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The Agrochemical Industry's Approach to Integrated Pest Control

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The agrochemical industry's approach to integrated pest control

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According to the F.A.O., 'IPM [integrated pest management; i.p.m.] is a pest management system that, in the context of the associated environment and the population dynamics of 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.' A number of national and international policy statements demonstrate that the agrochemical industry endorses the principles of i.p.m. and supports their application and further extension in practice. Industry will continue to participate actively by making contributions to the scientific information base, by offering technical solutions and by assisting in the educational process. An analysis of the present state and future development of the science and technology of i.p.m. components shows that extended realization in practice will be a slow and gradual process. The short and medium term contribution of industry will concentrate on improved uses of currently available pesticides in terms of timing, formulation and application technology, etc. In the long term and provided that the economic objectives are justified, industry will successively make available a set of new and more selective biologically active products.

1. Introduction

The professional and public literature abounds with definitions and explanations of integrated pest control, integrated pest management (or i.p.m., as it will be abbreviated in this paper). Upon reading this literature, one is led to conclude that the term means different things to different people, who, in turn, are pursuing different objectives:

for the missionary it is a panacea to remedy at once all the ills and irresponsibilities that have gone into 'conventional' plant protection;

for the environmentalist it is no more than a first and (in his opinion) insufficient step in his efforts to get chemicals eliminated from the environment;

for the bandwagon-scientist it is yet another 'buzz word' to frame his experiments to attract funds and public attention;

for the politician it provides an opportunity to promise his constituents a reduction of everything, including crop losses, production costs, risks, pesticides, pollution and energy;

for the expert or professional it is a systematic, conscientious and intelligent effort to exploit all available and emerging scientific knowledge to improve and safeguard crop production.

Being faced with this dilemma of diversity of opinions, I am tempted to take the advice of Boysie Day, the reputed veteran plant pathologist from the University of California at Berkeley, who told his audience 'not to try to define IPM [i.p.m.] and not to knock it. The important thing is, not what it is, but the fact that such diverse interests can agree on anything, even if it is only a slogan. – Its real meaning is that it is a commitment to stop shoving one another around and try to do things in a better way' (Anon. 1979).

2. Definition of i.p.m.

For the purpose of this paper and to be explicit, a definition of i.p.m. is necessary. The one chosen is international and has been agreed by the F.A.O. Panel of Experts on Integrated Pest Control (F.A.O. 1967):

> Integrated Pest Control is 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.

3. Basic policy of agrochemical industry

What is the agrochemical industry's basic position on this approach? Gifap, the International Group of National Associations of Manufacturers of Agricultural Products, has stated its policy as follows (Gifap 1977):

(*a*) to encourage the adoption of integrated pest control in accordance with the agreed definition (see § 2);

(*b*) to encourage R & D aimed at integrated pest control;

(*c*) to encourage its members to assist the F.A.O. and other bodies to train staff in integrated pest control methods;

(*d*) to recognize that integrated pest control calls for an extremely high level of technological skill and should only be encouraged where such skills exist or can be provided;

(*e*) to be prepared to take part in discussions, symposia, etc., concerned with integrated pest control within an agreed definition.

This policy statement by Gifap has been echoed by a number of national agricultural chemicals associations, including that of the United States, which has described its position in the following terms (N.A.C.A. 1979):

> We favour the best pest control methods available, whatever they may be. And we accept an industry responsibility to play a central role, through our research and field representation, in developing IPM-methods.

4. I.p.m. as a system

As already implied in the definition given above (§ 2) i.p.m. is a *systems* approach to crop protection. The main components and their interactions are shown in figure 1. Ideally, the unit to be managed consists of the entire ecosystem of a particular crop or crop area. The starting point is provided by the acquired knowledge of the dynamics of crop growth, the composition and dynamics of the pest population, the interactions among these features and between them and the associated environment (such as climatic and meteorological conditions). This information allows the more or less precise determination of an economic threshold or economic injury threshold, i.e. the pest population level above which a loss to the crop will occur that is greater than the cost of carrying out a particular pest control action.

