Role of Botanicals, Biopesticides and Bioagents in Integrated Pest Management

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Ever since the discovery of insecticidal properties of DDT in 1939, the synthetic chemical pesticides dominated in pest management programmes all over the world. The indiscriminate use of pesticides has created several problems, which came to limelight with the publication of "Silent Spring" by Rachel Carson. Overdependence on chemical pesticides in pest control has brought about problems like (1) pest resistance to pesticides, (2) resurgence of pests, (3) toxic residues on food, water, air and soil, (4) elimination of natural enemies and disruption of the ecosystem and (5) minor pests assuming major status. On the other hand, use of botanicals, biopesticides and biocontrol agents (natural enemies) offer a good alternative to manage the insect pests and diseases in an ecofriendly way. Because, mostly they are (1) naturally occurring, (2) they have high specificity to target pests, (3) no or little adverse effect on beneficial insects, (4) resistance development to them is slow or less common, (5) they have no unknown environmental hazards, (6) have less residual activity and (7) are effective against insecticide resistance species of insects. Due to the above reasons the role of biopesticides and bioagents is considered as a potent and reliable tool in Integrated Pest Management Programme (IPM) to manage insect pests.

BOTANICALS AS BIOPESTICIDES

Phytochemicals are classified as either primary or secondary plant metabolites. Of the estimated 3,08,800 plant species very few have been surveyed and most remained unexploited and unutilized for pesticidally active principles. Till date, about 2400 plant species have been reported to possess pesticidal properties belonging to 189 families among which about 22 families contain more than 10 plant species in each family with anti insect properties. Approximately, more than 350 insecticidal compounds, >800 insect feeding deterrents and quite a good number of insect growth inhibitors and growth regulators have been isolated from various plant species but, apparently only few have achieved the commercial status.

Among the currently marketed biopesticides in the world major ones include pyrethrins, rotenone, nicotine, ryanodine, sabadilla, neem based products and toosendanin. During last few years' plant essential oils comprising mono and sesquiterpenoids are being developed as green pesticides. Some of these oils are well known insect toxins, repellents and deterrents. Some of these essential oils are marketed as Cinnamate, Valero, EcoPCO and Bioganic. Rose mary oil as Hexacide has been released and is effective against aphids, whiteflies,

thrips and mites on a variety of crops like cotton, strawberry, grapes, squash and many ornamentals.

Neem based pesticides: - Maximum number of pesticidal plants belong to family Meliaceae. Among this neem, *Azadirachta indica* A.Juss has been found to be promising. Neem based pestidcides are marketed in India in different trade names containing 300, 1500, 3000, 5000, 10000 and 50000ppm of azadirachtin in it. Some of them are Ozoneem Trishul, Margocide OK, Godrej Achook, Nimbicidine, Bioneem, Neemark, Neem gold, Neemax, Rakshak, Econeem, Limnool and Repelin containing 300ppm of azadirachtin. Besides neem seed kernel extract (NSKE) 5%, neem leaf extract, neem cake powder is also used for pest and nematode control. In addition to neem products currently efforts are being made to develop phytochemicals based pesticides from annonin (*Annona reticulata* L.), citrus limnoids (*Citrus* spp.), Karanj (*Pongamia pinnata*) and Mahua (*Madhuca latifolia*).

Pest control action of neem:- The farmer of rural India traditionally mix 2-5 Kg of shade dried neem leaves with 100Kg grain or they soak empty sacks overnight in water containing 2-10Kg of neem leaves per 100 litres of water and then dry these sacks before filling them with grain to get rid of stored grain insects. Some farmers also mix ground neem leaf paste with mud used for making earthen containers for grain storage. Earlier reports of twentieth century envisaged that locusts invading western India did not attack neem leaves. During 1962, locust invasion to North-West India, the standing crops of Indian Agricultural Research Institute, New Delhi Experimental Station could be saved by spraying with 0.1% neem-kernel suspension @ 300-600 litres per hectare. Although locusts settled on the crops but no feeding was observed on the treated crop, whereas untreated crop in adjacent areas were severely destroyed.

Almost all parts of neem tree, viz., leaf, drupes, bark and seed contain a pool of biologically active constituents, including the triterpenoids azadirachtin, salanin and meliantriol. These compounds give protection against more than 100 species of insects, mites and nematodes including economically important pests like desert and migratory locusts, rice and maize borers, plant hoppers of rice, pulse beetle and rice weevil, root-knot and reniform nematodes, and citrus red mite. Modes of pest control by neem include antifeedant, growth regulatory, repellent, hormonal or pesticidal action in larva and/or adult stages of these pests. It is probably because of the pest control activity, idol of "Lord Jagannath" is made up of neem tree trunk which will not be attacked by wood boring beetles, termites and last long. That also proves the use of neem as a pest control agent in ancient India.

