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PESTICIDES
CURRENT AND FORESEEABLE TRENDS IN PRODUCTION AND USE[1/].

by

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The synthetic pesticides industry as we now understand it is a young industry dating from the end of the Second World War, since when it has grown from one worth about £200 m. at the user level in 1950 to somewhat over £1500 m. in 1972. These figures exclude the socialist countries which, together, were estimated to have sold some 13% of the world sales in 1970. If that percentage held for 1972, and there is no reason to suppose that it had altered appreciably, the pesticides industry is currently worth about £1750 m. These figures are for sales of formulated products at the user level and in some instances may include sales from one country as exports and sales of the same material after importation into another. Nevertheless, they are considered to be reasonably near approximations of the size of the industry.

The difficulty encountered in compiling statistics of this kind is shown in an article in Farm Chemicals (1) [Jan 1972 135, No 1, 18] dealing with the United States market in pesticides where it stated: "Over the years the basic yardstick for measuring the US market has been the US Tariff Commission's Report ' U.S. Production and Sale of Technical Synthetic Organic Chemicals'. This report covers sales of technical material at the manufacturer's level. But questions are now being raised about the accuracy of these figures under today's practice of marketing finished formulations of proprietary products. For example, very few herbicides are sold in technical form. Furthermore, while basic manufacturers do sell some of their goods to distributors at 'Manufacturer's prices', they also sell direct to dealers and consumers at higher price levels. Therefore the Tariff Commission's figures probably do include formulations and are not solely sales of technical materials."

Similar conditions obtain for many sets of returns from Departments of Trade and Industry, Commerce and Customs and Excise, in that not only are technical materials and their formulations grouped together but occasionally are also grouped with yet other kinds of products. For example, the British Department of Trade and Industry makes a return of 'Pesticides and Allied Products'. This is the situation in countries where statistical data are relatively reliable, in many developing countries without the resources to maintain records, the position is more difficult.

However, if the data which are available are combined with information from industry and private consultants and from specific surveys undertaken occasionally by government departments, a picture emerges which is probably a good approximation to the actual position at any one time. Repeated over the years such combinations enable a trend in production and demand over the years to be traced.

Whereas, ten to fifteen years ago it was relatively easy to forecast trends, it is more difficult to do so today because of changing and stiffening legislation and regulations about the production, sale and use of pesticides now occurring in many countries, being superimposed upon the trends dictated by changes in the patterns of agriculture. This, however, is not the place to discuss the rights and wrongs of this legislation, which in the view of many of us has gone much further than is necessary in some developed countries, but to try to see what effect it may have on pesticide use patterns world-wide.

Let us examine the trends as far as we can. The following diagrams illustrate the breakdown of use by areas and by kinds of pesticide. In 1950, the North American Continent (and mainly the USA) accounted for about half of the world's use of pesticides and at that time insecticides accounted for 2/3 of the value of pesticides sold, fungicides and herbicides together accounting for the remaining 1/3.

By 1968, the end-user value of pesticides had increased six-fold and the rest of the world (excluding the socialist countries) had overtaken the North American Continent and accounted for about £685 million against the £545 m. of the N.A.C. By this time, world-wide, the use of fungicides and herbicides had increased faster than the use of insecticides, which at that time accounted for about half of the value.

Fig. 1. End-user Value of Pesticides 1950

North American Continent £100 m.	1950	Insecticides 2/3 £133.3m.
Rest of the World £100 m.	£200 m.	Fungicides and Herbicides £66.7m.

Fig. 2. End-user Value of Pesticides 1968

North American Continent £545 m.	1968	Insecticides ½ £615 m.
Rest of the World £685 m.	£1230 m.	Fungicides and Herbicides £615 m.

During this period the developed countries were using insecticides both for agriculture and some public health purposes but in the developing countries, particularly in the earlier part of the period, the main use of insecticides was in public health programmes and these were mainly malaria control. But rightly in the early, post second World War period were concentrating on getting cultivation techniques right before advocating pesticide applications. A very good example of this was given by my own team working at Ilonga, in Tanzania in the middle 1950's, on the control of cotton pests. With properly grown and fertilised cotton, large increases in yield resulted from pesticide applications which amounted in value to about eight times the cost of the pesticide treatment. On the African shamba-grown cotton, grown in the traditional way, the increase in yield from pesticide treatment failed to pay for the treatment.

Let us examine another recorded estimate of world sales of pesticides for 1970 prepared by Chemische Industrie International. They are industry estimates of sales of formulated products by manufacturers.

Fig. 3. World Sales of Pesticides 1970

	Value $ m.	Value £ m.	% of World Market
USA	1300		45
Canada	60		2
Federal Republic of Germany	220		8
France	170		6
U.K.	90		3
Netherlands	60		2
Sweden	10		< 1
Finland	5		< 1
Spain	40		1
Portugal	15		< 1
Other Western Europe	90		3
Japan	230		8
Australia	60		2
Eastern Bloc	375		13
Other	200		7
Total	2925		100

Reference to the first two entries shows that use in the USA is about 22½ times that in Canada and so is the lion's share of the N. American Continent market.

