Pest Management: A Student Commentary on Contemporary Problems

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INTRODUCTION

By the year 2000, there may be over 6 billion people in the world. Unless it is controlled, urban development will increasingly overrun more of what we consider today to be our best agricultural land. The world population will only be able to feed itself in the future if man has the ability to drive a maximum yield from crop plants and animals produced on limited land resources (McKelvey 1969) and reduce the human population increase. Future demands for space, food, and fiber, combined with the concern for environmental quality, will impose new constraints on pest control specialists. Nickel (1973), however, stated that intensification of land use in most areas of the world may result in a depletion of soil fertility, soil erosion, deterioration of soil physical properties, uncontrolled weed growth, and increased pest insect and disease problems.

To protect his resources and obtain the most from agricultural and forest lands, man will need to use pesticides. His dilemma is that in order to protect some resources, he must use more pesticides; conversely, to protect other resources, he must use less pesticides (Entomological Society of Canada 1970). Pesticides are in part responsible for the abundance and variety of foods enjoyed by many in the more affluent nations of the world (Coppock 1972).

The adverse side effects of insecticides on non-target organisms and insecticide interaction within the environment are well documented (Ripper 1956, Hayes 1960, Carson 1962, Akesson and Yates 1964, Rudd 1964, Newsom 1967, Mrak 1968, Terriere 1968, Graham 1970, Cope 1971). The result has been a rise in a number of serious environmental problems having a direct influence on pest control (Stern et al. 1959, FAO 1966, National Academy of Sciences 1969, Smith 1970). It is becoming more apparent that man must develop pest management systems for future crop and environmental protection.

So much has been published recently on the topic of integrated control and pest management that one could easily become overwhelmed by the vast amount of information on the subject (Smith 1970). My philosophy of pest management and integrated control, which is in agreement with that of the FAO (1973), has been misinterpreted by many associated with agriculture. Some people consider integrated control and pest management to be synonymous. To some extent, confusion may be justified.

In a broad sense, "pest management" is a new term for a philosophy that has been around for years and practiced by many well-informed applied entomologists and plant pathologists with ecological backgrounds. Ripper (1944), DeBach (1951), Griffiths (1951), Pepper (1955), and Pickett et al. (1958) were some of the early advocates who with foresight emphasized an ecological approach to insect pest control. Snyder (1960) has shown that plant pathologists have for decades practiced disease control using this philosophy. Wilhelm (1973), also a plant pathologist, expressed the view that most successful lasting pest control measures, no matter how arrived at, result from the application of ecological principles.

It is not my intention to review all the existing pest management literature or programs. The purpose of this commentary is to expose some of the problems of today and put forth ideas for the future. First, a discussion of the philosophy of integrated control and pest management as expressed by the FAO (1973) Panel of Experts is necessary.

INTEGRATED CONTROL AND PEST MANAGEMENT

The early consideration of integrated control by Ripper (1944), Pickett et al. (1946), Smith and Allen (1954), Bartlett (1956), and Stern et al. (1959) emphasized the importance of combining biological and chemical control methods. This concept was defined by Stern et al. (1959) as "applied pest control which combines and integrates biological and chemical control." Further, "chemical control is used as necessary and in a manner which is least disruptive to biological control; integrated control may make use of naturally-occurring biological control as well as biological control effected by manipulated or introduced biotic agents." This philosophy, later stressed by Bartlett (1964), may have been brought about by social, political, or economic pressures which developed in the late 1940's and 1950's resulting from increased environmental awareness.

As the literature became laden with documentation concerning adverse side effects from pesticide usage and as evidence of the hazards of intensive pesticide usage mounted, a broader concept of integrated control arose. Now, not only is it considered to be a combination of chemical and biological control, but it has become a concept incorporating many different methods of pest control. The latest integrated control concept has been defined by Smith and van den Bosch (1967), the FAO (1968a), and Smith (1969a, b) and reaffirmed by the FAO (1973) as "a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economic injury."

