UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

05055

Distr.
LIMITED

ID/WG.154/14
11 May 1973

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Workshop on Pesticides

Vienna, Austria, 22 May - 1 June 1973

# THE ROLE OF PESTICIDES IN MODERN PEST MANAGEMENT PRACTICES[1]

by


J. R. Brazzel
UNIDO Consultant
Hyattsville, Maryland, USA


1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

id.73-3780

The use of chemical pesticides in recent years has contributed greatly to man's health and improved standard of living throughout the world. Since the introduction of the vast array of pest control agents following World War II, we have witnessed the most effective control of pests of agricultural and public health importance ever known. This includes many pests for which effective control had never been achieved prior to the use of pesticides. In fact, as pointed out by Newsom (1965), we learned of the importance of many pests which had not been suspected prior to their control by chemicals.

Pesticides are highly effective and positive for control of pest outbreaks. In fact, when pests populations reach economically damaging levels, there is little other than pesticides which can be used to avoid damage. Therefore, it is expected that pesticides will continue to be a major tool in pest management. Yet, in spite of the benefits realized in recent years, scientists and the general public are in broad general agreement that serious disadvantages are associated with the use of pesticides. This is particularly true for the use patterns which evolved in the 1950's and 60's. Most of these problems are associated with the indiscriminate and almost complete reliance upon pesticides used in a pest prevention scheme. This has resulted in development of insecticide resistant strains, disruption of the ecosystem with emergence of minor pests as major pests, pesticide residues on the harvested crop and other human hazards and, in some cases, general contamination of the environment.

There is evidence at present of an ever increasing trend toward an era of pest management and away from excessive and indiscriminate use of pesticides. Governmental agencies, researchers, grower organizations, and industry are working at the need to make changes in our strategies for pest control and the role of pesticides in this integrated approach.

Before we go into the details of pest management, let us examine the advantages and disadvantages of pesticides. First the advantages.

1. A vast array of chemical control agents are available. It is possible to quickly select a pesticide or pesticide combination which will control effectively almost any pest situation involving artaropods, weeds, nematodes, and diseases. This has enabled growers to increase yields in spite of pest problems which reoccur year after year and were formerly the limiting factor on production.

When new pest problems arise because of changing agricultural practices or because of accidental introductions, we can usually solve the problem or purchase time for solving the problem by selecting an effective pesticide. Thus the spotted alfalfa aphid, _Therioaphis maculata_ (Buckton), was held in check with insecticides in the western United States for the 5 years that were required to develop resistant alfalfa varieties, introduce parasites, and devise an integrated pest management system (Stern et al., 1959; Stern and van den Bosch 1959). Without insecticides the spotted alfalfa aphid would have eliminated alfalfa as a forage crop from the western United States. When the cereal leaf beetle, *Oulema melanopus* (L.), invaded the United States in 1962, malathion proved effective in slowing its spread and averting huge losses. A crash program of parasite introduction and distribution and breeding resistant varieties of cereals seems to be giving us the upper hand (Knipling 1968). An infestation of Mediterrean fruit fly was discovered in Florida in 1956, and in 1957 this species was eliminated with bait sprays containing malathion--even though the pest had already occupied one million acres (Steiner et al. 1961).

2. Pesticides act quickly and positively in most instances. Methods of control are required which are widely applicable and effective to cope with such problems as widespread insect outbreak which may develop over a short period of time. Pesticides have the advantage over other suppression alternatives in being able to effect a more rapid and higher level of control over a broader range of pests than any other available.

Unlike some of the alternative methods, insecticides are effective against high pest population densities, and they can minimize crop damage even if pest density already exceeds economic threshold levels at the time of application. Insecticides can halt transmission of vector-borne plant, animal, and human diseases. Indeed, countless millions of people, citizens of every nation, owe their lives to the availability of insecticides. There appears to be an irreversible trend to growing annual crops in vast monocultures. This type of agroecosystem is inherently unstable, and the grower must constantly be alert to a pest outbreak and the need to react quickly. Often insecticides are the grower's only means of protecting his investment and income.