To exploit the described features in time to initiate appropriate control measures, the growing crop, the pest complex and the environmental conditions must be surveyed, scouted or monitored, and expected further developments predicted by appropriate forecasting methods and techniques. The steps mentioned so far can already be modelled into a system of considerable complexity.

The short-term tactics or long-term strategies to be used for managing a pest or a pest complex rely on the judicious selection and combination of various techniques, including cultural measures, chemicals, biological and physical methods, pest genetics and plant breeding.

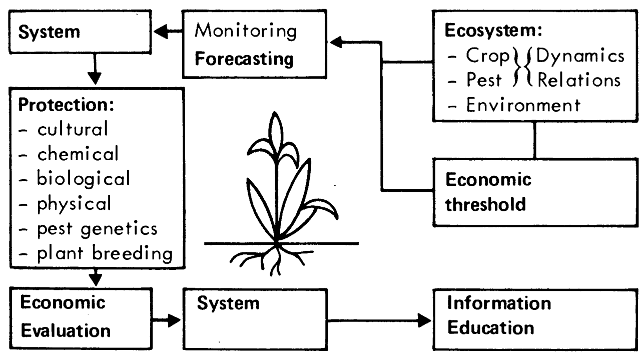

FIGURE 1. Main components of i.p.m. system and their interactions.

As pest management is only one element of the total production system of a crop, its economics must be evaluated in terms of their impact on overall crop productivity and on profitability to the farmer or grower.

All the components and interactions so far described can again be subjected to systems analysis and be integrated into models for the management of production. The required collection, storage and retrieval of data are facilitated by the availability and constant improvement of modern electronic information techniques.

The ultimate, and in many ways the most difficult and crucial, step is to pass on the acquired information to the farmer who has to be convinced of the need to implement the available components of the system in practice. This can only be achieved by a systematic and continuous educational process.

In looking at the complexity of integrating all components of a crop ecosystem it becomes apparent that implementation of i.p.m. in practice can only proceed stepwise and in tune with the generation of the required scientific knowledge and techniques.

5. Present status of i.p.m., and future trends

As most available i.p.m. literature covers either principles or specific crops, specific geographic areas or even isolated components, it is difficult to assess or even quantify the present status and future trends on an international level. Since such information is important to the agrochemical industry for directing its own activities, we have attempted to conduct within our own organization a first survey by questionnaire, the contents of which were verified by local i.p.m. authorities. The survey was confined to those five industrialized countries that have the highest volume of pesticide sales: the U.S.A., Japan, France, Brazil and the Federal Republic of Germany, which together absorb close to 60 % of the world market (table 1).

In the first part of the survey we examined the present and expected future uses of different i.p.m. components (except chemicals) and the research effort devoted to them. Table 2 shows

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in some detail the information collected in the area of *insect control*. The codewords and the corresponding symbols listed in this table were defined by uniform, objective and, as far as possible, quantifiable criteria.

The use of cultural measures to knowingly and specifically suppress insect pest populations (such as the rotation of crops, the timing of planting and harvesting, the management of trash or stubble, the planting of border or trap plants, the destruction of alternative host

Table 1. Pesticide use in countries surveyed for i.p.m. (percentages of world market) (1980 data)

U.S.A.	29
Japan	11
France	7
Brazil	5
Fed. Rep. Germany	4.5
total	*ca.* **57**

Table 2. Five-country survey of i.p.m. components for the management of insect and mite pest populations in terms of their present use, medium-term development and research effort devoted to them

	present use and trend					research effort				
method	U.S.A.	Japan	Brazil	France	F.R.G.	U.S.A.	Japan	Brazil	France	F.R.G.
cultural measures	2,↑	1,↓	1,↓	0,↓	1,↓	2	1	1	1	1
preservation, predators/parasites	2,→	1,↓	2,↓	1,↓	1,↓	3	2	2	0	1
biological, pest genetics	1,→	1,↓	1,↓	0,↓	1,↓	3	2	1	3	1
plant breeding	3	1	1	2	1	3	1	1	2	1

Symbols: 0, nil; 1, limited; 2, sizeable; 3, extensive; ↓, slow; →, intermediate; ↑, rapid.

plants, soil and water management practices, fertilizer usage, sanitation) is limited in most countries, except in the U.S.A. where it appears to be sizeable.

