



Review Paper

Habitat Manipulation for Biological Control of Insect Pests: A Review

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Abstract

Habitat manipulation, which is also referred to as “Ecological Engineering”, focuses on reducing mortality of natural enemies, providing the supplementary resources and manipulating host plant attributes for the benefit of natural bio-agents. This can be achieved by enhancing the plant diversity and by providing adequate refugia in the agro-ecosystem. Strips harvesting in Lucerne was found to enhance predator or parasitoid population. Strips with taller growth had greater natural enemies population than in more recently harvested strips. Kairomone extracts from scales of *Helicoverpa armigera* (Hubner) was found to enhance the effectiveness of the predator *Chrysoperla* sp. and the egg parasitoid *Trichogramma* sp. when sprayed on cotton fields. Creating a raised “Beetle Bank” with perennial grasses within the field, will provide suitable over wintering habitat for several natural enemies. “Envirofeast” when sprayed in cotton fields attracts various natural enemies. Habitat manipulation is an emerging technology in biological control programme, which encourages biodiversity and leads to stability and sustainability of agro ecosystem. It integrates well with other methods of biological control.

Keywords: Ecological engineering, habitat manipulation, refugia and envirofeast.

Introduction

There are three broad methods of biological control. They are introduction (classical biological control), augmentation and conservation. Augmentative biocontrol consists of mass multiplication and periodic release of the natural enemies into the crop fields for the suppression of pest species. Conservation biocontrol aims at preserving the natural enemies available in the ecosystem to bring about effective management of the pests of crops. In habitat manipulation we manipulate the agricultural area and surrounding environment with the aim of conserving the natural enemies or modified the cropping system to augment or favor the natural enemies.

Habitat manipulation is another form of conservation Biological control. “Habitat manipulation is manipulation of agricultural area and surrounding environment with the aim of conserving or augmenting population of natural enemies”. Habitat manipulation is also referred to as ‘Ecological engineering’. It is an emerging technology to enhance biological control in an agro system by preserving or enhancing its plant diversity or providing adequate refugia for pest’s natural enemies¹.

Habitat manipulation involves altering the cropping system to augment or enhance the effectiveness of a natural enemy. Many adult parasitoids and predators benefit from sources of nectar and the protection provided by refuges such as hedgerows, cover crops, and weedy borders. Mixed plantings can increase the diversity of habitats and can provide alternative food sources and shelter to natural enemies.

Habitat Manipulation Approaches

Top down Control: Here herbivores (second trophic level) are suppressed by the natural bio-agents (third trophic level) and this type of approach is seen in ‘Augmentive biological control’.

Bottom up Control: In this approach, manipulation within-crop, such as green mulches and cover crop (first trophic level) will act on pests directly. This type of approach is seen in habitat manipulation of ‘Conservation biological control’ (figure 1).

Ecological Engineering Techniques: i. Limited and Selective use of pesticides, ii. Alternate food source, iii. Right diversity, iv. Refugia, v. Microclimate, vi. Alternate host /Prey insect, vii. Behavioural manipulation, viii. Host plant resistance, x. Other cultural practices.

Limited and Selective Use of Pesticides

When both pesticides and natural enemies are employed in a crop, conflicts can be reduced by use of following selectivity principles of insecticides. These selectivity insecticides will be needed especially in a crop management system, in which key pests are not currently controlled by biological methods but where natural enemies are important in control of secondary pests. The Pesticide control Act of 1972, came into being. It emphasizes the proper application of pesticides to ensure the greater protection of man and the environment. To spare the natural enemies, insecticidal application should be based on selectivity principles such as physiologically selectivity, ecologically selectivity, behavioural selectivity and selectivity through improved application².



Figure-1
Approaches

Physiological selectivity

Insecticides that are intrinsically selective for the phylum Arthropoda or the class Insecta alone or even more desirable for a few related insect species are few in number, but interest in their development is increasing.

Acaricide: Specific acaricides like dicofol, ovex, tetrasul, tetradifon and others, are almost entirely specific to the Acarina (mites and ticks) and are essentially non-toxic to insects, wildlife, humans and higher animals. They have an important role to play in pest management.

Biological Toxins: The insect bacterial toxins of *Bacillus thuringiensis* Berliner (Bt) has an almost specific effect against a small group of lepidopterous larvae like cabbage looper, boll worms, gypsy moth etc. and is being widely used as specific insecticides.