3. Often a single pesticide or a mixture of pesticides can be used to control the entire complex of pests attacking many high-value commodities. By contrast many alternative methods are highly selective. Therefore, control with broad spectrum chemicals is often achieved with little labor and with a favorable cost/benefit ratio from the user's standpoint.

4. Pesticides permit the individual grower to protect his commodity irrespective of any actions taken by his neighbors. By contrast, a number of the alternative methods are ineffective unless applied against the entire pest population of an agroecosystem. Nevertheless, the individual grower can protect his commodity more effectively and at a lower cost if he and all other growers act in concert. For as Knipling (1973) has shown, uniform suppression applied against the total pest population over a period of generations will achieve greater suppression than a higher level of control on most but not all of the population each generation.

5. A number of insecticides can be used selectively with little adverse effects on beneficial arthropods or wildlife. Metcalf (1972) recognized six types of selective insecticide uses.

(a) Intrinsically selective insecticides. The effectiveness of the toxin of *Bacillus thuringiensis* is largely limited to larvae of a number of lepidopterous pests. Many of the new hormonal type materials currently under development are selective to varying degrees. A number of acaricides show little toxicity to insects including such materials as ovex, chlorbenside, dicofol, tetrasul, tetradifon, thioquinos (Eradex[R]), oxythioquinos (Morestan[R]), and others. Under conditions of actual use TDE (DDD) shows considerable selectivity for the redbanded leafroller, *Argyrotaenia velutinana* (Walker). Similarly, Dilan[R] shows some selectivity for the Mexican bean beetle and the saltmarsh caterpillar (Gasser 1965). Although not in commercial use, isopropyl parathion is 240 times less toxic to honey bees and 100 times less toxic to *Opius* spp. parasites than to house flies (Metcalf 1965).

(b) Selectivity through systemic action. Sucking arthropods such as aphids, mites, thrips, and leafhoppers are amenable to selective control by systemic insecticides which quickly penetrate the leaf cuticle and are translocated throughout the xylem tissue. Such insecticides include demeton, schradan, and oxydemeton-methyl. Other more persistent systemics are often applied as granules to the soil root zone when the seed is planted. These materials are translocated and concentrated in the most rapidly growing aerial tissues and include phorate, disulfotan, aldicarb, and carbofuran. Depending on the formulation and soil moisture, aldicarb applied in furrow controls sucking insects and boll weevil for more than 1 month. This control can be extended substantially by making an additional side-dress application (Bariola et al. 1971).

(c) Fugitive broad spectrum insecticides. Beneficial species can sometimes survive the application of short-lived broad spectrum materials if they are in a resistant stage such as the pupal stage, if they are in protected locations such as hedgerows, or in alternatively sprayed strip crops. Zectran®, a broad spectrum carbamate, has been registered in the United States to control spruce budworm, Choristoneura fumiferana (Clemens) (Tucker et al. 1969; Pillmore et al. 1971). Although Zectran is highly toxic to mammals and birds, it can be safely used for spruce budworm control because only 0.15 lb/acre is required and because Zectran undergoes rapid photo- and biodegradation, has a low degree of cumulative toxic action, and a low toxicity to fish. The development of this use of Zectran and demonstration of its safety is the culmination of a decade of search for an alternate to DDT. Van den Bosch and Stern (1962) found that mevinphos did not kill Trichogramma semifumatum (Perk.) in host eggs and that the residue dissipated so rapidly that newly emerging adult parasites were spared.

(d) Ecologically selective insecticide use. By precise application and timing, the effects of insecticides on nontarget organisms can be avoided or minimized. For example, attempts are made to minimize honey bee destruction by applying methyl parathion late in the evening when bees are not working the blossoms, or if possible after bloom is completed.

The tsetse fly, Glossina swynnertoni Aust., was eliminated from a 35-square mile area by applying endosulfan or dieldrin to its preferred resting sites (Chadwick et al. 1965). The applications were made to the undersides of tree branches 1-4 inches in diameter, 4-9 feet above ground, and inclined less than 35 degrees from the horizontal.

