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Plant Protection Chemicals in 2000 AD

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Plant protection chemicals have evolved gradually. First to be used were the inorganics. Around 1930, dithiocarbamates, fungicides came but the real era of organics as plant protection chemicals started around 1942 with the discovery of DDT, closely followed by 2, 4-D, HCH, organo-phosphates and cyclodiene insecticides. Ten years later came the discovery of more potent chemicals like carbamates and triazine herbicides. The publication of "Silent Spring" by Rachel Carson in 1966, brought about an intense awareness of environmental safety, and introduction of newer plant protection chemicals became increasingly difficult. The new generation of non-lethal plant protection chemicals like the insect growth hormones and pheromones which would have radically changed the situation, did not become practical, 1975 saw a most important discovery of photostable extremely potent synthetic pyrethroids with which began the present era of high potency chemicals. Today synthetic pyrethroids are very potent and very selective insecticides with low mammalian toxicity. But they have many other defects. Future ones, now evolving with intensive efforts from many groups of workers, promises better type of synthetic pyrethroids. Other new type of insecticides have also come up. These are: (a) The proinsecticidal carbamates, (b) chemicals working on alternative target in the insect systems such as monoamine oxidase inhibitors-and (c) chitin-synthesis inhibitors.

In the field of fungicides, the systemic fungicides are undergoing further refinements and new chemicals like the triazoles will probably become the fungicides of the future. In the field of herbicides, the sulphonyl ureas have created a sensation as extremely potent weed killers requiring only a few grams per hectare. Further, the concept of herbicide safener may create a breakthrough in the years to come. The future of agrochemicals may, however, be more in the area of plant management alongwith plant protection judging from many new plant growth regulators anounced recently. All these new developments will require new strategies for formulations and a major problem that awaits solution is how to reach such small quantities uniformly over the area to be treated. Formulation and application of pesticides will therefore see a much more revolutionary development. Pesticide will also need to be fitted in better as a component of integrated pest management, such as cultural and biological, and in this way alone the full benefit of new developments and discoveries with future chemicals can be realised. Other questions like biodegradability, selectivity and development of resistance will need fresh look.

Evolu ion of Pesticides

Pesticide science is barely 40 years old. Prior to 1930 very little plant protection was practised. The advent of organic pesticides really began with the discovery of DDT (1939-42) followed by pesticides like BHC, 2,4-D, cyclodienes, etc. Although these were potent, safe to handle with lower mammalian toxicity, yet all of them had greater persistence in the environment. It was considered to be a desirable property at that time.

In the mid 50's the organophosphates and the carbamate group of chemicals were introduced as biodegradable pesticides. Many of them were nonselective and extremely hazardous with high mammalian toxicity. These three groups of chemicals, the organochlorines, the organophosphorous and the carbamate group of chemicals, dominated the insecticides field for a long time.

The 60's brought in a radical change in our concepts of pesticides. Two notable reasons are responsible for this. Firstly, the publication of "Silent Spring" by Rachel Carson in 1962 which brought in intense awareness amongst the public regarding the environmental effects of pesticides finally leading to very stringent regulatory measures. This made the introduction of new chemicals extremely difficult.

Secondly, great hopes were generated about the possibility of using non-lethal methods of insect control, applying such tools like chemosterilants, hormonal (JH, MH, mimics, anti JH) and behaviour, altering chemicals (attractants, repellents, anti-feedants, sex lures). For more than a decade their chemistry and biological effects continued to provide excited hopes to all those concerned with pest control but these third generation pesticides did not become fruitful. In spite of great efforts and investments, only a few JH analogues like methoprene (1) and CGA-13353 (2) reached commercial stage but only for small volume-specific applications.

Fourth Generation Pesticides: The 3-H Era

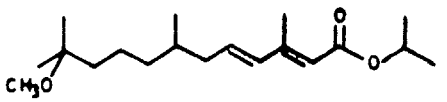
The mid seventies saw the introduction of synthetic pyrethroids which are revolutionary in many respects. Permethrin was the first one, followed closely by others. These are extremely potent, often requiring 10–100 g/ha., much less toxic, and have the right type of biodegradability (table 1). Apart from their potency and selectivity, these ushered in a new era of hope and optimism for all concerned in the business of pest control chemicals.