Another estimate for the same year, published in Farm Crops (ibid.) gives the value of the US market at the user level at a little over $1,500 m.

It is interesting to study further the breakdown in particular countries and regions of pesticides into insecticides, herbicides, etc. It is only possible to do this in a few instances. Taking the year 1968 that we considered earlier, the pattern in the U.S. itself was rather different from the global picture and in itself indicative of a trend which users elsewhere are starting to follow.

Fig. 4. Breakdown of Pesticides according to End-user Value USA 1968

Fungicides	7%
Herbicides	57%
Insecticides and Rodenticides	36%

The interesting feature of this diagram is the large increase in the use of herbicides which began in the early 1960's. Between 1964 and 1966 in the U.S.A. herbicide use on farms increased by 37% whereas the overall use of pesticides increased by only 10%. The most important herbicides were 2.4-D and atrazine with 35% and 20% respectively of the total herbicide market in 1966. Two years earlier 2.4-D accounted for 41% of the herbicide market and atrazine 13%.

A trend of increased herbicide use also showed itself in Britain and probably many other developed countries in which men were leaving the land for more lucrative work in factories. During the 1960's the trend in the UK (2) (Pesticides and Allied Products Returns of the Dept. of Trade and Industry) is shown in Fig. 5.

Fig. 5. Comparison of Manufacturers' Sales of Pesticides in the UK in 1963 and 1969

1963

N.R. and P.	5%
Fungicides	20%
Insecticides	32%
Herbicides	43%

N.R. and P.: Nematicides 2%, Rodenticides 1, Plant Growth Substances 2%

1963 total value at manufacturers' level £18.39 m.

1969

N.R. and P	3.6%
Fungicides	9.9%
Insecticides	19.7%
Herbicides	66.8%

N.R. and P: Nematicides 1.1%, Rodenticides 0.5%, Plant Growth Substances 2.0%

1969 total value at manufacturers' level £35.18 m.

Unfortunately, a further breakdown into percentages of actual active ingredients is not available; nevertheless compounds such as paraquat, simazine and chlorthiamid are increasing in use while the well-tried 2.4-D and MCPA, although decreasing as a percentage of the total (increasing) market, are still used to a large extent on cereals and pastures - especially in mixtures with other herbicides.

At the British Insecticide and Fungicide Conference 1971, J.F. Newman (3) reviewed the changing patterns of pesticide use in Europe as seen by industry. He summarised the situation in a paragraph which stated:

> "The pattern of pesticide usage in Europe differs from that of other parts of the world, although is broadly similar to that of North America, as shown in the table. In the developed areas of Western Europe and North America manual labour is becoming increasingly scarce and expensive and the pesticide market is dominated by herbicides. In the underdeveloped tropical countries with plentiful cheap labour herbicides are less used but the demands for the control of insect-borne disease, to ther with a high incidence of agricultural insect pests, result in insecticides taking top place."

Fig. 6. World Use of Pesticides by Groups of Products - Source. J.F. Newman (loc. cit.)

Country	% total use in each area		
	Herbicides	Insecticides	Fungicides
N. America	61	25	7
W. Europe	49	25	23
Far East	25	45	21
Africa	31	42	28
S. America	30	53	16
Australia and N.Z.	45	38	16
C. America and Caribbean	33	51	15

The outstanding insecticide over the whole of the synthetic pesticides era has been and still is the "founder member", DDT. It is the insecticide of choice in malaria control programmes, and of the farming community for those pests for the control of which it is suitable. It is cheap, safe and easy to handle and use and has a human health record second to no other synthetic organic chemical. The persistence, which makes it so valuable in public health programmes - indeed makes those programmes possible, is the property which has caused some apprehension in conservation circles and which has resulted in restrictions in use, and even complete bans in some developed countries.

Clearly legal action of this kind is bound to have an effect upon future use. This will mean that pest control progammes in many instances will cost more and often the replacement compounds will be dangerous or very dangerous to handle.

The other factors which will have an effect on future use are:

(i) the development of resistance by a pest to the pesticide being used against it,

(ii) the discovery of new compounds which will enable a given pest to be controlled more effectively or to be controlled adequately but more cheaply.

