objected to this approach and strongly advocated the purchase of CompuPro personal computers. Dr. Gary Smith, IPM Analyst, was hired to manage the computer system and worked with outside consultants in developing the final structure and needed equipment.

IPM Analyst Gary Smith and Biometeorologist Joyce Fox work at an IPM terminal.

Two workgroups, one for weather data and one for pesticide information, were established to advise on this part of the program.

The IPM/Weather Workgroup was composed of biometeorologists and IPM core personnel and charged with making recommendations as to the kinds of efforts and weather data that should be considered in the IPM program. The composition of this group was designed to provide coordination and liaison between the IPM Project and the several state and federal agencies involved with collecting and distributing weather data. Members were

L. Myrup, Chair	Biometeorologist	Land, Air and Water Resources (LAWR), UC Davis
J. Goodridge	State Climatologist	Department of Water Resources, Sacramento
R. Hamilton	Meteorologist	National Weather Service, UC Riverside
J. Hatfield	Biometeorologist	LAWR, UC Davis
L. Hawkins	IPM	CDFA, Sacramento
R. Pease	Earth Sciences	UC Riverside
G. Smith	IPM Analyst	UC Davis
L. Tanigoshi	Entomologist	USDA, UC Riverside

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The Computerized Pesticide Information Workgroup, involving both the IPM Project and CDFA, was formed because of the importance of providing current, legal pesticide label information. This workgroup determined format, content, audience, etc., with regard to pesticide information to be included in the system and developed protocols for computer security and operational procedures for handling the pesticide label information. Members were

M. Stimmann, Chair	Pesticide Coordinator	CE, UC Davis
L. Hawkins	IPM	CDFA, Sacramento
G. Reese	Pesticide Registration	CDFA, Sacramento
N. Toscano	Entomologist	CE, UC Riverside
V. Sevacherian	Entomologist	UC Riverside
V. Burton	Entomologist	UC Davis
G. Smith	IPM Analyst	UC Davis
R. Fleck	Food Protection and Toxicology Center	UC Davis

The final design for the initial hardware configuration included one central computer and three district computers, with plans for having at least one user terminal in each agricultural county and on the three agricultural campuses and field stations. The central site hardware included a "processing" computer and associated storage and communication equipment. "Development" terminals for local programmers and for local and remote researchers would attach directly to the central processing computer.

Research Grants Program

Implementing this program with internal state funds ran counter to the traditional process that all University funds from the State were allocated to departments with only general guidelines as to how they were to be allocated to specific tasks. The new IPM program was calling for a grants process that would foster interdepartmental, multidisciplinary research activities, with no departmental control. As soon as it was announced that the IPM Project had been funded, department chairs lobbied their deans. "Take the $1.125 million, divide it among the three entomology departments and we will do the IPM research." "Just give the $1.125 million to the plant science departments for the geneticists/plant breeders, as the only way to really reduce the use of pesticides is through genetic modification imparting insect and disease resistance." To have an AES–CE research grants program funded outside the traditional department–county structure was indeed a threatening event, particularly since there would be peer review of proposals and results, and grants would be cancelled if the participants did not deliver as they had proposed.

To initiate the grants program, the IPM Project established a technical committee (members by year are given in appendix XI), chaired by the associate director. Functions of the committee were to identify research needs, evaluate IPM commodity workgroup research proposals for funding and for compliance with grants terms, make recommendations for allocation of funds, and help determine how and when specific research packages should be made available for IPM implementation. The committee organized IPM commodity workgroups and set up formal review criteria for funding research. The Technical Committee also recommended policies on the computer network and IPM manuals production process. The group established a policy that described who had access to the network, what the priorities were for use of the system, and how day-to-day decisions would be made.

Members of alfalfa IPM commodity workgroup review research needs and priorities. Clockwise from left: Joe Hancock, Benjamin Lownsberry, Mike McKenry, Dave Gilchrist, Robert Norris, and Charlie Summers.

A series of IPM commodity workgroups were organized to evaluate the pest management programs in a particular commodity, identify data gaps, solicit research proposals, evaluate these, and make recommendations on funding. Members were drawn

from the University's research and extension staff whose work responsibilities involved that commodity area. Care was taken to provide representation from all the pest control and crop management disciplines among the active committee members. These workgroups were a radical innovation in that it was the first time that researchers working in the same crop, but from different disciplines, had met to discuss pest problems from a systems approach. Major emphasis was placed on development, refinement, and verification of crop-growth and pest-interaction models and on developing field-monitoring techniques and decision-making guidelines, which could be made available to growers in the near future. Interdisciplinary research proposals were encouraged wherever the state of the art permitted such investigation. Special care was taken to consider regional differences in crop development, varieties, and pest problems when developing each research plan, so that resulting information would benefit pest management throughout the state. The Project established workgroups for eight commodities: alfalfa, cotton, grapes, almonds, citrus, rice, tomatoes, and walnuts.

The Technical Committee evaluated the workgroup recommendations, prioritized them, and made recommendations on funding to the director. Much heated discussion took place in these meetings as opinions clashed about how best to define and approach the goals of the program. One of the debated issues was whether the IPM Project should fund research projects in plant genetics and breeding. Because of attempts by the crop departments to hijack the entire research budget, and because the length of time between discovery of some new gene for pest resistance and actually having a commercial variety was so long (typically 8 to 10 years), the decision was made to exclude such proposals from the priority list for the relatively small amount of research funds IPM would have available for grants.

In the first year, 26 projects were funded for a total of $246,111, including seven projects in alfalfa, five in cotton, and 12 in grapes. The total funds for research were essentially start-up monies, since the grants process involved in establishing the program allowed for only a partial year's funding. Included in the 26 projects were two "cross-commodity" projects, "Simulation Models for Major Vertebrate Pests of California" with Terry Salmon, CE UC Davis as principal investigator (PI), and "Development of Weather Systems for California and Dissemination of Weather Data for IPM," with Jerry Hatfield in Land, Air and Water Resources at UC Davis as PI.

Details of all funded projects can be found on the UC IPM Web site at www.ipm.ucdavis.edu/fundedprojects.html.

II. THE FORMATIVE YEARS

July 1, 1980 to June 30, 1986

Organization and Administration

IPM Project Technical Committee meeting in March 1982. From left, Al Grigarick, Howard Ferris, Ivan Thomason, Andy Gutierrez, and John Baritelle.

Ivan Thomason returned from sabbatical and took over as director of the Statewide Integrated Pest Management Project on July 1, 1980. Jim Lyons remained in the Project as associate director for industry and government relations. Andy Gutierrez continued as associate director for science and technical development.

The Project underwent two structural changes in the early period. The Policy Advisory Committee (PAC), originally written into the legislation because some environmental and consumer groups remained suspicious of the University's intent and ability to free itself from the influence of the pesticide industry that had been embedded in the Division of Agricultural Sciences' administration, met for a second time on October 30, 1980. The University had some apprehension about having public members involved in its programs, but once the public members had the opportunity to learn about the program and see how it was operated, they became some of its best advocates. One way this support was demonstrated was that the Project's budget was soon incorporated into the Division's regular budget and no longer viewed as a separate, limited-life package. A second, related event was that the PAC expressed the opinion that the program had developed according to plan, and because of the regular involvement of CDFA and USDA scientists in its committees and decision process, there was no need for their committee to continue. No further meetings were called.

During 1980, the Project director had to provide a report to the Legislature. Item 361 of the 1980 Conference Committee's Supplemental Report on the Budget Bill recommended that: "UC shall, not later than December 15, 1980, submit a report to the legislative budget committees updating the reports and plans regarding integrated pest management which were submitted to various legislative committees pursuant to the supplemental language of Item 346.1 of the Budget Act of 1979."

The 1979 Supplemental Language required two reports, as follows:

1) The University of California (UC) shall include at least one representative of the Director of Food and Agriculture on the policy and technical committees which are charged with making policy and funding recommendations to the Project director and the Vice President for Agricultural Services.

UC shall prepare a multi-year work plan to guide research relating to integrated pest management. UC shall allocate any funds made available by the Legislature for integrated pest management in accordance with the priorities and criteria set forth in the plan.

In preparing the plan, the UC shall familiarize itself with the environmental assessment of pesticide use and regulations completed by the Department of Food and Agriculture in 1979 and shall, insofar as they are completed, address the actions recommended in that report in its research program plan. The UC shall, further, familiarize itself with the process by which the Resources Secretary is currently reviewing state pesticide regulations for their environmental protection sufficiency and shall, in the research program plan, address any issues identified in that process to the extent they relate to integrated pest management and to the extent that this process is completed.

The UC will, in preparation of the plan, consult with the Department of Food and Agriculture, Resources Agency, and the Department of Health Services.

The research program plan shall be submitted to the Joint Legislative Budget Committee and the appropriate policy committees of the Legislature by March 1, 1980.

2) UC shall report to the legislative budget committees and the appropriate policy committees by January 1 of each year on the progress of the statewide integrated pest management program, including a list of research grants funded by the program in the previous year. The report shall also describe how research priorities in integrated pest management identified by the Director of Food and Agriculture are addressed by the statewide integrated pest management program and the reason for any differences in priorities between the director and the University. Finally, before purchasing any computer equipment, the University shall thoroughly evaluate its computer equipment needs. In particular, attention should be given to: (1) leasing rather than purchasing equipment, (2) utilizing a commercial time-share service, and (3) coordinating with the Department of Food and Agriculture's pesticide information systems. The January 1, 1980 report shall provide the details of the computer equipment augmentation program.

The director responded to both parts of the Budget Conference Committee's request in a report submitted in December 1980 (appendix VI).

During the 1981-82 fiscal year, several changes in administration occurred. Ivan Thomason resigned as director and returned to full-time teaching and research in the Nematology Department at UC Riverside. Jim Lyons was asked to return as the IPM Project director. Lyons had resigned as associate dean at UC Davis and now served half time as assistant director of the Agricultural Experiment Station in the office of the vice president—agricultural sciences; he would serve as director of IPM as part of those duties. Concomitant with these changes, Andy Gutierrez resigned to return full time to the Division of Biological Control, UC Berkeley, and Howard Ferris, Department of Nematology, UC Riverside, was appointed associate director. Mary Louise Flint became assistant to the director and chair of the Technical Committee.

In the earliest years, administrative support was furnished by the dean's office in the UC Davis College of Agricultural and Environmental Sciences. However, in 1982 Leah Hansen was employed by the IPM Project as an administrative assistant and Suzanne Roodzant as a senior clerk, and IPM took over its financial and personnel administration. By 1982-83, staffing reached 22 and remained stable at about that number. See appendix XII for a complete list of staff, by year. The 1981 organizational chart (figure 1) describes the structure of the Project at the beginning of this period, and the 1984 chart (figure 2), the structure near the end.

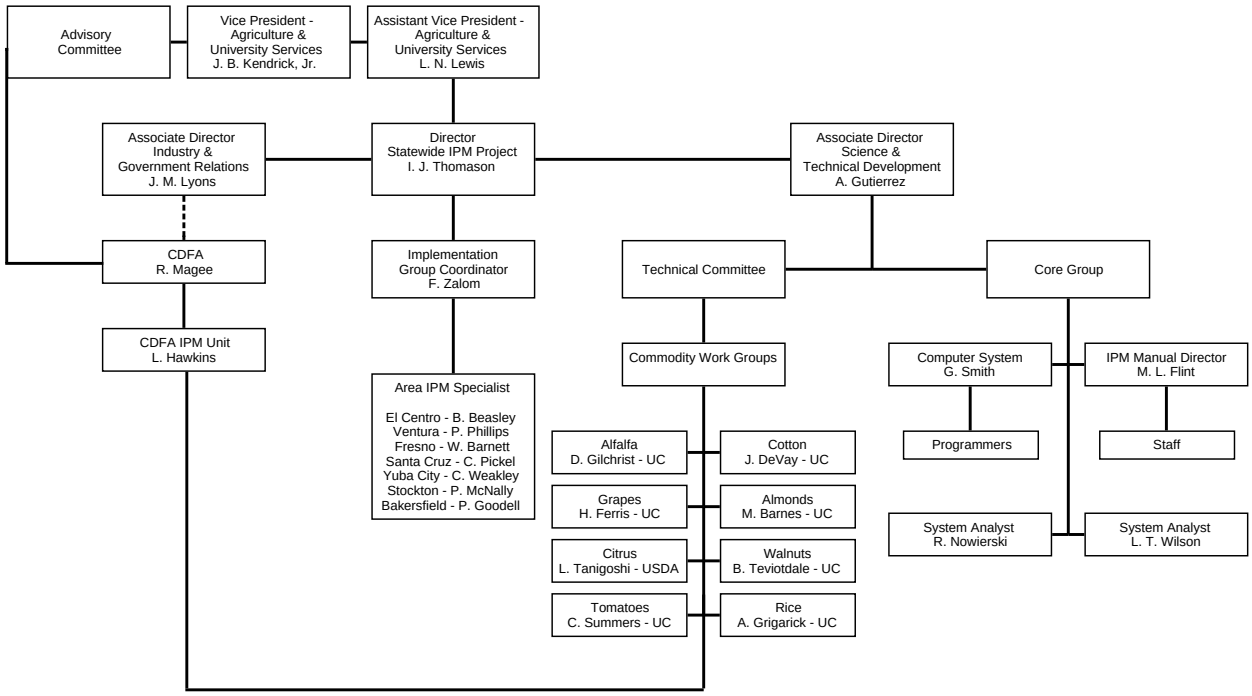


Figure 1. 1981 Statewide IPM Project Organizational Chart.

In March 1982, Vice President Kendrick established a committee to review the overall operations, communications, administrative structure, and effectiveness of the IPM Project. The committee was not charged with evaluating research or implementation programs for technical accuracy or validity. The Evaluation Committee's membership was divided into three subcommittees charged with assessing different aspects of the Project's operation. The subcommittees and their membership were as follows:

Subcommittee on Coordination and Administrative Structures

Hal Reynolds	UC Riverside, Chair
John Anderson	UC Berkeley
Bill Hambleton	CE, Fresno County
Larry Rappaport	UC Davis

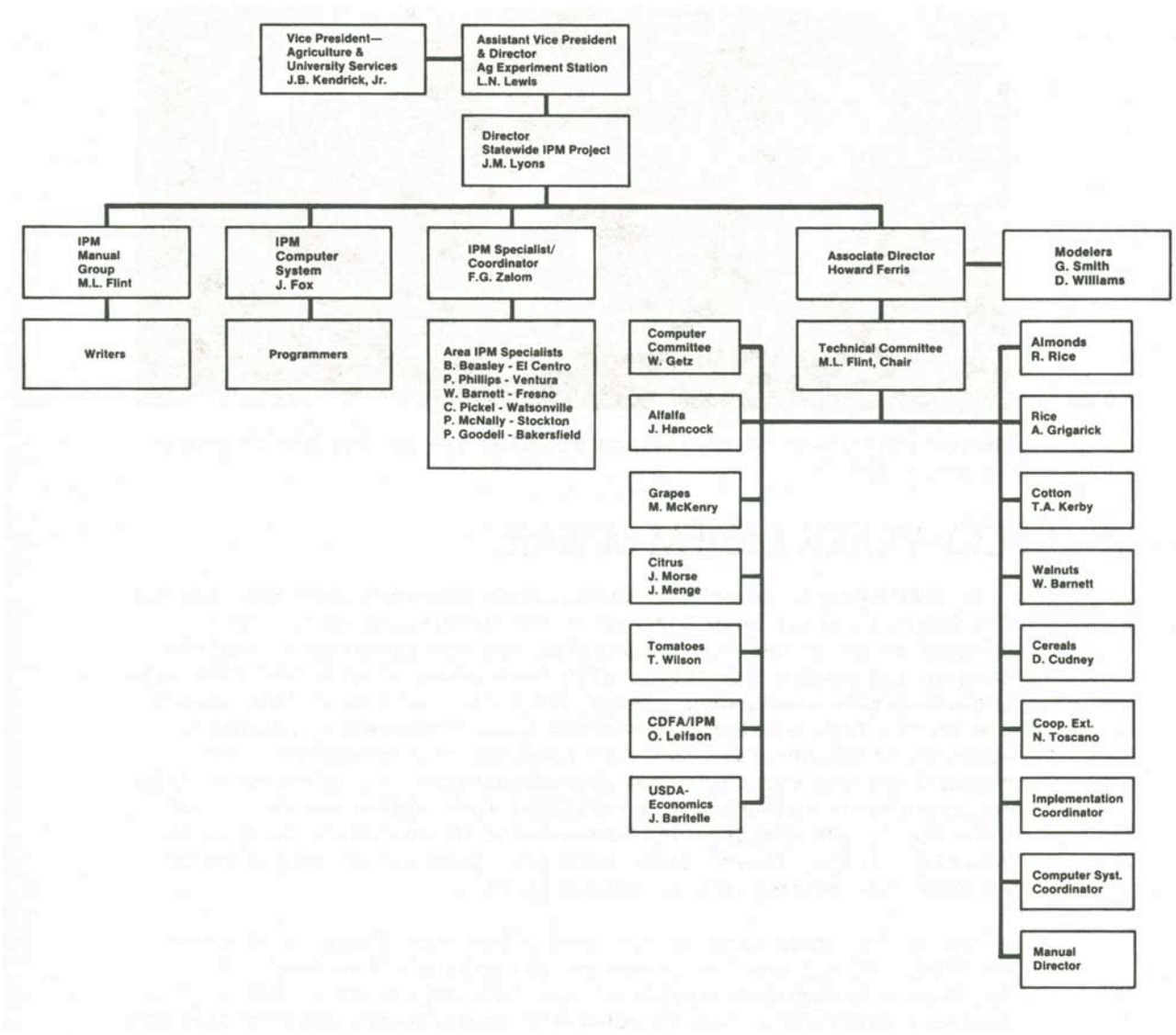


Figure 2. 1984 Statewide IPM Project Organizational Chart.