Pest management has become one of the most popular and publicized topics in entomology (Smith and Hagen 1959, Stern et al. 1959, Messenger 1965, FAO 1966, 1968a, b, Geier 1966, Clark et al. 1967, Smith and van den Bosch 1967, Smith 1968, National Academy of Sciences 1969, Rabb and Guthrie 1970, Madsen and McMullen 1971, Pimentel 1971, Proceedings Tall Timber Conference 1969, 1971, 1972, 1973, Stark and Gittins 1973). Stark (1970)[2] presented a summary of integrated

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[2] R. W. Stark. 1970. Integrated control, pest management or protective population management? Paper presented at AAAS Symp. on Theory and Practice of Biological Control, Dec. 30–31, 1969. Boston, Mass.

control and pest management including the evolution of its philosophy, definitions, and outlook for the future.

Many people feel that pest management and integrated control are essentially the same. This has led to considerable confusion and controversy; some would even prefer a different term than "pest management" such as "pest population management," "protective population management," or "integrated pest management." Stark (1970)[2] felt that integrated control and pest management should be considered two distinct entities. Pest management should be considered a component of resource management, and integrated control one approach by which regulation of pest populations is achieved. This is essentially the philosophy of the FAO (1973), i.e., pest management includes "all approaches ranging from single component control methods to the most sophisticated and complex control systems." Pest management, therefore, embrances the many known methods of pest control or regulation such as quarantines, host resistance, biological control, integrated control, supervised control, microbial control, genetic manipulation, cultural methods, physical and mechanical methods, hormones, antimetabolites, antifeeding compounds, attractants, repellents, sterilization, chemical pesticides, and legislative control (National Academy of Sciences 1969). Here is where the confusion lies. To some people, integrated control may still appear to lie somewhere between chemical control and natural (including biological and microbial) control. By the broad definition of the FAO (1973), however, integrated control should be considered one approach to control in a pest management system. Integrated control relies on "the fullest use of natural mortality factors complemented when necessary by artifical methods . . . chemical pesticides should be used only where economic injury thresholds would otherwise be exceeded." Integrated control is therefore a distinct, more specific concept, whereas pest management "is a general term which applies to any form of pest population manipulation invoked by man" (FAO 1973). This philosophy is important, and it should be understood and accepted by all concerned. The pest management specialist must be the proverbial middle-of-the-roader; he cannot be biased personally in favor of one specific approach over another, i.e., biological control, chemical control, etc.

SIGNIFICANCE OF ECONOMIC INJURY LEVELS

It is important to remember what a pest is. According to Clark et al. (1967), pests are species which affect or conflict with man's profit, convenience, or welfare and that pest status originates in 4 ways: (1) by the entry of species into previously uncolonized regions; (2) by changes in the characteristics of the species that did not previously compete or otherwise interact directly with man; (3) by changes in man's activities or habits, rendering him sensitive to the existence of species to which he was previously indifferent; and (4) by increases in the abundance of species whose interactions with man were previously negligible because of the low numbers at which they occurred. Pest problems are often manmade (Uvarov 1964), and we have to take time to determine if a particular species is really as important as we sometimes make it out to be.

There are basically 4 kinds of pests present in agroecosystems: key pests, occasional pests, potential pests, and migrant pests (Smith and van den Bosch 1967). While the total number of potential pests may be high in an agro-ecosystem, there are usually only one or 2 key pest species. A key pest is characterized by a generally high abundance of its damaging stage at the time the crop is susceptible. A key pest may be either a "real pest" (e.g., not induced by pesticides) or an "induced pest." Occasional pests cause economic damage only in certain places or at certain times. Such pests are usually under adequate environmental control and their densities can often be regulated by an integrated control approach because applied control measures may not be necessary at regular intervals. Potential pests cause no significant damage under prevailing conditions. Care must be taken not to alter their status when controlling key or occasional pests. Migrant pests are non-residents of the agroecosystem and enter periodically, usually for short periods.