In a survey reported by Farm Chemicals (loc. cit.) enquiries were sent to ten major US and four major European pesticide companies. The report states that:

"The projections of the four major European pesticide producers who participated in this confidential survey were surprisingly close to those of the American companies." The figures at US manufacturers' level for the domestic and export markets would climb to $1299 m. in 1975 from $952 m. in 1971. At the user level for 1971. the value is put at around $1,600 million rising to $2,000 m. by 1975 "if government regulations don't further restrict the use of pesticides and if increasing demands for more research data don't force still more slowdowns in the development of new products." In their projections for the world market at the end-user level the European companies forecast $4,580 m. in 1975, some $100 m. above the estimate of the American companies. This is a growth rate of about 8% a year. Tabulating these we have:

Fig. 7. Forecasts of US and World Markets

Year	Value in $ m. U.S.		
	US market		World market
	Manufacturer's level	User level	User level
1971	952	1,600	3,000
1975	1,299	2,000	4,480 (4,580)*

* Estimate by European companies

While there is no breakdown for the world market, the estimates for the different classes of pesticides for the US market, projected to 1973 is tabulated below:

Fig. [illegible]. Breakdown of US Market (user level)
Source - Farm Chemicals

Classification by use	Type of compound	Value at user level $ million 1971	1975
Herbicides	Arsenical	8.3	5.6
	Phenoxy cpds	48.2	40.0
	Phenyl ureas	72.5	101.3
	Carbamates	103.0	138.0
	Triazines	340.0	441.3
	Benzoic acid der.	72.0	88.0
	Others	413.0	556.0
Insecticides	Arsenicals	22.5	13.5
	Botanicals	12.5	18.0
	Carbamates	82.0	155.0
	Organo chlorines	101.0	56.0
	Organo phosphorus cpds.	281.0	342.8
Fungicides	Copper compounds	15.8	16.3
	Mercury compounds	5.6	3.7
	Dithiocarbamates	34.0	47.5
	Phthalimides	24.3	29.7

The picture in other developed countries will probably be very similar to the pattern for the USA, but it is unlikely that developing countries will be using quite so wide a range of more recently developed compounds. Nevertheless, provided legislation in developed countries does not cut off supplies of organochlorine insecticides from the developing ones, pesticide use in the latter should continue to increase at a steady rate. The position could be serious if supplies of DDT, aldrin, dieldrin, chlordan and heptachlor were cut off from those countries. In most instances crop protection would cost more and in many situations would be less efficient for, particularly in the control of soil insects, there are no satisfactory substitutes. The following table gives the price in $US/lb. of a range of commonly used insecticides (4) :

Fig. 9. Cost per lb. of commonly used insecticides

Compound (technical product unformulated)	Price $/lb.
Aldrin	0.992
Dieldrin	1.665
DDT	0.179
Heptachlor	0.973
Malathion	0.900
Parathion	0.780
Parathion (methyl)	0.780
Lindane	1.406
Chlordane	0.602
Endrin	2.469
Dichlorvos	3.750

Reference was made earlier to the research and development effort which has been put into the pesticides industry since its inception following the discovery of the biological properties of the insecticide DDT on the one hand and the 'hormone' herbicides MCPA and 2,4-D on the other. The enormous range of products discovered and developed in the last 25 years has been such that it has become necessary to coin internationally accepted common names for these compounds.

This is done by the International Standards Organization through one of its technical committees of which the secretariat is provided by the British Standards Institution which itself has been active in the pesticide nomenclature field for more than 20 years. Common names have been given to over 300 compounds.

Insecticides of vegetable origin. (The botanical insecticides)

Plants of different species synthesise a number of compounds, some of which are biologically active themselves and some which are used as intermediates in the synthesis of biological compounds. Examples of the latter are diosgenin in yams and hecogenin in sisal which are used for the synthesis of the cortico-steroid drugs. Examples of the former are alkaloids, fluoracetic acid, pyrethrins and related compounds, rotenone, nicotine and ryania which find application in medicine or agriculture. Some of the compounds have been used as fish poisons.

Sodium fluoracetate is a compound highly toxic to many species including mammals and birds. It also acts systemically as an insecticide but is never used for this purpose. It is used as a rodenticide* in special circumstances in which other species can be prevented from having access to it.

The most used product is pyrethrum extract, the active ingredients of which have a unique property of rapid knock-down of insects - particularly house-flies and mosquitoes - as well as being lethal if present in sufficient amount. If insufficient is used the knock-down is reversible. They are, nevertheless, highly toxic to many insect species.

One of the difficulties associated with insecticides of vegetable origin has been the difficulty of obtaining uniform products. The plant material from which they are derived is obtained from different parts of the world and having been harvested at different times in the growing period and stored under different conditions before it is prepared and formulated for sale and use.

For this reason these insecticides, except the pyrethrins, have been replaced generally by synthetic compounds.

Included in the above-mentioned list are compounds which have been synthesised in an attempt to simulate and, if possible, improve upon the biological and physical properties of some of the naturally occurring botanical insecticides. The best known of the synthetic compounds are allethrin, tetramethrin and resmethrin. As

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* It is synthetic sodium fluoracetate, not the plant extract, that is used for this purpose.