The application of insecticides to seeds is one of the most efficient ways of protecting the germinating seed and the seedling with minimal environmental disruption. As little as 1 ounce per acre of phorate or disulfaton used as a seed treatment for cotton gave control of thrips equal to two foliar sprays applied during the growing season (Clower et al. 1966). More than 1 month of protection against the cereal leaf beetle can be obtained by treating oat seed with proposure (Baygon) at 4 ounces or less per 100 lbs. of seed and is far superior to the conventional use of 1 lb. of carbaryl per acre (Ruppel et al. 1970).

Croft and Barnes (1971) have shown that insecticide-resistant strains of predaceous mites can be selected in the laboratory and subsequently released in the field to provide superb spider mite control despite insecticidal applications for codling moths.

(e) Selectivity through restricted treatment. Sensitive pest detection methods are becoming available which permit pest managers to restrict treatment to parts of the crop actually infested. For example, in southern California virgin female baited traps are used to detect those citrus trees actually infested with California red scale; so that selective treatment of only infested trees can be accomplished (Shaw et al. 1971). Similar methods show promise for use against the Comstock mealybug in central California (Moreno et al. 1973). Remote sensing techniques are used in northern Mexico to identify individual trees that are most likely heavily infested with the citrus blackfly and brown soft scale (Hart and Myers 1968, Hart et al. 1973). Studies on the green peach aphid in the State of Washington showed that the pest normally overwinters in the egg stage on peach trees in the western Washington potato-growing areas. Up to 30 thousand eggs of the pest may overwinter in each peach tree. When these hatch in the early spring they feed on various hosts, become viruliferous, and move into potato fields to transmit leafroll disease. Young potato plants are particularly sensitive to damage by the virus. Ecological surveys in a 275-square mile area showed that the area had no more than 5,000 to 6,000 peach trees. Yet these relatively few trees served as a reservoir for the green peach aphid population which later moved into a potato-growing area consisting of about 80,000 acres of potatoes. By spraying the peach trees to deplete the overwintered population and thus delay the buildup of the survivors, it is estimated that at least one spray application costing about $9 per acre on 80,000 acres of potatoes becomes unnecessary (Powell and Mondor, 1967). Additional savings to the potato growers result from increased yields of potatoes. This is an excellent example of the strategic use of insecticides in minimum amounts in order to achieve pest management. The method involves insecticide treatments of host trees that probably would not exceed

100 acres, if compressed into one area, versus at least one application of insecticide on [illegible] acres of potatoes in the absence of such program. A similar program was initiated in the potato-growing area of Idaho in 197[illegible].

The codling moth in the western United States is a key pest of apple and other orchard crops. More insecticides have been applied per unit area to control this pest than for any other insect in the United States (Knipling 197[illegible]). An ecological study of the codling moth was undertaken in a 25-square-mile area in Washington State in which less than 500 acres of apples are grown. This study showed that a relatively few noncommercial trees are responsible for producing most of the codling moths. During the summer of 1970 about [illegible],400 noncommercial trees were removed and the fruit was removed from the few remaining trees or they were sprayed with diazinon. This sanitation program reduced the population by 96 percent (Butt et al. 1972) and has greatly reduced the need for additional control measures.

(f) Selectivity through use of baits or attractants. The bait formulation for control of the imported fire ants, *Solenopsis invicta* Buren, and *S. richteri* Forel is so effective that only 1.7 grams per acre of mirex are needed. Selective lures combined with insecticides can be used to eliminate incipient infestations of certain fruit flies or to eliminate entire established populations from islands. For example, the male oriental fruit fly attractant, methyl eugenol, was combined with naled in small cane fiber squares. With this male annihilation formulation the oriental fruit fly was completely eliminated from the island of Rota and this program required no more than [illegible] grams of toxicant per acre (Steiner et al 1965). Use of synthetic lures in this way is ecologically acceptable because the lures are highly specific and only responding insects are eliminated.

The aggregating pheromone grandlure is experimentally used in the United States to draw boll weevils into trap rows of cotton treated with the insecticide aldicarb.