Subcommittee on Program and Budget

Don Dahlsten	UC Berkeley, Chair
Seymor VanGundy	UC Riverside
Jim DeVay	UC Davis

Subcommittee on Usefulness (Delivery Systems)

Nick Toscano	CE, UC Riverside
Warren Johnston	UC Davis
Cal Qualset	UC Davis

The full report is given in appendix VII. For each topic there was discussion of strengths and weakness. The general conclusions and recommendations were as follows:

> As a general conclusion, the Review and Evaluation Committee found the UC Statewide IPM Project has been highly successful in bringing together a large number of scientists from a broad range of discipline to focus on the complex interaction of crop and pest management. Opinion was expressed that the State of California and the University can be particularly proud that the program has achieved such success in a relatively short period of time.
>
> As with any project of this magnitude, there is a need for constant evaluation and adjustments to keep a focus on the primary objectives and to make improvements where needed. The major area of concern revolves around the issue of "communication" and the following specific recommendations should be considered:
>
> 1) Increase use of established Experiment Station and Cooperative Extension lines to inform departments and their chairs, program directors, campus-based disciplinary specialists, and county-based farm advisors of the procedures priorities and progress of the Project.
> 2) Involve the above lines of communication within the Experiment Station and Cooperative Extension to provide greater input in establishing research priorities and in developing proposals.
> 3) Involve area IPM specialists more closely within the commodity workgroups of the Project and be sure they have representation on the Technical Committee.
> 4) Encourage greater interaction between the campus-based disciplinary CE specialists and the IPM Project so that there is a better linkage among all of the disciplines involved.
> 5) Provide for greater interaction between those involved in the IPM commodity workgroups and the various marketing order/industry funded commodity groups. This would ensure more efficient use of the collective funds available for research on the various commodities.

Field Implementation

As stated previously, the primary goal of the IPM program was to have integrated pest management practices implemented in the field. A key element in delivery of information to growers was the opportunity to employ area-based CE staff. Their implementation efforts made it possible for research done in the Agricultural Experiment Station to be quickly tested and validated in the field and for information on these methods to be passed on to growers. To facilitate their activities and to introduce the concept of an area IPM specialist into the existing county-based CE structure, Frank Zalom, as the extension IPM coordinator, systematically met with county CE staff throughout the state at their office conferences and in other venues to listen to their concerns about the new program and to repeatedly explain the purpose and benefits of the program. Another event that greatly facilitated the acceptance of the program surfaced with the employment of Carolyn Pickel and Bill Barnett as the first area IPM specialists. Carolyn was an

Carolyn Pickel in a field of Brussels sprouts.

advisor in Santa Cruz County working on integrated pest management programs with apples and pears but also took on a project to manage pest problems with Brussels sprouts on the Wilder Ranch. Her success in this project was duly noted by Assemblyman Sam Farr and hence gave the IPM Program a good friend in the Legislature. Bill was an entomology advisor in Fresno County who was highly respected by his peers in the San Joaquin Valley. Bill had been a private pest control adviser before joining CE and also had the confidence of many in the private sector. He was invaluable in helping smooth the integration of the new area IPM advisors into the established CE county-based structure.

Bill Barnett (center), and students in a hands-on training class at Kearney Agricultural Center, Parlier.

However, the question of their duties and responsibilities, and the title of advisors vs. specialists (an issue that would surface again in several ways as time went on), arose with the first three area IPM advisors. As they began to be involved in their program activities, they ran into the vagaries of a peer-reviewed merit and promotion process. Who were their peers? The individuals expressed concern that they were doing work more closely related to specialists than advisors, and that their advancement should be made on that basis. After discussion with the Cooperative Extension director, the administration decided that the area IPM advisors could be reclassified as specialists, but with the understanding that they would be specialists with a small "s" to distinguish them from the disciplinary UC CE "big S" Specialists. At this time there was no administrative relationship between CE specialists and campus departments, so with a simple decision by the CE Director, they all became area IPM specialists. As the Project moved forward to add two additional positions, they were recruited and appointed as area IPM ("little s") specialists. Dr. Phil McNally and Dr. Pete Goodell were recruited and hired as area IPM specialists in April and May 1981, respectively.

Phil Phillips, left, with UC IPM since 1980, talks with a strawberry grower.

By the end of the 1980-81 fiscal year, seven area IPM specialists were in place throughout the state. Their assigned areas of responsibility and headquarters location were

William W. Barnett	Central San Joaquin Valley (Fresno)
Charles A. "Bud" Beasley	Desert Areas (El Centro)
Peter Goodell	Southern San Joaquin (Bakersfield)
Phillip S. McNalley	Northern San Joaquin Valley (Stockton)
Phillip A. Phillips	South Coast Counties (Ventura)
Carolyn Pickel	Central Coast Counties (Watsonville)
Craig V. Weakley	Northern Sacramento Valley (Yuba City)

Early IPM implementation staff meeting. Clockwise from left: Ivan Thomason, Craig Weakley, Jim Lyons, Bud Beasley, Phil Phillips, Pete Goodell, Frank Zalom, Bill Barnett, and Phil McNally.

An area IPM specialist had the day-to-day responsibility of getting practical information about integrated pest management out to users. The existence of a staff of area IPM specialists was one important way the IPM Project differed from many other research programs in universities across the country. Having such county-based CE specialists associated with the Project allowed an IPM program to be followed from its early research stages to its use in the field by commercial growers and pest control advisers; many other programs were stymied by their inability to put the results of their research to practical use. Campus-based researchers also benefited from having frequent interaction with those who would later implement the program. In addition, the area IPM specialists kept close contact with the IPM manuals group as it prepared extension publications that would help them deliver programs.

Area IPM specialists acted as a special resource on IPM for farm advisors. Farm advisors called on them to assist in workshops or advised them on how to meet the pest management needs of growers and PCAs in their county. Area IPM specialists kept farm advisors up to date on the latest IPM developments and often cooperated with them in research and demonstration projects involving such techniques as monitoring, sampling, and evaluating treatment thresholds and alternative pest management strategies. At the request of farm advisors, an area IPM specialist could work with growers or PCAs directly on the farm, or in workshops or other educational forums. The relationship between an area IPM specialist and a farm advisor was a long-term, day-by-day one as compared to statewide CE specialists who helped solve specific new or special problems and provided training within a single discipline.

The area IPM specialists reported through their statewide coordinator to the pest management program director, UC CE. The UC IPM Project director and the UC IPM Technical Committee advised them on their activities. County directors within the area IPM specialist's designated region also advised on promotions and local activities. Each of the area IPM specialists had earned an MS or PhD degree in some field of plant protection and had several years of practical field experience before joining the IPM Project.

The key functions of the area IPM specialists were

- Coordinating and demonstrating IPM programs over a multi-county area;
- Participating in field research coordinated by Agricultural Experiment Station researchers and CE specialists;
- Adapting IPM research for commercial agriculture;
- Conducting applied research to meet local pest management needs;

- Providing a practical perspective on UC IPM Project research priorities;
- Keeping farm advisors up to date about the latest IPM information;
- Cooperating with farm advisors to promote IPM programs in the private sector.

The area IPM specialists played the pivotal role in bringing the results of most major IPM research programs to the field, and their jobs required that they move their emphasis from crop to crop every few years so that in time they would have been involved in most major crops in their region. Once a program was well adapted for commercial use in their area, county farm advisors were expected to gradually take over the job of seeing that local growers and PCAs learned about it. Because of the periodic movement from one crop to another and the fluidity of their positions, one area IPM specialist suggested that they would be better termed "IPM facilitators" rather than specialists. Their expertise was to be in developing, rather than maintaining, programs.

In the 1980s, computers began to play a greater role in agriculture, especially in pest management. The first priority for use of the IMPACT computer system, as the Project's computer network became known, was county implementation, and all of the area IPM specialists took part in demonstrating the Project's computer system to county staff and other interested people. Pete Goodell surveyed the use of microcomputers in agriculture in the southern San Joaquin Valley counties and organized a local "computers in agriculture" group to assess software and hardware needs for agricultural uses.

Frank Zalom suggested that it would be more effective if a second coordinator could be developed within the Project to share responsibilities, and in 1984 Bill Barnett was appointed as area IPM advisor/coordinator for tree fruit and nut crops. Frank remained as IPM specialist/coordinator with responsibilities for field and row crops.

In 1985 the issue of the title "area IPM advisor" vs. "area IPM ("little s") specialists" once again arose. After several years as IPM specialists, two concerns became apparent: one was their job description, and the other was the impact of their job description on criteria used in their merit and promotion reviews.

It became clear that standard farm advisors with commodity responsibilities recognized the need to develop long-term management strategies to ensure the health of a given crop industry in their county. The area IPM advisor performed basically the same function, incorporating appropriate monitoring, sampling, threshold evaluation, and alternative management strategies to improve existing agronomic or horticultural systems. To vigorously implement IPM strategies and technologies developed in the research system, the Project needed the area IPM staff to follow the model of an advisor, not the model of a standard specialist. And this distinction began to surface in some of the merit and promotion packages. Several of the area staff asked to be reclassified to advisors because of their perception that they were being disadvantaged in the system when classified as specialists. As in the first year of the IPM Project, this was a fairly simple administrative issue, and the decision was made to reclassify all the area staff as area IPM advisors.

Concomitant with this change, all of the area IPM advisors were invited to attend the IPM Technical Committee meetings and to evaluate proposed research with special emphasis to applicability for

their areas. This established a more direct line of communication within the program to enhance the linkage between research, education, and field implementation.

Sue Blodgett, left, leads grower meeting in a Sonoma County vineyard.

In 1985, Craig Weakley left his IPM position to become the pomology farm advisor in Sutter County. As a result, the Project began a search for an area IPM advisor for the Sacramento valley region.

In 1989 Dr. Sue Blodgett joined the Project as an area IPM advisor located in the Sonoma county CE office with responsibility for serving the north coast region. Her position was out of the normal pattern for area advisors since the county provided her salary and the IPM Project provided her support. This brought the total cadre of area advisors to eight.

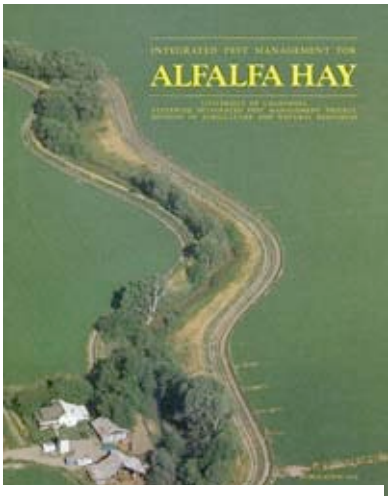
IPM Manuals

The IPM manual group, established in January 1980, was a key part of the implementation effort from the beginning. The manuals and the photographs prepared along with them provided a useful communication tool for the area IPM specialists and farm advisors. The manuals rapidly became a very attractive and visible marketing tool not only for promoting integrated pest management to growers and PCAs in California, but to gain more recognition for the IPM Project itself. An IPM manual steering committee, with representatives from CDFA and UC CE, provided guidance on general manual production issues, but the real key to their success was the active cooperation of the UC AES and CE experts in the IPM commodity workgroups and the IPM advisors. Drafts of the manuals, written by the staff in consultation with IPM commodity workgroup members, were revised based on review by researchers and comments from grower and pest control adviser representatives. The manuals, each about 100 pages during the early years, were designed as a series and followed a similar format, which was enhanced with publication of each new manual: a general discussion of crop biology and production practices in relation to pest damage; seasonal monitoring charts and guidelines; and a key to pest- and stress-induced damage. What really set these books off from any previous pest control guides was the emphasis on the ecosystem and crop ecology, biological control, practical monitoring guidelines, and the systems approach to managing pests. Over the years, the illustrations became increasingly spectacular: color photos of life stages, damage symptoms, and natural enemies accompanied the discussion of each major pest, and many line drawings, charts, and forms enhanced the discussion.

One early stumbling block in the evolution of the manuals was the decision by the UC ANR Publications group in Oakland that they did not have the staff to help with the production of the IPM manuals. As a result, not only did the fledgling IPM manual group have to write the text and supervise photography for the books, they had to obtain and supervise an outside source of graphic design and publication production. Director Flint found a freelance contractor, Naomi Schiff of Seventeenth Street Studios, to assist in these tasks, as well as freelance editors. The new publication ideas brought on by this collaboration resulted in more attractively designed books that could be produced with color photographs at a less expensive price and more rapidly than previous ANR

publications. Several years later ANR Publications adopted many of the production ideas initiated in the IPM manuals. In the end, the IPM manuals were marketed through ANR Publications and have proved to be an important source of their income over the last 20 years.

By the end of 1980-81, the manual group was well organized and productive. A manual on alfalfa had been published, one on walnuts was in press, and one on tomatoes was in the final production stages. A rice manual had been drafted; manuals for citrus and cotton were in the advanced planning stages, and color photographs of key pests and plant growth stages were being taken. In addition, Mary Louise Flint produced the Project's first comprehensive annual report describing activities and accomplishments of the Project. These reports were widely distributed throughout the Division, Legislature, commodity groups, and various agencies and organizations with interest in IPM on an annual basis and provide a history of the program.



The first edition of *IPM for Alfalfa Hay*, the first manual from UC IPM, was published in 1981.

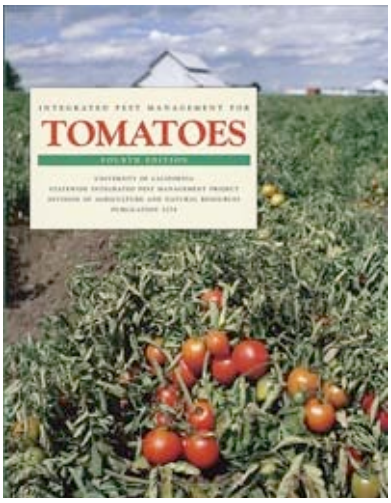
A related project undertaken by the IPM manual group during the early 1980s was a contract with the CDFA to assist in its regulatory functions by compiling directories of pesticides and pesticide alternatives for tomatoes, alfalfa, and grapes. CDFA established a committee to advise on development of these directories, and Tobi Jones, the directory coordinator, worked closely with other IPM manuals staff, IPM advisors, and other UC CE staff to create the needed documents.

By the end of 1980-81 staff of the IPM manual group located at UC Davis were

Mary Louise Flint	Director
Jack K. Clark	Photographer
Brunhilde Kobbe	Senior Writer
Paul Rude	Senior Writer
Tobi Jones	Coordinator for CDFA Directories

By 1982 three books were completed: IPM for Alfalfa Hay, IPM for Walnuts, and IPM for Tomatoes. These manuals received national attention, and several other states asked to participate in the production of future books. For instance, the Western Regional W-161 group for cotton and the states of Arizona and New Mexico helped to finance and contributed expertise to the cotton IPM manual. The potato IPM manual, initiated in 1984 as a western regional IPM manual, was supported by the Western Regional W-161 group, and the land-grant universities of Idaho, Washington, Colorado, Oregon, and Montana. Industry groups also enthusiastically embraced the IPM manuals and provided support. The California Almond Board provided partial funding for the almond IPM book. During 1982, Barbara Petersen (later Ohlendorf) was hired as a senior writer to work on the almond book, and Betty Rudd was employed as a secretary for the group. Dr. Larry Strand joined the IPM manual staff as a senior writer in 1984 to produce the potato manual.

Nine IPM manuals were produced by the Project from 1981 through 1986. These were manuals for alfalfa hay, walnuts, tomatoes, rice, citrus, cotton, almonds, cole crops and lettuce, and potatoes. The tomato book sold out after 3 years and was revised in 1985. More than 20,000 copies of the books were sold by 1987, indicating that the Project had reached many growers and pest control advisers through this medium. A 1987 survey of California pest control advisers showed that 86.4% of PCAs owned at least one IPM manual, with an average ownership of 3.8 manuals. Clearly, the IPM manuals were having an impact on California's pest management industry.



New editions of *IPM for Tomatoes*, originally published in 1982, were released in 1989, 1990, and 1998.

A new thrust for the Project was development of manuals for pest control professionals studying for their professional licenses. An agreement with CDFA provided funding to revise and produce new study guides for licensed and certified pesticide applicators. In 1978, Mike Stimmann, working under Ed Swift as the Pesticide Safety Training Coordinator, hired Jack Litewka to work with him, and the two of them collaborated and wrote the first Pesticide Application and Training Manual and study packets for pesticide applicators. Now, some years later, the material was becoming out of date and in 1986 CDFA executed a memorandum of understanding with the IPM manuals group to revise and produce new study guides. IPM manuals director Mary Louise Flint had a great interest in producing study guides for applicators as well as PCAs. She hired Patrick Marer (later O'Connor-Marer) as a senior writer on this project, and he worked closely with Mike Stimmann, then the UC Pesticide Coordinator, and Mary Louise to develop the new training materials. With a PhD in entomology and a PCA license, and as a farmer growing prunes, walnuts, and other tree fruits, Patrick had unique qualifications for this assignment.

Computer Systems

After evaluating the needs of the IPM computer network and analyzing the eleven bids submitted, the Project selected a Prime Computer, Inc. configuration for its system because of the following capabilities:

- Inter-machine management in a statewide computer network;
- Database management, including a capacity to support data storage needs for agricultural field information, pesticide registration material, meteorology, and research;
- Computational capabilities to further IPM research projects and support the scientific aspects of the user-oriented IPM program.

After the selection was announced, the IPM Technical Committee, computer staff, and administrators began setting procedures and goals for the IPM network. The Technical Committee set overall policy for use of the network. Research and implementation programs would be submitted to a subcommittee of the Technical Committee for review before they were put on the computer. Other specialized committees would discuss relevant procedures. For example, a research database committee reviewed and selected among existing programs for data storage and

manipulation, statistics, and graphics. The IPM Weather Workgroup prepared specifications for a uniform system for weather monitoring and data collection.