Baculovirus (NPV, OBV): About 40% of all viruses reported from insects are Nuclear Polyhedrosis Viruses (NPVs). Most of these have been isolated from Lepidoptera (80%), Hymenoptera (7%) and Diptera (3%).

Ecological Selectivity: Ecological selectivity obtained by the discriminating use of even the most broad-spectrum insecticide can be employed in many cases for the development of effective, economical, and ecological sound pest-control programs. The development of such programs is presently limited to some extent because of lacking knowledge in the ecology and biology of pest-natural enemy crop complexes.

Life Table: Pest life table describes in critical detail the stages in their life cycle that contribute most to the pest population, and the key factors like parasitism, predation, disease, food supply, migration, weather are responsible for the density dependent or density independent regulation of population trends. This information is critical due to the planning of the most effective insecticide intervention, their timing and their integration with other key factors.

Dosage: The use of reduced dosages is an important first step in beginning the transition program towards the successful pest management of many insects.

Behavioural Selectivity: By properly timing and placing the insecticide in relation to insect behaviour, we can reduce the insecticide application rates.

Timing Application by Light or Pheromone Trap

It has been emphasized that a major goal in moving into pest-management strategies is done when necessary insecticide applications for routine treatment insecticide is scheduled. This change would substantially decrease the number of treatments and the volume of insecticide necessary for the satisfactory control of many important pests. Two important techniques mentioned here are especially suited for guiding insecticide interventions for the control of many destructive lepidopterous pests of the farmyard.

Ultraviolet or Black Light Traps: Lepidoptera in particular are selectively attracted to black light traps, emitting Ultra violet light. The use of these traps is done at three per square mile. It traps the moth of the Tobacco horn worm (*Manduca sexta*). The Ultra violet or black light trap reduces the insecticide treatments necessary for hornworm control by about 90% in North Carolina³.

Sex Pheromone Traps: Sex pheromones of important insect pest are rapidly being isolated and identified, and many are available commercially.

Attractant: Many residue problems could be avoided if it were not necessary to apply insecticides to food crops. With increasing knowledge of the sensory communication among insects, especially in the elucidation of the chemical pheromones regulating mating behaviour and chemical kairomones responsible for attraction to sites for feeding and oviposition, there is abundant opportunity to use these chemical messengers to attract insect pests away from food crops and to alternate the sites treated with insecticides.

Selectivity through Improved Application: Reduced dosage program have been put in place over the past 10 years. This approach canters on using chemicals that degrade quickly (non-persistent) and applying them in the most appropriate time of the day.

Selectivity through Non-Persistence: Non-persistent, rapidly degradable insecticides such as nicotine, tetraethyl pyrophosphate and mevinphos can be used to achieve substantial selectivity if applicators are properly timed.

Selectivity with Systemic Insecticides: Systemic insecticides usually show pronounced selectivity, especially against sucking plant pest such as aphids, mites, leafhoppers and sometime chewing insects. Insecticides such as demeton and oxydemeton

methyl applied to plant foliage rapidly penetrate the leaf cuticle and are translocated throughout the xylem tissue. They act as stomach poisons to sucking insects, with little or no harm to parasites, predators and pollinator.

Selectivity with Seed Treatments: The application of insecticides to seeds before or at the time of planting offers the most efficient and concentrated means of protecting the germinating seed and the seedling plant. Such applications are minimal in dosage and least disturbing to the environment.

Selectivity with Formulation: Use of granular formulation do not contact with natural enemies on foliage or the air and hence the natural enemies are unaffected by such application Plant derived material like natural (alkaloids) or mineral compounds (cryolite) do not damage predators and parasitoids. Encapsulated Pyrethroids were also found safe to predatory mites.

Alternate Food Sources: Some parasitoids obtain needed resources from host while others require access to non-host foods. Floral nectar which is taken by many species can result in increased rates of parasitism. Extra floral nectar is produced by various plants such as Cotton (*Gossypium hirsutum*) and faba bean (*Vicia faba*) and is an important food source for many adult parasitoids (table 1).

Table-1

Increased parasitism due to the presence of alternate food sources

Parasitoid	Pest	Crop	Food Sources
Campoletis chloridae	Helicoverpa	Chickpea	Coriander
Aphelinus mali	Aphids	Apple	Erygium sp.
Lixophaga sphenophori	Rhabdoscelus obscurus	Sugar cane	Euphorbia sp.