Pyrethrum: - From the flowers of *Chrysanthemum cinerariaefolium*, two formulations of Pyrethrum i.e. Pyrethrum 0.2% dust and Pyrethrum 1% EC are registered for use against insect pests in vegetables and Pyrethrum is also used in combination with other insecticides as synergists for the control of household pests.

Niotine Sulphate: - Nicotine is the extract from tobacco. Two formulations i.e. nicotine 40% solution and 10% DP are registered in India for export only.

Parthenium hysterophorous:-The extract of this plant contains parthenin, pyroparthenin, anhydroparthenin and photoparthenin.These are sesquiterpene lactones which exercise cytotoxic, antitumour, allergic, antimicrobial, antifeedant, phytotoxic, insecticidal actions. The ovicidal action has also been demonstratd in *Dysdercus koenigi*.

***Vitex negundo*(Begunia): -** The alcoholic, methanol and petroleum ether extracts of leaf (5 and 10%) are reported to be effective against 2nd and 3rd instar larvae of *S.litura*. The leaf and branch extract caused repellency against paddy pests. The petroleum leaf extract caused malformed pupae in rice leaf folder.

***Acorus calamus* L. (Bacha) :-** Powdered rhizome used for destruction of fleas, bed bugs, moths, lice etc. It is effective in killing insect pests of stored rice without any residual effect. Ether extract of rhizome shows ovicidal and mutagenic properties. The rhizome yields oil (1.5-3.5%, dry weight) containing asarone up to 82% and its beta isomer and other ingredients which is believed to be insecticidal.

***Adhatoda zeylanica* (Basanga):-** Leaves contain an essential oil (0.075%) chiefly containing limonene and an alkaloid vasicine. An infusion of leaves used against white ants and red spiders of tea. Leaf extract controls *Callosobruchus chinensis* (pulse beetles), petroleum ether extract works against *C.maculatus* and methanol extract against *Spodoptera litura*. All these extracts exercised antifeedant action.

***Anacardium occidentale* (Cashew nut):-** Cashew shell liquid contains phenolic constituents (2.7% of total oil). Several new pesticides have been prepared from cashew nut shell liquid. The shell oil is used to kill mosquito larvae.

***Ageratum conyzoides* (goat weed - Pokasungha):-** The leaf, flower and root extracts were reported to be toxic to *Dysdercus koenigii* (Red cotton bug) *and Tribolium castaneum* (Red flour beetle) and *Gnorimoschema operculella* (Potato tuber moth).

***Andrographis paniculatus* (Bhuin Nimba, Chireita):-** The leaf and seed extracts exercised antifeedant property against grass hoppers and whorl maggot in rice and the acetone leaf extract caused antifeedant action to *S.litura* and *Leptocorisa acuta* (rice gundhi bug).

***Catharanthus roseus* (Sadabihari):-** Leaf extract in water is a phagodeterrent against S.litura and aqueous leaf extract has toxicant action against YSB. The root extract acts as antifeedant against *S .litura.*

***Clerodendron inermi* (Genguti): -** Leaf extract in petroleum ether caused ovipositional deterrent effect in *C. chinensis* and toxicant effect on *A. moorei.*

***Plumbago zeylanica* (Dhalachita):-** The bark and root extract in alcohol caused toxic effect in *L. erysimi.*

***Melia azadirach* (Maha Nimba):-** It is a close relative of neem. The active principle is tetraterpenoid (limonoids). Plant extracts have behavioural, physiological and toxic effects which have been tested on *E. varivestis, N. lugens, M. separata* and *P. xylostella.*

***Pongamia glabra* (Karanja):-** The oil extracts have been reported to be repellent for BPH, WBPH, Epilachna beetle, maize borer, citrus butterfly etc.

***Annona squamosa* (Custard apple):-** This contain sesquiterpenes like á-pinene, â-pinene etc. These act as feeding deterrent against *A. moorei, N. lugens, H. armigera, N. nigropictus, S. litura, E. vigintioctopunctata.* A near relative *Annona reticulata* Linn. show insecticidal properties against *Tribolium castaneum.* Root, stem, leaves, and seeds possess insecticidal properties than other species. Root bark contains alkaloids anonaine, liriodenine, norushinsunine and reticuline. Leaves and stem contain an alkaloid that yields sapogenins.

***Strychnus nuxvomica* (Kochila):-** The seed extract (5, 10 and 15%) were effective against *Sylepta derogata* (Cotton leaf roller).

