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"Integrated pest management is a holistic approach in modern agriculture"

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Abstract
Various researchers estimated that insects came into existence 350-500 million years ago. Insect pests cause heavy losses to the commodity in cultivated area and as well as in stored products in term of quality and quantity. Alternate host and soil is the best reservoir for insect pest in off season. The managements of insect pest can be done through many approaches like cultural i.e. crop rotation, seed treatment, weed eradication, fluctuation in sowing time, sanitation of plant debris, soil solarization, use of resistant cultivars; Mechanical i.e. use of traps (pheromone, light & sticky traps), removale of effected plant or part and eradication of various stages of pest from field; Biological i.e. natural enemies (*Chrysoperla spp*., *Coccinellidae spp*. and *Trichograma* spp. etc.) and biopesticides (*Bt. Beauveria bassiana*) and Chemical strategy. Cultural, Mechanical and Biological strategies are effective only at initial stages of attack, and they can not manage at sever attack. Chemical strategy is very effective but also very delicate to environmental pollution, residual effect. Development of chemical resistance in insect pest is major problem when continuous and singly application of chemicals. Therefore, all the methods have same limitation and draw back, so, integration of various strategy of pest management (IPM) is for most need in near future of sustainable agriculture.

Keywords: pest management, modern agriculture, pheromone, light & sticky traps.

Introduction
Plant protective tools play important role in healthy crop production. Modern agriculture mostly depends on chemicals *i.e.*, fertilizers and pesticides. Indiscriminate use of chemicals in agriculture is risky due to environmental pollution and health hazards to human beings, animals and beneficial microbes. For second green revolution, it is necessary assimilate alternative management strategies which are eco-friendly but sustainable for long duration. Eco-friendly strategies (Integrated Pests Management) *i.e.*, management of pests through bio agents, botanicals and agronomic practices play important role in sustainable agriculture.

Why need of bio pesticides?
Environmental safety is one of the leading drivers of bio pesticide usage because chemical pesticides also kill beneficial insects [bees, butterflies etc. who help in honey production (honey) and pollination] and microbes (*Rhizibium*, entomopathogenic fungus etc.). Non-toxic to non-target organisms, including beneficial insects and wildlife, many biopesticides also are biodegradable. They decompose quickly and do not negatively impact surface water and groundwater. Biopesticides typically are effective in small a quantity which eliminates pollution concerns sometimes associated with traditional chemicals. In addition, biopesticides are manufactured from naturally occurring raw materials in an environmentally responsible and sustainable manner.

Integrated Pest Management (IPM)
Modern concept of pest management is based on ecological principles and integration of different control tactics into a pest management system Integrated control was defined by Stern *et al.*, (1959) as applied pest control which combines and integrates the biological and chemical control. Later the concept of pest management has gained importance. The idea of managing pest population was proposed by Geier and Clark 1961 who called their concept as

protective management which later was shortened as pest management. Later Smith and Van Den Borsch in 1967 mentioned that the determination of the insect numbers is broadly under the influence of total agro ecosystem and the role of the principle element is essential for integrated pest management. In 1972 the term IPM was accepted by CEQ (Council of Environmental Quality). In early stage, IPM was a technical approach designed to reduce the number of pesticide application.

Cultural practices
The manipulation of cultural practices at an appropriate time for reducing or avoiding pest damage to crops which are utilized by the farmers to maximize their crop productivity or farm income is known as cultural management. The cultural practices make the environment less favorable for the pests and or more favorable for its natural enemies. It is the cheapest of all methods.

Field sanitation
For minimizing the infestation of insect pests, we should be use of clean cultivation as method. In rice crop, the incidence of stem borer, leaf folder, plant hopper is reduced by field sanitation. Removal of cotton sticks by I^st^ August every year was enforced under the cotton pests act, 1911 which helped in reducing the incidence of pink bollworm in erstwhile Madras State (Dhaliwal and Arora, 2006) [3].

Deep summer ploughing
Summer ploughing can markedly influence the soil environment and affect the survival of insect pests or their natural enemies. Immediately after harvest of wheat crop in April-May is helpful in exposing the resting grubs of rice root weevils to their enemies like birds and to the action of sun and wind. Diapause stage of insect pests in soil break by the disc plough which reduce the population of insect pests in upcoming crops.