Synthetic Pyrethroids of Future

The commercial synthetic pyrethroids of today have some undesirable qualities. Firstly, these are highly lipophilic and therefore tend to get concentrated in the leaf waxes. This prevents their metabolism and residues efficacy and in some cases increases persistence unduly. Their lipophilic nature also makes them extremely toxic to fish. Although they are highly insecticidal specially towards lepidopterus insects, towards the acaris (ticks and mites) they are not active. They have extremely low vapour pressure and therefore have no fumigant action.

Table 1 *Commercial synthetic pyrethroids and their mammalian safety ratio*

Compound	MSR LD_{50} RAT/LD_{50} HF
Parathion	2
DDT	11.3
Carbaryl	17
Fenvalerate	900
Permethrin	1400
Cypermethrin	4200
Decamethrin	~6000



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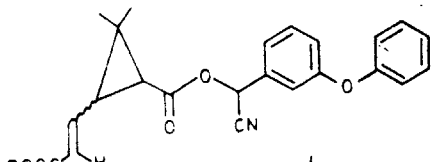

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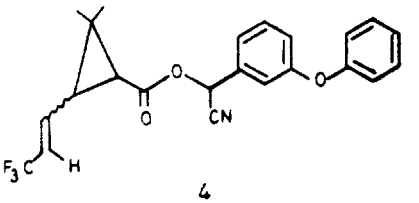

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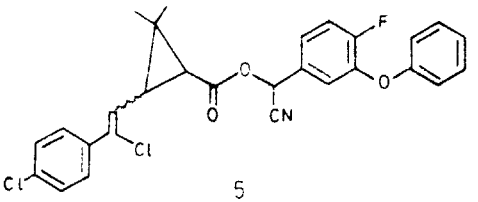

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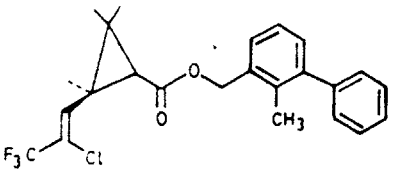

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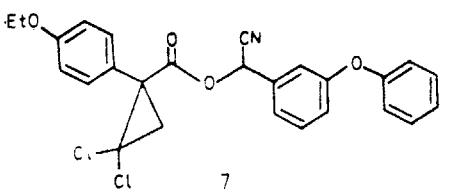

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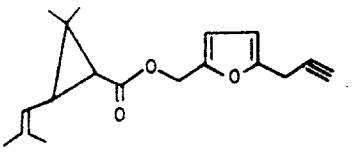

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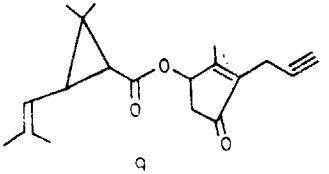

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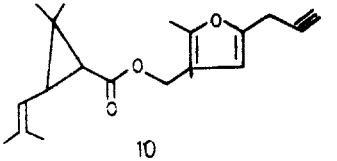

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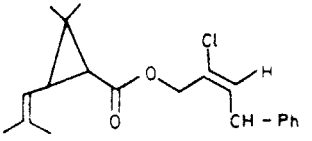

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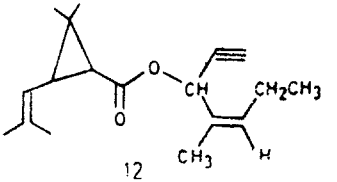

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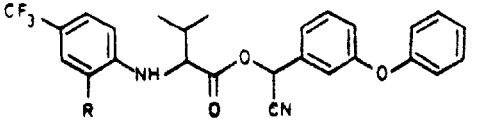
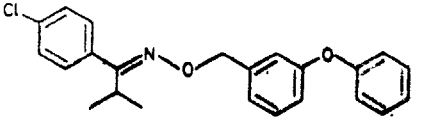


13, R=Cl
14, R=F



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Hence in order to be effective they require direct contact with the insect. Further their biological activity depends on highly specific stereochemical structure. Technical routes to produce single isomers have succeeded only in case of Decamethrin. In other cases the technical products are isomeric mixtures and often do not have the desired potency. There is need therefore for discovery and development of new pyrethroids, free from at least some of these defects. Intense activity from many different groups of workers in this field have already shown the possibility of introduction of several new types of pyrethroids suitable for specific applications and free from some of the defects mentioned. The range of structural features within which the insecticidal activity is retained has been widened and in some cases exceeded to a level barely considered possible a decade ago. A whole range of pyrethroids with wide spectrum activity—some having more toleranceto fish, others having better knock down activity than pyrethrum-II, some having improved volatility for fumigant action in indoor use—have been discovered and many of them are now being developed.