The equilibrium position of the key pest population density is above the economic injury level probably because of the failure of existing natural controls or because of the recognition of a very low economic threshold. The equilibrium position of occasional pests is usually below the economic injury level. When natural mortality factors are interrupted, the population density may rise above the economic injury level. Potential pests have an equilibrium position below economic injury levels but have the potential of causing economic injury if their equilibrium control mechanism is disturbed. For example, a potential pest may rise to what is known as a secondary pest in outbreak proportions because its natural enemies were previously eliminated as a consequence of a pest control procedure.

Economic injury levels are a key element of integrated control. Most important in this concept is the economic threshold (action threshold), which is the point at which an artificial control measure must be administered to prevent the pest population from increasing to a density that will cause economic loss. The determination of economic injury levels is not easily made; in this connection there is a need for long-term quality research. Often the work may be tedious and boring, and research on economic thresholds and injury levels frequently does not yield annual publications or quick recognition. An economic injury level must be established for each pest on each crop within separate ecosystems. The population levels of pest species and natural enemies must be monitored continuously. Also, it is extremely important that we understand the phenology of the plant and associated insects (beneficial and harmful) in order to develop economic injury levels and pest control recommendations (Falcon 1973).[3]

CONFRONTATION AND UNDERSTANDING AMONG PROFESSIONALS

Recently I attended 2 meetings pertaining to pesticide usage which I feel exemplify several problems which exist today in integrated control and pest management. The first meeting was concerned with the use of lindane for the control of the western pine beetle, *Dendroctonus brevicomis* LeConte, and the 2nd meeting was a symposium entitled "Agricultural Chemicals, Harmony or Discord for: Food, People, and Environment."

The lindane meeting was called by the Insect Committee of the California Forest Pest Control Action Council, because a few forest entomologists felt that a reasonable argument for the continued use of lindane to control

[3] L. A. Falcon. 1973. Proceedings IBP integrated pest management conference on economic injury evaluation, Apr. 5–6, 1973. Dallas, Tex.

this species had not been presented. In my opinion, lindane is not essential for control, as adequate pest management can be achieved by stand management, other cultural practices, and biological control (Browne et al. 1971).[4] However, it was astonishing to observe the complete disregard for and lack of ecological foresight on the part of some who attended. As it turned out, the initiative in favor of the continued use of lindane won by a vote of 21 to 20. This was the first time that the pro-lindane people have been opposed so vigorously and on such a broad basis and called to justify their recommendation for continued use of this compound.

The agricultural chemical symposium (Swift 1971) was designed to reach the general public[5] and was divided into sections based on the need for chemicals, the problems associated with them, and the proposed solutions to these problems. The need for chemicals and the problems associated with their use received equal time. Both pro and con speakers were verbally worked over vigorously by representatives of opposing sides. There were representatives from the chemical industry who expressed attitudes similar to those of Fraser (1965) and Hansberry (1968), who in my opinion depart appreciably from a balanced perspective in crop protection. On the other side, Huffaker (1971b) and van den Bosch (1971) presented data on pesticide interference with natural enemy populations, and Georghiou (1971) discussed resistance of insects and mites to pesticides. One should not argue against the potential of biological control whether it be naturally occurring or classical; there have been successes (Doutt and DeBach 1964, Huffaker and Messenger 1964, Commonwealth Institute of Biological Control 1971, Hagen et al. 1971, Huffaker 1971a, Huffaker et al. 1971). Yet, the total abandonment of chemicals should not be encouraged. I did not expect great results or future policies to come from this symposium, but it brought opposing camps together. There is a need for more gatherings of this kind in the future. I agree with Ehler (1971), who pointed out that there is a polarity, but I wonder if anything can or will be done about it. Few of our problems are going to be solved until everyone involved, i.e., private industry, public agencies, concerned environmentalists, are willing to work out pest problems mutually.

I have met researchers who considered themselves to be working in pest management. After conversing with some of them, though, I wonder if they really knew what pest management was. For example, they seemed to lack an appreciation for the concept of density-dependence vividly explained by Huffaker et al. (1971), for host-parasite (parasitoid) or predator-prey interactions, and for the complimentary use of chemicals which are important in the development of pest management programs. This situation was amplified by Varley et al. (1974) as follows, "If pest management is to be put on a sound basis, the biological system with which we wish to interfere must be sufficiently well understood for us to model it mathematically so that we can predict which method will have the most satisfactory outcome."