Sowing time
The changing in sowing time help to minimize pest damage by producing asynchrony between host plant and pest or synchronizing insect pests with their natural enemies for crop production with available alternate host plants of the pest or by production followed by destruction of crop residues before the insects can enter diapause (Dhaliwal and Arora, 2006) [3].
Early sowing of crop helps to escape the attack of sorghum shoot fly, cucurbits red pumpkin beetle, gram pod borer in gram and early shoot borer in sugarcane. In cotton crop, sowing till mid may the crop can escape damage from late session pests *Helicoverpa armigera* and *Bemisia tabaci* (Dhawan, 1999) [4].

Seed rate
Adoption of appropriate seed rate ensures proper stand, spacing and crop canopy that help in adoption of proper spray technology and checks the unwanted growth of crop. Use of high seed rate is recommended in those crops where removal infested plants is helpful in minimizes the incidence of insect pests, *viz.,* maize borer in maize and sorghum shoot fly in sorghum.
The use of appropriate seed rate in cotton leaf curl virus affected areas helps to maintain proper crop stand even after roughing of the diseased plants at the early stage (Dhawan, 1999) [4].

Crop rotation
Crop rotation is most effective practice against pests that have a narrow host ranges and dispersal capacity. Lady's finger followed by cotton will suffer from increased infestation of pests. Hence if a non-host crop is grown after a host crop, it reduces the pest population *e.g.*, Cereals followed by pulses. Cotton should be rotated with non-hosts like ragi, maize, rice to minimize the incidence of insect pests. Groundnut with non-leguminous crops is recommended for minimizing the leaf miner incidence. Crop rotation is important to break continuity in insect pest build up.

Use of resistant variety
Use of the resistant varieties to help enhances the crop production whereas the susceptible crops have low production due to infestation of insect pest. Shakti and Jyoti potato cultivar resistant against aphid, white fly, cutworm and leaf hopper. Parbhani Kranti (Bhendi cultivar) is resistant against white fly.

Trap crops
A trap crop is an attractive host plant that attracts insects away from the main crop during a critical time period. The basic principle of trap cropping is that insects have preference for host plants and will move to a preferred host if given a choice. Insects are highly attracted to reproductive stages of host plant over the vegetative stages and trap cropping uses this attraction to good use. Generally, the trap crop is considered 'sacrificial' because it protects the valuable main crop when pest populations exceed normal levels. The target insect must be controlled in the trap crop with timely insecticidal applications or by mechanical removal. Since the 1930s, there have been many reported cases of successful trap cropping for management of various insect pests resulting in great reduction in the use of pesticides. The benefits of trap cropping include reduced dependence on insecticides, low cost of trap crop seed, conservation of natural enemies, and better crop and environmental quality. Remember, trap cropping is not a 'silver bullet' solution to all our pest problems because it does require more pest management skills and the knowledge of insect behavior. Also, not all insects can be controlled with trap crops.
Growing of susceptible or preferred plants by important pests near a major crop to act as a trap and later it is destroyed. Trap crop may also attract natural enemies thus enhancing natural control.
In South India or even North Eastern India, *Jatropha* sp., *Calotripis* sp. or even cowpea are grown as hedge plant to trap harmful red hairy caterpillar. Blue hubbard squash or other susceptible variety can be used as a trap crop to attract and retain cucumber beetles, squash vine borers, and squash bugs.

Trap crop	Main crop	Insect pest
Castor	Chillies	Tobacco caterpillar *Spodoptera litura*
Tomato	Citrus	Fruit sucking moths *Otheris* spp
Marigold	Cotton	American bollworm *Helicoverpa armigera*

Intercropping
Corn has been intercropped with beans in Nicaragua where due to interference with leafhopper movement, corn leafhopper (*Dalbulus maidis*) could be controlled automatically. Intercropping of sweet potato (*Ipomoea batatas*) with maize and cotton gives effective result.

Monoculture of cotton was also found to harbour more insect pests then cotton intercropped with ground nut, cow pea and soybean. The intercrop of cow peas in cotton helped in the colonization of *Coccinallids* and also enhanced the parasitism of spotted bollworm (Dhaliwal and Arora, 2006) [3].

Proper irrigation

The survival of many insect pests depends on the amount of moisture in soil which affects the insect life stages. Soil moisture level greatly affected the quality and quantity of nutrients available in host plants.

Sap sucking insects like aphids, jasids and white fly are especially sensitive to changing water level in their host plants. Maximum egg laying capacity of mustard aphid reared on *Brassica campastris* cv yellow *sarson* and *raya* (*B. juncea*) host plant was recorded when the water level was maintained continuously above the field capacity. In the sugarcane crop internode borer, white fly and stalk borer increases their numbers in water logging condition (Dhaliwal and Arora, 2006) [3].