Thus, the tertiary butyl and neopentyl esters(3), discovered by Tessier et al. (1982) at Rousel-UCLAF, and cyhalothrin (4) discovered by Bentley et al. (1980) possess in addition to insecticidal activity strong acaricidal properties. The compound FCR-1622(5), having a para chlorophenyl group in place of the E-chlorine in the vinyl side chain and a flourine atom in the metaphenoxy benzyl alcohol part, is the most persistant wide spectrum pyrethroid known today. It is being developed specially as a soil insecticide where other pyrethroids gets degraded very soon. Compound(6) discovered by Engel et al. (1982) is another interesting variation having a metaphenyl benzyl alcohol in place of the usual MPBA. The methyl group adjuscent to the phenyl group prevents rotation and ensures asymmetry in the molecule needed for enhanced biological effects. Here again the replacement of the E-chlorine atom by a trifluoromethyl group widens the spectrum of activity. Compound(6) has the widest known spectrum of activity and is effective @ 45 g/ha. GH-380(7) is a remarkable pyrethroid with low fish toxicity discovered by Holan et al. (1978) From very early times pyrethroids having higher volatility to have fumigant action and suitable for knockdown, insecticidal as well as repellent effects were preferred for indoor use. This was achieved earlier by incorporating a propargyl group in various pyrethroids like Furamethrin(8), Prallethrin(9) and Proparthrin(10) (Katsuda et al. 1969). Of these Prallethrin, having in addition very good knockdown activity, is being developed by Sumitomo Chemical Company as an anticockroach agent. Others are in use in mosquito coils, and heated mats. This group has now undergone an expansion by the addition of several other very volatile pyrethroids. Thus, Butethrin(11) discovered by Sota et al. (1971) is an excellent mosquito repellent because of its very volatile nature. Empenthrin(12) also known as Vaporithrin has a good promise as a moth profing agent for woolens and carpets. Its high vapour pressure ensures that clothes are safe to wear shortly after being treated with this chemical. It is also interesting in having an unsaturated aliphatic side chain in place of the usual cyclic structures. As mentioned earlier the formation of mixtures of isomers in technical products of most pyrethroids reduces biological efficacy. Several groups of workers have tried to discover new pyrethroids free from this limitation. Thus the amino isopropyl acetate(13) based on a natural L-amino acid, discovered by Katsuda et al., (1967), gives a single isomer when esterified with proper alpha cyanometaphenoxy benzyl alcohol. Fluvalinate(14) discovered five years later by Henrick et al. (1980) is the most

potent compound of this series. It also has acaricidal activity.

The oxime ether (15) discovered by Bull et al. (1980) is another remarkable variation having an oxime ether group in place of the usual ester group in pyrethroids. It is not only free from the isomer problem but it is also acaricidal. The problem of isomers in technical mixtures have been tackled in Fenpirithrin (16), also known as DOW-417 in which the pyridine ring in place of the usual benzene ring in the MPBA part ensures ready epimerisation of the chiral centre making both R & S isomers active.

In most cases the dominant factor determining the intrinsic potency of the pyrethroids is its shape. It is difficult to predict which of the compounds will ultimately be the chemical of future but it is inconcievable that the entire spectrum of biological activity will be covered by any one of these new pyrethroids. At the moment deltamethrin which is a single isomer, technically produced on large scale, has the highest intrinsic activity and mammalian selectivity. But there are indications that the bio-isomers of some of the new compounds may exceed this activity. The number of the synthetic pyrethroids of different type which are making appearance every year is enormous and it is difficult to predict which of these will stand the test of time. However, for ecological as well as practical reasons pyrethroids of different types will be in use simultaneously to cater for differing needs. Future may also see a judicious (blend) of two or three pyrethroids to obtain maximum advantage in a particular situation, just in the same way as nature has provided a mixture of pyrethrum I and pyrethrum II combining knockdown with killing properties.

