Proc. Indian natn. Sci. Acad. **B52** No 1 pp 10–16 (1986)

Pest Control Strategies for 2000 AD

K N MEHROTRA
Division of Entomology, Indian Agricultural Research Institute, New Delhi 110 012

The agriculture as practised in the country today, is primarily based on high-yielding dwarf varieties, high inputs of chemical fertilizers, increased irrigation and the use of pesticides. The most commonly used pesticides, the chlorinated hydrocarbons, organophosphates and carbamates suffer from: (*a*) the products are too persistent and too wide acting and thus are conducive to pollute the eco-system in which they are used; (*b*) they are too toxic for man and domestic animals; and (*c*) many insect pests have developed resistance against these compounds which has led to a situation of ever-increasing search for newer toxic compounds. The ecologically sound and environmentally acceptable insect control tactics include host plant resistance, biological control, cultural control, pheromones attractants, repellants, insect growth regulators and selective pesticides. One or a combination of these techniques are used to evolve a sound method for integrated pest management (IPM), which also includes pesticide management. There is an acute need for basic and fundamental researches which can provide back up technology for formulating IPM Programmes for various pest species.

Key Words: Pest Control

Tropics are most suitable regions of the world for high plant productivity — comparative abundance of water, solar radiation, high temperature and short growth periods are conducive for a large net productivity of vegetable biomass. It has been estimated that 70% of the dry organic matter of plant origin is produced in the tropical countries. Ecological conditions which are favourable for plant growth also favour pest build-up. India is primarily a tropical country and has more than its share of pests and diseases in both agriculture and public health (Mehrotra 1979a & b, 1983 a). A comparative statement of the number of diseases reported in temperate and tropical zones of the world is given in table 1. Besides this, the incidence of insect-borne diseases

Table 1 *Crop diseases in temperate and tropical regions*

Crop	Number of diseases reported	
	Temperate Zone	Tropics
Paddy	54	500
Maize	85	125
Citrus	50	248
Tomato	32	278
Beans	52	250

is also high. According to a very conservative estimate, the annual crop losses amount to Rs. 15,000 crores in agriculture alone (Rangaswami 1983) and the man-days lost due to insect-borne diseases, specially malaria, may be anywhere between 20–25 million man-days/year.

In order to increase agricultural production many changes have been adopted in our cropping strategies in recent years. These are the use of dwarf varieties and higher fertilizer dosage; increased irrigation sources and intensive cropping; large areas under single crop, extension of new crops in non-conventional areas; large scale movement of seeds and new cultivars; varying levels of deviations from accepted norms of crop sequences. Statistics regarding agricultural production, malaria incidence and pesticide usage in the country for past two decades (table 2) reveal that : (*a*) gross cropped area increased marginally, i.e. 12%, during the two decades from 1960 to 1980; (*b*) during the same period area under irrigation was nearly doubled from 28 to 57 million ha; (*c*) the high yielding varieties (H Y V) programme, initiated in 1967, covered nearly 25% of the cropped area by 1980, (*d*) the total food production increased from 74 million tonnes to nearly 130 million tonnes, and (*e*) both the fertilizer-consumption and the pesticide-consumption in agricultural sector increased 20-fold (fertilizer from 0.24 million tonnes in 1960 to 5.5 million tonnes in 1980; and pesticides from 2000 tonnes in 1960 to 43,000 tonnes in 1980), the ratio of pesticides to fertilizer, remained nearly constant at 1 : 100 although the total pesticide consumption increased by only 2-fold (from 23,000 tonnes in 1960 to 58,000 tonnes in 1980). Interestingly enough, the use of insecticide in public health sector which was higher than the agricultural sector until 1966, became almost equal in 1970 and declined significantly thereafter. (at present it is one-third that of agricultural sector).