Specific measures to preserve. enhance or introduce beneficial insects that as predators or parasites are natural enemies of insect or mite pests, are applied on a limited scale in three and to a sizeable extent in two countries.

The application of biological control methods (such as hormones, microbial and viral preparations or living insect pathogens) and of pest genetics (for example the rearing and release of sterilized male insects) is at present limited and confined to specific local pest problems.

Plant breeding activities to develop and introduce crop varieties resistant or tolerant to insect and mite pests are extensive in the U.S.A., sizeable in France, and limited in the other countries.

The future development. i.e. the trend in further extension of the described insect management practices is predicted to be slow in most countries, except for the U.S.A., where further extension is expected to proceed at an intermediate or even rapid rate.

The present research effort devoted to the listed control procedures, which is likely to affect the speed of their further extension, varies between limited and sizeable in most countries, except for the U.S.A., where it is again judged to be extensive.

For evaluating i.p.m. developments in the area of *plant pathogen control* (i.e. the management of fungal, bacterial and viral pests), the collected information has been condensed into table 3, which is a shortened version of the preceding table. The present use of cultural practices to suppress pathogens (among which sanitation, seed treatment and trash management have high priority) is already sizeable. Future developments are predicted to be slow and the corresponding research effort is limited.

TABLE 3. FIVE-COUNTRY SURVEY OF I.P.M. COMPONENTS FOR THE MANAGEMENT OF PLANT PATHOGENS IN TERMS OF THEIR PRESENT USE, MEDIUM TERM DEVELOPMENT AND RESEARCH EFFORT DEVOTED TO THEM (CONDENSED VERSION)

method	present use	trend	research effort
cultural measures	sizeable (to limited)	slow	limited
biological	limited (to nil)	slow	sizeable (to limited)
plant breeding	sizeable (to extensive)		sizeable (to extensive)

TABLE 4. FIVE-COUNTRY SURVEY OF I.P.M. COMPONENTS FOR THE MANAGEMENT OF WEEDS IN TERMS OF THEIR PRESENT USE, MEDIUM-TERM DEVELOPMENT AND RESEARCH EFFORT DEVOTED TO THEM (CONDENSED VERSION)

method	present use	trend	research effort
cultural measures	extensive	slow	limited
mechanical/physical	extensive(mechanical)	stable to decreasing	limited
biological	nil	slow	limited (to nil)

Biological control methods (such as the use of specific microbial pathogens against fungi and bacteria) are applied on a very limited scale, and, in spite of an apparently sizeable research effort, further extension is predicted to be slow. On the other hand, the development and introduction of disease-resistant cultivars has been sizeable and (as judged by the present research effort) will continue to be so.

Since the management of weeds (more than of insects or pathogens) has always been a part of particular production systems, the impact of present i.p.m. efforts on *weed control* is likely to concentrate on specific problems related to new crop production technologies (table 4). Cultural methods (such as crop rotation, soil preparation, and timing of planting) are already practised extensively. The same applies to mechanical methods (ploughing, harrowing, discing, etc.). Future developments in these two areas of weed management are likely to be dictated by energy considerations, soil erosion phenomena, water shortages, and even by the availability of new chemicals, including plant growth regulators. The present use of biological control methods against weeds (such as weed-killing insects and pathogens) is practically nil and their future expansion will be slow and confined to single weed species that infest large areas of particular ecosystems.

A number of i.p.m. components that are essential for *systems analysis* and modelling are listed in table 5, which demonstrates that present scientific knowledge on economic thresholds and on insect, pathogen and weed dynamics is limited. The same applies to the present use of crop–pest modelling systems, electronic data evaluation procedures and specific pest-monitoring devices. However, the research effort is sizeable in most areas and countries, and a continuous flow of new and applicable information is to be expected.