The Proinsecticides

Another field of intense future activity is modifications of certain well known chemicals which are good insecticides but whose high insecticidal activity cannot be utilised because of high mammalian toxicity. If these can be made selective, their utilization will be better. Selective pesticides based on widely different rates of metabolism between mammals and insects are known. Malathion and Acephate are well known examples but these were discovered rather fortuitiously and not by proper design. The knowledge gained from study of their metabolism, is now being applied specially to design modifications of known pesticides which will make the insects regenerate their own toxicant. This approach has been variously termed as introducing a delay factor or a safener. Following are some examples:

(1) *The proinsecticidal Methyl carbamates*

In many respects the N-methyl carbamate insecticides like carbofuran and carbaryl, introduced in the mid fifties, are good insecticides. They are easy to crystalise and therefore technical grade materials are easily obtained in a high state of purity. However, their low mammalian selectivity is against their ready acceptance. Based on the observations of Fahmy et al. (1966) that the N-acetyl derivatives of methyl carbamates have reduced mammalian toxicity without loss of insecticidal activity, a large number of new derivatives of methyl carbamate insecticides with improved mammalian toxicity have been discovered and a good number of them have now reached the stage of commercialisation. The first of these proinsecticidal carbamates was carbosulfan (17) of FMC Corporation, USA, followed currently by ONCOL (18) of Otsuka Chemical Corporation, Japan. Both these are N-sulfenyl derivatives of carbofuran. Amongst the acyl derivatives of carbofuran the compound CGA-73120 (19) and the quaternary ammonium salt

UC-54229 (20) are in high state of development. The mammalian toxicity of all these derivatives are very much lower than carbofuran. The last one developed by the Union Carbide (India) may become the first insecticide discovered and developed in our country. It is water soluble, easy to formulate and is a good insecticide for rice pests. It is also much more photostable, CGA-73120 (19) is being specially developed as a good soil insecticide.

Another variation of this class of proinsecticidal carbamates are the N, N-thiobiscarbamates. Larvin (21) being developed by Union Carbide of USA is a typical example of this type. Technically this type is simple to prepare by reacting two moles of the original methyl carbamate with one mole of sulphur dichloride or monochloride[16]. These are extremely potent larvaecides. Compound U-56,295 (22) being developed by UPJOHN (USA) is another interesting type being a N-phosphinothionyl derivative of a N-methyl oxime carbamate like methomyl. Its mammalian toxicity (8000 mg/kg) is remarkably low yet it is as potent as methomyl in its insecticidal activity.

(ii) Proinsecticidal organophosphates

The idea of allowing insects to make their own poison has been recently extended to some organophosphorous compounds and a large number of new alkylaminothio derivatives of methamidophos shown in (23) have been prepared recently and evaluated[17]. All these compounds retain their high insecticidal property but show much less mammalian toxicity, however none are better than acephate. Future may see the practical application of some of these types of organophosphorous derivatives.

(iii) Proinsecticidal pyrethroids

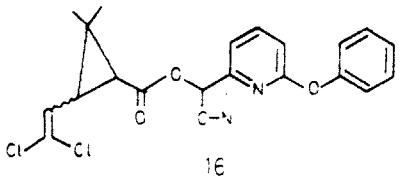
Even the new synthetic pyrethroids seem to have yielded derivatives which become insecticidal pyrethroids after metabolic conversion to the original compounds by the insect. Tralomethrin (24) and Tralocythrin (25), the dibromo adducts of deltamethrin and cypermethrin respectively, seem to exhibit insecticidal potency irrespective of their stereochemistry. Biochemical evidence[18] suggests that such compounds react chemically with biological thiols and loose bromine atoms to yield active pyrethroids from both the diastereomers. Thus chirality no longer remains a constraint at the side chain of the original compound.

Similar ideas have been applied to convert the oxime ether pyrethroids to their N-methyl as well as formamide derivatives (26) and (27) respectively. These undergo hydrolysis and oxidation in the insect to regenerate the active oxime ether pyrethroid.

The concept of making proinsecticides with high selectivity will undoubtedly be exploited further in future.