Table 2 *Agricultural production, malaria incidence and pesticide usage*

Year	Gross cropped area (million hectares)	Area under irrigation (million hectares)	Area under high yielding varieties (million hectares)	Fertilizer consumption (million tonnes)	Total production of food-grain (million tonnes)	Pesticides use in agriculture (thousand tonnes)	Total pesticides consumption (thousand tonnes)	Pesticides in public health (thousand tonnes)	Malaria incidence (millions)
1	2	3	4	5	6	7	8	9	10
1960	152	28	Nil	0.24	80	2.0	23.0	21.00	—
1966	163	32	1.7	1.1	74	7.45	17.14	9.69	0.15
1970	165	38	15.3	2.3	108	10.2	19.0	8.8	0.69
1975	170	43	31.8	2.9	121	43.4	58.6	15.22	5.16
1976	167	43	33.6	3.4	111	36.7	48.9	12.2	6.49
1977	172	45	38.9	4.2	126	39.9	58.3	18.4	4.74
1978	173	48	40.1	5.1	131	43.7	58.4	14.7	4.14
1979	171	52	38.3	5.3	108	42.0	50.6	8.6	3.06
1980		57	45.2	5.5	126	40.6	56.1	15.5	2.84

The number of pesticides used in agricultural sector have always been far more diversified than in public health sector, which has used mainly DDT, HCH and malathion.

Present plant protection and public health practices rely heavily on insecticides for insect pest control. The concept of an insecticidal umbrella (Pradhan 1971), for controlling insect pests, has undergone a tremendous change in the minds of general population and currently the pesticides have been accused as the principal villain in the degradation of the environment. Although there has been a reduction in the amount of pesticides used per unit area in agriculture, since pre-DDT era to present day, there is still a room for improvement (table 3). At present we are using nearly 300–500 g of pesticides (active ingredient) per hectare but it is hoped that in future pesticides could be used at the rate of approximately 10 g of pesticides per hectare. This reduction in the environmental load of pesticide would be possible only if tremendous amounts of research inputs are provided by the entomologists, nematologists, plant pathologists and agricultural chemists.

Despite the fact that pesticides have been accused as a principal villain in the degradation of the environment, their use in agriculture continue to go up. It was nearly 200 tonnes in 1955, may reach 75,000 tonnes in 1985, 100,000 tonnes in 1990 and 200 thousand tonnes in 2000 AD. The amount of pesticide used in the country compared to other countries like Japan, USA and Europe is still infinitely small (table 4) and even in the year 2000 AD it would not reach anywhere near the European standards. Similarly the plant protection coverage which was nearly 2.4 million ha in 1955–56 gradually increased to 80 million hectares in 1984-85 and may reach 110 million hectares by 1990. Although the Insecticide Act (1968) brought considerable discipline in the use of insecticides in the country, still a lot more needs to be done.

The changed agronomic practices including high-yielding varieties (HYV), increased irrigation and use of hard core insecticides, both in agriculture and public health sectors, it is claimed, (Chapin & Wasserstrom 1981, 1983) have led to change in pest pattern and precipitated insecticide-resistance alarmingly in insect-vectors transmitting human diseases and to some extent in agricultural pests. Although such views are very much biased and have been refuted (Sharma & Mehrotra 1982a & b, 1983, 1985), they nevertheless point towards the necessity of reorientation of our plant protection methodology. Pest control is not a matter of simply spraying the crop but is also concerned with conservation of environment. For this to be effective, a multi-disciplinary research work is required to evolve a sound method of integrated pest management (IPM) both for public health and agricultural pests. As far as agriculture is concerned, pest control

Table 3 *Evolution of pesticide used in the country*

Period	Quantity (a.i./ha)
Pre-DDT	10—1 kg
Post-DDT (1945–55)	5—1 kg
1955–1964	0.5—0.1 kg
1965–1974	0.5—0.1 kg
Present	0.3—0.1 kg
Future	0.1—0.01 kg

Table 4 *Consumption of pesticides in different countries (1980)*

Country	g/ha
Japan	10,790
USA	1,490
Europe	1,870
India	336

strategies will have to be evolved for various crops in the different agro-climatic zones of the country. The IPM depends on multi-component suppression of pest population and rejects the prophylactic regular use of broad spectrum insecticides.

The main components which are incorporated in IPM are discussed below:

Host-Plant Resistance

Although researches on breeding plant varieties resistant to pest and diseases have been conducted in this country for the last 50 years and in fact we have relied mainly on the identification and utilization of host resistance in plant disease control, it had limited success (Mehrotra 1983b). A careful analysis, however, of the past and current approaches in this regard would reveal that, with few exceptions, research in this area has been carried out without either the basic understanding of the concept of durable resistance or the use of sound parameters for evaluation of such resistance. It is known that the introduction of new varieties/ agronomic practices lead to outbreak of pests and diseases either immediately or within 3-4 years of its introduction. This empirical approach must give way to more sound and reliable methods for breeding for resistance.