Maybe the researchers, practioners, and the rest involved in pest management today should get together so that everyone can play in the same ball park. Education for everyone, no matter how old or experienced they are, may be necessary for success in the future.

NEED FOR COMMUNICATION AND INTERDISCIPLINARY RESEARCH

We, as entomologists, might ask ourselves if we are really communicating with one another. For example, the American Society for Testing Materials (ASTM) has held meetings to organize a standards committee for pesticides. ASTM Committee E-35 was formed by 250 attendees of many disciplines including representatives from government, industry, technical societies, and academia. The committee should have a profound and lasting effect on the pesticide industry by developing standard definitions, classifications, biological test methods, and recommending procedures for pest control in relation to their efficacy, safety, and impact in all environments. A number of subcommittees were formed in the areas of fungal, insect, plant, bacterial, viral, nematode, and vertebrate control agents. Fisher (1973) reported on the progress of the 8 nematologists in attendance. Unfortunately, information on the entomologist attendance is not readily available. I feel that the results of these meetings should be of primary importance and concern to those involved in pest management. Furthermore, we need to express our opinions and communicate our views with one another, and the *Bulletin* is one readily available medium.

We might also ask if we are communicating with members of other disciplines. Entomologists and plant pathologists do not work together in California cotton, yet both are involved in extensive research programs. Much of the pest management literature today is concerned with insect pests. Cotton has pests other than pink bollworm, cabbage looper, lygus bug, and spider mites. Late in the growing season, the effects of *Verticillium albo-atrum* R. and B. in the San Joaquin Valley may result in reduced yields of cotton lint. van den Bosch et al. (1971, unpublished data) stated that repeated applications of certain insecticides to the foliage or soil could cause the bolls of cotton plants to mature later than normal. If this is so, this would seem to increase the importance of *V. albo-atrum*. There are many other interacting considerations to contend with. It is essential that plant pathologists, entomologists, soil scientists, water managers, etc., work together in developing pest management programs. Strickland (1966) emphasized the complex nature of crop protection and illustrated the need for an interdisciplinary approach to research. Many such programs across the nation are already in progress.

It may be possible that a control method for one pest, i.e., an insect, may have a detrimental effect upon the crop by creating a favorable situation for another pest, e.g., a nematode. Also, certain fungicides interfere with the predator control of some mites. For years, plant pathologists have been interested in a biological control approach similar to that employed by entomologists (Snyder 1960, McClellan 1973, Wilhelm 1973, Baker and Cook 1974, Huffaker 1974,[6] Snyder et al. in press). Also, Jorgenson (1970) has shown how it is possible to cause an antagonistic interaction between 2 pests, a fungus and a nematode. Entomologists can no longer afford to consider only the insect problems. I have always felt that

[4] L. E. Browne, D. L. Dahlsten, F. M. Stephen, and J. M. Wenz. 1971. Lindane for control of bark beetles in California. A statement against the use of lindane submitted to the Insect Committee of the Calif. For. Pest Control Action Council. 9 pp.

[5] D. Pearlman. 1971. An attempt to reassure the public on pesticides, Feb. 17, 1971; grim surge in "pesticide treadmill," Feb. 18, 1971. San Francisco Chronicle.

[6] C. B. Huffaker. 1974. The place and promise of biological management of crop pests. Paper presented at the conference for Interdisciplinary Res. to Develop Integrated Plant Pest Management Systems, held February 1974. Iowa State Univ., Ames.

there has been a gap in communication and very little understanding among members of different disciplines, especially entomology and plant pathology. Researchers of different disciplines are going to have to get together and set common goals, establish new working relationships, and cooperate with mutual funding.