In the second part of our survey we have collected some information on the actual use of i.p.m. in practice (table 6). The table lists the main crop of each country in terms of the acreages at present managed by i.p.m. techniques. The acreage of these crops subjected to i.p.m. varies between 4 Mha of cotton in the U.S.A. and 500 ha of apple orchards in Germany. When expressed as percentages of the total acreage of these crops, the results vary between 100 % (rice in Japan, which, however, is a particular historical development and where i.p.m.

Table 5. Five-country survey of systems modelling components of i.p.m. in terms of present use, currently available knowledge and research effort devoted to them (condensed version)

component	knowledge use	research effort
economic thresholds	limited	sizeable(limited)
Insect pest dynamics	limited	sizeable (limited)
pathogen dynamics	limited	sizeable (limited)
weed dynamics	limited (nil)	limited (nil)
pest–crop modelling	limited	sizeable (limited)
use of computer	limited (nil)	sizeable (limited)
monitoring devices	(limited (sizeable)	sizeable (limited)

Table 6. Five-country survey on the present use of i.p.m. systems in practice

(The table lists the main crop of each country in terms of acreage subjected to i.p.m. measures.)

country	crop	acreage ha (%)	control	main features	economics
U.S.A.	cotton	4.2×10^6 (70–75)	insect	improved info. spray timing	+
Japan	rice	2.6×10^6 (100)	insect (path.)	monitoring (forecasting)	?
France	deciduous fruit	15×10^3 (8)	insect (path.)	monitoring, spray reduction	+
Brazil	soybean	2.3×10^6 (25)	insect	monitoring, spray reduction	+
F.R.G.	apples	500 (5)	insect	monitoring, spray reduction	=

is limited to the official monitoring service) and 5 % (apple orchards in Germany). Control methods are confined to insect pests, with some minor attention to plant pathogens in two countries. The main components of the applied management systems are pest monitoring and improved information flow, which in turn have led to better timing of insecticide spraying and/or a reduction of the number of sprayings required. Other measures, such as the adaptation of cultural methods, the change to more selective insecticides, the use of biological control methods and the introduction of resistant crop varieties appear to be practised on a minor scale. The data thus demonstrate that we are still some distance from using complete insect management systems on large acreages of major crops.

As far as the economics of the described i.p.m. operations are concerned they have, on average, been reported to be beneficial to the farmers in three of the five countries surveyed. However, this assertion must be qualified by the fact that the R & D effort and also (at least in part) the monitoring and consulting activities have been funded from government resources.

The present status of i.p.m. and the medium-term trend can be summarized as follows.

(*a*) I.p.m. is an established feature in all countries surveyed. The completeness of present systems, the degree and perfection of coverage achieved and the approaches taken vary from country to country. Further extension and technical improvement is predicted to proceed at a slow (or at best at an intermediate) rate.

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(*b*) Insect control dominates the i.p.m. scene, with some attention given to pathogen or plant disease control. I.p.m. efforts in weed management are not yet very obvious and appear to be limited to specific problems related to new crop production technologies.

(*c*) The scientific information base of i.p.m. is at present limited. However, research efforts in a number of areas are sizeable and will generate a flow of applicable data.

6. Industry's contributions to i.p.m.

I contend that during the last 10–15 years the agrochemical industry has already made significant contributions to i.p.m. efforts and objectives, as noted below. These contributions are hardly noticed in present i.p.m. literature, in which pesticide properties and features are frequently degraded (and also discounted) by outdated and misleading information.

(*a*) Industry has succeeded in constantly increasing the biological activity of plant protection agents against their target organisms. This development has led to a continual reduction of application rates.

(*b*) There are numerous examples of the improved selectivity of recently introduced compounds, which compare favourably with the spectrum of activity of earlier standards.

(*c*) As new products have been introduced, those properties detrimental to the behaviour in the environment have constantly been diminished.

(*d*) Mammalian and eco-toxicity testing of pesticides has been extended in such a way that safety evaluations and risk assessments can be made, if not with complete certainty, with at least a considerable degree of confidence.

(*e*) Application techniques have constantly been ameliorated and have brought improved efficiency and targeting of pesticides.