Programmers at Davis, Parlier, and Riverside were hired in the fall of 1980. The network-support programming, which tied the network together, stored data, and communicated with the county terminals, was a major effort for the staff at that time because the Prime system was relatively new and there was little experience with it.

Before space was renovated and computer system installed, programmer Gabor Sepfy and senior programmer Buz Dreyer worked via modem.

In the first year of the Project, Jerry Hatfield, LAWR, UC Davis, had been awarded a cross-commodity research grant from the Project, "Development of Weather Systems for California and Dissemination of Weather Data for IPM." This project was the basis for obtaining and organizing the weather information needed to support IPM programs. He used these funds to hire and support a biometeorologist for this activity. Joyce Fox (later Strand) was employed on this grant, and, after the first year, she was relocated from LAWR to the Wickson Hall IPM facility to give her access to the computer so she could review programs and design. When pondering a third-year proposal for this grant, Hatfield suggested that the Project should employ Joyce directly rather than through the grant system; in 1981 Joyce joined the IPM computer systems staff.

The system became fully operational in 1981-82. The network—identified as the "IMPACT" (Integrated Management of Production in Agriculture using Computer Technology) system—consisted of one large central computer in Davis; three smaller district processor computers at Davis, Riverside, and the Kearney Horticultural Field Station at Parlier; 12 terminals in county extension offices; and several research terminals at the Berkeley, Davis, and Riverside campuses (figure 3).

Computer terminals in the counties gave extension personnel (including area IPM specialists) access to weather data, degree-day calculations, communications (news and mail facilities), models, data sharing, and some statistics and graphics packages. University research personnel also had access to these programs and could use programming languages to develop their own research programs, as could county personnel who requested use of program development capabilities.

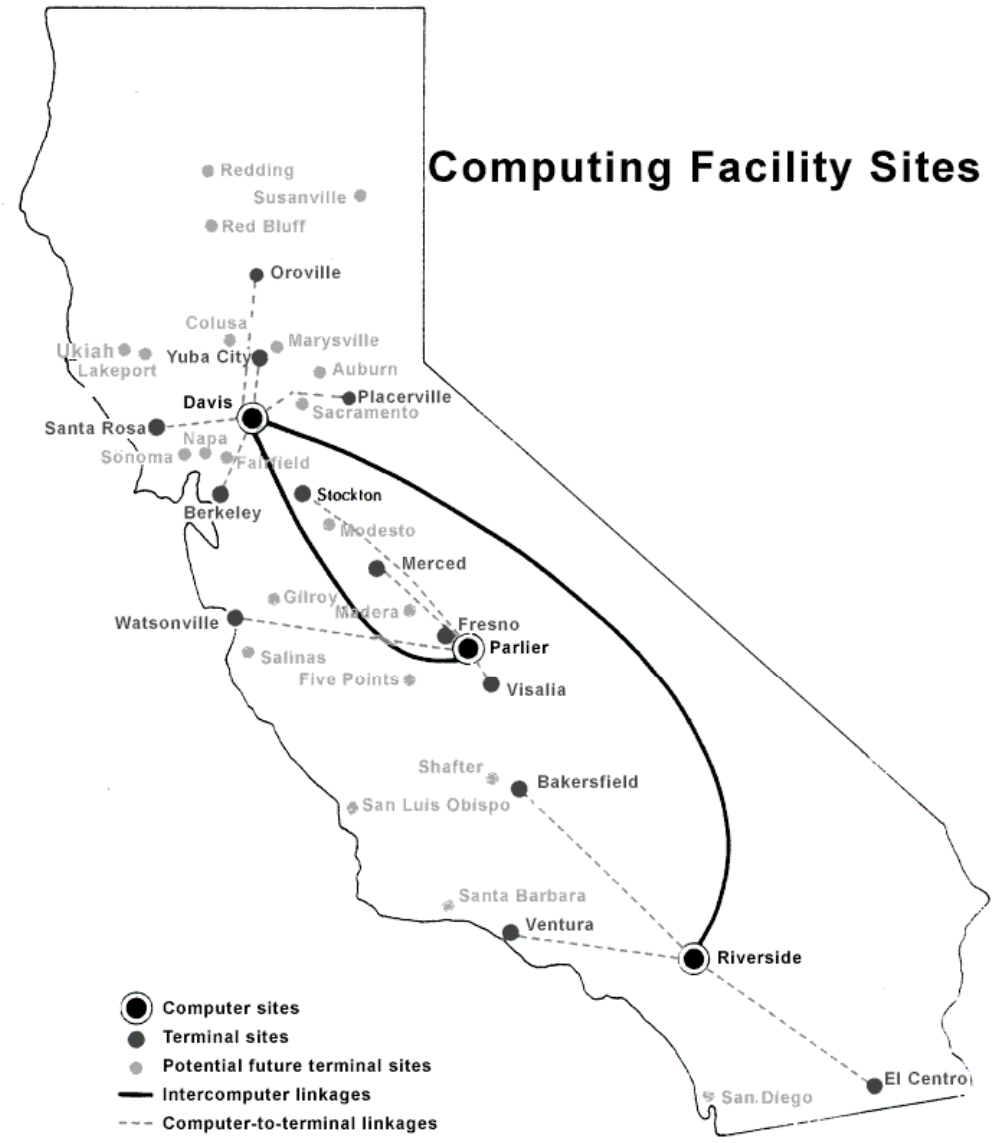


Figure 3. Statewide IPM Project IMPACT Computer Network.

Computer network staff members in 1982 were

Gary Smith, Coordinator
William (Buz) Dreyer, Senior Programmer
Edward G. Morgan, Senior Programmer
Joyce Fox, Biometeorologist
John Rasmussen, Programmer, Parlier, Kearney Res. & Ext. Center
Ann Strawn, Programmer, Entomology, UC Riverside

In addition to hiring computer staff and remodeling laboratory space for the new computer facility, the Project hired two researchers to provide expertise in systems analysis to commodity workgroups. Dr. Robert M. Nowierski, UC Berkeley, was assigned to work with the alfalfa

commodity group on sampling procedures for alfalfa insect pests and to work on the role of weeds in alfalfa stand decline. Dr. Ted Wilson, located at the Kearney Horticultural Field Station at Parlier, worked with the cotton group to improve IPM in that crop, including further elaboration of crop interactive models, sampling programs for spider mites and other cotton pests, and quantification of relationships between irrigation practices and pest problems.

Until 1983, six types of programs were available on the IMPACT computer system: general crop information, models or pest projections, weather data storage, degree-day calculations, news and mail programs, and research-mode programs. In 1983 a summary of the pest management recommendations published by the UC Division of Agricultural Sciences was added. This database included more than 6,000 individual recommendations that prior to this time, were published only in hard copy. While most of these were for using pesticides, some included biological or cultural control methods. Recommendations were cross indexed according to crop, pest species, pesticide or other control method, and the publication from which the recommendation was pulled. The elements of the program and its design were developed with Gary Smith, Buz Dreyer, and Joyce Fox, in consultation with Mike Stimmann and Melanie Zavala. Mike Stimmann, Statewide Pesticide Coordinator, CE UC Davis had the responsibility for maintaining the technical content of the database.

Area IPM advisor and staff member use IPM computer system from standard IPM terminal and printer installed in Fresno County CE office.

Hardware changes to the IMPACT computer system in 1984 made it more accessible to a broader range of users. New dial-up capability allowed county farm advisor offices that were equipped with CompuPro microcomputers, and researchers with their own microcomputers, to access the system using a telephone line and modem. Also about that time, the weather database expanded to include all weather data from the California Irrigation Management Information System (CIMIS). CIMIS, developed by faculty in LAWR at UC Davis for the California Department of Water Resources, was designed so that the data could be readily integrated with the IPM Project weather database, and came online with 43 automated agricultural weather stations located throughout the state.

The Project took a major step the next year by opening up the IMPACT computer system access to users from the University, government agencies and schools, and private sector businesses and individuals. With this advance, IPM's special resources, such as the extensive weather database and the pest management recommendations database, were available to all who could benefit from their use, though in fact relatively few had the necessary equipment. The computer group began developing software for microcomputers about this time also. The first programs written were the UC pest management recommendations database and a set of phenologies of insect pests of stone fruits.

Research Grants Program

Chairs of the Technical Committee. The following were chairs of this committee that oversaw the grants process during these years.

1980-81	Andrew Gutierrez	Biological Control, UC Berkeley
1981-86	Mary Louise Flint	IPM Manuals Group, UC Davis

During the first six years of the IPM Project, the research grants program was focused around individual crops and creating multidisciplinary teams in each crop that would foster a systems approach to pest management. An IPM commodity workgroup was established for each funded crop. The IPM commodity groups were the most important planning and decision unit for research funded by the Project during this period. The groups reviewed the status of research and pest management in the crop, identified data gaps, solicited research proposals, evaluated submitted proposals, and made recommendations to the Technical Committee on priorities for Project funding. Although studies of multi-crop significance (cross-commodity proposals) were funded, 95% of the research funds were directed through the commodity group system to the nine selected commodities: alfalfa hay, grapes, cotton, citrus, almonds, walnuts, tomatoes, cereals (wheat and barley), and rice.

This commodity-oriented approach to soliciting and funding research reflected the UC IPM Project's emphasis on protecting overall plant health and crop production. IPM commodity workgroups included a multidisciplinary array of research and extension personnel who worked in the crop but viewed it from such varied perspectives as agronomy, horticulture, plant pathology, entomology, nematology, weed science, soil and water science, mathematics, or economics. Research projects were often designed to be complementary, so the sum of a commodity group's funding requests over a few years could be viewed as a total package for an evolving IPM program in that crop. It was the responsibility of each commodity group to see that research led to methods suitable for grower use within a reasonable amount of time and provided a plan for making these methods available to growers and PCAs. In devising an implementation plan, commodity groups and researchers worked closely with area IPM advisors and other UC CE staff. They also participated in developing the IPM manuals.

Crop Models

Early in the grants programs, a research priority area identified by most IPM commodity workgroups was the development of a crop model that could be used to link research results from several projects and identify where future research efforts needed to be directed. A stated goal was to develop a crop model for all commodities except cotton; the cotton IPM commodity group planned to work with existing cotton models developed in other states. Many of the models were primarily phenological models for determining timing of developmental events, although a few included carbon pathway and yield components. Researchers designed all plant models to be linked with pest models. The 1983 UC IPM Annual Report provided an analysis of modeling biological systems and that is presented here in part, as it formed the framework for much of the research that followed.

Modeling Biological Systems. The commodity groups funded by the UC IPM Project placed considerable emphasis on the development of models of crop production systems and their associated pests. Models, in any sense of the word, are simplifications of larger, more complex systems, structures, or events. They promote understanding of the form and function of the system they represent. However, their accuracy is limited by their simplicity and by the modeler's understanding of the system.

In 1983 it was estimated that there were some four million biology-related publications in print. These publications contained information about the structure and functioning of biological systems at resolutions ranging from the molecular, through the population and community, to the global level. In crop and pest management, the interest is in biology at the population and community level. The crop is a population of plants, and its community includes the populations of pests and beneficial organisms that interact with the crop and with each other in the field. However, understanding the biology at this level depends on understanding biology at much finer levels of resolution. In other words, crop yield represents the summation of the molecular activities that occurred during the growing season to produce that yield.

Many variables must be considered to describe the interacting populations that form the community centered on a particular crop or sequence of crops. The human brain is capable of tracking the performance of a maximum of seven variables, provided they are independent and not interacting with each other. The biology of a crop production system is far more complex; as the number of interactions increases, there is a corresponding decrease in the number of variables that can be effectively analyzed. Fortunately, electronic technology can be employed to store and track the behavior of many variables. Basic to the use of such technology is the formulation of a model, stating the modeler's hypothesis about how the system functions at a specified level of resolution (in this case, the population or community level). The hypothesis is usually developed with equations that describe the processes and interactions within the system. A common constraint of models is that they require specification of the limits or boundary of the system being modeled. Such boundary decisions made to aid modelers may minimize important factors such as environmental perturbations, the geographic distribution of neighboring crops, and pest immigration. Nonetheless, hypotheses about the system, when formally stated as models, are then testable at the field level and can be reevaluated and refined based on field observations.

Types of Models. Several types of models are useful for crop and pest management purposes. Phenology models predict the timing of developmental events. They are frequently based on temperature or on units of heat summation called degree-days. The predicted events might include bud break, flowering, vegetative growth, fruit growth, or the appearance of various life stages of pest populations. Some phenological models take into account factors other than temperature, including humidity, chilling requirements, and other environmental conditions. Models at this level are useful for timing crop protection activities or for timing monitoring and assessment efforts for the detection of pest species.

More complex than phenological models are population models, which predict not only the timing of the events, but also their magnitude. For example, a pest population model would predict not only the occurrence, but also the magnitude, of the pest outbreak. When sufficient data are available on the impact of the pest on crop growth, the population model could be used to estimate the

expected crop damage. Such models provide a basis for economic threshold considerations, and ultimately for optimization of returns from the system, either in the short term or over a multiyear cropping sequence.

Other models fall under the category of management decision models. They include predictors of the relationship between the intensity of the monitoring or sampling effort and the associated precision of the pest population estimate. These models allow assessment of the risk involved in acceptance or rejection of a management decision. Management decision models may also project the efficacy of a management strategy given the current size of the pest population, the current development of the crop, and the current environmental conditions. Once again, the accuracy of the predictions and projections from such models is limited by understanding the complexities of the system and by necessary definition of a restricted boundary to the system. The models are extremely useful, however, in promoting an understanding of the structure of the systems, thereby revealing gaps in knowledge and appropriately and effectively directing research activities.

Part of the complexity of crop community management is the understanding of how individual pest populations interact with the crop and with each other. Such understanding can allow prediction of repercussions throughout the system resulting from perturbation of one population or of one part of the system. The interaction among the individual populations is primarily integrated by the plant, and the effect of this integration from a practical standpoint is reflected in yield and quality of the crop. Central to the UC IPM Project modeling activities was the development of plant models. These models described the important plant growth processes involved in crop production. They vary in their complexity, but all simulate the production of photosynthates under given conditions of temperature and sunlight, and the partitioning of that energy into respiration or production of leaves, stems, roots, and fruit over time. More complex models may account for varying supplies of water and nitrogen, impact of pruning, soil type, or other factors.

The Model Building Process. Each commodity group and researcher had a somewhat different approach to model building, but basic strategies were similar. The first step was determining the objectives of the model, the type of model, and level of complexity necessary to describe the system adequately. Relevant variables were then chosen and the model conceptualized. The boundaries of the system had to be clearly designated so intrinsic and extrinsic factors could be separated. The next step was to place the model in a mathematical framework. The parameters of the mathematical model were estimated through experimentation, analysis of data sets from collaborators, or review of available literature, or from the opinions of experienced specialists. Completing this step took several years if new experiments were necessary to collect the appropriate data. Once the parameters were estimated, the model could be translated into computer language and installed on a computer system. Lastly, researchers validated the model by comparing its simulations to field biology observations. Sometimes this process revealed the importance of a factor heretofore not considered of consequence for determining timing of events, yields, or population increase; such factors included chilling requirements, day length, or natural enemies. The validation process took several seasons if adequate historical data were not available.

Although an initial model structure may have been completed (as shown below in figure 4, a diagram of the Denison/Loomis Alfalfa Model), the model building process was never really finished. As research provided more detailed information about how a crop grows or how pests

damage the plant, the model could be developed into a more accurate predictor of events in the field. A model could only reflect the current state of knowledge about the factors affecting plant growth, and there is always room for improvement. However, modeling activities could effectively and efficiently direct research programs toward the prescribed goal of describing a crop or pest community. In the process, they provided a forum for integrating information, identifying critical data gaps, and for promoting interdisciplinary research.

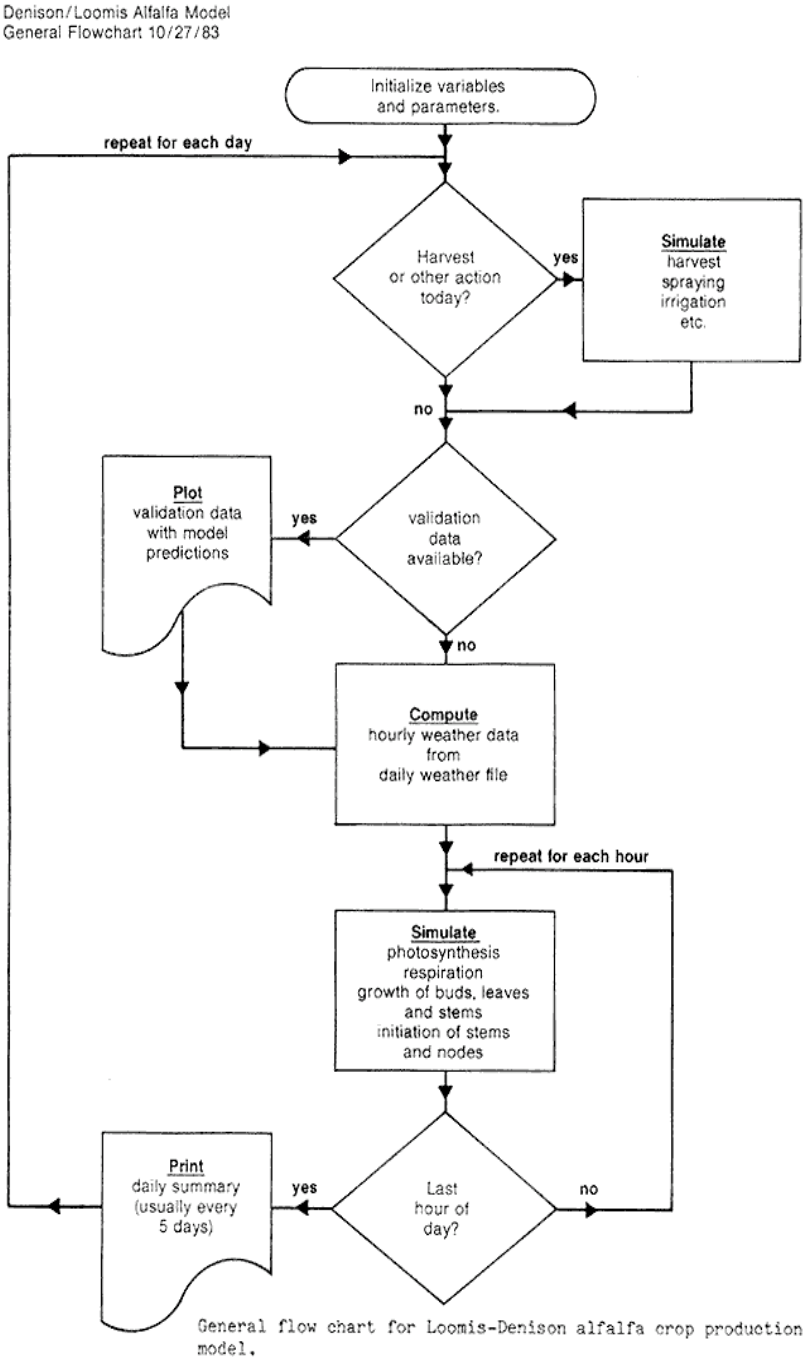


Figure 4. Denison/Loomis Alfalfa Model General Flowchart.