***Ipomea carnea* (Amari):-** The laboratory findings of More *et al.*,(1989) revealed that the leaf extracts at 5 and 10% concentration caused mortality in 2nd and 3rd instar larvae of *S. litura*.

Biopesticides can be of microbial (bacteria, fungi, virus, protozoa, nematodes etc.) or botanical (neem, tobacco, chrysanthemum, Karanj, Mahua etc.) origin and biocontrol agents (natural enemies) like predators (ladybird beetle, rove beetle, damsel fly, spiders, mirid bugs, lace wings, many aquatic bugs, *Gambusia* fish etc.) and parasitoids (*Trichogramma, Goniozus, Bracon*, etc.) play important role in IPM.

MICROBIALS AS BIOPESTICIDES

VIRUSES

Viruses are submicroscopic, obligate, intracellular pathogenic entities. Many viruses are active against insects. Approximately 60% of the 1200 known insect viruses belong to baculoviridae that can be used against 30% of all major pests of food and fibre crops. Majority of the baculoviridae those have been developed as bio-pesticide are bacilliform or rod shaped and include Nuclear Polyhedrosis Viruses (NPVs) and to a lesser extent Granulosis Viruses (GVs). Upon ingestion by the larvae the protein coat dissolves in the mid gut and the virions enter the epithelial cells of mid gut. Later they infect fat body, epidermis, tracheal matrix, muscle, gonads, haemocytes, nervous and endocrine system. After an incubation period of 5-7 days (sometimes 20 days) the larvae becomes sluggish, yellowish or pinkish in colour, swell slightly and then become limp and flaccid. Shortly before death the integument becomes very fragile. The dead larvae found hanging by their pro-legs from the top of the host plant. Finally they dry up and look like a dark brown or black cadaver. Presently, NPV's for *Helicoverpa* (Helicide, Heliocel, Biovirus H) and *Spodoptera* (Spodocide, Litucide, Biovirus S) are available in India and used @ 250-500LE/ ha for control of these two polyphagous pests infesting tomato, tobacco, arhar, cotton, vegetables, oilseeds etc. The need for propagating these in live organism and costs involved in producing have limited viruses as products of significant commercial importance. GV of *Chilo infuscatellus*, codling moth, potato tuber moth, cabbage butterfly are widely used for control of vegetable and field pests in advanced countries and some parts of India. These are produced by the farmer's co-operatives or cottage industries.

BACTERIA

A number of bacteria have been reported as entomopathogens but, bio-pesticides that have been most successful commercially are based on spore forming bacterium *Bacillus thuringiensis* (*Bt*). Over 30 *Bt* sub species have been discovered, but only half a dozen of them have been closely evaluated as pest control agents. *Bt* is known to infect at least four orders (Lepidoptera, Diptera, Coleoptera, Acarina) but lepidopteran larvae with gut pH of 9.0-10.5 are most susceptible. *Bt* is a crystalliferous spore former and in addition to endospores produces a parasporal crystal which contain delta endotoxin. Upon ingestion by susceptible individuals the delta endotoxin crystal is digested into active toxins which kill the insects or weaken the host so that the bacteria can readily invade the haemocoel from the gut and produce lethal septicemia. Some of the commercial products for control of lepidoptera include Dipel, Delfin, Biobit, Condor, Halt, Javelin, Bactin, Biolep, Bioasp, Thuricide and Bactospeine. They are normally applied in the field at a dose ranging from 0.5-1.0 Kg or litre/ha against pests of vegetable crops. Application during evening hours is recommended. The non-spore forming bacteria though have potential, have not been exploited so much in biological control of insect-pests.

FUNGI

Over 750 fungal species belonging to 100 genera are entomopathogenic. There are many examples where fungal pathogens have been used for the control of crop pests in India. The important genera are *Coelomomyces, Entomophthora, Massospora* belonging to Mastigomycotina; *Cordyceps, Podonectria, Torrubiella* belonging to Ascomytina; and *Aspergillus, Beauveria, Fusarium, Hirsutella, Metarhizium, Nomuraea, Paecilomyces* etc. belonging to Deuteromycotina. The development of fungal infections in terrestrial insects is largely influenced by terrestrial conditions. High humidity is vital for germination of fungal spores and transmission of the pathogen from one insect to another. Entomopathogenic fungi have several strains. They are known to produce toxins and nearly 33 toxins are known till date. Examples are *Metarhizium anisopliae* on *Oryctes rhinoceros* L.,*Fusarium oxysporum* on BPH, *Verticillium lecanii* on *Coccus viridis* (Green), *Beauvaria bassiana* on *Spodoptera litura* and *Helicoverpa armigera*. Some of the trade products of *Beauveria bassiana* available in Indian market are Boverin, Biopower, Ankush, Daman and Multiplex *Beauveria*. The dust/WP form is applied @ 1-2 kg/ha.