Biological Control

Despite the fact that viruses, bacteria, fungi and nematodes have been found to be useful as bio-control agents in management of many key pests and that most of these are compatible with insecticides, their use has not made much headway (Sankaran, 1985, Singh 1985 and Jayaraj 1985). Basic research in insect taxonomy, ecology and other disciplines that support biocontrol approaches need be greatly strengthened.

Cultural Control

Cultural methods of pest control both in agriculture (Chenulu & Mehrotra 1979) and public health (Sharma 1984) had been utilized with some success before the insecticides were used on an extensive scale. Soil temperature affects both the host and the pest pathogen and by judicious manipulations of soil temperature to the advantage of the host, pathogens can be kept under check. For example, by sowing wheat late in the season when the soil temperatures are low and corn early in the season when temperatures are high, damage due to *Fusarium roseum* var. cereals can be reduced effectively. Similarly shading has been reported to reduce damage to rice by the blast fungus *Pyricularia oryzae*. Early autumn sowing of short duration early maturing pea varieties saves them from wilt in north India.

Scab of potato caused by *Streptomyces scabies* is suppressed by high soil moisture. Thus irrigating potato fields at the time of tuber formation reduces scab incidence. Wet weather diseases such as haloblight and anthracnose of beans, early blight and charcoal rot of potatoes can be checked by furrow irrigation than by sprinkler irrigation. Panama wilt of banana has been successfully controlled by flood fallowing for several months. *Sclerotinia sclorotorum*, a common pathogen of vegetable crops, has been controlled by flooding for 3–6 weeks. *Streptomycea scabies* of potato and *Plasmodiophora brassicae* of crucifers are two classical pathogens which are controlled by adjusting soil reaction.

Club-root of crucifers is checked by increasing soil *p*H, from acid range to alkaline range of 7.5 and above. Similarly scab of potato is kept under check by lowering the soil *p*H to acid side. Texas root rot of cotton (*Phymatotrichus omovorum*) is another disease which keeps low in acid soils.

Time of sowing has been effectively used for avoiding the pests and diseases like wheat rusts, ergot of bajra and sorghum

midge. Early-sown wheat escapes rust damage. Similarly, bajra crop sown before 15 July gets less incidence of ergot in north India. Cultural methods have also been very successful in controlling white grubs on crops like groundnut and chillis.

Fheromones, Attractants and Repellants

Pheromones or semiochemicals and allelochems can be fruitfully utilized in monitoring pest populations as well as in controlling them. Eversince the first report in the country about the existence of a sex pheromone in the almond moth *Cadra cautella* (Mehrotra et al. 1967), a lot of progress coupled with large scale field trials, has been made to control the pink bollworm (Doane & Brooke 1981). Similar efforts are being made with *Spodoptra litura* and *Heliothis armigera* (Rao 1982). A kairomone for *Bracon brevicornis* has been reported which can be successfully used to increase the efficiency of this parasitoid (Atma Ram et al. 1982). Further studies have also revealed that an attractant-pesticide mixture can be successfully utilized for controlling *Dacus dorsalis* under field conditions (Bose et al. 1979). The work on repellants from plant sources like *neem* also holds good promise. Basic research in this area needs to be augmented and supported by various governmental agencies. One of the greatest advantages of using pheromones is that these are not only effective but also ecologically acceptable and their production and marketing is rather easier.

Insect Growth Regulators

Insects are characterized by moulting, which is controlled by various hormones including the neurohormones Wigglesworth 1970, Raab (1982). The juveno-memetic compounds which have been isolated as well as synthesized have a great promise. Indeed, some of these compounds are registered in other countries but they have as yet to make their appearance here (Sukh Dev 1985).

In this category of compounds also come the analogues of benzoyalphenyl urea. These compounds interfere in the synthesis of chitin at the time of moulting (Mehrotra 1976). The treatment with these compounds lead to the symptoms akin to juveno-mimetic compounds (Subramanyam et al. 1980, Gujar & Mehrotra, unpublished). These compounds are active against coleopterous, dipterous and lepidopterous species (Van daalen et al. 1972) and can thus be effectively incorporated into the IPM programmes.