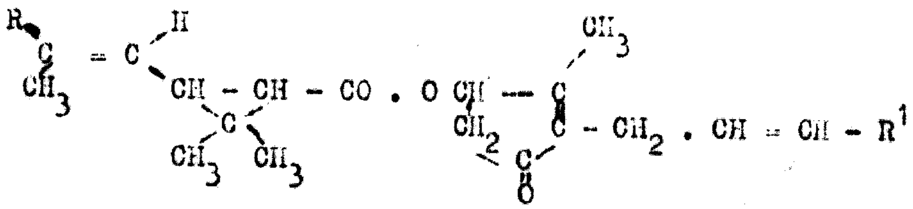
their names imply they are pyrethroids; they are more active than the naturally occurring pyrethrins to some insect species, are of relatively low mammalian toxicity and more stable chemically and physically than the natural extract. They are also costly, as are the natural extracts, and are unlikely ever to become widely used in agriculture, their main use being as components in aerosol formulat - ions for the control of flying insects in domestic and industrial (grain store) premises.

The mixture known as pyrethrum extract is obtained mainly from Pyrethium cinerariaefolium, indigenous to Dalmatia and also P. roseum and P. carneum. The active material occurs in the achenes of the flowers which are plucked, carefully dried and then extracted.

The drying process has to be carefully undertaken, avoiding excessive heating if done artificially. If dried in the open air, the flowers must be dried in thin layers, constantly agitated to ensure uniform drying and avoiding fermentation which occurs if the layers are too deep. The active ingredients are reactive molecules readily prone to oxidation. Once dry, the flowers should be stored in sacks, under as cool, well-ventilated conditions as possible.

The active materials are complex esters formed from three alcohols (pyrethrolone, cinerolone and jasmolone) and two acids (chrysanthemic and pyrethric). The main constituents are the esters of pyrethrolone which are known as pyrethrins I and II, each present to the extent of 33%. Cinerins I and II are present in total to the extent of about 25%. It is on the content of these four esters totalling a little over 90% of the activ material that most crops and extracts have been bought and sold for many years.

The general formula of the esters is:



		R	R^1
Pyrethrin	I	CH_3-	$-CH = CH_2$
"	II	$CH_3O.CO$-	$-CH = CH_2$
Cinerin	I	CH_3-	$-CH_3$
"	II	$CH_3O\ CO$-	$-CH_3$
Jasmolin	I	CH_3	$-CH_2CH_3$
"	II	$CH_3O\ CO$-	$-CH_2CH_3$

The chemistry of the compounds is complex. Each ester can exist in cis and trans geometric isomers and because there is an assymetric carbon atom in optically active isomers too. Useful references for the scientific aspects are (5) (6) (7) (8) and (9).

The East African countries Kenya and Tanzania produce large quantities of dried pyrethrum flowers and pyrethrum extract. The product is derived from C. cinerariaefolium which has been specially selected to produce high yielding strains. With care a high quality product can be produced but, as pointed out above, it is easy to lose a high proportion of the active product if conditions are allowed to favour oxidation of the active materials during the drying and extraction processes. Note. Some people are very allergic to compounds present in pyrethrum flowers and in the spent extracted material. Severe dermatitis can occur.

Other insecticides of vegetable origin which have been used in agriculture and horticulture in the past are:

(i) nicotine from the tobacco plant - generally from tobacco waste;

(ii) rotenone from Derris, Lonchocarpus and Tephrosia spp.

(iii) ryania from

The last-named grows in the Caribbean area and is fairly specific fo the maize pest, . This is a fluctuating market and extremely small.

Nicotine is used still to a limited extent for the control of asphids and mites either as dusts or sprays. It is highly toxic to man, as toxic as the more toxic organophosphorus compounds by which it has largely been replaced.

Several species of Derris, Lonchocarpus and Tephrosia contain rotenone and related compounds present in different amounts. For this reason the standardization of derris preparations has been difficult with the result that the final product has given variable control performance. Extraction procedures have been attempted but frequently the residues left in the finely-ground roots are still insecticidal. On account of this variability and the fact that derris and lonchocarpus preparations have no comparable property to the "knock-down" of pyrethrins they have generally become omitted from spray programmes in agriculture and horticulture. However, in developing countries where one or more of these species grow readily, it might be worthwhile re-examining:

(i) the indigenous pest species that can be controlled by rotenone and related products, and

(ii) if there are, examining the possibility of growing the optimum species (and making selections from it) and establishing a processing plant for producing field strength dusts or other formulations,

(iii) proper costing of the land used and alternative cash crops would need to be made.

The insecticides prepared from derris and lonchocarpus roots are relatively harmless to mammals although care should be taken not to inhale derris dust.

As far as the author is aware, no attempts have been made to synthesise pesticides based on the rotenone molecule or any particular part of it.

Pesticides more compatible with the human environment and integrated control systems

It is right that man should be conscious of the need to preserve the quality of the environment in which he lives and not to pollute it in the way in which he has tended to in countries which have industrialised. Such pollution offends all the senses. But the faster man reproduces himself, the greater is the need for food, clothing and industrial development to provide the requirements of the rapidly expanding population. Effluents from the factories which pollute the air, rivers and land around them can be made cleaner. In most instances the technology is known. Man can, therefore, have almost any degree of freedom from pollution that he wants provided he is prepared to pay for it.