In the near future, I would like to see a special meeting for interested members of the Entomological Society of America in conjunction with at least those of the American Phytopathological Society and the Society for Nematologists. A series of symposia with panel discussions including audience participation could be arranged for attendees with similar areas of interest, i.e., soil biology, vectors of plant diseases, insect and plant nematodes, current and future pest management strategies, etc. Submitted presentations could be limited to only those of an interdisciplinary nature.

Recently, a step in this direction was made by professors J. L. Apple (plant pathologist) and R. F. Smith (entomologist), who arranged and moderated a symposium entitled "Pest Management: An Interdisciplinary Approach to Crop Protection" held Feb. 28, 1974, during the 140th annual meeting of the American Association for the Advancement of Science in San Francisco, Calif.

PEST MANAGEMENT EDUCATION

Pimentel (1970) presented his detailed view of the necessary requirements to train the well-rounded pest management specialist of the future. The specialist must have an adequate background in entomology, plant pathology, plant breeding, agronomy, soil science, statistics, and agricultural economics. Supplemental education will depend upon the disciplines available at a specific institution. Pest management educational programs can be found in a few universities today.

Many undergraduate students upon finishing a formal education find that they have not gained experience in the field. In an effort to solve this problem, a commendable curriculum has been developed at Berkeley by the College of Natural Resources. It involves 28 faculty members from 3 departments. The students in this program have an opportunity to gain entomological field experience through a course offered in the summer session at one of the university's field research stations in the San Joaquin Valley. In my opinion, there are 2 limitations. One is that the curriculum does not provide students with adequate field experience in other disciplines, i.e., plant pathology, weed science, nematology, etc. The other is that the summer course must meet the demands of 3 campuses: Davis, Berkeley, and Riverside. There must be a way to aid more students in attending sessions like this, and more facilities must be made available. One solution to the latter problem is to provide students with an internship program to coincide with the academic curriculum. In that capacity they may serve as field scouts for consultants or supervised control specialists, earning income, experience, and academic credit. Though this would be better than no field experience at all, it cannot be a substitute for instruction provided in the field by experienced professors.

SUPERVISED CONTROL

Allen (1970)[7] presented some of the variables which influence pest control measures. These include the speed of population change, rate of instar change, time necessary to apply the control, how long it takes for the control to act, inclement weather, irrigation schedules, availability of labor, nearness to harvest, condition of bloom, and anticipated insect migrations. Supervised control specialists must become intimately familiar with these.

Few people in the crop production sector really know what a supervised control specialist has to offer his clientele. Supervised control as defined by the FAO (1973) "is a pest management system often based on applications of pesticides carried out under the direction of specialists; it ensures that the application in kind, amount, and timing is based on assessment of pest population densities, crop damage, and other ecological considerations such as natural enemies."

In California there is an organization called the Association of Applied Insect Ecologists. The objectives of this group are to represent persons engaged in professional pest management consulting who are not involved in the vending of chemical pesticides, to promote the recognition of professional pest management, to achieve maximum food and fiber production and quality with the minimum necessary pesticide load on the environment, to promote a forum for the interchange of information and ideas to optimize professional techniques and knowledge, to promote the study of professional pest management, entomology, and related fields, and to establish professional standards to insure the highest level of integrity. Many of California's supervised control and pest management specialists belong to this organization. With this philosophy in mind, the larger, more structured supervised control firms have established favorable grower-specialist relationships.

A company agent might explain to each prospective client that the policy as it relates to plant protection of the State of California, Department of Food and Agriculture, is to direct the attention of farmers to integrated methods of pest control. Integrated control is explained in terms relevant to the grower. A grower may expect improved timing of pesticide applications, lower pest control costs, and, possibly, a higher yield of crops. This may be accomplished by avoiding unnecessary use of pesticides as a result of information gathered from regular field checks of insect and disease populations.

One such company, California Agricultural Service,[8] offers (1) plant production analysis, modeled after the cotton "plant growth measurement" approach developed by Falcon (1973), which aids the specialists in pinpointing the responsible factors for varying yields in the same field, season after season; (2) an irrigation management system which benefits the grower by telling him when and how much water to apply; (3) weed and vegetation management; and (4) the service of aerial infrared photography.