Accomplishments of the Commodity Groups 1980-86

The commodity groups were instrumental in the Project's early success. Their interdisciplinary review of objectives and research proposals was innovative and encouraged an exciting new approach to pest management research. In many cases these groups brought together into cooperative projects workers from diverse disciplines that might not otherwise have interacted. Commodity groups also fostered better communication between research and extension workers in many commodities. The chairs of the IPM commodity groups served on the Technical Committee, and Technical Committee meetings provided a forum for discussion of common problems, suitable research approaches, and priorities among the commodities.

By 1986, many of the original research goals established by the commodity groups had been met. Between the beginning of the IPM grants program in 1980 and 1986, more than $4 million in research funds were awarded to 135 individual proposals with a duration that varied from one to five years, although most were completed in about three years. Data gaps and pest management research needs for all of the selected crops were identified. Existing information was translated into usable management guidelines in the form of integrated pest management manuals (with the exception of cereals, for which compilation of a manual had just begun). Major studies on crop growth as related to environmental factors and some biotic factors had been completed for all the commodities, and preliminary phenological or physiological models of crop growth were tested. Substantial information on the impact of many diseases and most major arthropod pests on crop growth had been collected. Sampling methods and decision guidelines had been developed for many important pests and demonstrated in the field. However, despite the completion of the original goals, each of the IPM commodity groups could identify new research needs for integrated pest management and were reluctant to pull out of the IPM Project to be replaced by new commodities, as had been anticipated in the original project plan. At the same time, many new commodities were interested in participating in the Project; however, the IPM Project organizational structure was not amenable to an infinite number of workgroups. A new structure was needed.

III. TRANSITION

July 1, 1986 to June 30, 1990

The year 1986 saw a transition from a commodity-based process for deciding on research funding to an IPM "area of research" basis. Because so few IPM programs were available at the start of the IPM Project in 1979, the original structure concentrated research efforts on six crops (with three more added later) so substantial results could be achieved in a few years. Commodities were chosen either because they were major users of pesticides or because preliminary IPM programs were already available. In 1979-80, research was funded in alfalfa hay, cotton, and grapes; funding for almonds, citrus, and walnuts began in 1981; tomatoes were added in 1982, and cereals and rice in 1983.

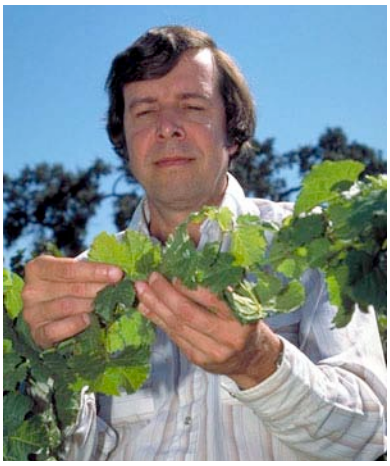
As the Project went on and goals were met, other commodities demanded that they be included in the process, but it was also clear that those currently being funded did not want to withdraw. Over a period of time, the IPM Project Technical Committee discussed the problem and recommended that modifications in the research review procedures be studied. Jim Lyons suggested that a possible solution was to have a two-step process whereby there would be a review by the existing CE commodity workgroups and a review by a set of "functional" IPM workgroups. Following these discussions, Jim Lyons appointed a small review committee to examine this issue. Mary Louise Flint chaired the committee that included Ivan Thomason, Ted Wilson, and Frank Zalom. As part of that process, Frank Zalom organized a meeting where AES researchers and CE pest management specialists met in a facilitated setting to determine the areas of IPM research that were particularly important to pursue. The entire group prioritized the research areas, and at the end of the meeting, functional IPM workgroups were identified and priorities of the workgroups set as a result of these recommendations. These recommendations were included in a May 1986 report of the committee, approved by Vice President Kendrick in July.

As a result of this process, the IPM commodity workgroups were replaced with six workgroups representing areas of research that cut across all commodities and pest management situations. Designated workgroup areas were

- Commodity-Pest Interactions
- Cultural Controls
- Biological Controls
- Systems Applications
- Monitoring Systems
- Implementation and Evaluation of IPM Programs

Organization and Administration

In July of 1987, Frank Zalom was asked to be acting director of the Project through December 3, replacing Jim Lyons who was to become the director of the newly mandated Center for Pest Management Research and Extension. On July 1, 1988, Frank was named director of the Project. He had served as associate director for research during 1986 and 1987, in addition to his duties as



Director Frank Zalom examines grape leaves.

extension IPM coordinator. When Frank became director, Joseph Morse, Entomology, UC Riverside, was appointed associate director for research. This restored the practice of having the associate director for research appointed from a campus other than the one on which the Project was housed. In 1989 the associate director for research also began to serve as the chair of the Technical Committee.

With the reorganization of the UC Division of Agriculture and Natural Resources (formerly the Division of Agricultural Sciences) in 1988, the Project assumed several new responsibilities, including: management of the USDA Smith-Lever funds for extension IPM demonstration programs and pesticide safety training of pest control applicators, pest control advisers, and farmworkers. The pesticide safety training responsibilities were consolidated within the IPM Education and Publications unit (formerly the IPM manual group) and Patrick O'Connor-Marer, was named pesticide training coordinator in 1988.

In 1989 when Peter Goodell, area IPM advisor in the southern San Joaquin Valley, took on the additional responsibility of Extension IPM Coordinator, which had been held by Frank Zalom since the inception of the Project. The coordinator duties involved reviewing the group's programs and progress, coordinating the IPM Project's needs with local demands, developing a unit affirmative action plan, developing focus projects reflecting UC-sponsored research, and serving as the extension IPM contact with federal extension programs. The 1986 organizational chart (figure 5) describes the structure of the Project at the beginning of this period, and the 1988 chart (figure 6), the structure at the end.

Pete Goodell took on the job of extension IPM coordinator in 1989.

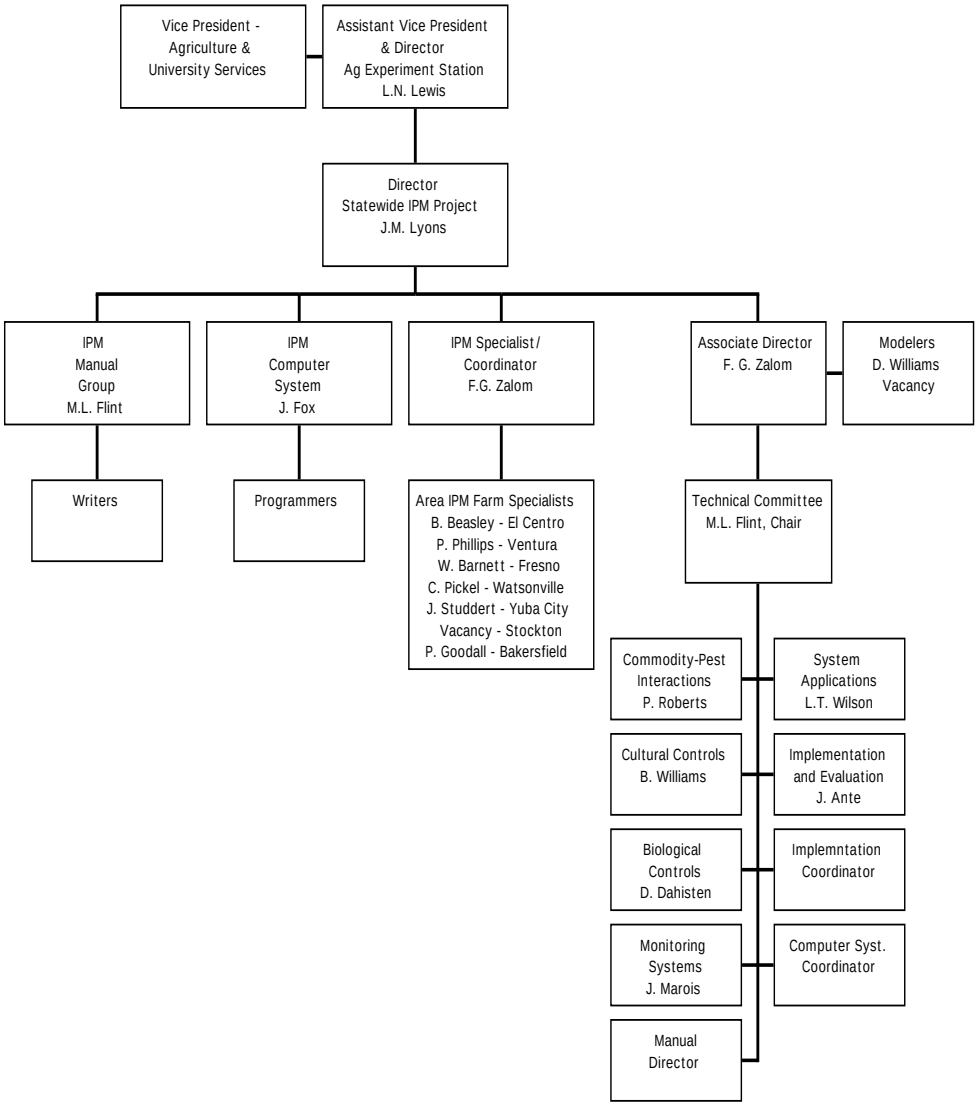


Figure 5. 1986 Statewide IPM Project Organizational Chart.

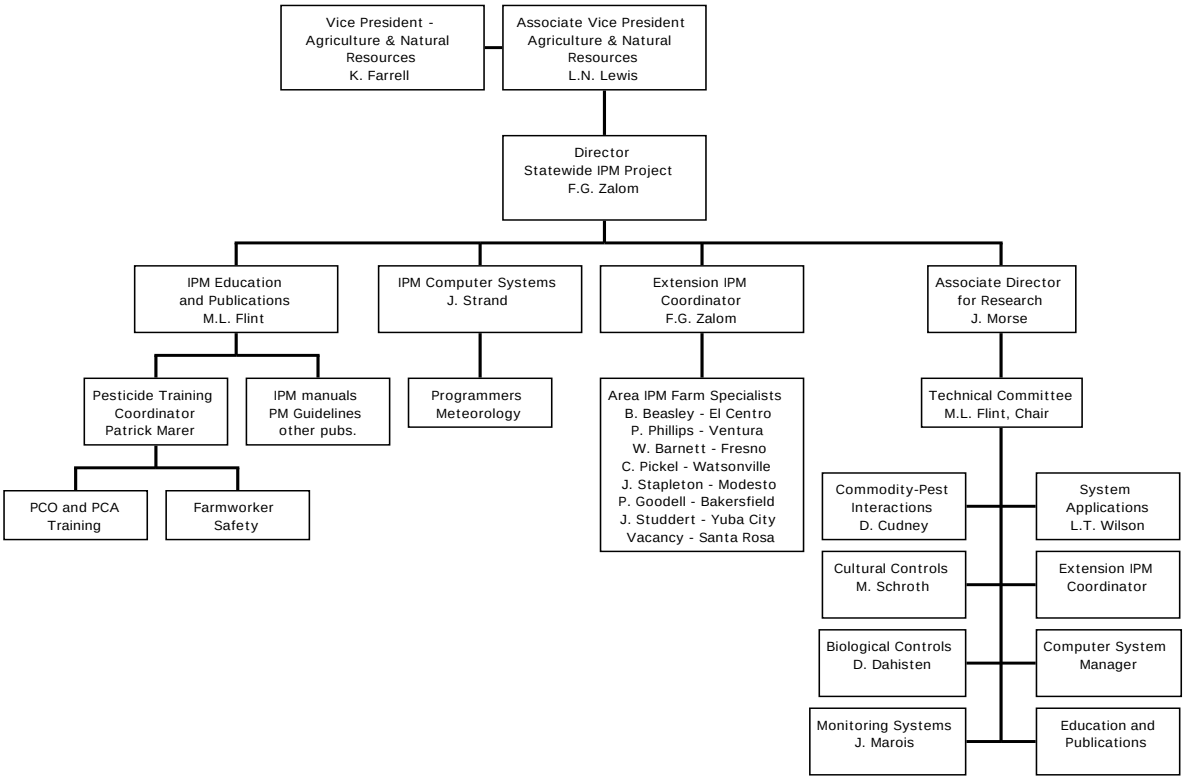
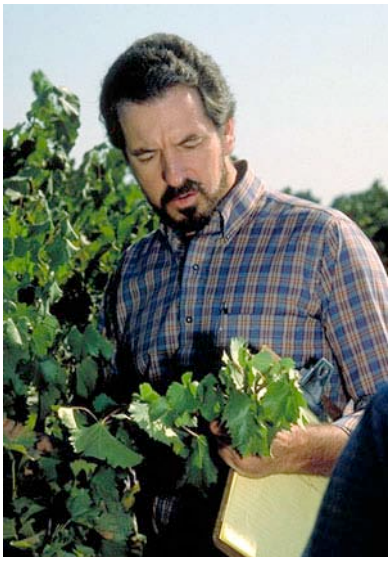


Figure 6. 1988 Statewide IPM Project Organizational Chart.

Field Implementation



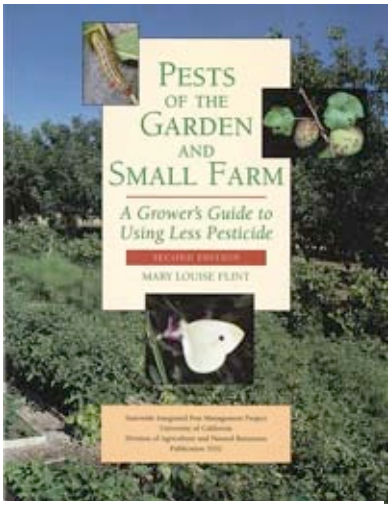
Area IPM Advisor Jim Stapleton joined the IPM Project in 1986.

Several personnel changes occurred in 1986. In August, John Studdert filled the vacant area IPM advisor position for the Sacramento Valley. The northern San Joaquin Valley position became vacant when Phil McNally left to take a research and development position in private industry. Bill Barnett, area IPM advisor in the central San Joaquin Valley, moved to the UC Kearney Agricultural Center at Parlier, and Bud Beasley, area IPM advisor in the desert valleys moved to the Riverside County CE office. Jim Stapleton was named to fill the vacancy in the northern San Joaquin Valley. Jim had a PhD in plant pathology, with a special interest in alternatives to pesticides, and had done extensive work in the controlling pathogens with soil solarization. In 1989, Sue Blodgett, an entomologist, joined the program as an area IPM advisor for the north coast region, based in the Sonoma County CE office in Santa Rosa to work on grapes, apples, and pears. Pete Goodell, area IPM advisor in the southern San Joaquin Valley, undertook the additional responsibility of extension IPM coordinator, now that Frank Zalom was director of the Project.

IPM Educations and Publications

The IPM manuals group (renamed IPM Education and Publications in 1988) took over many new responsibilities in the years 1986 to 1990. During the first five years of the UC IPM Project, the primary emphasis was on the development of IPM manuals for major agricultural crops, but during this period its activities diversified, and the group, still directed by Mary Louise Flint, became involved in a number of other projects related to communicating pest management information.

IPM Manuals and Books. By 1990, IPM manuals for nine agricultural crops had been produced. The Project released new ones on potatoes and small grains in the 1987 to 90 period and revised five previously published manuals. Keeping IPM manuals up to date started to become a major task for the group. Dr. Steve Dreistadt, an entomologist from UC Berkeley, joined the IPM Education and Publications staff as a senior writer in 1989 to revise the citrus IPM manual and to later write a book on landscape pests. June 1990 brought publication of a new manual, *Pests of the Garden and Small Farm: A Grower's Guide to Using Less Pesticides*, targeted at a new audience for the IPM Project: home gardeners and small-scale, diversified organic farmers.



Pests of the Garden and Small Farm was published in 1990 and revised in 1998.

Pest Management Guidelines. A new publication series, the UC IPM Pest Management Guidelines (PMGs) was established in 1986. These were brief, but comprehensive, descriptions of management options for all pests on a specific crop that could be made available via the IMPACT computer system and free through a desktop publishing format in the county UC CE offices. A major goal of this effort was to make the guidelines more timely and easier to access, as well as easier to update. Because unlike the IPM manuals, the PMGs would be rapidly updated, they could include pesticide suggestions. The University had stopped providing pest control guidelines and pesticide recommendations for most crops in the 1970s, and there was a strong demand for this information. The new PMGs included, however, not only pesticide suggestions, but also nonchemical management techniques, monitoring guidelines, and brief information on biology and identification.