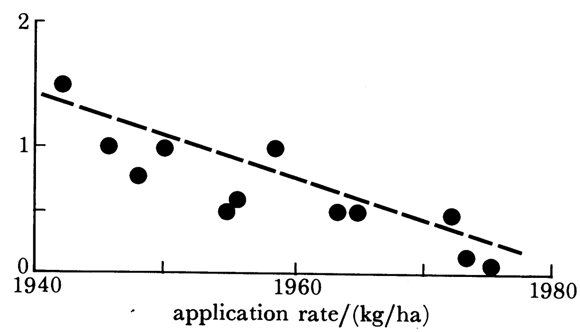

Figure 2. Evolution of rate of application of insecticides. Graph based on the following insecticides: DDT (1942), parathion (1946), dieldrin (1948), diazinon (1951), azinphos-methyl (1955), dimethoate (1956), carbaryl (1958), chlordimeform (1963), monocrotophos (1965), diflubenzuron (1972), permethrin (1973), deltamethrin (1975).

Some of these contributions will be illustrated by appropriate examples.

The rate of application of insecticides has steadily declined and has reached the 100 g/ha and even 20 g/ha range with the introduction of synthetic pyrethroids (figure 2). The same pattern of evolution can be demonstrated for fungicides and herbicides. Since for most compounds introduced, the decrease in use rates has not been accompanied by a parallel increase in mammalian or eco-toxicity, this development represents a significant reduction of what is often referred to as 'the loading of our environment with chemicals'. As we look ahead (and since energy requirements of pesticides are a constant argument in i.p.m. literature), it also means considerable savings in petrochemical energy.

The potential of pesticides to be distributed and accumulated in the environment is determined by a number of compound-related properties that are now well recognized and defined and which are listed on the left-hand side of figure 3.

The graph illustrates the evolution of these properties for a number of major insecticides, which have been arranged according to time of introduction. The steady decline of dispersal

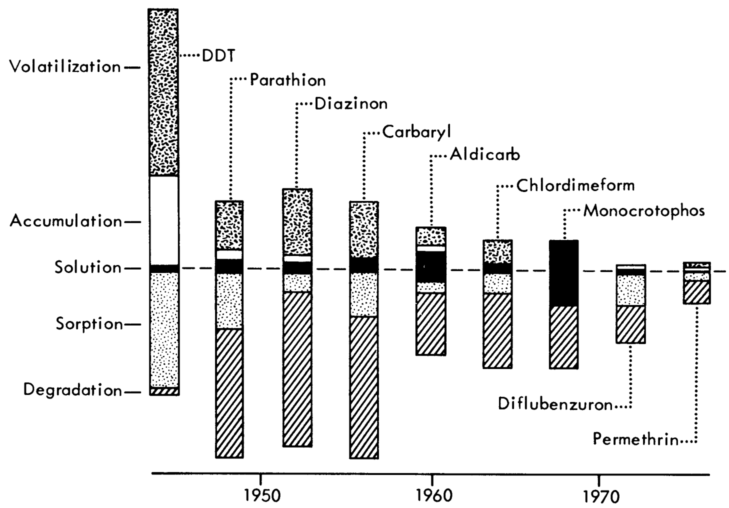

Figure 3. Evolution of the potential of insecticides to be distributed and accumulated (biomagnified) in the environment. Compounds arranged according to time of introduction. The potential of an insecticide to be distributed and accumulated in the environment is enhanced by its volatility and by its susceptibility to be partitioned into living non-target organisms (accumulation). The potential is reduced by a decreased rate of application (indicated by bar size), by the degradability of the insecticide and by its ability to be adsorbed on soil particles (sorption). Water solubility (solution) has a neutral position, because depending on conditions, it increases dispersal or increases degradation.

Category	Atrazine	Methidathion	Metalaxyl
Year of Reg.	1959	1969	1980
Acute	●● ●	●●● ●●●	●●●●●● ●●●●●●
Sub-chronic	● ◖	●●● ●●	●● ●●
Chronic	◖	●● ●●	●● ●
Special Studies	●	● ●	●●● ●●
Eco-Toxicology		●●●●● ●●●●●	●●●●●● ●●●●●●

Figure 4. Evolution of the number and type of mammalian and ecotoxicity studies required for registering a pesticide with the U.S. government authorities.

and accumulation potential is demonstrated by a steady reduction of bar size and by a shift of these bars towards the bottom half of the graph. This figure shows that it is not justifiable to generalize about pesticide properties by continuous reference to chlorinated hydrocarbons.