Clearly pesticides are versatile and useful tools for management of pests. Yet, our experience of the past 2 decades has revealed some of the shortcomings of pesticides which include:

1. The development of strains of pests which are resistant to a formerly effective pesticide is one of the most serious limitations in the use of pesticides. This phenomena is most prevalent in arthropod pests, but it is not restricted to this group. Brown (1968) listed over 200 species of mites, ticks, and insects which had developed resistence to one or more pesticides. A few pests have developed resistance to the point that alternate pesticides are not available for control such as the soybean looper, Pseudoplusia includens (Walker) (Newsom, 1970) and the tobacco budworm, Heliothis virescens (Fabricius), in parts of the United States and Mexico. Yet we have cases in which pesticides remain highly effective over long periods of selection pressure. An example is the boll weevil on cotton in the United States. Organochlorine pesticides such as dieldrin, endrin, and toxaphene gave highly effective control for approximately 8 years, then resistance became evident in 1954-55 (Roussel and Clower, 1955). Organophosphorus materials such as methyl parathion

guthion, and malathion were substituted for control and have been highly effective to date. The development of pesticide resistance is usually associated with complete reliance upon chemicals for pest control and the resulting high level of selection pressure upon the pest population. In an integrated control system there is usually less risk of resistance than one which relies completely upon chemicals (Smith 1970).

2. Another limitation of pesticides is their short-term temporary control as compared with most other control strategies. This is particularly true for the short residual materials to which we are shifting. This characteristic results in the need in most cases to make repeated treatments until the crop is harvested to prevent population resurgence of the primary pests and the emergence of secondary pests as major ones. This sequence of events is brought on by the upset of the ecosystem by the pesticide used against the major pests.

Our best defense against this situation is to use pesticides with some degree of selectivity for the target pest species, if available. We are seriously deficient in pesticides with adequate pest selectivity for most pest management situations. In these cases, it may be possible to time the treatment or reduce the dosage so that minimal impact upon biological control agents will occur and still hold the pest population below the economic threshold level. A basic principle of pest management is the maintenance of sub-economic pest populations, (Rabb 1970). This recognizes the fact that we must learn to live with and manage most of our pests on a continuing basis and that populations below the economic threshold are causing no damage. In fact, in most cases a sub-economic pest population is desirable as a food source for predators and parasites.

3. Pesticide residues on the treated crop and in the environment may persist for extended periods and present hazards to persons who harvest and consume the crop and other nontarget organisms. Drift of pesticides during foliar application frequently contaminates nontarget crops. A very serious problem with many of the more persistent pesticides is their concentration through food chains in nontarget organisms, including humans.

It is obvious that drastic measures will be necessary to solve these hazards. In the case of the persistent materials, it may be necessary to severely restrict or eliminate their use in certain cases. Substitute materials for such cases are generally more acutely toxic to nontarget organisms, usually have a severe impact upon pollinators (Swift, 1969) and natural enemies of pests, and have short residual, requiring frequent applications. This increases selection pressure upon the pest species and hastens development of pesticide resistance.

These problems point up the fact that a series of alternatives must be considered in the selection of a pesticide for a specific use. In selecting a pesticide from the available candidates, the pest manager must consider (1) efficacy on the target pest, (2) mammalian toxicity, (3) effects on nontarget organisms including pollinators, parasites, predators, and wildlife, and (4) fate in soil, water, air, and in the commodity. Thus individuals who wisely recommend an individual insecticide for a specific pest management program require an astonishing command of information.

In order to assist pest managers in making intelligent choices of insecticides, Metcalf (1972) has assembled the data in Table 1. He provides a numerical rating for most of the common insecticides with regard to their safety and effects on environmental quality and therefore with regard to their suitability for use in pest management programs. Ratings were based on (a) acute toxicity to humans and domestic animals, (b) toxicity to nontarget organisms, and (c) environmental persistence. Each category was assigned a rating of 1 to 5 with increasing hazard as shown below:

(a) Mammalian Toxicity--rat oral $LD_{50}$ mg. per kg.

1= 1000; 2= 200-1000; 3= 50-200; 4= 10-50; 5= 10

(b) Nontarget Toxicity--trout--$LD_{50}$ ppm

1= 1.0; 2= 0.1-1.0; 3= 0.01-0.1; 4= 001-0.01; 5= 0.001

pheasant--oral $LD_{50}$

1= 1000; 2= 200-1000; 3= 50-200; 4= 10-50; 5= 10

honey-bee--topical $LD_{50}$ mg. per kg.