NEMATODES

A number of nematodes are known to parasitize insects. Notable among them are *Neoaplectana carpocapsae*, which infects 10 different orders of insects. One of its strains DD-136 is used extensively for control of insect pests of orchards, vegetables, field crops, forests and turf crops. Another nematode *Tetradonema plicans* is used against sciarid flies and pests of cultivable mushrooms. Similarly *Romanomermis culicivorax* is marketed under the trade name "Skeeter" and *Steinernema feltiae* as "Doom", "Seek" and "Spear" is used for control of soil pests and termites. In India, *Rhabditis* sp. has been reported to be useful against *Holotrichia serrata* (white grub). The virulence of *Steinerma feltiae* to *Spodoptera litura* and *Helicoverpa armigera* have been well documented, the latter being more susceptible than the former. A trade product "Green Commando" is used for the control of lepidopterans.

PROTOZOA

More than 1000 species of protozoans pathogenic to insects have been described. Most of them are chronic debilitating agents, affecting host vigour, longevity and fecundity. Most of the protozoa considered for use are microsporidia and their spores enter in the host by ingestion. Once in the gut, they exude a long tube that injects the pathogens into the host tissue where it multiplies vegetatively in the cytoplasm of cell, gradually spreading throughout the body and causing a chronic disease that may or may not kill the host. In India *Farinocystis tribolii* has been found to be promising against *Tribolium castaneum.* "Noloc" is the formulation based on *Nosema locustae* infecting grasshoppers and is regarded as safe to use. *Nosema* has been evaluated for control of grasshopper, European corn borer and spruce bud worm. Another microsporidian, *Vairimorpha nectaris* infects 36 lepidopteran pests among which 20 are Noctuids. But, till date the protozoans are not properly exploited in pest management.

ADVANTAGES

1. Microbials are naturally occurring.
2. These have a high degree of specificity to target pests.
3. No or little adverse effect on beneficial insects.
4. Potential development of pest resistance to microbials is less common or may develop more slowly due to unique mode of action.

5. No known environmental hazards.
6. Less residual activity.

LIMITATIONS

1. Microbials have narrow spectrum of activity. They control only the target pest which is not economical when mixed populations are required to be controlled.
2. These are effective only when applied at specific development stage of target species.
3. Often slow acting.
4. Microbials have short residual toxicity, require frequent applications.
5. In order to be effective microbials require high application rate and thorough spray coverage.
6. Some of them require specific weather conditions to be effective.

BIO-AGENTS

Natural enemies including predators and parasitoids (indigenous or exotic) are reared in the biocontrol laboratories and supplied to the farmers for release in the crop fields to control specific pests.

The egg parasitoid, *Trichogramma chilonis* is released @2,40,000/acre to control the cotton bollworm. Similarly *T. chilonis* and *T. japonicum* is successfully used against sugarcane top shoot borer and rice yellow stem borer @1,00,000/acre. The larval parasitoid *Goniozus nephantidis* and *Bracon brevicornis* are released @1200/acre to control coconut leaf eating caterpillar,*Opisina arenosella*. These are to be released at inundative doses.

Out of several predators of destructive pests available in nature few are reared in the laboratory and successfully used in the field for control of crop pests. Notable among them is *Chrysoperla carnea*, which is released in egg or larval stage @1000/acre in cotton ecosystem to control cotton pests and @2500/acre in sunflower and rose to control their pests. Similarly *Cryptolaemus montrouzieri* adults or grubs are released @ 600/acre to control pests of grapevine and coffee.

LIMITATIONS

In spite of several advantages and ecosafety with the use of bioconrol agents there exists some limitations, viz., (1) they have narrow spectrum of activity and control only target pests, hence, not economical to control mixed populations,(2) these are effective only when applied at a specific developmental stage of target species,(3) they are often slow acting and degrade in the heat and sunlight quickly,(4) microbial have short residual toxicity, so require frequent applications,(5) to be effective they need high application rates and thorough coverage, (6) production cost of biopesticides and natural enemies is too high and they need sophisticated equipments and laboratories to be produced.

CONCLUSION

However, biopesticides and natural enemies of pests are likely to play an important role in IPM in modern agriculture for controlling pests of vegetables and fruit crops in near future besides grain crops, forest pests and pests of domestic and public health importance. Because of their slow active nature, we need to develop effective strategies for using them in agriculture. Extension workers and farmers need to be educated on their use. The price of the commercial biopesticides has to be competitive with synthetic chemical pesticides or alternately the government has to provide subsidies for encouraging their use in agriculture to safeguard human health.

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