By their very method of use and by some definitions of 'pollution', pesticides must 'pollute' every time they are used but whether or not the 'pollution' is important depends upon a number of factors. As far as pesticides are concerned, it is the persistent, organochlorine compounds which are being attacked on the grounds of pollution; more readily biodegradable compounds are being demanded by some conservationists.

The pesticides industry, like the drug industry, is research intensive. R.F. Naegele (10) stated: "Ten years ago, it was normal to estimate that the research and development work for a new product cost between one and two million dollars. The current figures for research and development prior to marketing fall somewhere between eight and twelve million dollars. That means the cost of developing a new product has risen a minimum of five fold." It is now more difficult than hitherto to discover new biologically active materials with novel properties. If further restrictions are to be imposed such as specificity to limited pest species, ready biological degradability, and very low mammalian toxicity, the cost will rise even higher. Clearly this kind of research is only practicable in developed countries backed by a large pool of trained scientists, laboratory equipment manufacturers and an active, virile chemical industry. Generally, the search for new active materials is made in large well-equipped industrial research laboratories although, exceptionally, they have been discovered in university and government laboratories. The situation is not very different from that described in papers read by Szabó (11) and myself (12) at the FAO/Industry Seminar on the Safe and Effective Use of Agricultural Pesticides in South America, São Paulo, Brazil, 1971.

In one respect, however, the situation has hardened in that the pressure against DDT, aldrin and dieldrin has increased and some Governments are demanding so much that some industrialists have cut back on their R and D programmes. Naegele (loc. cit.) in his evidence stated:

"I point out to you that many companies have stopped all R and D work on pesticides. Many other companies have cut back drastically their research efforts on new pesticides and diverted their funds to defensive research on existing products rather than the search for new and better products."

K.R. Fitzsimmons (13) wrote:

"It is obvious that these trends (increased usage of pesticides) place increased responsibility on those companies remaining in the production of agricultural chemicals for a continued supply of acceptable pesticides for chemical control. On this basis there are six ways in which industry is prepared to meet this continuing need." But industry, he pointed out, would expect some return from the public agencies.

Included in the six points were :

"1. Sympathetic consideration of our economic, public relations and political problems.

2. Practical federal regulations and special efforts towards unification of state use, registration and permit laws.

3. Substantial federal assistance in financing and expediting the increasingly stringent toxicological studies anticipated.

4. Better state and federal advisory services to users."

Thus it is obvious that in the USA the pressure of the Environmental Planning Agency is reaching the stage when industry is seriously considering whether investment in fields other than pesticides might not result in improved returns.

In other countries personal communications and statements in discussions at scientific meetings, e.g. of the Society of Chemical Industry Pesticides Group, suggest that industry would not desire or welcome financial contributions from government for toxicological research in connexion with its Pesticides Research and Development programmes.

Summarising, I believe that the largest firms will remain in the pesticides R and D business but that it will not expand as it has in recent years. The chances are that fewer new products will emerge than in recent years and that their patent position will be tied up very carefully indeed so that the expenses of development can be recouped, resources made available for further R and D and a fair profit returned to those who have put their risk capital into the business.

Chemical control relative to other forms (biological, cultural etc.) of control

In considering alternative approaches to the use of pesticides for insect control, R.H. Wright of the University of British Columbia (14) wrote:

"Future pest control measures must be contrived so as to irritate the insects and make them behave in a manner contrary to their own best interests. As a rule, host selection, mating and egg deposition in insects are regulated by signals emanating from the environment and because they are so vital to survival they have become genetically fixed and almost wholly automatic.

It is in these stereotyped behaviour responses that insects are most vulnerable. If we understand the signals that evoke the various kinds of behaviour, we can hope to misdirect the insect to its detriment and our gain and with the added assurance that if the insect learns to disobey the false signal, when the time comes, it will disobey the genuine one, too."

Some ideas arising from the above hypothesis, for example the use of food lures and sex attractants have been worked upon. The chemical constitution of the sex attractants of several species have been determined and in some instances laboratory and field experiments have been carried out. Field trials on gypsy moth control have, unfortunately, met with less success, generally, than laboratory work had suggested might be expected. Other investigations, for example, on the eelworm hatching factor have been interesting and difficult but have not, so far, yielded a practical means of eelworm control.

However, other biological and biological/physical methods have been developed with success ranging from marginally acceptable to outstandingly good.

In what might be called the "not so new" approaches there are:

(1) Biological control by parasites and predators which are generally species specific.

(2) Repellents - generally used against insects biting man.

(3) Attractants.

1. Biological control by parasites and predators. As well as the classical examples of biological control (a) the control of the citrus scale insect (*Icerya purchasi*) by the introduced vedelia lady bird (*Rodolia cardinalis*) and (b) the control of the prickly pear (*Opuntia inermis*) by the moth (*Cactoblastis cactorum*), Simmons (15, 15a) has given examples of other successful introductions. In recent years attention has been directed to the control of pests in closed environments, e.g. glasshouses, where

insecticide resistant spider mite and white flies have been successfully controlled by the use of predators (16, 16a).