1= 100; 2= 20-100; 3= 5-20; 4= 1-5; 5= 1

(c) Environmental Persistence--soil half-life

1= 1 month; 2= 1-4 months; 3= 4-12 months; 4= 1-3 years; 5= 3-10 years

Table 1--Pest Management Rating of Widely Used Insecticides (from Metcalf, 1972)

| Insecticide | Mammalian Toxicity | Nontarget Toxicity | | | | Environmental Persistence | Overall Rating |
|---|---|---|---|---|---|---|---|
| | | Fish | Pheasant | Bee | Average | | |
| Aldicarb | 5 | 3 | 5 | 5 | 4.3 | 3 | 12.3* |
| Aldrin | 4 | 4 | 4 | 4 | 4.0 | 5 | 13.0 |
| Azinphos-methyl | 4 | 3 | 2 | 4 | 3.0 | 3 | 10.0 |
| Carbaryl | 2 | 1 | 1 | 4 | 3.0 | 2 | 7.0 |
| Carbofuran | 5 | 2 | 5 | 5 | 4.0 | 3 | 12.0* |
| Carbophenothion | 4 | 2 | 4 | 4 | 3.3 | 2 | 9.3 |
| Chlordane | 2 | 3 | 2 | 2 | 2.3 | 3 | 7.3 |
| DDT | 3 | 4 | 2 | 2 | 2.7 | 5 | 10.7 |
| Demeton | 5 | 2 | 5 | 2 | 3.0 | 2 | 10.0 |
| Diazinon | 3 | 2 | 5 | 4 | 3.7 | 3 | 9.7 |
| Dicofol | 2 | 1 | 2 | 1 | 1.3 | 4 | 7.3 |
| Dieldrin | 4 | 4 | 3 | 4 | 3.7 | 5 | 12.7 |
| Dimethoate | 3 | 1 | 4 | 5 | 3.3 | 2 | 8.3 |
| Disulfoton | 5 | 3 | 5 | 2 | 3.3 | 3 | 11.3 |
| Dursban (R) | 3 | 3 | 3 | 5 | 3.7 | 3 | 9.7* |
| Endosulfan | 4 | 4 | 4 | 4 | 4.0 | 3 | 11.0 |
| Endrin | 5 | 5 | 5 | 2 | 4.0 | 5 | 14.0 |
| Ethion | 3 | 2 | 3 | | | 2 | 7.0* |
| EPN | 4 | 2 | 3 | 4 | 3.0 | 4 | 11.0 |
| Gardona (R) | 1 | 4 | 1 | 4 | 3.0 | 1 | 5.0* |
| Heptachlor | 4 | 3 | 4 | 4 | 3.7 | 5 | 12.7 |
| Lindane | 3 | 3 | 2 | 4 | 3.0 | 4 | 10.0 |
| Malathion | 2 | 2 | 1 | 4 | 2.3 | 1 | 5.3 |
| Methoxychlor | 1 | 3 | 1 | 1 | 2.3 | 2 | 5.3 |
| Methyl parathion | 4 | 1 | 5 | 5 | 3.7 | 1 | 9.7 |
| Mevinphos | 5 | 3 | 5 | 4 | 4.0 | 1 | 10.0 |
| Naled | 2 | 2 | 3 | 4 | 3.0 | 1 | 6.0 |
| Oxydemeton-methyl | 3 | 2 | 4 | 2 | 2.7 | 2 | 7.7* |
| Parathion | 5 | 2 | 4 | 4 | 4.0 | 2 | 11.0 |
| Phorate | 5 | 4 | 5 | 2 | 3.7 | 3 | 11.7 |
| Phosphamidon | 4 | 1 | 5 | 3 | 3.0 | 2 | 9.0 |
| Tetraethyl-pyrophosphate | 5 | 2 | 5 | 3 | 4.0 | 1 | 10.0 |
| Toxaphene | 3 | 4 | 4 | 1 | 3.0 | 4 | 10.0 |
| Trichlorfon | 2 | 1 | 2 | 1 | 1.3 | 1 | 4.3 |
| Zectran (R) | 4 | 1 | 5 | 5 | 3.7 | 2 | 9.7 |

*Insufficient data for accurate rating.