The evolution and extension of mammalian and eco-toxicity testing with time are shown in figure 4. In 1959 no more than five completed and two ongoing tests were sufficient to register a herbicide with the authorities in the U.S.A.; 10 years later the number of experiments from which data were submitted had increased to 30. Meanwhile, as demonstrated for a fungicide, the number has further risen to no less than 40 different studies. To minimize health and environmental hazards, these tests cover acute, subchronic and chronic mammalian toxicity, potential teratogenicity, mutagenicity, carcinogenicity, delayed neurotoxicity, multi-generation reproductive effects, and ecotoxicity to such varied non-target organisms as game, birds, fish, small aqueous and marine fauna and soil microflora.

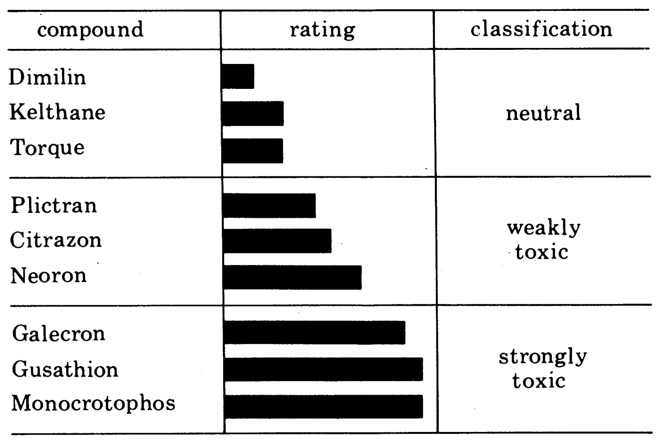

FIGURE 5. Results of routine laboratory testing and classification of the toxicity of commercial insecticides and acaricides to a predatory mite species (*Amblyseius fallacis*). The rating is expressed as relative mortality observed under the experimental conditions.

At present, industry is in the process of further modifying a number of its objectives and approaches to make additional and future contributions to i.p.m.:

screening and biological testing procedures are being extended and adapted to discover and exploit substance-related properties that fit i.p.m. technology;

the use of currently available compounds will be perfected by improved timing and targeting of applications;

formulation and application technology will be improved to increase efficiency further and reduce unwanted dispersal of pesticides;

the already intense search for new compounds with even better inherent selectivity and different, more specific modes of action will be continued.

By all of the activities mentioned above, industry will make substantial contributions to the i.p.m.-information base.

These approaches can again be illustrated by some practical examples. They are taken from the area of insect control, where, as we have seen, i.p.m. activities will be most intense in the immediate future.

Biological screening and testing procedures are not only extended to include new modes of insecticidal and insect-regulating activities (such as hormonal, anti-hormonal, ovicidal, repellent or sex-attractant effects) but also to testing the effects of existing and future compounds on beneficial insects and mites. Table 7 lists a representative selection of predator and parasite species from four important insect orders that are reared in an industrial laboratory and used for appropriate testing. Such testing allows the classification of existing and newly developed insecticides and acaricides with regard to their toxicity to specific beneficials. The results of a typical laboratory test are shown in figure 5, which classifies a number of

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existing insecticides into groups of neutral, weakly toxic and strongly toxic compounds in terms of their effects to a predatory mite.