Unlike the IPM manuals, PMGs were authored by UC CE specialists, farm advisors, or faculty, but were formatted, revised, and edited by IPM manual staff. The first of the PMGs was on almonds. This was developed at a meeting Frank Zalom organized in the Merced County CE office and which included all the pest management specialists and advisors who worked on almonds. At that meeting, the first draft of what would be included in the guidelines was produced. The IPM manual staff edited this draft, formatted it, and established the pattern for subsequent guidelines. Rod Adamchak was hired in 1986 to work on the PMG project, and Barbara Peterson Ohlendorf took over as Pest Management Guidelines Coordinator in 1988. Margaret Brush was hired as an editorial assistant (later assistant editor) to do desktop publishing. By 1990, guidelines for 20 different crops had been completed. Most of the guidelines had been updated once or more as pesticide registrations or management recommendations changed. The rapidly updated guidelines were a good complement to the more durable IPM manuals. In addition to being available on the IMPACT

computer system and via photocopying from the UC CE county offices, UC ANR Publications sold the whole set and updates through an annual subscription. They became a standard reference for PCAs and farm advisors.

Other Publications. The IPM Project initiated a series of special free publications in 1984 with a publication on *Managing Mites in Almonds: An Integrated Approach* by Marjory Hoy. By the end of 1990, eleven special UC IPM Publications had been produced. Several additional titles were added in the early 1990s. These publications are listed in appendix XIII. Several eventually were published as UC Agriculture and Natural Resources (ANR) publications and the series ceased in the mid-1990s, when it became easier to publish through the Division's publication house.

Interactive Diagnostic Systems. In 1987, IPM Education and Publications staff (especially Rod Adamchak, Larry Strand, and Mary Lou Flint) began to develop an interactive diagnostic system for cotton pests using a laser disc, a videodisc player, and computer. They also developed an interactive program for weed identification. About 5,000 slides from the UC IPM photo collection were put on laser discs in anticipation of this new technology. Few people acquired the necessary equipment to use these programs in the field, but they were demonstrated at grower and PCA meetings, to students, and at CE meetings. Early experience with this technology contributed to the Project's rapid adoption of the interactive CD-ROM technology that appeared in the 1990s.

Pest Management Photo Library. In the course of preparing IPM manuals, the Pesticide Application Compendium, and other publications, the IPM Project collected a library of high-quality photographs of pests, pest damage, natural enemies, and pest management techniques; Jack Kelly Clark, under the supervision of IPM manual staff, took most of the photographs. By 1990, the collection included more than 10,000 images and IPM Education and Publications initiated a system of coding and cataloging slides in a database on the IPM computer system for easy access. The slide collection became a highly valued resource used by many within UC ANR for images for publications and presentations.

Pesticide Application Compendium Series. In 1986, the IPM manuals group took on the responsibility for creating study guides for people preparing for pesticide applicator licensing exams. The first volume of the series, *The Safe and Effective Use of Pesticides*, compiled by Patrick O'Connor-Marer in cooperation with dozens of experts both within and outside the University, was published in 1988. Work began on a second volume in the series, *Residential, Industrial, and Institutional Pest Control*, which was released in 1991. In addition, Patrick was given responsibilities as the Pesticide Training Coordinator in 1988.

Farmworker Safety Training. Melanie Zavala joined the IPM Education and Publications group in 1988 as Farmworker Safety Coordinator, working under Patrick O'Connor-Marer's supervision. Melanie had previously worked with Mike Stimmann in the Office of Pesticide Information and Coordination (OPIC) as the farmworker safety training coordinator and served as a resource to farm advisors in the area of pesticide safety training for farmworkers. Melanie

developed several pesticide safety training videos and innovative bilingual educational products during her term with the UC IPM Project.

Continuing Education Programs for Pest Management Professionals. In 1988, PCA Seminar Coordinator Shirley Humphrey was transferred to the IPM Educations and Publications Group. Patrick O'Connor-Marer, with cooperation from others in the IPM program and UC CE, set up a series of continuing education programs for PCAs and applicators. Gale Chun (later Perez) took over from Shirley Humphrey as meeting coordinator in 1989. The continuing education program for pest control advisers featured an annual statewide education theme that was repeated at about eight locations throughout the state, and included additional local topics. These seminars, held during the years 1988-89, 1989-90, 1990-91, and 1991-92, and 1993-94, were very successful, drawing in about 1,500 attendees a year. Continuing education programs for pesticide applicators were initiated in 1988-89, but the presentation style was radically changed in 1990 to feature a hands-on format.

Computer Systems

Within IMPACT the most-used resources at this time were the UC pest management guidelines database and the weather database. Available crop and pest models were also widely used to provide learning tools and management information for farm advisors, PCAs, and growers.

Programs for microcomputers in production or nearing completion at this time included a codling moth model, models of insect pests of stone fruits and of vegetables, and a trap data management program useful for researchers or practitioners monitoring insects with traps. The Division began developing policy and procedures for distribution of this kind of software outside the University.

After UC IPM opened the IMPACT system to non-UC users, Joyce Fox Strand trained PCAs and growers to use the IPM Project’s computer programs.

The Project reconfigured and upgraded the original distributed computer system. All components of the new system were located in the IPM computer facility at UC Davis. Since there was no longer a district computer at Kearney Agricultural Center (KAC, formerly Kearney Horticultural Field Station) to oversee, UC IPM and KAC agreed to transfer the programmer FTE, filled by John Rasmussen, to KAC for their local computer support. Ann Strawn at UC Riverside continued to work on developing computer representations of research results, eventually relocating to join the Davis group.

Research Grants Program

Chairs of the Technical Committee. Chairs of the committee that oversaw the grants process during these years were:

1986-88	Mary Louise Flint	IPM Manuals Group, UC Davis
1988-90	Joseph Morse	Entomology, UC Riverside

The research-area workgroups (described above) were established in fall 1986. Each consisted of six individuals having expertise in the particular research area and appointed by the Project director for three-year, rotating terms. They included representatives from the Agricultural Experiment Station and Cooperative Extension and from the various pest management disciplinary areas. The chair of each functional group was appointed by the Project director and served on the Technical Committee; membership is shown in appendix XI.

During the fall of 1986, the new IPM workgroups met to establish minimum criteria and priorities for funding in their research areas. All funded proposals were expected to meet minimum criteria and address one or more of the IPM Project's general goals. Established priorities helped the workgroups determine which proposals to recommend for funding, given limited monetary resources. The Technical Committee made its final recommendations after reviewing proposals from all workgroup areas. Final funding decisions were made by the Project director. Progress reports on funded research were submitted annually and reviewed by the workgroups for evaluation of progress toward meeting stated goals.

Although the IPM Project disbanded its commodity workgroups, the Project kept strong links to commodity-oriented researchers by working closely with the existing Division of Agriculture and Natural Resources (DANR, formerly Division of Agricultural Sciences) workgroups. A workgroup or a designated subcommittee of the workgroup reviewed all research proposals related to its commodity and provided written evaluations for scientific merit and importance to the commodity for each. Workgroup chairs presented their highest-ranked proposals to the Technical Committee for consideration for funding. ANR workgroups could be used to meet the research needs of their commodity as well as the goals of the IPM Project. UC IPM shared annual progress reports with commodity workgroups to keep them informed about projects funded in their commodity.

This reorganization of the IPM Project research grants program had many benefits. By involving individuals and groups outside the original nine IPM commodities, the Project was infused with new enthusiasm and new ideas. The new procedures allowed funding in commodities with very limited acreage but with great potential for IPM implementation. The new workgroups reinforced the Project's interest in areas such as biological control, implementation, and evaluation, for which the Project received fewer proposals than desirable in the past. Proposals received more critical technical reviews in the research-area workgroups, especially in areas such as systems analysis, economics, and biological control, where expertise was limited in many of the IPM commodity groups.

IPM Internship Program

An internship program for graduate and undergraduate students was also established in 1987-88. The purpose of the program was to provide educational opportunities and field management experience to students interested in IPM. Motivating students to do field research, improving training in the design of agricultural experimentation, and introducing students to the type of work cooperative extension personnel were also special goals of the program. Each student had to be sponsored by a UC CE advisor or specialist or a member of the UC Agricultural Experiment Station. A small committee was established to review these proposals and make recommendations for funding.

Three internships were funded in 1987-88. These projects and their sponsors were

- Field Evaluation of a Presence/Absence Sequential Sample Plan for Pink Bollworm Eggs in Cotton. Sponsor: Bud Beasley, Area IPM Advisor, Riverside.
- Evaluation of the Effects of Insecticides on Beneficial Parasites in Manure Communities on Caged-Layer Poultry Facilities. Sponsor: Brad Mullens, Entomology, UC Riverside.
- The Effect of Soil pH on the Biological Control of Ring Nematode and Bacterial Canker of Stone Fruits. Sponsors: Bruce Jaffee and Howard Ferris, Nematology, UC Davis.

The internship program funded four additional internships in 1988-89. No internships were funded in 1989-90, but the program resumed for two years in 1991-93 through a gift from Lucky Stores.

Research Accomplishments of the First Decade

The University of California Statewide IPM Project was created by legislative mandate in July 1979 to implement and accelerate research and extension activities in integrated pest management in the state. By January 1980, an administrative structure had been established, 27 research proposals had been funded, and staffing for the Project had begun. Over the next decade, 222 research projects were funded in over 35 different commodities or pest management situations. Research projects funded during the first decade are listed in UC IPM Publication 10, *Bibliography of Research, 1980-1990*, available from IPM Education and Publications.

As the first decade drew to a close, the IPM Project commissioned James Grieshop and Robert Pence of the Department of Applied Behavioral Sciences, UC Davis to provide an independent evaluation of accomplishments and impacts of UC IPM-funded research. To conduct their evaluation, Grieshop and Pence sent questionnaires to the 229 individuals who had been principal investigators on UC IPM-funded research between 1979 and 1988 (a total of 180 projects). Surveys queried principal investigators about the interdisciplinary nature of proposal research design, useful products or information produced, including publications, and any evidence they might have indicating that results of their research were being used by practitioners in the field. Surveys were returned by 73% of the principal investigators, representing 90% of all 180 funded projects. A report of their findings is published in Grieshop, J. I. and R. A. Pence, "A sketch of 10 years of integrated pest management research outcomes," *California Agriculture* 44(5): September-October 1990. Much of the information presented here is taken from that article or directly from the surveys themselves.

Fostering Interdisciplinary Research. An important early goal of the Project was to foster an ecological systems approach to pest management research. The original IPM Project research review workgroups addressed specific crops and were comprised of individuals from the various pest management and horticultural sciences who worked on these crops throughout the state. These workgroups provided a mechanism for interdisciplinary discussion and an impetus for numerous new working relationships. Nearly two of every five projects involved researchers from two different agricultural science disciplines and two or more different institutions. Over half of all investigators involved CE farm advisors to assist in evaluation of the practical usefulness of the proposed research and 65% involved farm advisors in implementation, suggesting further interdisciplinary bridges.

Research Products. The ultimate goal of IPM research is to develop information, techniques, devices, or other products that are useful to practitioners in the field. Table 1 lists products identified by principal investigators as having resulted from their research. In all, 91% of the responding projects laid claim to an identifiable product. Not all of these research products were yet in the hands of practitioners, however. Forty-three percent stated that their products were currently being used by PCAs and growers. Many of the others stated that the research provided a basis for conducting subsequent research (55%) or obtaining subsequent funding (32%). Presumably this further research would lead to practitioner-oriented products sometime in the future.

Table 1. Products Categorized by Research Products.

	Projects	
Product/Information	**Number**	**Percentage**
Published papers	138	77
Refereed journal papers	104	58
Data bases	61	39
Decision-making procedures	59	37
Nonchemical pest control procedures	56	35
Sampling procedures	49	31
Computer programs	31	19
Chemical pest control procedures	21	13
Equipment	12	8

Publications. Over 75% of funded projects produced some sort of publication; many of those that didn't were projects that were just getting started or still under way. Principal investigators responding to the survey listed 578 publications, including 104 refereed journal articles as well as popular press articles, extension bulletins, and book chapters. Citations for publications resulting wholly or in part from UC IPM funded research are listed in UC IPM Publication 10, *Bibliography of Research, 1980-1990,* available from IPM Education and Publications at UC Davis.

Nonchemical Pest Control Procedures. Over the decade, the IPM Project focused substantial effort toward developing nonpesticidal management methods for pests. Numbers of projects directly aimed at such cultural and biological control alternatives increased dramatically in the second five years, especially in the area of biological control. For instance, two biological control projects were funded in 1980-81, 3 in 1984-85, 7 in 1987-88, 11 in 1989-90, and 19 in 1990-91. Of 52 projects funded for 1990-91, 34 were in the nonchemical control areas of cultural controls or biological controls. Many of these projects were too recent to be part of the survey or had not yet yielded products. Even so, surveyed PIs identified 56 nonchemical pest control procedures resulting from

their IPM-funded research. Table 2 lists those that were being used at the time of the survey by at least some California growers.

Table 2. Nonchemical Pest Control Methods Developed or Improved through UC IPM Project Funded Research and Currently Being Used by Some California Growers.

Fruit and Nut Trees, Berries, and Vines
Biological control of greenhouse thrips in avocado. Biological control of citrus thrips with *phytoseiid* mites. Biological control of citrus mites. Skirt pruning for management of Phytophthora brown rot in citrus. Predators to control spider mites in various tree and vine crops including use of pesticide resistant strains. Sanitation practices for navel orangeworm management in almond orchards. Water management practices for reducing damage by mites in almonds. Ground cover management practices that impact pest management in almond orchards. Managing cover crops to reduce navel orangeworm overwintering survival in almond orchards. Frequent irrigation cuts nematode damage in half in stone fruit. Vine canopy management for Botrytis bunch rot control in grapes. Vineyard canopy management practices for mites, leafhoppers, pathogens, and other pests of wine grapes in San Joaquin Valley. Granulosis virus for biological control of Western grapeleaf skeletonizer. Blackberry refuges to encourage biological control of the grape leafhopper. Irrigation guidelines to reduce losses in Central Valley vineyards. Hot water treatment of plants for foliar nematode on strawberries.
Vegetable Crops
Use of tomato resistance and tolerance for management of nematode pests. Effect of cover crops and nitrogen on lettuce corky root. Biological control of the tomato fruitworm and beet armyworm within fields of processing tomatoes. Biological control for leafminer in fresh market tomatoes. Effects of overirrigation and water stress on Phytophthora root rot of tomatoes. Release of natural enemies for the biological control of the southern green stink bug.
Field Crops
Weed control in establishing alfalfa stands through use of an oat companion crop. Evaluation of plant resistance for root knot nematode management in alfalfa roots. Water management alternatives for reducing damage in alfalfa. Development and evaluation of genetic materials and strategies to control foliar and crown diseases of alfalfa. Integrating water depth effects on weed management in rice. Identification of insect and fungal parasites important in control of aphids in cereals. Identification of fungus disease and insect parasites important in controlling aphids in sugarbeets in California. Revitalization of disease-free regions, planting times, and other cultural controls for beet yellows virus management. Cultural control of pink bollworm with crop rotation in cotton.

Table 2. Continued.

Other
Leafminer parasites for control of the leafminer on commercially grown chrysanthemums.
Biological control of crown gall in California nurseries.
Cultural control of ground squirrels through burrow destruction.

Sampling and Decision-Making Procedures. To make better pest management decisions, growers and pest control advisers need research-based guidelines that tell them when actions must be taken to prevent unacceptable pest damage. Fifty-nine projects contributed to the development of decision-making procedures, some of which were already in field use at survey time. These decision-making procedures are listed in Table 3.

Table 3. Decision-Making Procedures Developed Wholly or Partially through UC IPM Funded Research.

Fruit and Nut Trees, Berries and Vines
Forecasting shot hole disease on almonds.
Management guidelines for navel orangeworms and webspinning mites in almond orchards.
Treatment thresholds for spider mites in almonds and grapes using spider mite day units.
Treatment thresholds for citrus thrips based on percent infestation and scarring of fruit.
When to apply pesticide for control of California red scale.
Management guidelines for Phytophthora root rot and citrus nematode infestations in citrus.
Treatment thresholds for citrus red mite.
Economic injury levels for California red scale for southern California coastal and interior and San Joaquin Valley citrus using pheromone monitoring techniques.
Guidelines for increasing reliance on biocontrols with predaceous mites in citrus.
Degree-day models for Washington navel orange growth.
Management guidelines for omnivorous leafroller and orange tortrix in grapes.
Treatment thresholds for spider mites in grapes using spider mite day units.
Determine scab infection period for apple and pear scab management.
Management decision rules for apple pests including leafhoppers and aphids.
Role of ring nematode in preventing bacterial canker complex in stone fruit.
When to control X-disease insect vector in cherry and peach.
Management guidelines for foliar nematode on strawberries.
Guidelines for management of walnut blight.
Livestock
What time of year and which drug to use on intestinal worms in beef cattle.
Choosing insecticides to minimize impact on beneficial parasites in manure communities of cagelayer poultry.
Poultry IPM scouting program for cage-layer facilities.*

Table 3. Continued.

Vegetable Crops
Comparison of natural and pesticidal control of *Bernisia tabaci* in cantaloupe fields for the reduction of lettuce infections yellows virus.
Treatment levels for tomato pinworms on fresh market fruit.
Management guidelines for leafminers in fresh market tomatoes.
Damage thresholds for tomato fruitworms and beet armyworm in processing tomatoes.
Treatment threshold for tomato fruitworm incorporating parasitization of eggs by *TrIchogramma*.
Disease thresholds for yield loss due to Phytophthora root rot of tomatoes.
Guidelines for using plant resistance and tolerance for nematode management in tomatoes.