The honey bee, trout, and pheasant were chosen as nontarget organisms because they are somewhat typical of three nontarget groups and because they have been used in many assays (Pimental 1971).

The compounds in Table 1 have been segregated by Metcalf (1972) into the following four classes:

(1) suitable for use in pest management (rating 4-7) carbaryl, chlordane, Cardona, malathion, methoxychlor, naled, trichlorfon.

(2) caution for use in pest management (rating 8-10) azinphos-methyl, demeton, diazinon, dicotol, dimethoate, Dursban, lindane, mevinphos, methyl parathion, phosphamidon, oxydemeton-methyl, tetraethyl pyrophosphate, toxaphene, Zectran.

(3) to be used for pest management only under restricted conditions. (rating 11-13), such as seed or soil treatment with aldicarb, carbofuran, disulfoton, phorate, parathion, EPN, endosulfan, or indoor treatment with DDT.

(4) little if any place in pest management (rating 13-15) aldrin, dieldrin, endrin, heptachlor.

Obviously we must evaluate each pest problem in its peculiar setting and use the most appropriate control strategy including the most appropriate insecticide. Therefore, this categorization of insecticides requires qualifications in certain instances. Nevertheless this categorization is a laudatory first approximation to quantifying important characteristics of insecticides as a basis for rational selection of specific insecticides for specific uses in pest management programs.

Pesticide use in a pest management system may be divided into three general categories as follows:

1. Carefully timed applications directed at a strategic or weak point in the pest's life cycle and designed to exert a suppressive effect upon subsequent population buildup. Excellent examples of this strategy are the systems used to control diapause populations of pink bollworms and boll weevils in cotton. These two pests are the key pests in most of the cotton acreage in the United States. They require early season treatment and then the applications must be continued for the remainder of the season. It has been found that meaningful reductions in overwintering populations of these key pests can be attained by control measures directed at them during diapause development in fall. The pink bollworm control consists of regulation of the planting and plant destruction dates and by cultural practices designed to destroy diapause larvae. The boll weevil control consists of 1-3 applications of phosphate insecticides in the fall with crop destruction as soon as harvest permits (Brazzel, 1961). The control measures are most effective when done on an area-wide basis. These fall-applied suppression measures delay economically damaging populations of these pests for one or more generations in the following year. This allows more effective use of natural control factors for secondary pests in midseason and reduces the amount of insecticide used. Thus several measures, all of which are effective primarily against high populations when combined and applied against the total population, can suppress it to such low levels that a

full season may be required for the population to recover to damaging levels.

Another example involves the control of codling moth on apples in Washington. Butt et al (1972) found that approximately 95 percent of codling moths which attacked commercial apple orchards originated in noncommercial trees. Removal of abandoned trees and treatment of the others which would not be removed, reduced the pest populations, resulting in requirements for less control action. In most cases, particularly with a mobile pest such as insects, the success of such approaches depends upon the area-wide total population suppression concept. This requires near 100 percent participation by growers to realize the full potential of the action.

2. Selective preventive treatments may be made with a minimal quantity of pesticide during the growing season to provide suppression pressure upon a reoccurring or developing potential pest problem and cause the least possible chance of disrupting natural control forces. An example of this is the use of seed treatments for control of thrips infestations on cotton. Another would be the spot treatment of localized infestations of boll weevil during the early season period. Maximum use should be made in such cases of pesticides with some degree of selectivity for the target pest if available.

3. Another category of pesticide use is for inseason treatments made when economic threshold levels of pests are exceeded despite all other pest suppression measures. While alternate nonchemical pest

control measures may be preferred, it is inevitable that under present agricultural practices economically damaging pest populations will occur and we must have positive control methods for these situations. At present, pesticides are our only resource to use in such cases.

It is imperative that, when used in such cases, usage be compatible with the pest management scheme. They should be used only when needed, based upon pest population assessment, and selected for both efficacy against the pest and the potential for causing disruption in the ecosystem.