New Targeted Insecticides

The insecticides, so far described, all act on nervous system of the insect, a target common to both insects and mammals. For quite some time the insecticide chemists have been aware that there are other targets in the insect which can be suitably involved in the lethal process. Some success has been achieved in the past by developing insecticides inhibiting other enzyme systems. Thus amidines, of which chlorodimeform and amitraz are well known examples, act by inhibiting the enzyme monoamine oxidase, specially interfering with octopamine receptors. These have a large spectrum of activity, insecticidal as well as acaricidal. They also possess an unique combination of lethal and sublethal action. The sublethal effects on locomotion, feeding and oviposition are important added benefits[20]. Recently a thiourea derivative, dipofene



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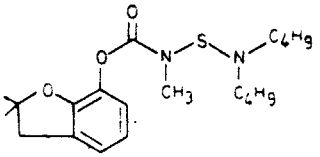

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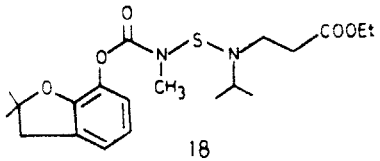

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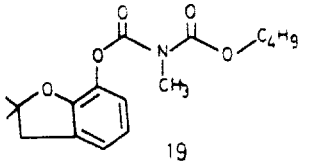

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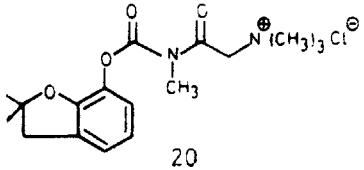

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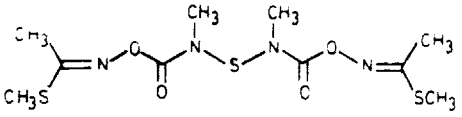

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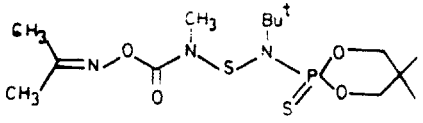

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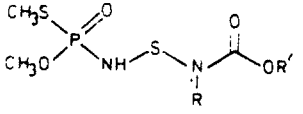
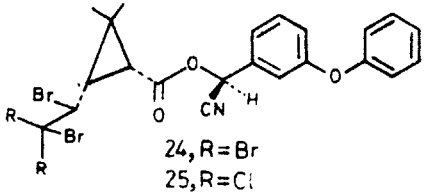
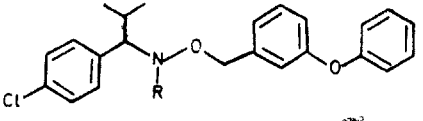


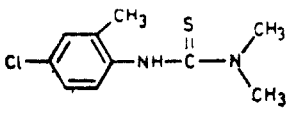
R=Et, n-Pr, i-Pr, t-Bu
R'=Me, Et, n-Pr, n-Decyl
23



24, R=Br
25, R=Cl



26, R=CH_3
27, R=CHO



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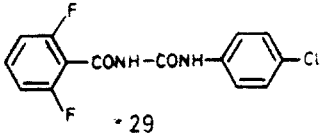

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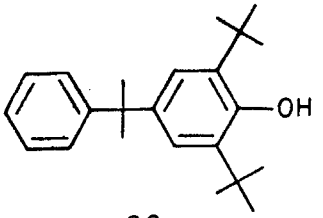

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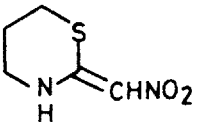

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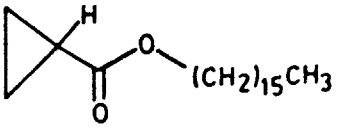

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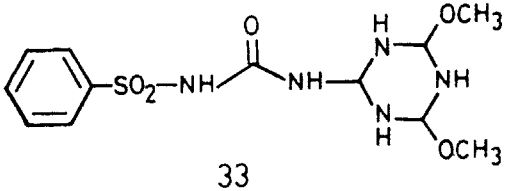

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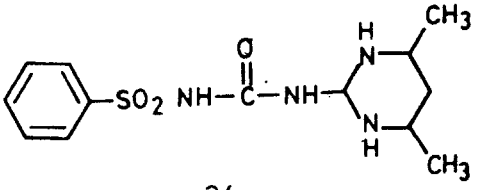

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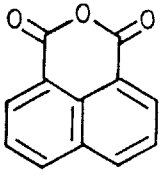

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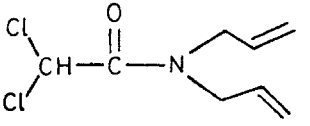

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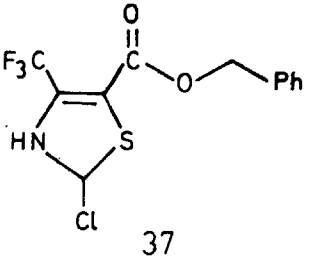