All too often, however, in other attempts at control by predators, the pest reaches a stage of effecting serious economic damage before the parasite or predator gains control. Also, under some climatic and other conditions favourable to the pest, in circumstances when normally effective control is obtained, the pest will reproduce faster than the predator as, for example, white fly in the UK on tomatoes in the summer of 1972.

2. Repellents can be passed over as being useful in certain special circumstances, e.g. for the prevention of being bitten by midges in recreational areas, particularly fishing, where such insects abound.

3. Attractants are of two main groups:

(a) food lures or baits, and (b) sex attractants

Baits treated with stomach-poison insecticides have been very successful in controlling swarms of locusts at the hopper stage. DDT and BHC resistant houseflies have been effectively controlled by baits containing organophosphorus insecticides, under conditions in which control could not have been secured by contact action. Experiments have also been undertaken in which a chemoserilant has been incorporated in the bait in place of an insecticide. One such, recently reported, (17) described attempts to control cabbage root fly using TEPA in a sugar syrup bait. An economic control was not obtained. There seems to be little point in exchanging a pesticide for an equally or more dangerous methylating agent such as TEPA. Nevertheless, if a relatively safe (to mammals and birds) effective insect chemosterilant were to be discovered a successful method of use would be needed. Pilot experiments with effective but more dangerous compounds are fully justified to establish the conditions under which safe compound could subsequently be used to achieve effective control.

Sex attractants were used first for the assessment of gypsy moth populations in Pennsylvania USA before and after spraying operations. The excised glands of a few female moths were placed in traps at intervals throughout the target area before and after treatment. The numb   of male flies caught gave an indication of the total moth population. Since then the chemical structures of the sex attractants of several insect species have been elucidated and some synthesised in commercial quantities. Jacobson and Jones (18) found that, according to their laboratory method of evaluation, a synthetic compound, (+)-12 - acetoxy-cis-9-octadecen-1-ol, was in fact more attractive to males than the naturally occurring compound (+)10-acetoxy-cis-7-hexadecen-1-ol.

Sex attractants could theoretically be used to eradicate the male moths of a population by attracting them to their death by contact or vapour-phase insecticide in traps. Such a technique would be highly specific. Attractants could also be used in another way. It was observed in the laboratory that male gypsy moths would attempt to copulate with inanimate objects treated with the attractant. It could appear that diversion of the mating instinct by the use of suitably impregnated objects might secure a population decrease if carried out on a large scale. In trials carried out in the US, lures of this kind had virtually no effect on normal mating behaviour and achieved no reduction in moth population (19). Much more needs to be known about the mating behaviour and the concentrations of attractants required before such techniques will achieve economic control in the field.

Bridging the older biological methods and the newer ones is one based on the fact that insects as well as higher animals are susceptible to attack by bacteria. Bacillus thuringiensis is toxic to Lepidoptera and unlike several other micro-organisms attacking insects can be cultured under laboratory conditions. Although the isolation of the bacterium from infected silkworm larvae dates back to 1901/2 (by Ishewata), the development and use of the product as a bacterial insecticide is of recent times. For this reason it has been grouped with the 'more recent' methods which include:

(1) use of bacterial poisons
(2) release of sterile males and the use of chemo-sterilants
(3) interference with behaviour control agents.

1. Bacterial poisons. Preparations based on B. thuringiensis have been available commercially in the USA for a few years, but so far they have not been used in large quantities even though many important insect pests of crops belong to the order Lepidoptera. Apart from the difficulties of handling the product in the field its cost/effectiveness is not adequate. In order to produce an effective pesticide at the right price, very high yielding strains of the Bacillus are required.

(2) <u>The sterile male technique</u>

One of the most striking successes in insect control in recent years has been the control of the screw worm, <u>Callitroga hominvorax</u>, which is an ectoparasite of cattle. In the USA it is of great economic importance and cost the industry some years ago from $25 to 100 million annually. The technique consists of releasing large numbers of sterile male flies which compete with the natural males within the population and gradually reduce the population because females which have "mated" with sterile males lay only infertile eggs. The technique is interesting and valuable in that, the smaller the population becomes, the more effective the control agents become because the released sterile males increasingly outnumber the natural ones. However, the method is not universally applicable; several criteria within the pest species have to obtain:

(i) the natural population must be relatively small
(ii) the females must only mate once
(iii)* the species must be easily reared in captivity.

The factory which was built for the screw worm control programme is capable of producing 100 million sterile males a week (20). The males are sterilised in the pupal stage by irradiation. An ambitious programme in the southern states of the USA with a wide barrier zone along the Mexico/US border has been reported to be running into problems. Nevertheless the earlier work in Curaçao and Florida was extremely successful.