In the United States we have initiated recently a series of pest management action programs which are a cooperative endeavor of the research, extension, and regulatory agencies. These programs are designed to achieve a better balance between pesticides and alternate control strategies in our pest control efforts. We feel that we have many proven control techniques for many crop pests which are not being used by growers. In most cases growers hesitate to change from their pesticide based programs, particularly if they are still effective. The objectives of the program are to: (1) show the grower the value of a supervised control program based upon population assessment as compared with treatment based upon calendar date or plant growth stages; (b) assist the grower to modify his present control procedures and integrate new pest suppression methods into his production system.

This cooperative effort was initiated in 1971 with two projects. This increased to 22 projects in 1972 and we will have 39 projects in 1973.

The projects essentially amount to a large-scale demonstration area of several thousand acres with growers actively participating. They are scheduled to last for 3 to 5 years and we expect the growers and private pest management consultants to carry on thereafter.

These programs are based upon population assessment or scouting to collect the necessary data upon which to base pest control decisions. They are established on crops where research has developed promising alternate control methods which can be integrated into the pest management system. We presently have projects on cotton, corn, potatoes, apples, vegetables, peanuts, grain sorghum, citrus, alfalfa, pears, and tobacco. This activity is presently oriented strongly toward control of arthropod pests. However, there are components of weed, disease, and nematode control in many of the programs. This expansion to include the total pest complex and the entire cropping system is expected to continue.

These projects are being developed around the following basic requirements for an effective pest management approach to pest control:

1. We must have dependable pest population assessment methods.

2. We must have established reliable economic threshold level of pests.

3. The systems to be used must be operationally and economically feasible for the grower.

4. We must have adequate numbers of properly trained personnel to execute the programs.

5. The producer must develop confidence in the system and use it.

The ultimate objective of these projects is to realize a pest management system where maximum possible reliance is placed on pest suppression measures other than pesticides with pesticides used selectively.

Ideally, the solution to the problems associated with the use of pesticides would be to develop alternate nonchemical control methods for use. Scientists concerned with pest control have recognized for years that integration of a series of control methods is the only way to meet the problems associated with a rapidly changing agriculture and the pest complex including insects, weeds, nematodes, diseases and others. A great deal of progress has been made in development of alternate control methods, many of which are now in use. However, these control systems are much more difficult to execute than the routine application of pesticides, and in many cases cannot be applied immediately (Smith, 1962). There is general agreement among pest control specialists that pesticides are one of our prominent alternatives for pest management and we must learn to use them in such a manner that we realize their advantages and minimize the disadvantages.

References Cites

Hariola, H. A., W. L. Ridgway, J. R. Coppege. 1971. Large-scale field tests of soil applications of aldicarb for suppression of populations of boll weevils. J. Econ. Entomol. 64: 280-4.

Brazzel, J. R., T. B. Davich, L. D. Harris. 1961. A new approach to boll weevil control. J. Econ. Entomol. 54(4): 723-730.

Brown, A. W. A. 1968. Insecticide resistance comes of age. Bull. Ent. Soc. Amer. 14: 3-9.

Butt, B. A., J. F. Howell, R. H. Moffitt, and A. E. Clift. Suppression of populations of codling moths by integrated control (sanitation and insecticides) in preparation for sterile moth release. J. Econ. Entomol. 65: 411-4.

Chadwick, P. R., J. S. S. Beesley, P. J. White, and H. T. Matechi. 1965. An experiment on the eradication of Glossina swynnertoni Aust. by insecticidal treatment of its resting sites. Bull. Entomol. Res. 55: 411-9.

Clower, D. F. 1966. Ann. Prog. Rept, La. Agric. Expt. Sta., Baton Rouge, La.

Croft, B. A., and M. M. Barnes. 1971. Comparative studies on four strains of Typhlodromus occidentalis. III. Evaluation of releases of insecticide-resistant strains into an apple orchard ecosystem. J. Econ. Entomol. 64: 845-50.

Gasser, R. 1965. Use of insecticides in selective manners. Proc. FAO Symp. Integr. Pest Control 2: 109-13.

Hart, W. G., and V. I. Myers. 1968. Infrared aerial photography for detection of populations of brown soft scale in citrus groves. J. Econ. Entomol. 61: 6 7-24.

Hart, W. G., S. J. Ingle, M. R. Davis, and C. Mangum. 1973. Aerial photography with infrared color film as a method of surveying for citrus blackfly. J. Econ. Entomol. (in press).