Reducing Pesticide Use. One goal of the IPM Project has been to reduce the pesticide load on the environment. Many projects focused on development of biological information or computer models and thus indirectly addressed this goal. However, many others, especially those listed under the research areas of biological control, cultural controls, and monitoring systems, would lead to reduced pesticide use. Of those surveyed by Grieshop and Pence in 1989, 57 projects, or 36%, stated they had evidence for pesticide reduction as a result of their IPM-funded research. Table 4 shows principal investigators' perceptions of the effect of their research on pesticide use. The 1989 UC IPM Annual Report focused on reducing pesticide use, and examples of projects that reduced pesticide use are detailed there.

Table 4. IPM Research Projects Categorized by Effect on Pesticide Use Reported by Principal Investigator.

	Projects	
Effect on Pesticide Use	**Number**	**%**
Reduction	57	36
No effect	37	23
Unknown	48	30
Research still in progress	15	9

Specialized Field Sampling Techniques. Many pests require development of specialized field sampling or monitoring techniques or laboratory procedures before pest managers can assess their identity, population levels, or potential severity in the field. Twenty-eight such techniques and procedures were developed through IPM-funded research. Development of sampling procedures often goes hand-in-hand with the development of decision-making guidelines. Most of the already-developed decision-making and sampling procedures were for use in the nine commodities that were the focus of IPM Project research in the first seven years of its existence; however, by 1989, similar techniques were under development for such diverse commodities as street trees, poultry houses, nursery crops, forests, and wooden structures.

Computer Programs. The IPM Project had sponsored the development of a number of computer programs to assist in making pest management decisions. In 1989 most of these were being developed for personal computers so that practitioners could use them in their day-to-day decision making. A number were released and were available from the IPM Project. Others were more research-oriented models designed to help researchers better

understand the complex ecosystems in which pest problems arise. A few were educational models that could be used to illustrate the dynamics of pest management decision-making to students. Table 5 lists computer programs developed through UC IPM research.

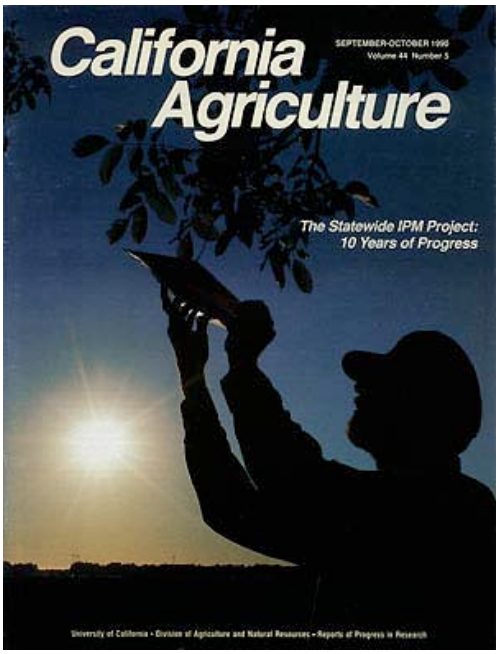
Table 5. Pest Management Computer Programs Developed through UC IPM Research

WHEAT: A model for predicting wheat growth stages. TOMDAT & TOMSIN: Tomato plant phenology models. CALEYICOTTON: Cotton crop management software programs. MINGROW: Model for managing leafminer on commercially grown chrysanthemums. GPM: General population model on IMPACT for simulation of citrus pests. DDU: Degree-day utility software. ALFALFA: Alfalfa growth and development model. SIMETEO: Stochastic weather simulation for IPM. CARICE: A rice growth model. GRAPE: Model for analysis and integration of plant growth and associated pests. NOW program: Navel orangeworm computer simulation.
Cereal and wild oat phenology and growth model. Flower phenology model for Washington navel oranges and California red scale. Belding ground squirrel control educational model. Development of weed population dynamics model for barnyardgrass and other weeds. Walnut tree phenology model. CALEX/PEACH: An expert system for diagnosing peach disorders. DD-MAPPER: A climate matching model. CALEX/STONEFRUIT: A model for spider mite management in stone fruit and almonds. Crop growth and development model for processing tomatoes. Fruitworm and beet armyworm linked models for processing tomatoes. Preliminary almond bloom and fruit phenology model.

* Those followed by (*) were still in research phase and not yet in field use in 1989. Principal investigators indicated the rest were being used by commercial growers or pest control advisers in California.

IV. THE SECOND TEN YEARS AND BEYOND

July 1, 1990 to April 3, 2003



On the tenth anniversary of the Statewide IPM Project, a special issue of *California Agriculture* ("The Statewide IPM Project: 10 Years of Progress," Vol. 44 (5) Sept/Oct 1990) summarized research and extension activities over the previous decade. The Statewide IPM Project's research and extension activities were growing well as it entered its second ten years, but it was also being hit hard by budget cuts. The permanent base support for the IPM Project was reduced by over $240,000, resulting in the loss of two academic positions including an area IPM advisor; reduced supplies, equipment, and travel for IPM staff; the elimination of opportunity funds that were used for program evaluation and analysis; and a reduction of $65,000 in research grant funding. The Project began focusing on external support from state and federal agencies as well as the private sector, to obtain funds for program enhancements.

In 1992 The National Environmental Awards Council presented the program with a Certificate of Environmental Achievement and recognized it as an "outstanding program in the Renew America 1992 Environmental Success Index. "In 1994 the California Legislature passed a resolution recognizing the Statewide IPM Project's success in improving pest management and reducing pesticide use over the previous 15 years, and in 1998, the program was again presented with a Certificate of Environmental Achievement by the National Environmental Awards Council.

A Special Section of *California Agriculture*, 54:6, November-December 2000, was devoted to summarizing advances during the twenty years of the IPM Project and how IPM evolves to battle new pests as they arrive.

Organization and Administration

Although the IPM Project was well established, it underwent several significant changes following its tenth anniversary.

New Location. In March 1999, the IPM administrative office and information systems group were relocated from Wickson Hall to the Robbins Hall Annex, also in the central part of the campus. The building was extensively remodeled to make it suitable for the program.

Pesticide Education Program. In 1993, the Pesticide Education Program (later the Pesticide Safety Education Program) became a separate management unit under the leadership of Pesticide Training

Coordinator Patrick O'Connor-Marer. Although housed in the same buildings as the IPM Education and Publications unit, Patrick O'Connor-Marer now reported directly to Project Director Zalom. Patrick became responsible for all study materials and educational programs related to pesticide applicators. Mary Louise Flint remained responsible for educational programs and study materials for pest control advisers.

Exotic Pests and Diseases Research Program. The UC IPM Program joined with the Center for Exotic Pest Research (CEPR) at UC Riverside to prepare a proposal for a USDA-Cooperative State Research, Education and Extension Service (CSREES) Special Research Grant. The proposal, prepared by Frank Zalom in consultation with CEPR Director Mike Rust and ANR Program Leader Joseph Morse, was successful and $1.1 million was made available for a competitive grants program in 2001-02 to address exotic pests and diseases that threaten agricultural, urban, and natural systems in California. The structure of this competitive grants program was modeled after the IPM grants program, with a request for proposals, a series of review panels, and a technical committee to recommend funding. A second grant ($1.4 million) was successful for 2002-03, and another was prepared for 2003-04 to continue the research program.

The Exotic Pests and Diseases Research Program issued its first report in 2002.

Resignation of Frank Zalom as Director, October 2001. After 14 years as IPM Project director, Frank Zalom resigned, effective October 31, 2001, to become a full time entomologist in the Entomology Department at UC Davis. Former director Jim Lyons served as interim director during the 16 months it took to recruit a new director.

A Review: Statewide Special Programs and Projects in the Pest Management Area, January 10, 2001. In 2000, ANR Associate Vice President Henry Vaux asked Jim Lyons to undertake a review of the several programs and projects that had activities in pest management. A particular focus of the review was to address how activities among the various groups could be better coordinated and whether any consolidation or reorganization would be beneficial. The report (appendix IX) was completed in January 2001, and two parts directly related to the IPM Project. One was a recommendation that an external search be conducted to replace Frank Zalom as director. This was acted upon and a new director chosen (see the section that follows).

The second item involved the potential retirement of Mike Stimmann, who was both director of the Center for Pest Management Research and Extension (CPMRE) and the statewide pesticide coordinator. The report recommended that when Mike retired, the CPMRE should also be "retired" since all of the putative duties had been essentially superceded by the reorganization of DANR that had resulted in the creation of program directors in subject matter areas, one of which was pest management. The report also recommended that when Mike retired, his responsibilities as statewide pesticide coordinator should be transferred to Rick Melnicoe, who was director of the USDA Western Region Pest Management Center (WRPMC) that was housed on the Davis campus in the Department of Environmental Toxicology. This was to occur with a transfer of a 0.25 FTE from

Mike's DANR position to Rick Melnicoe, who up to this point was totally funded by the USDA grant. It was also recommended that Rick be appointed as an assistant to the director of IPM to link the WRPMC and the IPM Program more closely. The primary function as pesticide coordinator was continued responsibility for validating pesticide recommendations embedded in UC IPM's pest management recommendations. This transfer took place in April 2002, upon Mike's retirement.

Statewide Program vs. Statewide Project. The program was initially identified as the Statewide IPM Project, but over time, it was referred to as the Statewide IPM Program as often as not. The 1994 legislative resolution identified it as a "program," as did other internal documents. The only factual difference is with the notion that "project" can have a temporary connotation, indicating that it has a finite life and will terminate when completed. "Program" reflects an ongoing effort, and hence in 2002 after 23 years, this became the uniform reference to what was once a "project."

Bylaws, November 2002. An issue that arose periodically was the question of whether research review panel (formerly "workgroup") members, and particularly panel chairs, could serve on a panel and also be principal investigator or cooperator of a proposal submitted to that panel's subject area. For a period of time the office of the vice president—ANR (OVP) allowed PIs to serve as members and chairs of review panels, but then they reversed that policy. Since this reversal greatly limited the pool of qualified scientists available (and/or willing) to serve on the panels, the OVP eventually recanted their decision and told the IPM Program that it could use whatever policy as stated in the bylaws. This led the program to recognize that bylaws had never been developed, so Interim Director Jim Lyons set out on that task, obtaining formal approval of a set of bylaws on November 1, 2002 (appendix X). These bylaws codified the program's established practices and, on the conflict of-interest issue, stated that, "if the PI or cooperator of a proposal is a member of an IPM review panel, a different panel must review the proposal. Panel chairs are eligible to submit proposals (as a PI or cooperator), however they will not be allowed to participate in the discussions related to their proposals."

Rick Roush joined UC IPM as director in 2003.

New Director. An international search for a new UC IPM director was initiated in the spring of 2001 after Frank Zalom announced his intention to resign as director, effective October 31, 2001. Jim Lyons was asked to serve again as interim director until a permanent director could be chosen. The process was completed on March 3, 2003, when Dr. Richard (Rick) Roush arrived and assumed the duties as director. Rick received his BS in entomology at UC Davis in 1976 and his PhD in biological control with Dr. Marjorie Hoy at UC Berkeley in 1979. After finishing his degree, he spent time at Mississippi Sate University and Cornell University, and most recently in Adelaide, Australia, where he was director of the Cooperative Research Centre for Weed Management.

The 1994 organizational chart (figure 7) describes the structure of the IPM Program through the end of this period.

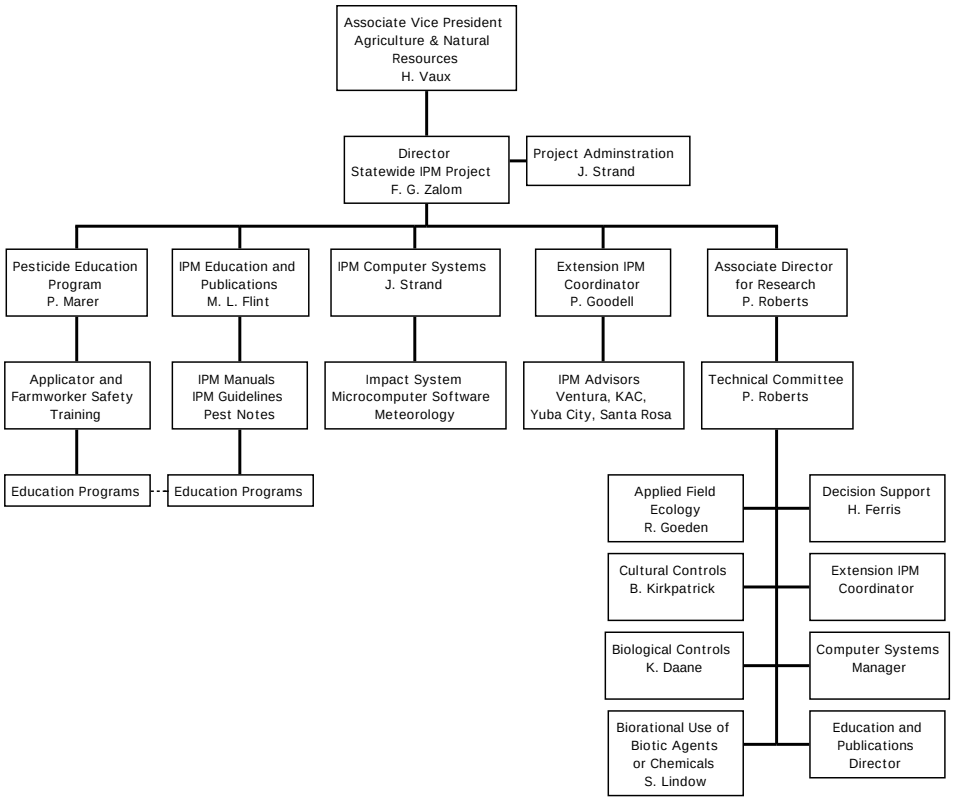


Figure 7. 1994 Statewide IPM Program Organizational Chart.

Field Implementation

Establishment of a "Core" Group at Kearney Agricultural Center (KAC). Changes in the administration of CE specialists were proposed in 1990-91 to comply with the new administrative procedures instituted within DANR by Vice President Ken Farrell. Among other changes, the new structure required that all CE FTE had to report through campuses or regions and could no longer report directly through directors of statewide special projects such as UC IPM. In order to achieve a clear understanding of reporting lines and expectations for regions/campuses hosting a position from a special project, a Memorandum of Understanding (MOU) had to be developed between the special project and a regional/county director or a dean/department chair. Such MOUs were developed for all the area IPM advisors at that time. Frank Zalom took the opportunity of this administrative change to propose that an interdisciplinary core of IPM specialists be developed at KAC to represent the four core pest management disciplines of entomology, nematology, plant pathology, and weed science. To accomplish this, Jim Stapleton, a plant pathologist, and Pete Goodell, both a nematologist and an entomologist, would be relocated to KAC. Bill Barnett, an entomologist, was already located at KAC, and a vacant FTE would be recruited as an IPM weed scientist at KAC. Four area IPM advisors would remain in county locations: Bud Beasley in Riverside, Sue Blodgett in Sonoma, Phil Phillips in Ventura, and Carolyn Pickel moving from Santa Cruz County to fill the vacancy in Sutter-Yuba counties. It was also planned that those area IPM advisors choosing to return to the title of area IPM "specialist" could do this by aligning with a department. Pete Goodell was accepted by the Nematology Department at UC Davis and Jim

Stapleton by Plant Pathology at UC Berkeley. However, realities of the budget cuts for 1990-91 made it impossible to transfer these advisor positions to specialist positions and hence the change was never instituted. The core group was assembled at KAC, but they remained area IPM advisors and reported through the regional director. Frank Zalom became a CE specialist and entomologist in the AES in the Entomology Department at UC Davis, reporting through the campus dean.

In April 1991, the core team at KAC published the first issue of "Plant Protection Quarterly," a newsletter that published reviews of pest management research and activities. Information in the newsletter targeted farm advisors and Agricultural Experiment Station researchers.

Lucia Varela explains pest identification to Spanish-speaking vineyard workers.

Other changes occurred in the area IPM advisor staffing during this period. In 1992, Sue Blodgett took a leave of absence for a year and entomologist Dr. Lucia Varela replaced her in an acting appointment. When Sue decided not to return to UC, Lucia was appointed to the position permanently. Carolyn Pickel was relocated from Santa Cruz County to Sutter County in the Sacramento Valley region. In July 1992, Dr. Tim Prather joined the group of IPM advisors at KAC. Tim's training in weed science complemented the others in the group, and he had a special interest in the use of geographical information systems (GIS) to compile maps of geography, soil conditions, weather, and cropping patterns that would make weed surveys more effective and less time consuming. In his time at KAC, Tim helped establish hands-on training in weed seedling identification for PCAs. In October 1994, Walt Bentley, an entomology farm advisor in Kern County, joined the IPM team at KAC to fill the

Weed ecologist Anil Shrestha checks a weed in a cotton field.

Walt Bentley monitors pistachio tree with beating stick and tray.

Tim Prather checks weed identification with a hand-held computer program.

position left by Bill Barnett's retirement. Dr. Cheryl Wilen joined the staff in September 1995 as area IPM advisor in the southern region, headquartered in San Diego. Her focus was on IPM for ornamental horticulture including greenhouse, nursery, and landscape situations important in the ag-

urban interface. Tim Prather resigned his position with the IPM Program in 2000 to accept a faculty position in Idaho. This left a vacancy in the weed science position at KAC. Dr. Anil Shrestha joined the core group at KAC as a regional IPM advisor/weed ecologist in March 2002. Anil had several years of experience in weed management, cropping systems, and sustainable agriculture.

It is interesting to note that about the time that Tim Prather was being courted for a faculty position in Idaho, the issue of area IPM advisors becoming area IPM specialists arose again as a possible means of enticing Tim to stay in California. However, the administration resisted this change with the justification that the function of advisor was one of the key components that has allowed the California IPM program to succeed in a way no other state has been able to approach. As specialists become more involved with individual research efforts tied to a campus department, implementation activities have historically suffered.