The criteria which are necessary do not apply to many species but there is the possibility of combining a purely chemical, initial treatment to reduce the numbers and then following with large numbers of sterile males. Considerable highly specialised work is involved in determining the irradiation dose which will sterilise the males but not interfere with their competitiveness in relation to the normal males. Tsetse flies have been considered as a possible, suitable species for this technique, although it is very difficult to rear them in captivity (21, 22).

3. Interference with behaviour control agents

An interesting example of this kind of approach is the work on the eelworm hatching factor referred to earlier. Cysts of the eelworm, Heterodera rostochiensis, are stimulated to hatch by exudates from the roots of solanaceous plants particularly tomatoes and potatoes of which the eelworm is a serious pest. If the stimulating exudate could be identified and then synthesised it might be possible to trick the cysts into hatching when no suitable food material was available. The larvae would then die for although the cysts are viable for several years the hatched larvae need food from a favourable plant for survival. It might be possible to synthesise a similar but less expensive and possibly more stable compound which would achieve a sufficiently adequate reduction in eelworm population to enable susceptible crops to be grown where previously would not have been possible. Several workers have been working on this difficult problem (23, 24, 25) but so far without a successful control method being developed from it. With more knowledge of the nature of the active material it may be possible to use other techniques than inducing hatching of the cysts in the absence of a host plant. It is conceivable that another chemical could be used to react with the factor and neutralize its effect. In this way the susceptible host crop could be grown without the cysts hatching. Progress in this and related fields calls for research of a high quality and is very appropriate for first class, well-equipped laboratories in which the combined approach of chemists and biologists is possible. There is still a long way to go before this and similar methods become practical control procedures. One other very important point must be remembered Any control procedure developed, of whatever nature, must be economically, as well as biologically, viable or it will not succeed. It would seem that although some of the new approaches have interesting possibilities, it would be unwise to assume that they will make chemical control obsolete in the foreseeable future. For this reason UNIDO should continue to encourage local formulation of pesticides in developing countries.

Pesticide Manufacture and Formulation

It has already been pointed out that it is unlikely that developing countries will use the range of pesticides available in developed areas. This means that they are dependent upon the older compounds, some of which are being forced out of use in developed areas by legislation on pollution. In Japan the manufacture of DDT has been prohibited and in the USA it was thought a few months ago that manufacture there might cease in 1973. Pressure against other organochlorine compounds is continuing, particularly in the USA, where hearings about the cyclodiene insecticides are planned for the near future. Developing countries would be seriously at risk if supplies of DDT, BHC, aldrin, dieldrin and chlordane were to be denied them. For many purposes substitute insecticides are not available. In circumstances where they are available, they are generally more expensive or more dangerous to handle or both. Whereas a ban on the manufacture of DDT in the USA could be serious for developing countries for a short time, there are several DDT plants in developing areas of which the capacity could be increased in time to meet the deficit. On the other hand, if aldrin and dieldrin were to be cut off it would be more serious for the developing countries as there are no manufacturing plants outside the USA and Europe.

Other papers at this meeting consider in more detail than is possible or necessary here the questions of the manufacture of active ingredients and of their formulation into products that can be used in agricultural or public health programmes. Reference has already been made to papers prepared for the FAO/Industry Seminar held in São Paulo in 1971 (11,12) on the same subject. In these attention was drawn to the limited range of active ingredients that it would be practicable to manufacture in developing countries, whereas on the other hand the possibilities of formulation were considerably wider. However, there are current trends in formulation, particularly of newer pesticides, which call for increased sophistication. Just as there is pressure in some developed countries on some groups of pesticides, there is also pressure on certain aromatic solvents, stabilisers and emulsifying agents used in emulsifiable concentrates and water dispersible powders.

A few specific examples will illustrate these trends. In the first place many of the newer pesticides have much lower chlorine contents than for organochlorine group of compounds. They are, therefore, more inflammable and when being ground as for example in water dispersible powders, create a greater explosion hazard than do the organochlorine compounds. There is a need, therefore, for special switchgear and spark-proof equipment throughout formulation sheds, which, although desirable, was not essential hitherto.

The Environmental Planning Agency in the USA now has a list of approved formulation ingredients. It would be much simpler if there was a list of those which are not approved. Non-ionic emulsifiers and their blends of chain length 14-30 carbon atoms are not included. They are alleged to cause heart muscle damage in experimental animals. Benzene is not permitted and xylenes are under pressure as unsuitable solvents. Perchlorethylene, used mainly as a dry-cleaning fluid, is unpopular in Holland on account of the pollution from dry cleaning factory effluents in canals. This would not seem to be a good reason for restricting its use in pesticide formulations. More appropriate measures would appear to be a tightening of the effluent regulations. It will, therefore, become increasingly difficult to make satisfactory emulsifiable concentrates in which form over 80% of pesticide products are now sold.