Biological control

About 11000 bio pesticides that parasitizes harmful insects. Domestication of predators, parasites, frog, spiders etc. which can attracted and kill the harmfull insects is practiced by farmers.

Codling moth is a pest that damages fruit trees such as pears and apples. The Cydia pomonella granulosis virus is applied as a foliar spray onto eggs prior to hatching. The larvae need to ingest the virus prior to entering the fruit. If sprayed on the eggs, the larvae ingest the virus while eating the shells after hatching, get infected, and die. Cydia pomonella granulosis virus is used typically in rotation with other control measures in both organic and conventional agriculture, and can be used in conjunction with mating disruption. It can reduce or eliminate use of organophosphates and pyrethroids for conventional agriculture and protect against pest resistance to Spinosad for organic agriculture. Because it degrades in sunlight, it must be reapplied every 7-10 days.

Chinese scientists reported in cotton field that spiders can kill upto 90% of the harmful insects by nurturing the spiders in shallow pits dug in cotton field. They save upto 60% of the pesticides previously used.

The most widely used microbial pesticides are subspecies and strains of Bacillus thuringiensis (Bt), accounting for approximately 90% of the biopesticide market (Chattopadhyay and others, 2004). Each strain of this bacterium produces a different mix of proteins and specifically kills one or a few related species of insect larvae. When ingested by insect larvae, Bt releases endotoxins (proteins) that bind to the intestinal lining of the insect midgut. The endotoxin binding creates pores in the intestinal lining, paralyzing the digestive system and causing death. Bt is primarily used to control lepidopteran pests (moths and butterflies), which are some of the most damaging crop pests. However, Bt can also be used to control a broad range of other pests including specific species of mosquitoes, flies, and beetles. Researchers have identified between 500 and 600 strains of Bt. Approximately 525 insects belonging to various orders have been reported to be infected by Bt toxins (Thakore, 2006). Bt endotoxins are also the most common basis for genetically modified pest resistant crops.

About 60 percent of natural control of insects in many crops including rice is due to the biological control agents, which have to be protected and conserved by avoiding unnecessary use of chemical pesticides. The amount of damage caused by the major pests of rice is governed largely by the activity of natural enemies (Rao *et al.*, 1983) [13]. Biocontrol agents fit in very well with most of the other components of IPM (Srivastava, 1992) [16].

Inundative release of *Trichogramma* spp. to control stem borers and leaf folders in rice fields is being practised by the Central Biological Control Stations, located across the country, under the Directorate of Plant Protection, Quarantine and Storage, Government of India. Egg parasitoids like *T. japonicum, T. brasiliensis; T. chilonis* and *T. exigua* being mass multiplied and released in farmer's fields have been reported to be successful against stem borers, (Mathur, 1983) [10]. The inundative release of exotic parasite *T. japonicum* @ 20,000 per acre was effective in reducing stem borer infestation (Gupta *et al*., 1987) [6]. Four to nine releases of *T. japonicum* @ 1,00,000 adults/ha starting from 20 to 38 days after transplanting with an interval of 7-10 days resulted in 3.7 to 59.0% decrease in leaf damage due to leaf folder. Leaf damage was found to have negative correlation with the number of parasitoid releases (Bentur *et al.*, 1994) [1].

Botanicals used in insect pest management

In India, there are various plants known for insecticidal property and are popular as pesticides. Smokes of gums of various trees are used as mosquito repellent and insecticide which are popular since ages. The smoke of tea leaves, orange and lemon peels are also used for same purpose.

Chrysanthemum (decorative plant) is very important natural plant insecticide due to the source of pyrethrins. Pyrethrins are an effective pesticides concentrated in flowers @ 1-2 % of dry weight. Pyrethrin content is maximum at high altitudes.

Leaf and fruit extract of bael used against pests in certain region of India. Leaf extract of black mustard (*Brassica nigra*) is also considered as pesticide for jute when leaf extract of brown mustard (*B. juncea*) is an important pesticide for paddy burn spot.

Neem formulations are safe to the humans and environment and incapacitate insects through repellency, feeding deterrency, reproductive inhibition and oviposition deterrence.

Chemical strategy

Chemical strategy is very effective but also delicate to environmental pollution, residual effect in grain and killing the non-target organisms (Kumar and Singh, 2017). So, at last when other strategies are failed, recommended chemicals should be apply in recommended doses.

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