Knipling, E. F. 1968. The role of chemicals in the general insect control picture. Bull. Entomol. Soc. Amer. 14: 102-7.

Knipling, E. F. 1973. Entomology and the management of man's environment. Plenary address, 14th Intern. Congr. Entomol., Canberra, Australia, Aug. 22-30, 1972. Proc. Int. Congr. Entomol. (in press).

Metcalf, R. L. 1972. Selective use of insecticides in pest management. In implementing practical pest management strategies. Extension Service, USDA, and Cooperative Extension Service, Purdue Univ., Lafayette, Inc., pp. 74-91.

Metcalf, R. L. 1965. Requirements for insecticides of the future. Proc. FAO Symp. Integr. Pest Control 2: 115-33.

Moreno, D. S., D. K. Reed, J. G. Shaw, and I. M. Newell. 1973. A sex lure trap for the survey of the Comstock mealybug. J. Econ. Entomol. (in press).

Newsom, K. D. 1965. Essential role of chemicals in crop protection. Proceedings of the FAO symp. on integr. pest control, 11-55 Oct. Rome. p 95-108.

Newsom, L. D. 1970. The end of an era and future prospects for insect control. Proc. Tall Timbers Conf. on Ecological Animal Control by Habitat Management (2): 117-36.

Pillmore, R. E., E. L. Flickinger, and M. L. Richmond. 1971. Forest spraying of Zectran and its safety to wildlife. J. Forestry 69:721-7.

Pimental, D. 1971. Ecological effects of pesticides on nontarget species. Executive Office of the President, Office of Science and Technology, 220 pp.

Powell, D. M., and W. T. Mondor. 1967. The value of spraying peach trees for control of the green peach aphid Myzus persicae (Sulzer), and suppression of leafroll on potatoes in the Columbia Basin. Proc. 6th Ann. Washington St. Potato Conf., pp. 173-5.

Rabb, R. L. 1970. Concepts of Pest Management. North Carolina State University, Raleigh, N.C. pp. 6-29.

Roussel, J. S., and Dan Clower. 1955. Resistance to the chlorinated hydrocarbon insecticides in the boll weevil. Louisiana Agr. Expt. Sta. Circ. 41.

Ruppel, R. F., J. Valarde, and S. L. Taylor. 1970. Integrated control of the cereal leaf beetle. Michigan State Univ. Res. Rept. 122: 5-6.

Shaw, J. G., D. S. Moreno, and J. Fargerlund. 1971. New red scale detector. Calif. Citrograph 56: 149-50.

Smith, R. F. 1962. Principles of integrated pest control. Proc. North Central Branch, Ent. Soc. Amer., 17, 7 pp.

Smith, R. F. 1970. Concepts of Pest Management. North Carolina St. Univ., Raleigh, N.C., pp. 6-29.

Steiner, L. F., G. G. Rohwer, E. L. Ayers, and L. D. Christenson. 1961. The role of attractants in the recent Mediterranean fruit fly eradication program in Florida. J. Econ. Entomol. 54: 30-5.

Steiner, L. F., W. C. Mitchell, E. J. Harris, T. T. Kozuma, and M. S. Fujimoto. 1965. Oriental fruit fly eradication by male annihilation. J. Econ. Entomol. 58: 961-4.

Stern, V. M., and R. van den Bosch. 1959. The integration of chemical and biological control on the spotted alfalfa aphid. Field experiments on the effects of insecticides. Hilgardia 29(a): 103-30.

Stern, V. M., R. F. Smith, R. van den Bosch, and K. S. Hagen. 1959. The integrated control concept. Hilgardia 29: 81-101.

Swift, J. E. 1969. Unexpected results from substitute pest control methods. Symposium on biological impact of pesticides in the environment. Oregon State Univ. Corvallis.

Tucker, R. K., and D. G. Crabtree. 1969. Toxicity of Zectran[R] insecticide to several wildlife species. J. Econ. Entomol. 62: 1307-10.

van den Bosch, r., and V. M. Stern. 1962. The integration of chemical and biological control of arthropod pests. Ann. Rev. Entomol. 7: 367-86.

[redacted]

13. 8. 74