Selective Pesticides

Till todate the insect nervous system has been the main target of the various pesticides used in plant protection. The selectivity was devised on the basis of the metabolic rates of the toxicants. Exhaustive studies on the physiology and biochemistry of the nervous system suggest that the nervous system is still a good target for synthesizing new compounds. Variations in the properties of enzymes acetylchilonesterase (Mehrotra 1976, 1980, Hema 1983), carboxylesterase (Mehrotra & Phokela 1982, 1983, Phokela & Mehrotra 1984a & b), choline acetyltransferase (Mehrotra 1961, Mehrotra & Dauterman 1963, Ajri & Mehrotra 1977, Yu & Booth 1971, Baille et al. 1975) and neurotransmitter receptor protein (Sattele 1980) would be an ideal target for selectivity. Evidence from various sources suggests that these enzyme systems and proteins in insects are certainly different in their properties than their counterpart in mammalian systems.

The knowledge of the interaction between plants and insects is very crucial and important in this regard. Despite the tremendous modifications created by plant breeders in cultivated plants, it is seldom backed up by plant physiological studies with an aim for controlling pests and diseases.

It is only recently, after it was known that the plants are also involved in a complex warfare with pests and with each other, that plant scientists have started taking an active interest in these studies in an endeavour to integrate physiological studies in plants and animals for the control of pests and diseases.

In conclusion, it may be stated that in coming years, insect control by chemicals will reach a stage of sophistication, of course through a sound knowledge of basic researches in insect biochemistry and physiology, which would enable one to control a particular insect pest species with a specific chemical without harming others. These chemicals will be easily biodegradable and will also not have the undesirable effects on the environment. Out of about a million species of insects known today, not more than 100 have been studied from physiological or biochemical point of view and that too not exhaustively. Further work on new species of insects may yet reveal new biochemical and physiological adaptations which are very essential for them but are either absent or unimportant in other forms of life. Finally, a word of caution; the ease with which insects are able to adapt themselves to newer environment, it is likely that they may develop some degree of resistance to some of the new chemicals as well. It is, therefore, imperative for human survival that we must know our adversary far more fully than we know it today and that we must devise newer ways of dealing with it, faster than it can adapt itself to these. Safeguarding of crops from insect pests and diseases would require the active support, guidance and sponsorship of the official agencies for quite some time to come.

References

Ajri D S and Mehrotra K N 1977 Localization and distribution of choline acetyltransferase in nervous tissues of desert locust, *Schistocerca gregaria* Forskal; *Indian J. exp. Biol.* **15** 573–575

Atma Ram, Tiwari L D, Mehrotra K N and Ram Das 1982 Evidence for the presence of a kairomone in *Corcyra cephalonica* Stainton larvae for *Bracon bravicornis* Wasmael; *Z. ang. Entomol.* **93** 338–341

Baillie A C, Corbett J R, Dowsett J R, Sattele D B and Callec J J 1975 Inhibitors of choline acetyltransferase as potential insecticide; *Pestic. Sci.* **6** 645–653

Bose P C, Tiwari L D and Mehrotra K N 1979 Preliminary studies on the control of fruit fly in guava orchards by insecticide baits; *Indian J. Entomol.* **41** 388–390

Chapin G and Wasserstrom R 1981 Agricultural production and malaria resurgence in Central America and India; *Nature* (*Lond.*) **293** 181–185.

—— and —— 1983 Pesticide use and malaria resurgence in Central America and India; *Soc. Sci. Med.* **17** 273–190

Chenulu V V and Mehrotra K N 1979 Plant protection in India — prospects and retrospects; *Commerce* **139** 83–86

Doane C C and Brooks T W 1981 Research and development of pheromones for insect control with emphasis on the pink bollworm; in *Management of Insect Pests with Semiochemicals* ed E R Mitchel (New York: Plenum Publications) pp 285–303

Hama H 1983 Changed acetylcholinesterase and resistance in leaf and plant hoppers; in *Pesticide Chemistry, Human Welfare and the Environment* Vol. 3 eds J Miyamoto and P C Kearney (Pergmon Press) pp 203–208

Jayaraj S 1985 Role of insect pathogens in plant protection; *Proc. Indian natn. Sci. Acad.* **B51** (in this issue)

Mehrotra K N 1961 Properties of choline acetylease from the house fly, *Musca domestica* L.; *J. Insect Physiol.* **6** 215–221