IPM Advisor Cheryl Wilen monitors field-grown cornflowers.

Building Partnerships. In the 1990s, community-based alliances of growers, pest management professionals, and researchers began springing up throughout the state to meet the challenges of finding reduced-risk pest management approaches. In most of these alliances, Cooperative Extension provided crop, pest, and IPM expertise, while producers, pest control advisers, and other interested organizations provided pragmatic direction to research and implementation. Each alliance worked cooperatively to review the current system and develop a plan. Frequent field meetings and demonstrations were a cornerstone of every program. Throughout the process, there is an active exchange of ideas, experience, and knowledge. For most crops, these alliances truly invigorated pest management systems.

The first group to use this model was the Merced Almond BIOS (Biological Integrated Orchard Systems) in 1988, which addressed issues related to insecticide reduction, fertility management, and cover crops, and was funded by UC Sustainable Agriculture Research and Education Program. Since that time, the California Department of Pesticide Regulation has used this general model of participatory extension and research to develop a competitive grants program for pest management alliances (PMAs) directed at promoting reduced-risk practices.

UC Statewide IPM Program advisors and specialists have been leaders in developing and coordinating successful PMAs in prunes, almonds, walnuts, cotton, pears, and nurseries. Active involvement in PMAs allowed IPM advisors to enhance and multiply their extension efforts. Each program was different and measures of success vary. The cotton PMA grew out of a successful alliance of UC Cooperative Extension and industry that saw the amount of pyrethroid, carbamate, and organophosphate insecticides used in San Joaquin Valley cotton drop by almost 60% between 1995 and 1999. The prune PMA evolved through the merger of several other cooperative efforts and strong leadership from the California Prune Board and has seen quick adoption of methods. Successful alternatives were found for all insect pests in prunes except aphids. The walnut PMA moved ahead demonstrating practical methods of using biological control for codling moth,

validating a walnut blight model, and other reduced-risk practices. Each alliance not only moved the science of pest management forward, but also enhanced the extension of IPM information.

IPM Education and Publications

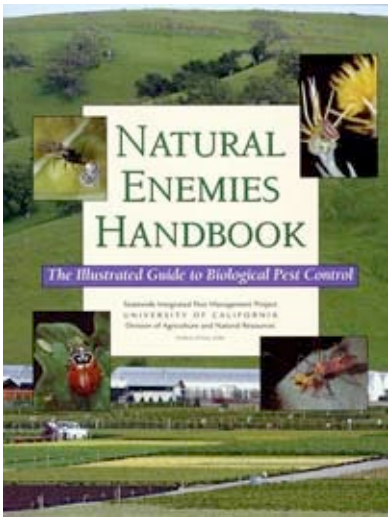
Education and Publications staff in 1997. Clockwise from left, Peg Brush, Steve Dreistadt, Larry Strand, Shawn King, Patty Gouveia, Cheryl Reynolds, Barbara Ohlendorf, and Mary Louise Flint.

In the years between 1990 and 2002, the IPM Education and Publications group continued to diversify its products and its audiences. At the beginning of the decade almost all of the group's products were produced on paper. By 2003, a substantial portion of the publications was on electronic media. The target audience grew as well. In the 1980s, almost all IPM publications were aimed at agricultural audiences. In the 1990s, IPM publications began to serve urban and suburban audiences as well.

The successful IPM manuals series continued to thrive. By 2003, there were 14 books covering 20 different crops. New titles came out on apples and pears (Ohlendorf), strawberries (Strand), stone fruits (Strand) and floriculture and nurseries (Dreistadt). Ten of the original manuals had been substantially revised as second editions. As each new book came out, the format and content improved on previous manuals. Later manuals had more photographs and larger ones, more line drawings and information on monitoring, more identification helpers, indexes, and more comprehensive bibliographies. Average length of the manuals went from 96 pages in the 1980s to over 200 pages in 2000. Almost 100,000 copies of these manuals had been sold. They had become a standard item in every PCA's bookshelf.

New books were produced to address the pest management needs of California's growing urban and suburban population. *Pests of the Garden and Small Farm*, published first in 1991 and revised in 1998 as a second edition (Flint), provided home gardeners and organic growers with IPM information for growing fruits and vegetables with low toxicity inputs. It included a diagnostic reference table of problems on 30 different fruit and vegetable crops. *Pests of Landscape Trees and Shrubs* (Dreistadt), released in 1994, was modeled after the *Pests of the Garden and Small Farm* format and addressed pest problems and IPM solutions on ornamental trees and shrubs. This book was extremely popular and became a study guide for several professional certification programs, including those for arborists and nurserymen. Both of these books became standard references for UC's master gardener programs; a great impetus for writing them was the lack of reliable research-based resources available for these volunteers who provide much of UC's outreach to urban audiences.

The Natural Enemies Handbook: An Illustrated Guide to Biological Control (Flint and Dreistadt) was released in 1998. This attractive publication, co-published by ANR Communications Services and UC Press, was selected by Choice Magazine as one of the Outstanding Academic titles of 1999, received the Silver Medal from the Agricultural Communicators in Education Association, and was honored as a faculty author selection at the UC Davis Faculty Authors Celebration 1998. It served a student as well as a practitioner and garden audience.



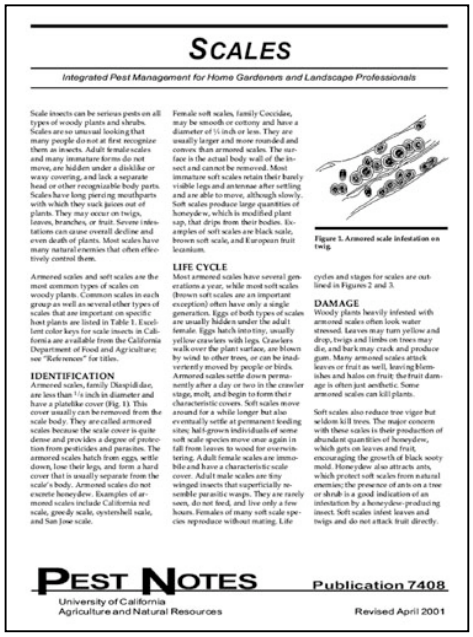
A number of other smaller publications were produced during this decade. These included *Managing Insects and Mites with Spray Oils* (1991), *Color Photo Guides for Sugarbeet Pests, Dry Bean Pests and Onion/Garlic Pests* (1995 and 1996). Other titles were *Whiteflies in California: A Resource for Cooperative Extension* (1995), *Reducing Insecticide Use and Energy Costs in Citrus Pest Management* (1992), and *The Natural Enemies Poster*. All of these are now available as ANR Communication Services publications.

Compiling and updating the *UC IPM Pest Management Guidelines* for agricultural crops continued to be an important task for the IPM Education and Publications group in the 1990s. By 2003, PMGs had been written for 43 individual crops or crop groups. In 1995, a major joint project with the UC IPM computer systems group was putting the PMGs on the UC IPM Web site. For all of the PMGs, staff identified hyperlinks to photos to illustrate pests, pest damage, natural enemies, and management techniques. As hyperlink editor for a group of PMGs, each senior writer continues to add new photographs as guidelines undergo major revisions (usually on a three-year schedule). These links and illustrations have made the guidelines more useful on the Web site. Many changes occurred in the dissemination of the PMGs, which were first primarily in paper format produced in PageMaker. Later they were produced as Word files only and placed on the Web as HTML and PDF formats. The PMG production staff (Shawn King, Peg Brush, and Barbara Ohlendorf) had to work very closely with the computer systems staff to develop protocols to interface paper and electronic production, and many innovative solutions were devised. The subscription offered by ANR Communication Services for the PMGs ended in 2000.

The weed photo gallery was introduced in 1998. The text is compiled by IPM Education and Publications staff and photos selected from the UC IPM photo collection. Weed scientist Joe DiTomaso reviews text and photos for all new weed galleries. By 2003, more than 150 weed species were covered. In 2003 a similar photo gallery for natural enemies was initiated.

A major project in the late 1990s was the development of a study guide and exam questions for pest control advisers to incorporate more IPM concepts. The impetus for this project came from the PCA organizations that were frustrated at outdated study material and exams that did not reflect current pest management technologies. Working with committees of experts from the University and the private sector, Patricia Gouveia (hired in 1995) and Mary Louise Flint developed knowledge expectations for all PCA licensing areas that detailed what PCAs should be expected to know to be licensed. Study guides were identified in most of the licensing areas that could address these knowledge expectations, and a special IPM textbook, *IPM in Practice: Principles and Methods of*

Integrated Pest Management was written to clearly outline integrated pest management concepts, methods, and tools. This book was released in 2001 and became a standard IPM text for many colleges. Pools of exam questions that addressed each of the identified knowledge expectations were written for each area. This involved consultation with experts from within the University and the private sector for all seven licensing areas and for IPM. Final exam questions for all areas were submitted to California Department of Pesticide Regulation (CDPR) in 2003, and new exams were initiated by CDPR that year. Emily Thacher Blanco came on board in 2001 to finish up exam questions and format them in LXR software, which allows them to be easily evaluated and tracked by CDPR. This project of upgrading the licensing exams took six years and involved more than 100 people.


SCALES

Integrated Pest Management for Home Gardeners and Landscape Professionals

Scale insects can be serious pests on all types of woody plants and shrubs. Scales are so unusual looking that many people do not at first recognize them as insects. Adult female scales and many immature forms do not move, and lack a distinct head or other recognizable body parts. Scales have long piercing mouthparts with which they suck juices out of plants. They may occur on twigs, leaves, branches, or fruit. Severe infestations can cause overall decline and even death of plants. Most scales have many natural enemies that often effectively control them.

Armored scales and soft scales are the most common types of scales on woody plants. Common scales in each group as well as several other types of scales that are important on specific host plants are listed in Table 1. Excellent color keys for scale insects in California are available from the California Department of Food and Agriculture; see "References" for titles.

IDENTIFICATION

Armored scales, family Diaspididae, are less than ⅛ inch in diameter and have a platelike cover (Fig. 1). This cover usually can be removed from the scale body. They are called armored scales because the scale cover is quite dense and provides a degree of protection from pesticides and parasites. The armored scales hatch from eggs, settle down, lose their legs, and form a hard cover but is usually separate from the scale's body. Armored scales do not excrete honeydew. Examples of armored scales include California red scale, greedy scale, oystershell scale, and San Jose scale.

Female soft scales, family Coccidae, may be smooth or cottony and have a diameter of ⅛ inch or less. They are usually larger and more rounded and convex than armored scales. The surface is the actual body wall of the insect and cannot be removed. Most immature soft scales retain their barely visible legs and antennae after settling and are able to move, although slowly. Soft scales produce large quantities of honeydew, which is modified plant sap, that drips from their bodies. Examples of soft scales are black scale, brown soft scale, and European fruit lecanium.

LIFE CYCLE

Most armored scales have several generations a year, while most soft scales (brown soft scales are an important exception) often have only a single generation. Eggs of both types of scales are usually hidden under the adult female. Eggs hatch into tiny, usually yellow crawlers with legs. Crawlers walk over the plant surface, are blown by wind to other trees, or can be inadvertently moved by people or birds. Armored scales settle down permanently after a day or two in the crawler stage, molt, and begin to form their characteristic covers. Soft scales move around for a while longer but also eventually settle at permanent feeding sites; half-grown individuals of some soft scale species move once again in fall from leaves to wood for overwintering. Adult female scales are immobile and have a characteristic scale cover. Adult male scales are tiny winged insects that superficially resemble parasitic wasps. They are rarely seen, do not feed, and live only a few hours. Females of many soft scale species reproduce without mating. Life cycles and stages for scales are outlined in Figures 2 and 3.

Figure 1. Armored scale infestation on twig.

DAMAGE

Woody plants heavily infested with armored scales often look water stressed. Leaves may turn yellow and drop, twigs and limbs on trees may die, and bark may crack and produce gum. Many armored scales attack leaves or fruit as well, leaving blemishes and halos on fruit; the fruit damage is often just aesthetic. Some armored scales can kill plants.

Soft scales also reduce tree vigor but seldom kill trees. The major concern with these scales is their production of abundant quantities of honeydew, which gets on leaves and fruit, encouraging the growth of black sooty mold. Honeydew also attracts ants, which protect soft scales from natural enemies; the presence of ants on a tree or shrub is a good indication of an infestation by a honeydew-producing insect. Soft scales infest leaves and twigs and do not attack fruit directly.

PEST NOTES Publication 7408

University of California Agriculture and Natural Resources

Revised April 2001

The Pest Note series of short answer pest management publications for home, garden, and landscape was launched in 1995. At this time, UC had almost no short answer publications for this audience and few people in the system willing to write them. The series was first set up as camera-ready publications with line drawings so county UC CE offices could photocopy them and give them out for free. With the development of the UC IPM Web site, they quickly also became online publications with hyperlinked color photographs. By 2003, Pest Notes for 109 different pests, including arthropods, weeds, pathogens, and vertebrates, were available and several others were under production.

Cheryl Weber Reynolds was hired in 1995 to assist in the production of the UC IPM Program's first interactive CD-ROM. This was a joint project with Mary Lou Flint, Joyce Strand, and Pam Geisel of UC CE Fresno. *The UC Guide to Solving Garden and Landscape Problems* was released in early 2000. It contained more than 2000 screens and 4800 photographs to help gardeners and landscapers identify over 600 pests and disorders. A second CD-ROM, *The UC Guide to Biological Control* written by Mary Lou and Cheryl, was released in 2002. A third CD-ROM on managing snails and slugs was created and released as a limited-edition training tool.

By 2001, the program decided to focus on using the Web for interactive educational tools rather than CD-ROMs. Several new products were produced on the UC IPM Web site. The IPM and water quality part of the site was created to meet a real need by master gardeners and local agencies to answer residential queries about pesticides and water quality and how to reduce impacts. An interactive key to household ants was produced and placed on the Web site in 2001. An interactive guide to lawn care, the "UC Guide to Healthy Lawns," was first placed on the

Web in 2002 and was expanded in 2003. A special training session for master gardener coordinators was held in March 2003 to train them how to use interactive tools and information sources on the Web.

The IPM Education and Publications office became involved in several educational programs related to urban use of pesticides and water quality. The group worked with the City of Modesto to create information cards for residents of that city in 2000. Also, in a more extensive project with the City and County of Sacramento, staff created a series of consumer pest cards that informed residents about alternatives to organophosphate insecticides. These cards eventually became the statewide consumer pest cards used by many county offices and master gardener programs and the Quick Tips on the UC IPM Web site in both English and Spanish. Jodi Azulai joined the IPM Education and Publications staff in 2000 to help coordinate a training program for master gardeners in Sacramento County on water quality and IPM. This program was very successful, and several other county programs adopted the binder and related educational materials. The program was recognized with a CDPR IPM Innovator Award in 2001 and will serve as a starting point for future programs.

During the 1990-2003 period, staff was involved in a number of educational programs to extend information found in their publications. After the release of *Pests of Landscape Trees and Shrubs*, Steve Dreistadt and Mary Louise Flint, along with Patrick O'Connor-Marer, organized a series of statewide conferences to promote the concepts and techniques presented in the book. The programs were held in public arboretums so hands-on activities and diagnostic tours could be incorporated. Since 2000, Mary Louise and Steve organized and co-sponsored the California Association of Nurseries and Garden Centers CCNPro Education Days for retail nursery professionals. The UC IPM Program also organized and sponsored a conference for public agencies in March 2002, to promote networking between UC scientists and public agency personnel who were charged with carrying out IPM programs in parks, schools, playgrounds, and public buildings. Staff members were also closely involved with the IPM for Schools program coordinated by CDPR, including participating in pilot training programs and working with the CDPR staff to create an interface between UC IPM's Pest Notes and their pesticide hazard information in the IPMHELPR.

Pesticide Safety Education Program

PSEP staff in 1997. Clockwise from left, Kathy Garvey, Pat O'Connor-Marer, Melanie Zavala, Jenny Weber, Diane Clarke, and Gale Perez.

The UC IPM Pesticide Safety Education Program (PSEP) was begun in 1988. It assumed responsibility for developing study materials and educational programs for California's pesticide handlers and pesticide safety information for individuals who work in areas where pesticides are used. In 2002, there were about 26,000 certified commercial applicators, 40,000 certified private applicators, and more than 70,000 non-certified mixer-loader-applicators in California. In addition, nearly 1,000,000 agricultural workers labor in fields that may have been treated with pesticides. State and federal laws mandate training for anyone working with pesticides or working in areas where pesticides have been applied. In

2002, Pesticide Safety Education Program staff included a coordinator (Patrick O'Connor-Marer), two bilingual pesticide educators (Jennifer Weber and Tim Stock), a meeting planner (Gale Perez), a writer (Diane Clarke), an administrative assistant (Rosa Rossiter), and a 0.3 FTE evaluation specialist (Sonja Brodt). Former staff, including writers Mark Grimes and Kathy Garvey, contributed to developing study guides for commercial pesticide applicators. Bilingual pesticide educators Melanie Zavala and Guadalupe Sandoval developed many of the Spanish-language training materials and pioneered both the hands-on workshops and the statewide train-the-trainer programs. Research and outreach grants and income from program activities provided support for most of these positions. The Pesticide Safety Education Program became an integral part of the NIOSH-funded Western Center for Agricultural Health and Safety, and O'Connor-Marer served as deputy director for the Center.