Ruud (1974)[9] feels that the biggest hurdle for the supervised control specialist of the future is to overcome grower fearfulness. Researchers such as those at the University of California are continuously finding new solutions to problems, but the new technology is seldom practiced by some growers. For crop protection information, many growers often come in contact only with other

[7] W. W. Allen. 1970. Lecture in Entomology 210: Principles and Problems in Agric. Entomology. Dept. of Entomological Sci., Univ. Calif., Berkeley.

[8] Mention of a company name or proprietary product does not necessarily imply endorsement by the Univ. Calif.

[9] L. Ruud. 1971. Personal communication. Calif. Agric. Serv., Kerman, Calif.

growers or pesticide salesmen. Farm advisors and county extension agents tend to deal with a limited number of growers, because they are good cooperators. Furthermore, numerous growers are reluctant to try something new and tend to rely on the old ways, i.e., calendar-determined spray schedules, applying a control procedure at the first sight of any insect in the field. Many growers logically fear crop loss and cannot afford the risks they feel are involved in using newer, less established procedures. They often operate on rigid time schedules which are more suitable to chemical pesticide applications, and most nonchemical methods of pest management usually do not bring about the immediate degree of contol obtainable by chemical ones (Council on Environmental Quality 1972).

SOIL BIOLOGY: A FREQUENTLY NEGLECTED COMPONENT OF PEST MANAGEMENT RESEARCH

Soil microarthropods serve to mechanically fragment organic debris, distribute these fragments through the soil, infest the soil with microorganisms, and to alter it both chemically and physically as it passes through or becomes part of their bodies (van der Drift 1958, Ghilarov 1963, Karg 1963, Kuhnelt 1963, Macfadyen 1963, Crossley and Witkamp 1964, Engelmann 1968, Edwards et al. 1970).

In the past, not enough emphasis has been placed on soil investigations. The fauna of the soil contains many predatory groups. The influence of resident soil predators in regulating the abundance of economic species is poorly understood. According to Rudd (1964), soil biology is "the single most neglected area of pest control research." Impoverishment of the predatory soil fauna may influence the suitability of the soil as a refuge or reservoir for pest species. It has been suggested that 90% of all insects spend at least some part of their life in the soil (Buckle 1921). A substantial percentage of insects and mites of economic importance either undergo larval development, pupate, overwinter, or aestivate in the soil or in the overlying crop debris of the soil surface. It should be obvious that entomologists working to develop integrated or ecosystem approaches to pest management need to direct more attention to possible mortality or antagonistic factors in the soil habitat (Price 1974).[10]

I feel very strongly about the importance of this area of research, and am involved in an interdisciplinary project to provide information on the influence of modern agricultural practices on the nature and abundance of soil microarthropods and the incidence and activity of soil-borne plant pathogenic fungi in cotton agro-ecosystems of California's San Joaquin Valley. For example, after establishing a history of a particular field, it may be possible to make a reliable forecast of disease problems, as techniques for determining the levels of pathogens under field situations have been established (Bateman 1963, Stanghellini and Hancock 1970, Ashworth et al. 1972, Weinhold 1973, Yarwood 1974).

CONCLUSION

There are many methods and techniques used today for crop protection (National Academy of Sciences 1969, Proceedings Tall Timbers Conference 1969, 1971, 1972, 1973, Rabb and Guthrie 1970, Ehler 1971). The FAO (1966) has set general guidelines for integrated pest control, and a specific set of guidelines for cotton integrated control has been presented (Smith and Falcon 1973, Falcon and Smith 1974).

I feel that all the emotional propaganda displayed in the past by environmentalists has had some value. It has placed pressure on politicians, pest control operators, and researchers. Pesticides are a continuing source of environmental contamination and must be handled properly. A great many persons have become aware of the problems associated with pesticides and these should be kept in mind while developing new chemicals and techniques.