This information can then be exploited for appropriate studies and extension under practical field conditions. The results of a 3 year large-scale field experiment on apples, initiated in 1977, are summarized in table 8. The data demonstrate that by the consistent use of the selective insecticide diflubenzuron, insect damage to apples was kept at a tolerable level, and at the

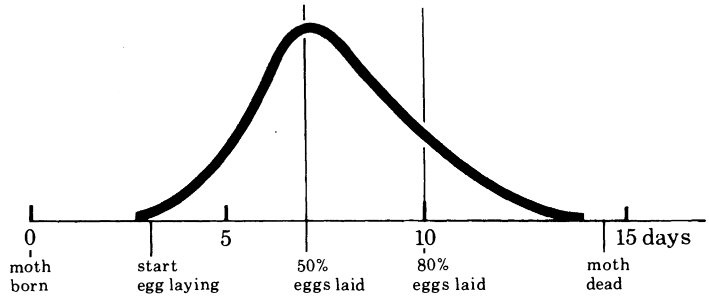

Figure 6. Timing and targeting of the application of the insecticide monocrotophos (at 2 × 350 g a.i./ha) to fit the main appearance, life cycle and egg-laying habits of *Heliothis armigera* populations in Sudanese cotton.

Table 7. List of beneficial insects (predators, parasites) reared and used for routine toxicity testing of insect and mite control agents in an industrial laboratory

Order	species	crops
Coleoptera	*Coccinella septempunctata* (ladybird)	most crops
Heteroptera	*Anthocoris nemorum* (flower bug)	deciduous fruit
Hymenoptera	*Coccygomimus turionella* (parasitic wasp)	forestry
Neuroptera	*Chrysopa carnea* (green lacewing)	most crops

Table 8. Gradual establishment under field conditions of a predatory mite population (*Amblyseius finlandicus*) that suppresses secondary outbreaks of a mite pest (European red mite) by the consistent use of the selective insecticide diffubenzuron

(The broad-spectrum insecticide azinphos-methyl has been used for comparison. The experiment started in 1977, in an apple orchard with 90 trees in the southern part of Switzerland.)

compound	insecticide effect: damaged fruit in 1980 (%)	European red mite mobile stages†, eggs‡, July 1979	European red mite mobile stages†, eggs‡, March 1980	predatory mite mobile stages†, Sept. 1980
azinphos-methyl	1.3	2770	3218	40
diflubenzuron	1.4	490	374	180
control	41.8	360	263	300

† Per 100 leaves. ‡ Per branch.

same time permitted the gradual establishment of a predatory mite population that controls the European red mite, a serious secondary mite pest on apples.

Improved timing and targeting of insecticide sprays can be achieved by systematically exploiting the dynamics of a pest population and its most sensitive stages of development. Figure 6 demonstrates such an approach to the large-scale control of *Heliothis armigera* in

Sudanese cotton. After appropriate field monitoring, the aerial application of the insecticide monocrotophos was synchronized with the main appearance and 15-day life cycle of the moth population and to its egg-laying habits. By this timing the two sequential sprays were efficiently and accurately spaced to reach the major portion of young larvae during their most sensitive stage, i.e. immediately after hatching.

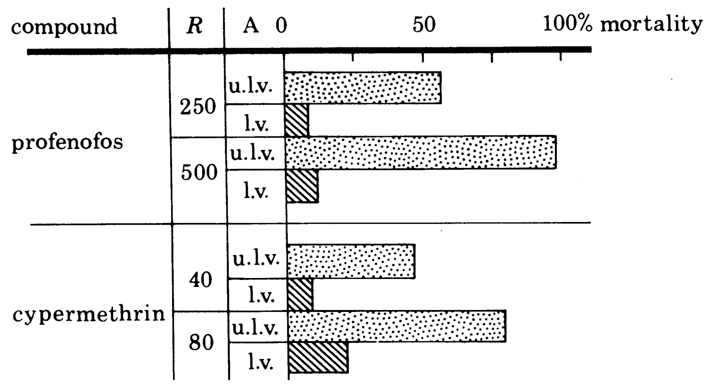

Figure 7. Comparison of efficiency of low volume (l.v.) and ultra-low volume (u.l.v.) sprays of the insecticides profenofos and cypermethrin in killing *Heliothis virescens* larvae. *R*, rate of application (grams active ingredient per hectare); A, application method.