Since the program began, staff wrote and published more than 6,200 pages of information on ways to reduce risks when applying pesticides and how to handle and use these materials safely and legally. Publications include 11 study manuals for certified applicators, 14 instructor manuals for people who train pesticide handlers and agricultural fieldworkers, and 18 informational manuals and pamphlets for employers. In addition, staff produced 10 pesticide safety videos and two training games, and contributed many articles to trade publications and technical journals. Many of the program publications are available in Spanish and others have been translated into Japanese and Punjabi. Several of the study manuals are used as textbooks in various states and some were translated into other languages for use in Cuba, South America, Southeast Asia, Russia, and the United Arab Emirates. The program also became involved in several research projects to develop and test effective ways to bridge language, cultural, and educational barriers when extending pesticide health and safety information to California's workforce. One successful project involved using English-as-a-second-language (ESL) and English-for-specific-purposes (ESP) concepts to help Hispanic and Hmong farmers read and understand pesticide labels.

PSEP produced this publication in Spanish in 1991, and updated it in 1998.

The program offered ongoing train-the-trainer workshops throughout California each year for employers, labor contractors, and others responsible for training pesticide handlers and agricultural fieldworkers. The program also conducted annual workshops throughout the state for health care providers, supplying them with much-needed information on recognizing and managing pesticide poisoning. Program staff pioneered hands-on workshops for training pesticide handlers in the early 1990s, a concept adopted by community groups in several counties. Program staff presented information on pesticide-use risk reduction at more than 50 county Cooperative Extension educational meetings and master gardener training programs each year. Staff members were often asked to assist farm advisors in training Spanish-speaking farmworkers on ways to avoid exposure to pesticide residues.

Computer Systems

Throughout the 1980s and 1990s, UC IPM added new resources to its computer system and enhanced others, but use of the system was limited by the difficulty users had with the technology for connecting to the online system. However, when the World Wide Web entered onto the scene in the mid-1990s, computer manufacturers, software producers, and telecommunications providers provided streamlined systems to jump the connection hurdle. With the technology factor removed as an issue, UC IPM was well-situated to take advantage of the Web as a much-improved distribution system. The program had been building computerized IPM content for almost 15 years, and was ready to rework that information to incorporate the advanced features of the Web.

In 1995, the computer group began converting its primary resources from the IMPACT computer to the World Wide Web, and the process was completed in 1996. Immediately, UC IPM's Web site (www.ipm.ucdavis.edu) was the most content-rich site available for pest management. Through the Web, UC IPM could be reached by anyone in the world looking for the information provided there and information could be linked with other documents and sites with useful information on related subjects. Pest management guidelines and other documents could be illustrated with color photos and line drawings to help readers identify pests or understand how IPM methods worked.

Work on databases and software in support of the University's statewide pest management extension and applied research programs continues. Products have been designed to improve information delivery, research, and education by county extension offices, and to be used in the testing of research findings and delivery to the public and private sectors. Almost all software and databases are written for the Web. This allows new versions to be distributed easily and supports Unix, Macintosh, and PC platforms with little extra effort.

Advice to Growers, Landscapers, and Residential Users. Particularly after the move to the World Wide Web, the information systems group worked closely with the IPM Education and Publications unit to develop online materials for farmers, residential users, and landscapers. The original Web site, opened in October 1995, featured the *UC IPM Pest Management Guidelines*, UC's recommended alternatives for controlling pests on crops, commercial turf, and in homes and landscapes. In contrast to the printed version or the earlier IMPACT computer version, the Web guidelines could be illustrated with high-quality color photos of the pest's life stages and its damage, which added greatly to the usefulness of the materials.

Over time, materials were added to help readers better identify pests and beneficial organisms. The weed photo gallery contains descriptions and photos of more than 125 weeds commonly found in California farms and landscapes. The natural enemies gallery gives photos, descriptions, and some information about the targets of the beneficial organisms. Interactive keys, including a key to common household ant species and keys to various aphids, have also been developed. Additional landscape and garden materials include an interactive "UC Guide to Healthy Lawns" and a set of pages describing the effects of home pesticide use on water quality. These materials are lavishly illustrated and prepared designed to be not only informative but to grab the viewer's attention.

A number of resources were developed in cooperation with researchers to help growers make better decisions when managing their crops. Some examples:

- Degree-day calculator that, along with weather data from IPM's extensive database or a grower's own station, lets growers and PCAs time pesticide sprays better.
- Cotton planting forecasts, made daily during planting season, help growers know when conditions are right to get a good stand of cotton.
- Dormant spray alternatives calculator to help stone fruit and almond growers determine costs of alternatives to dormant organophosphate sprays.
- Silverleaf whitefly resistance monitoring update for the desert valleys.
- Processing tomato weather network postings of disease severity calculations for blackmold
- Index of risk of grape powdery mildew infection posted daily.

California PestCast. In 1995, U.S. EPA gave a grant to UC IPM to develop a public-private weather network in support of crop-disease model research validation and outreach to encourage adoption of these models for improved disease management. Through partnerships with industry, networks were established in Mendocino, Lake, Fresno, Madera, Santa Cruz, and San Joaquin counties, and a tomato network reached from Fresno County through the southern Sacramento Valley. These, and a few individual stations, supported disease model validation projects on 15 projects on 11 crops. The effort built on an earlier cooperative project between UC IPM, Extension Plant Pathologist Doug Gubler, Adcon Telemetry, and growers in Napa, Sonoma, and Kern counties to validate and implement Gubler's grape powdery mildew model.

PestCast weather station in a tomato field.

Pesticide Information. With funding from USDA-Extension Service, the computer group developed a database that summarized the pesticide use reports from CDPR by site, chemical, county, and month. The database provided the first opportunity for individuals to access the pesticide use data gathered in response to the 100% reporting requirement that went into effect January 1, 1990. Each year's data was added as it became available from DPR, and by 2001 the database summarized 39 million records for years 1990 through 2000.

Crop and Pest Models. CALEX/Cotton, a project funded through the IPM grants program, was an expert system designed to help growers manage several aspects of cotton production, such as fertilizer, irrigation, and pests. The information systems group worked with the large CALEX team of research and extension scientists to develop the program as a saleable product. UC IPM first distributed the computer program in 1988, and during each of the next three years, staff revised it to add new information developed in the field. CALEX/Cotton was a first attempt to bring together information on the interactions among the various management tasks related to growing cotton to help growers make better decisions. The program wasn't a commercial success, but it served as an integrating tool; in building the program, researchers were able to see how practices fit together, how much was being required of growers or pest control advisers, and the need for new tools to streamline data gathering for decision making related to cotton.

Through the Web site, users have access to interactive models of about 20 specific pests and to a database that describes models of crops, insects and mites, nematodes, weeds, and diseases, as reported in the scientific literature.

UC IPM Program Information. The Web site distributes descriptive materials about the IPM Program and its publications, workshops, and other resources. It contains the UC IPM annual reports, descriptive materials about program activities, and a database describing all projects funded through the UC IPM competitive grants program and the Exotic Pests and Diseases Research Program.

Research Grants Program

Chairs of the Technical Committee. Chairs of this committee that oversaw the grants process during these years were:

1990-92	Joseph Morse	Entomology, UC Riverside
1992-96	Philip Roberts	Nematology, UC Riverside
1996-99	John Menge	Plant Pathology, UC Riverside
1999-2002	Michael Rust	Entomology, UC Riverside

Review of the Research Grants Program

In 1991, the Technical Committee reviewed the existing workgroups and priorities to determine if they reflected the strategies and tactics that could most efficiently be applied toward meeting the stated goals of the IPM Program. As a result of this review, the biological controls and the cultural controls workgroups would continue with only minor changes in priorities. A new workgroup for the biorational use of biotic agents or chemicals was recommended, which reflected the potential for improving and applying pest control alternatives such as microbial agents, attractants, and repellents. Another new workgroup, applied field ecology, would focus on interactions between pests, their hosts, biotic factors that regulate their abundance and the abiotic environment. A new workgroup for decision support would focus on development of tools that would assist pest managers in more efficiently monitoring or predicting crop and pest status. These new workgroups replaced the previous workgroups on commodity-pest interactions, monitoring systems, and systems application.

In November 1994, Frank Zalom undertook an external review of the research program, designed to define the agenda for the IPM Project for the subsequent five years. This review, by an *ad hoc* IPM research program advisory committee, was to set parameters for research proposals that would be submitted by potential investigators. At a meeting held on the Davis Campus on October 27, 1994, 26 individuals who represented a diverse cross section of grower groups, agencies, and related organizations (see appendix VIII) were invited to meet with the IPM Technical Committee to discuss the structure of the grants program and current priority research areas. The review committee indicated that the existing workgroup structure was adequate to address priority research needs. However, it recommended that some mechanism be established such that growers, PCAs, and others could have input into prioritizing projects to be funded. The breakout groups assigned rankings to the general research areas, identifying weed management and postharvest pests as the most significant areas that should receive more emphasis. Resistance management, economic and environmental evaluation, and roadside weed control were rated lowest of the priority areas identified.

As a result of the *ad hoc* committee's recommendations Frank reported back (see appendix VIII) that the Project would take the following actions: report to the DANR administration about the committee's concerns that additional pest management research emphasis was needed in the areas or weed (vegetation) management and postharvest pests and recommend that DANR consider additional staffing for the study of both weed management and postharvest pests; emphasize these research areas in its request for proposals to ensure an understanding that research proposals in these areas were both appropriate and welcome; and solicit from commodity groups and other interested organizations a list of priority concerns for pest management research and the reasons for their concerns as a meaningful approach to obtaining external input into the grants process. When UC IPM conducted a survey of 54 commodity groups and organizations, 24 responded. These identified almost 250 individual issues related to about 30 crops or specific sites, and 150 invertebrate, disease, weed, and vertebrate pests.

A Profile of IPM Research Results from 1989-1999. Karen Klonsky and Ben Shouse surveyed principal investigators funded under the UC IPM Competitive Grants Program to examine the evolution of the IPM Project from 1989 through 1999 (*California Agriculture* 54:6, pages 20-21, 2000). Survey respondents helped characterize the distribution of grants by commodity area and discipline, the degree of collaboration fostered, research goals, and outcomes of research.

The following is taken from the *California Agriculture* article:

> In the last decade, almost half of the projects funded involved fruit, nut, or vegetable crops, and another quarter addressed field crops. The remaining projects focused on livestock, nursery and flower crops, and urban or landscape pests, or did not specify a commodity, focusing instead on general techniques. In all, 194 funded research projects investigated 45 different crops. By contrast, during the Project's first 10 years, it focused 80% of research funding on eight major crops or commodities (alfalfa, citrus, tomatoes, cotton, rice, grapes, walnuts, and cereals).
>
> *Collaboration.* Klonsky and Shouse's data was based on completed surveys from 78% of the principal investigators to whom surveys were mailed, representing 153 of the 194 projects that

received IPM grants between 1989 and 1999.

Entomology was the discipline most often included in the research projects (45%), followed by plant pathology (21%). Most (70%) were managed by two or more investigators. While only 17 projects (9%) involved principal investigators from different academic disciplines, 49 projects (25%) involved principal investigators from different institutions (table 1)**.** The rates of interdisciplinary cooperation and cross-institutional studies were lower than during the first 10 years of the program, when rates of 38% and 36% respectively, were identified (Grieshop and Pence 1990). From these results, it appears that collaboration of principal investigators is more likely to occur within disciplines, but across institutions as researchers look beyond their own institutions to find co-investigators with the necessary technical expertise and interests to develop IPM research proposals. Principal investigators reported receiving assistance from a variety of cooperators (table 2). Notable among these were UC farm advisors, who were the most frequent participants of any group in every stage of the research process except providing field trial space. They were seldom principal investigators on proposals although they were essential collaborators in developing proposals, managing field trials, and collecting data.

Growers participated in the research projects either as individuals or through commodity groups. Field-trial space was provided by growers for well over half of the IPM Projects, and these growers assisted in managing almost one-third of those field trials. Clearly, the generous support of growers is critical to the research program funded by the UC IPM Program. However, growers were much less likely to be involved in data collection or interpretation of the results than in other aspects of the research either as individuals or through a commodity group.

Of other individuals and organizations outside of UC, representatives of commodity groups were twice as likely as growers, public agencies, or state-licensed PCAs to be involved in research proposal development, but none of these groups participated in more than 10% of proposals in terms of field trial management, data collection, or interpretation of results.

Research Outcomes. The principal investigators responding said research outcomes included publications, pest-control methods and equipment, and computer decision aids. About two-thirds of the UC IPM research projects resulted in 480 publications, of which 220 appeared in peer-reviewed journals. Web-based publications emerged from 10% of the projects. Virtually unknown 10 years ago, Web dissemination of information will undoubtedly continue to expand in the coming years.

While 30% of the projects resulted in nonchemical pest-control procedures, less than 10% developed synthetic chemical pest-control procedures, reflecting the general goal of UC IPM to develop strategies and tactics that permit pest managers and growers to move away from the use of synthetic pesticides toward biorational materials and other risk-reducing approaches. Developing decision-making protocols and sampling procedures continue to be important goals of IPM research.

Fewer resources were directed toward developing computer programs for clientele than in the

first 10 years of the program. This may reflect increasing sophistication of the general public in using software such as spreadsheets for their own decision making, increased use of the Web, and an increase in software development by the private sector.

Pest Control Methods Developed. During the 1990s, the USDA's National Agricultural Statistics Service began to classify growers' approaches to pest control as prevention, avoidance, monitoring, and suppression, and this has become one tool for measuring IPM adoption. Preventative measures act to decrease the likelihood of an infestation through techniques such as using pest-free planting material, sanitation of equipment to avoid spreading weed seeds, destroying overwintering habitat for insects, and irrigation scheduling to avoid disease infestations. Avoiding exposure to pests means planting resistant varieties, crop rotation to break pest cycles, and choosing locations that are relatively pest-free. Suppression includes methods used in response to a pest outbreak to avoid reaching economically damaging levels. Monitoring is typically used in conjunction with suppression methods for information used in making the control decision.

Most of the research projects (77%) included pest suppression as a method of pest control and 40% focused solely on pest suppression (Table 3). The most common suppression method investigated was biocontrol/natural enemies (38% of projects), followed by chemical pesticides (14%) and organically acceptable microbial and botanical pesticides (13%). Over one-third of the projects developed monitoring procedures. One-fifth of the projects focused on avoidance practices such as use of resistant cultivars in an IPM program, crop rotation, timing of harvest, and trap crops, while one-fifth focused upon cultural practices used to prevent infestations.

Research Goals. Klonsky and Shouse's analysis did not measure the adoption of IPM techniques, but rather documented the goals of the researchers. In many cases, the projects had multiple goals. Almost three-quarters of the projects were directed toward reducing pesticide use, and two-thirds of the projects were undertaken to improve the efficacy of pest control. Other frequently mentioned goals were lowering the cost of pest control, increasing the social acceptability of pest control systems, increasing the use of natural controls, and providing pest management methods for organic production. In particular, 39% of the projects developed methods appropriate for organic production.

The regulatory atmosphere that has evolved over the last decade to emphasize soft (environmentally benign) *and* risk-reducing approaches is a reflection of society's continuing concern for environmental and health impacts of continued use of broad-spectrum synthetic pesticides. IPM research hopefully will help growers and pest managers meet challenges posed by issues such as the Food Quality Protection Act, loss of methyl bromide, the Clean Water Act's Total Maximum Daily Load Program, and, of course, profitability.

A challenge of the UC IPM Competitive Grants Program over the next 10 years will be to set priorities that will enable the development of practical soft and risk-reducing approaches that can be implemented by farmers and other pest control practitioners in California.

Cited Reference

Grieshop JI, Pence RA. 1990. Research results: Statewide IPM's first 10 years. *Cal Ag* 44(5): 24-6.

Table 1. Distribution of IPM Projects by Principal Investigators' Institutional Affiliation

Institution	Funded Projects (n=194)		Survey Response (n=153)	
	Number	%	Number	%
Cross-institution*	49	25	40	26
UC Davis	60	31	48	31
UC Riverside	41	21	36	24
UC Berkeley	32	17	20	13
Cooperative Extension	4	2	3	2
Statewide IPM Project	7	4	5	3
USDA	1	1	1	1

*Defined as more than one UC campus or Cooperative Extension office and more than one academic department on the same campus.

Table 2. Assistance Provided by Institutions and Individuals at Various Stages of the Research Process (n = 153)

Persons Assisting	Develop Research Proposal	Provide Field Trial Space	Manage Field Trial	Collect Data	Interpret Results
Growers	20 (10)*	106 (55)	51 (26)	13 (7)	10 (5)
Commodity groups	41 (21)	7 (4)	9 (5)	3 (2)	5 (3)
Agencies	16 (8)	8 (4)	8 (4)	7 (4)	7 (4)
PCAs	23 (12)	15 (8)	17 (9)	9 (5)	5 (3)
Farm advisors	75 (39)	37 (19)	56 (29)	50 (26)	43 (22)
IPM advisors	22 (11)	6 (3)	13 (7)	13 (7)	14 (7)
Faculty	54 (28)	10 (5)	12 (6)	20 (10)	42 (22)
CE specialists	42 (22)	4 (2)	12 (6)	21 (11)	30 (15)
UC IPM staff	3 (2)	1 (1)	0 (0)	2 (1)	5 (3)

*Numbers in parentheses are percents of total number of projects.

Table 3. Methods of Pest Control Developed by IPM Research Projects

Methods of pest control	Projects	
	Number	%
Prevention	30	19
Avoidance	31	20
Monitoring	52	34
Suppression:	119*	77
Natural enemies/biocontrol	59	38
Chemical pesticide	22	14

Microbial pesticide	17	11

Table 3. Continued.

Physical control (e.g., barriers, flooding, burning)	16	10
Spot/precision application	16	10
Reduced-risk pesticide	13	8
Cultivation and related techniques	11	7
Adjustment of planting density	4	3
Botanical pesticide	3	2
Mating disruption	3	2
Antibiotics	1	1
Genetic engineering	1	1
Other	8	5

*Column entries and total do not match due to multiple responses.

UC IPM Publications

A complete list of publications from the UC IPM Program is in appendix XIII.

Appendices

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