On this account considerable attention is being given to suspension concentrate formulations which are thixatropic gels ensuring stability until used, when shaking and agitation ensures a liquid 'structure' for the application to be made in conventional equipment.

Although these are the trends in developed countries, together with granules and microencapsulated products, it is probable that most pest problems in developing countries (and very many in developed countries) will be dealt with perfectly satisfactorily with the older established water-dispersible powder and emulsifiable oil formulations. Only where distinct technical and economic benefits derive from one of the newer types of formulation would it be worthwhile, in my view, installing new equipment in a formulation plant in a developing country.

REFERENCES

(1) Farm Chemicals Jan 1972, 135, No. 1 18.

(2) Dept. of Trade and Industry Pesticides and Allied Products 1963: 1969.

(3) Newman J.F. Proc. 6th Brit. Insect. Fung. Conf. 1971. Vol. III 741.

(4) ADCS Pesticides Review 1971.

(5) Elliot, M. The relationship between the structure and the activity of the Pyrethroids. Bull. Wld. Hlth. Org. 1970 44, 315.

(6) Yoshihiko Nishizawa. Development of New Synthetic Pyrethroids, Bull. Wld. Hlth. Org. 1970, 44, 325

(7) Elliot, M. Structural requirements for pyrethrin-like activity. Chem. and Ind. 1969, 776.

(8) Wickham, J.C. The laboratory evaluation of synthetic pyrethroids as insecticides. Proc. 3rd Brit. Pest. Control Conf.

(9) Elliot, M. et al. 5-benzyl-3-furylmethyl chrysanthemate: a new potent insecticide. Nature, 1967, 213, 493.

(10) Naegele, R.F. Statement before House Committee on Agriculture Congress of the United States. (1971).

(11) Szabó, K. The National Pesticide Industry - Aims and Implications. Paper presented at the FAO/Industry Seminar on the Safe and Effective Use of Agricultural Pesticides, São Paulo, 1971.

(12) Galley, R.A.E. Economic factors involved in the synthesis and formulation of agricultural pesticides. An industrial view. FAO/Industry Seminar on the Safe and Effective Use of Agricultural Pesticides, São Paulo 1971.

(13) Fitzsimmons, K.R. "Role of industry in advancing new pest control strategies." Pest Control strategies of the future. p. 352 Agricultural Board. Division of Biology and Agriculture, National Research Council, National Academy of Sciences, Washington D.C. 1972.

(14) Wright, R.H. British Columbia Research Council, Personal communication on alternatives to insecticides, 1965.

(15) Simmons, F.J. 35th Annual Report 1963/64 of the Commonwealth Agricultural Bureau, London.

(15a) Simmons, F.J. J.R. Soc. Arts, 115, 880 (1967).

(16) Hussey, N.W. Some economic considerations in the future development of biological control. "Technological economics of crop protection and pest control" - Soc. Chem. Ind. London. Monograph No. 36, 1970.

(16a) Glasshouse Crops Research Institute. Growers Bulletin No. 1 "The Biological Control of Cucumber Pests." 1972.

(17) Finch, S. and Skinner, G. Chemosterilization of the cabbage root fly under field conditions. Ann. app. Biol. 73, 243 (1973)

(18) Jacobson, M. and Jones. W.A. Insect Sex Attractants II. The synthesis of a highly potent gypsy moth sex attractant and some related compounds. J. Org. Chem., 27, 2523, 1962.

(19) Waters, R.M. and Jacobson, M. Attractive action of gyplure masked by impurities. J. Econ. Ent., 58, No 2, 370 (1965).

(20) Campion, D.G. Biological Control of Pests: A screw worm factory in Texas. Trop. Sci., 7, 92 (1965)

(21) Poots, W.H. Sterilization of Tsetse Flies (Glossina) by Gamma Irradiation. Ann. Trop. Med. Parasit. 52, No. 4, 484

(22) Yeo, D. The effect of sterile males upon a natural population of tsetse flies. Trop. Pesticides Research Inst. East Africa. Misc. report No 156. 1956.

(23) Todd et al. The potato eelworm hatching factor.

(24) Clarke, A.J. and Shepherd, A.M. Synthetic hatching agents for Heterodera schachtii Schm. and their mode of action. Nematologica, 10, 431 (1964).

(25) Clarke, A.J. and Widdowson, E. The hatching factor of the potato-root eelworm. Biochem. J., 98, 862 (1966).

(26) Coutts, H.H. and van Tongeren, W.A., The formulation of Tetrachlorvinphos for ULV applications. Proc. 6th Br. Insectic. and Fungic. Conf. (1971). Vol. 2, 507.

(27) Smith, R.N. and Johnson, M.A. Ultra Low Volume and Ultra Low Dosage Spraying with Chlorophthalonil. Proc. 6th Br. Insectic. and Fungic. Conf. (1971) Vol. 2, 512.

(28) Furmidge, C.G.L. and Shenton, T. "Formulation - Some Factors Affecting Pesticide Performance" SPAN (in the press)

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