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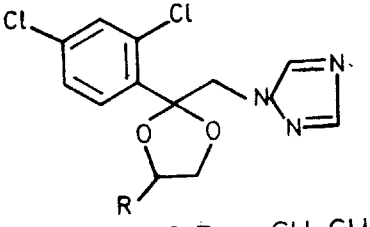
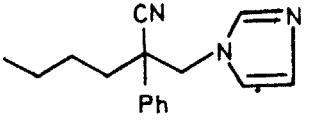


38, R = $-CH_2CH_3$

39, R = $-CH_2CH_2CH_3$



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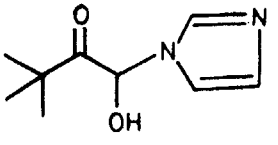

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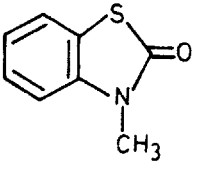

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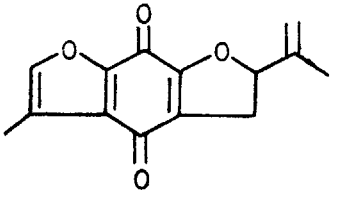

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(28) has been added to this group and intense efforts are going on to develop other potent MAO inhibitors.

Insect chitin synthesis and inhibition of cuticle selerotization has been recognised for many years as a selective target for control of pests. The chitin inhibitors, Dimlin and Diflubenzuron (PH-6040) (29) are being developed as practical compounds after their initial discovery in 1976. These are nonlethal insecticides of very low mammalian toxicity. Based on the early discovery of MON-0585 (30) by Sacher (1971) which blocks the developmental cycle of insect larvae at the pupal stage irrespective of when the exposure takes place, other compounds are being developed. Inhibitors of other enzyme system like those involved in oxidative phosphorylation and inhibition of nerve impulses by blocking GABA-ergic transmission with compounds like picrotoxin, bicyclic ketones, and benzodiazepenes have been the target of chemists and many compounds having such properties have been discovered. If breakthrough takes place, some of these undoubtedly may become insect control agents of future.

A very novel approach has recently been made by Pimprikar et al. (1979, 1880 a, b) by using well known dyes like rose bengal and erythrosine. They seem to act by generating singlet oxygen inside the translucent body of the insect larvae even in diffused light and have many advantages of having low mammalian toxicity water solubility and require only light as the source of energy.

Other New Types of Insecticides

Besides well established types mentioned earlier, many new types of molecules having insect control properties have now been discovered. Thus the nitromethylene thioketal derivative (31) recently discovered by Soloway et al. (1978) after screening a large number of nicotine models, is remarkable as a broad spectrum insecticide having not only low mammalian toxicity but also low fish toxicity. Unfortunately the compound undergoes easy degradation in sun light, preventing its further development for outdoor use. This lead can surely be developed for future insecticides with low fish toxicity. Similarly, cycloprate (32) a novel fatty ester of cyclopropane carboxylic acid has acaricidal property. Such simple structures with little modifications to uncommon amino acids, and uncommon sugars may play an important role in future pest control programme. At present these are known to be involved in plant defence mechanisms.

Herbicides

Herbicides are the fastest growing amongst agricultural chemicals. The well known herbicidal chemicals like 2,4-D, triazenes, ureas, diphenyl ethers and non-selective ones like paraquat had dominated the field for a long time. As a result of the study of their mode of action and biochemistry, many new structures having herbicidal activity has been discovered and are now being developed. The rapid obsolesence of older herbicides can be illustrated with just one example of the chemicals needed for control of wild oats in wheat. In the early seventies it was Tribunil which required 3 kg/ha. It was quickly following by Dosanex, which had to be applied at the rate of 1.5 kg per hectare. This has become obsolete and now even more potent and selective chemical isoproturon, active at the rate of 750 gm per hectare is in use. This kind of evolution has taken place with other classes of herbicides as well. However, the real breakthrough to high potency era in this field has been announced very recently with two examples of very high potency herbicides. Chlorsulfuron (33), earlier known by the code name of

DPX-W 4189 and now being commercialized under the trade name of Glean, is a good wheat herbicide controlling broad leaf weeds and some grasses at a fantastically low dosage of 5–35 gm/hectare with additional advantage of low mammalian toxicity and low soil persistence. A closely related compound sulfometuron methyl (34), being commercialized under the trade name of OUST, is also a high potency herbicide controlling weeds in turf.