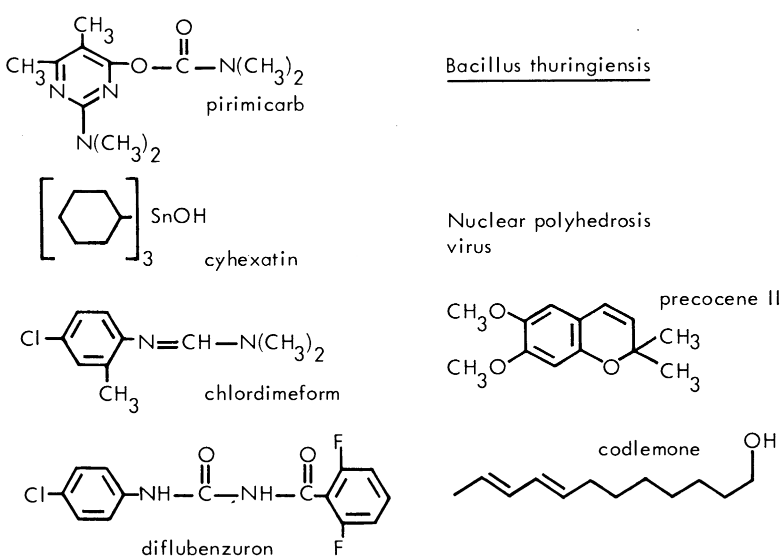

Figure 8. Chemical structures and/or common names of present and potential future selective insect and mite control agents that fit i.p.m. objectives and strategies.

Future improvements in application technology will depend on a more extensive, systematic and imaginative employment of the physical and physico-chemical parameters that control the behaviour of sprays and their deposits on both crops and target organisms. Figure 7 compares the efficiency of low volume and ultra-low volume sprays of two different insecticides in killing *Heliothis virescens* larvae. The figure shows that even at half the rate of application, ultra-low volume sprays, which exhibit a controlled droplet spectrum, improved retention and more equal distribution on the target, are much more efficient than their low volume counterparts. Although ultra-low volume spraying is not a desirable system under all conditions, the comparison demonstrates the scope of increased efficiency that can be achieved by the control of application parameters.

Adequate selectivity is an essential prerequisite for insecticides to be used in i.p.m. systems. Although a considerable degree of selectivity can be achieved against various pests by following the approaches described above, i.e. timing and targeting, and controlled application and formulation, the most desirable objective is the availability of a range of inherently selective insecticides. As shown by the examples on the left-hand side of figure 8, industry has already provided a number of compounds, such as pirimicarb, cyhexatin, chlordimeform and diflubenzuron, which fulfil the criterion of adequate selectivity in different pest management procedures and on a variety of different crops. Compounds related to, or with modes of action similar to that of, diflubenzuron are currently being extensively synthesized and tested for biological activity. It is to be expected that this effort will produce new insecticides with appropriate selectivity.

Insecticidal microbial and viral preparations such as *Bacillus thuringiensis* and nuclear polyhedrosis virus, which have a high degree of selectivity, are currently available and used on a limited scale. However, modern biotechnology would appear to offer the opportunity of improving the economics and activity of these and similar biological preparations.

Although insect growth regulators such as juvenile hormone mimics are confined to very specific and limited uses at present, derivatives of juvenile hormone antagonists (represented by the structure of precocene II) are being intensively investigated. The same applies to insect sex-attractants or pheromones as exemplified by codlemone, the sex pheromone of the codling moth.

Although the real potential in practice of some of the chemical and biological approaches described above is difficult to evaluate at present, I am confident that industry will successively make available a set of new insect and mite control agents that fit i.p.m. objectives and technologies. However, this statement must be qualified by the fact that such agents will have to meet economic criteria that justify the large and risky investment in research and development.

7. Conclusions

The high scientific and technical standards required to master the complexities of optimal i.p.m. systems and strategies call for a well organized and efficient interdisciplinary approach among all branches of agricultural science, technology and administration. Straightforward and unbiased cooperation between the various professional organizations involved is also essential. I believe that the agrochemical industry is as competent as any of the participants in making substantial contributions, not only by providing the appropriate chemicals but also in making the correct decisions regarding their judicious and economic combination with other components. Chemicals will continue to be an essential part of i.p.m. strategies for the foreseeable future.

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