—— 1976 Selectivity : The aim in insect control by chemicals; *Proc. Indian natn. Sci. Acad.* **46B** 207–211

—— 1979a Rural prosperity through pesticides — future trends; *Pesticide Information* **4** (4) 80–86

—— 1979b Plant protection; in *50 Years of Agricultural Research and Education* (New Delhi : Indian Council of Agricultural Research)

—— 1980 Some aspects of acetylcholonesterases in insects *Natn. Acad. Sci.* Golden Jubilee Commemoration Volume, Allahabad pp 311–320

—— 1983a Benefits and hazards of pesticides to society; *Pesticide Information* **9** (3) 38–42

—— 1983b Major achievements through research in plant protection; in *Agricultural Research and Education Systems for Development* eds. A P Saxena and V S Bhatt (New Delhi : Indian Council of Agricultural Research) pp 359–362

—— and Dauterman W C 1963 The N-alkyl group specificity of choline acetylase from the house fly, *Musca domestica* L. and the two-spotted spider mite, *Tetranychus telarius* L.; *J. Insect. Physiol.* **9** 293–298

—— and Phokela A 1982 Properties of carboxylesterase (EC 3.1.1.1) from *Brithys crini* (F.) (Lepidoptera: Noctuidae); *Proc. Indian natn. Sci.* **B48** 571–576

—— and —— 1983 Properties of carboxylesterase (EC 3.1.1.1) from nervous tissues of the desert locust, *Schistocerca gregaria* Forskal; *Proc. Indian natn. Sci. Acad.* **B49** 392–399

——, Singh V S and Mookherji P B 1967 Evidence for the presence of a sex attractant in females of almond moth, *Cadra cautella*; *Indian J. Ent.* **29** 30

Phokela A and Mehrotra K N 1984a A comparative study of the inhibition of acetylcholinesterase and carboxylesterase from the nervous tissues of the desert locust, *Schistocerca gregaria* F.; *Proc. Indian natn. Sci. Acad.* **50B** 10–14

—— and —— 1984b Properties of carboxylesterase (EC 3.1.1.1) from the fat body of desert locust. *Schistocerca gregaria* Forskal; *Proc. Indian natn. Sci. Acad.* **B50** 349–354

Pradhan S 1971 Revolution in pest control; *World Sci. News* **8** 41–47

Raabe M 1982 *Insect Neurohormones* (New York: Plenum Press)

Rangaswami G 1983 Biodegradation of pesticides; *Pesticide Information* **9** (3) 55–63

Rao K N 1982 Pheromonal control of insect pests of agriculture in India — problems and prospects; *Pesticides* **16** (9) 1–4

Sankaran T 1985 Role of insect pathogens in plant protection; *Proc. Indian natn. Sci. Acad.* **B51** (in this issue)

Sattelle D B 1980 Acetylcholine receptors of insects; *Adv. Insect Physiol.* **15** 215–315

Sharma V P 1984 Integration of malaria vaccines in the health delivery system in India; in *Proc. Indo-U.K Workshop on malaria*. ed. V P Sharma (Delhi: Malaria Research Institute) pp 169–184

—— and Mehrotra K N 1982a Return of malaria; *Nature* **298** 210

—— and —— 1982b Malaria resurgence; *Nature* **300** 212

—— and —— 1983 Final words on malaria's return; *Nature* **302** 372

—— and —— 1985 Malaria resurgence in India — a critical study; *Social Sci. & Med.* (in press)

Singh S P 1985 Integration of biological control methods in pest management; *Proc. Indian natn. Sci. Acad.* **B51**

Subramanyam B, Rao P J and Tiwari L D 1980 Juvenomimetic effects of diflubenzuron on *Achaea janata*; *Indian J. exp. Biol.* **18** 324-325

Sukh Dev 1985 Trends in development of insect growth regulators in plant protection; *Proc. Indian natn. Sci. Acad.* **B51** (in this issue)

Van daalen J J, Meltzer J, Mulder R and Wellinga K 1972 A selective insecticide with novel mode of action; *Naturwissen* **59** 312–313

Wigglesworth V B 1970 *Insect Hormones* (Edinburgh: Oliver and Boyd)

Yu C-C and Booth G M 1971 Inhibition of choline acetylase from the house fly and mouse; *Life Sci.* **10** 337–347