Herbicide Antidotes or Safeners

The concept of high selectivity has been approached in a novel way in the field of herbicides by the development of chemical antidotes or safeners. When used alongwith a herbicide these chemicals selectively protect the crops from herbicide injury. The first discovery in this field was made way back in 1962 by Hoffman (1962) who showed that 1,8-naphthalic anhydride (35) prevents injury to maize from the thiocarbamate herbicide EPTC. The concept remained unexploited for a long time until Pallos et al. (1978) showed that N,N-diallyl dichloroacetamide(36) is an effective safener for EPTC in maize. It is now commercial. Mention may be made of Flurazole (37) a safener for acetanalide herbicides. Cioxymetrinil and CGA-92194, both benzacetonitrile safeners for sorghum, are the latest compounds in the field. As with other compounds there will be many new advances. Future development and use of the safeners will enable better use of existing herbicides.

New Fungicides

The fungicide field so far has not seen a breakthrough in the high potency and high selective directions. Instead a whole new range of heterocyclic ring systems have been discovered as fungicide of future. Many new fungicides with this property have been found are now under development. A particularly interesting class of fungicides belongs to azole group. These function by interfering with the ergosterol biosynthesis in fungi. New compounds of this type under development now are the triazoles, Etaconazole (38) and Propioconazole (39) which are not only systemic but have much wider spectrum controlling mildew, rust as well as apple scab. Further examples are new imidazole fungicides, Fenpropanil (40) and the antidandruff agent Climbazol (41). The thiazole fungicide Chlorobenthiazone (42) is a new fungicide for controlling rice blast disease with many advantages. It provides an interesting breakthrough to a new class. All these new groups will make future control of plant pathogenic diseases much more effective and economic.

Development of Leads from Nature

Nature has always provided leads for development of new dyes, drugs and insecticides. A vast number of natural products having biocidal activities have been discovered from plant, animal and microbial sources, but have been exploited only to a limited extent in the examples given above. A very attractive field for future development is that of the phagorepellents which will play an important role to prevent the spread of viral diseases of plants by repelling their vectors. The crude extract of neem containing azadirachtin as the repelling factor is now being increasingly used in agriculture but a very large number of other types of structures such as azugarin and glycosides like xylomonin are known phagorepellents. So far, none of these have been adopted as models for synthesis. Attempts to made model substances from well known natural insecticides like rotenone and nicotine have not been so far very successful. Some natural compounds like dihydrocyperaquinone (43) are even more

potent inhibitors of oxidative phosphorylation than retenone but much simpler to synthesise. Such compounds do not seem to have attracted attension as yet. There are many uncommon aminoacids and sugars which may play the role of antimetabolites in insects but so far have been implicated only as defence chemicals in plants. Other examples from phytoallexins and allelophathic agents can also serve as models for future synthetic analogues. SAR studies with such synthetic models may create new breakthroughs as in the case of synthetic pyrethroids. As mentioned earlier, future will also see increasing use of oils and fats suitably derivatized as pest control agents, as these are natural agents and are based on renewable sources.

Table 2 *Pesticides of microbial origin*

Class	Examples
Antifungal	Blasticidin-S Polyoxins Validomycin
Antibacterial	Streptomycin
Miticide	Tetranactin
Insecticide	B. Thuringensis
Herbicide	Bialaphos
Growth Regulators	Gibberellins

Impact of Other Scientific Advances on Future Pesticides

Pesticide chemistry has created new awakening and interest of the entire scientific community. There is interaction from other fields and this is bound to grow.

One may expect a fall back from the rapidly advancing field of *genetic engineering and biotechnology* which might lead to a new chapter in crop protection. Although, the ideal goal of engineering high yielding crops, resistant to pests and diseases, is a long term program, some immediate short term gains from this science is possible. Thus there is immense scope for improving the yield and quality of already known chemicals of microbial origin shown in table 2 by improving the strains of the respective cultures. Their high cost of production at the moment is against their large scale use. This may change in future with breakthroughs in biotechnology. Genetic engineering may also help in evolving strains of plants giving better yield of known natural pesticides. One may expect newer strains of chrysanthemum giving much higher yields of pyrethrum or of a new strain of neem giving azadirachtin as the principal constituent.