I agree with Smith (1970) and Doutt and Smith (1971) that chemical pesticides are our most powerful tool in the management of pests. New pesticides which are safer and more effective in integrated control and pest management programs will have to be developed (FAO 1973). We must remember that chemicals have prevented major disasters in agriculture and human health. Integrated control does not dictate the total abandonment of chemical pesticides; it encourages more intelligent use of them. Today there still are growers who practice a complete unilateral approach to pest control (pesticide syndrome) where treatments are made whether they are necessary or not and alternative measures are seldom explored (Doutt and Smith 1971). Yet for many crops no alternatives exist. We need a better understanding of the causes and nature of ecological disruptions. A change of attitude away from inflexible pesticide applications based on the calendar should be encouraged. There is a need for more research on the assessment of pest damage and the tolerance level at which a crop can produce an optimum yield in the presence of the pest. In doing so, we must consider that the grower needs an acceptable cash return.

Will the pest management specialist of the future be able to handle pest problems, have the appropriate training and education, be able to operate as a field experienced specialist, be able to take risks for new horizons, and be able to adapt to changing concepts (McKelvey 1969)? The pest management specialist of the future will have to work with and at times be answerable to entomologists, plant breeders, agronomists, phytopathologists, soil scientists, economists, agricultural policy makers, farmers, businessmen, and the general public. The future of pest management will lie in the hands of the well-trained, competent specialists (Council for Environmental Quality 1972) who will largely have the knowledge and technical ability obtained from the educational institutions they attended.

I fear that many of the old "must-sell" pesticide salesmen of the past are calling themselves pest management specialists today. Some may not have been educated and/or conducted research as have the integrated control and supervised control specialists. If this is so, we have a moral obligation to see that the pest management specialist of the future is creditably competent by gaining training from an approved institution and experience in the field.

There have been many recommendations on the way in which future training of specialists should be conducted (National Academy of Sciences 1969, Pimentel 1970, Adkisson 1971, Ehler 1971, Couch 1973[11]). Though there may be initial drawbacks, I am confident that suc-

[10] D. W. Price. 1974. Personal communication. Division of Entomology and Parasitology, Univ. Calif., Berkeley.

[11] H. B. Couch. 1973. Current status of undergraduate programs in plant protection in the United States. Prepared for the 8th Annual Conference of the Assoc. of Plant Pathology Dept. Chairmen, held Sept. 6, 1973. Univ. Minn., Minneapolis.

cess will be accomplished through such programs. We have an obligation to educate the growers, the pest managers of the future, and the public. An intensive university extension program is necessary to extend knowledge and awareness to those who need it.

There are many integrated control and pest management programs in progress and developing throughout the world (Huffaker 1971a, FAO 1973, Falcon 1973[8]). I have not mentioned how pest management can be related to medical and veterinary entomology, ornamental and fruit tree problems, forest disease-insect interactions, insect vectors of plant diseases, biological control of weeds, population dynamics, urban problems, plant disease management, and the economics of pest control (DeBach 1964, Proceeding Tall Timbers Conference 1969, 1971, 1972, 1973, Huffaker 1958, 1971a, Smith 1972). These areas will require special attention in the future. For example, Borden (1971) reported that problems arise in forest insect pest management because it is becoming increasingly difficult to define a forest insect pest. It is difficult to evaluate and predict insect damage. The forest ecosystem is far more complex than an agricultural monoculture, and recently, many forest environments are being managed under a multiple-use policy.

With the nature and increasing complexity of agro-ecosystem investigations and extensive research necessary for the study of insect population dynamics, it may be necessary to utilize a systems approach. This philosophy has been favored by Stark (1966), Watt (1966, 1970), Stark and Smith (1971), and Mott (1973). Field researching entomologists and systems analysts working together can plan logical investigations, prepare interacting system models, possibly predict future populations and damage, and devise control strategies under a variety of situations.

As many present-day pest management programs fail to include all the components of the agro-ecosystem (McClellan 1973), there is need for an interdisciplinary approach to the pest management philosophy in which programs are established to integrate the areas of entomology, phytopathology, nematology, soil science, plant nutrition, weed science, agricultural engineering, and economics. Only with this approach can future pest management programs be successful.

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