Pesticide chemistry is already reaping the benefits of advanced *mathematical modelling* and *QSAR analysis* applied successfully earlier in drug development. Such analysis in the field of herbicides and synthetic pyrethroids have already indicated the requirement of functional groups as well as stereochemical and physico-chemical parameters needed for optimum activity. It has not yet reached a predictive stage but intense efforts are being made to see whether computer aided models incorporating optimum parameters suggested by QSAR analysis can help in the design of high potency pesticidal molecules. Such computer aid will also be utilized by the chemical technologists to devise simplified energy saving technical routes for many of the high cost chemicals today.

In fact the concept of "Integrated Pest Management", so well known to the entomologists all over the world today, can only be used if advances from all other related fields are incorporated properly.

Some Questions

The increased tempo of discovery of high-potency high-selective pesticides in recent days have raised several interesting questions which merit consideration for future developments.

A question very often asked is "Have we reached the limit of potency"? Table 3 shows the present situation with respect to deltamethrin the most active commercial insecticide of today in comparison with some of the first generation chemicals like DDT and 2,4-D. But it also shows the existence of several other toxic chemicals which are more active per unit weight. Botulinum toxin, for example, is several orders more active biologically. Deltamethrin has been already surpassed in potency by a new pyrethroid, alphamethrin, active at one gram per hectare level, now under development. This shows that human ingenuity has not yet exhausted the possibility of designing and discovering compounds exceeding the potency of present day chemicals. In fact *high potency era may have just began.*

But whether high potency chemicals are desirable or not is another question. Several considerations show that potency alone is not a desirable factor. A major difficulty encountered with these high potency chemicals, is their appropriate formulation and application strategy. In conventional spray applications with these chemicals there is considerable wastage as even the smallest drop in the spray contains many times more than the lethal dose. Reduction of droplet size causes drift problem. Further smaller the quantity greater is the loss by abiotic and biotic metabolic processes, allowing only a small fraction to reach the target.

Table 3 *Limits of intrinsic activity*

Toxicant	Species	ED_{50} (mg/kg)
DDT	House Fly	7-14
Parathion	House Fly	2
Deltamethrin	House Fly	0.002
TCDD	Guinea Pig	0.0006
Botulinum toxin	Human	0.00002

Thus, unless formulation and delivery technologies are improved to meet the new situation, little is gained by increasing potency alone. On the other hand increased potency may mean reduced environmental impact and possibly increased benefit cost ratio as cost comes down in future. On the other hand in the case of a repellant, specially if it acts in vapour phase, high potency would be a very great advantage.

High selectivity is another constantly debated question. Some selectivity such as between mammals and fish on one hand and insects on the other hand, is desirable and at least between mammals and insects have been achieved with the pyrethroids. The possibility of chemicals safe for the fish and birds but deadly to the insects is being persued. But selectivity between pests themselves is perhaps not desirable. High selectivity in such cases leads to quicker development of resistance as fewer genes are involved in the process. Broad spectrum chemicals having multiple site of action and specially the chemicals, acting by modes of action other than the present day neurotoxins, would therefore gain prominence in future.

The pesticide scenery in the world today is undergoing rapid advancement. It can be judged by the current explosion in the number of publications and books dealing with different aspects of the subject. The IUPAC, in recognition of the importance, had organised three international conferences on the subject in the last decade alone. The future is therefore an era of hope and optimism.

The Indian Scenery

It is well known that Indian agriculture and public health depends heavily on old first generation organochlorine pesticides. The use of these chemicals has slowly increased in the country and today stands at

about 70,000t. per annum. Even now, by the standards of developed countries, we use very little pesticides most of which goes for saving cash crops only. However, even with this meagre use there is a tremendous impact on food production. Today we enjoy self sufficiency in food production but this may well be a temporary respite specially if we continue with our conservative ideas and use these outdated tools of agriculture. The estimated requirement of food in India in the year 2000 is 220 m. tonnes (NCA Report 1976'). It should be possible to meet this if the existing potential is largely tapped by harmonius use of all inputs. So far the primary attention of planners and scientists has been on varietal development and fertilizers. Pesticides being highly complex, did not receive due attention and actually suffered from the unmerited emphasis placed on hazards and pollution. Let us hope that pesticide use will expand and modernise in India by adopting these newer chemicals and novel agents. Only then we can increase agricultural productivity by tapping the yield potential.

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