Right Diversity

Intercropping: In quantification studies, herbivore population were reduced in 56% of cases, increased in 16% of the cases and unaffected in 28% of the cases of studies where intercropping was done. Intercropping is considered to be more beneficial to generalist species of natural enemies than specialists. Intercropping chickpea with coriander was found to increase the activity of *Campoletis chloridae* and decrease the population *Helicoverpa armigera*⁴.

Non-crop Vegetation: Non-crop vegetation may be favoured by natural enemies for oviposition sites. It has been observed that *Coleomeglla maculata* lays more eggs on a weed, *Acalypha ostryaefolia* than the sweet corn (*Zea mays*), even though the plant supports a few prey. Planting of water chestnut (*Eleocharis* spp.) in rice fields maintains the parasitoid, *Tetrastichus shoenobii* against yellow stem borer of rice, *Scirpophaga incertulas* in rice crop, which also parasitizes the *Scirpophaga* spp. in water chestnut⁵.

Providing Refugia: Plants, which shelter the natural enemies during unfavourable periods like winter in high altitudes, dry seasons in tropical areas, are called so. Artificially created grasses sown on raised earth bank are termed as Beetle banks⁶. They are sown with perennial grasses, like Cocksfoot (*Dactylis glomerata*) and Yorkshire fog (*Holcus lanatus*). The width of the beetle bank should be 2 to 3 feet and about 0.4 m height ideally. It provides habitat for birds, small mammals, invertebrates and predators like carabids and Staphylinids. “Envirofeast” when sprayed in cotton fields attracts various natural enemies².

Micro Climate: Generally bare soils are unfavourable for many natural enemies because of high temperature, low relative humidity and low soil moisture. Growing rye grass (*Lolium multiflorum*) helps in reducing the temperature of the soil surface in maize (*zea mays*) fields, thereby increasing the survival of *Trichogramma brassicae*.

Alternate Host/Prey-Insect: Colonization of alternative insect hosts may improve synchronization between pests and its natural enemies. Alternate host of natural enemies can also be made available through vegetation diversity where they can multiply in large numbers before attacking the largest host.

Higher parasitism of *Acherontia styx* egg on sesame by *Trichogramma Chilonis* in cotton-sesame intercropping results in the increased parasitism of *Helicoverpa armigera* eggs in cotton. Collection and rearing of *H. armigera* eggs from cotton plants in intercropping revealed 31.5% parasitisation by *T. Chilonis* whereas no egg parasitism was observed in pure cotton crop⁷.

Behavioural Manipulation: Molasses grass (*Melinis minutiflora*) when intercropped with maize, reduce the infestation of crops by stem borer and increase the parasitism particularly by the native larval parasitoid, *Cotesia sesame*⁸. The plant releases volatile substances that repel stem borers, but attracts parasitoids without being damaged.

Plant Variety: Varietal variation in the attraction of rice natural enemies is marked. The number of natural enemy can be preserved in tolerant/resistant varieties. The tritrophic relationship involves the host plant, insect pest and natural enemy. The population dynamics of *Nilparvata lugens* and its natural enemy was recorded on three rice varieties viz., Jaya (susceptible), Jyothi (moderately resistant) and Kanakom (resistant) in rice fields of RRS, Moncompu, Kerala.

Transgenic Crops: Incorporation of desirable genes into crops responsible for the production of the crystal proteins for killing the pests has been achieved on cotton, corn, and potato. Generally the transgenic crops are considered safer to predators and parasitoids. The crystal proteins and the pollen produced from these plants were generally considered safe to Anthocorids and Chrysopids.

Other Cultural Practices: There are several agricultural practices that make the environment less favourable to insect pests, like soil management, growing cover crops, water management etc,

Soil Management: Population interrelationship among various organisms is best studied in soil. pests and natural enemies which pass some part of their life cycle in soil. Also, soil is a major reservoir for inoculums of insect pathogen. For example, the Nuclear Polyhedrosis Virus of cabbage pest (*Trichoplusia ni*) is more persistent in less acid soils and liming of soil for virus conservation has been recommended⁹.

Water Management: Manipulation of relative humidity and wetting periods (through crop spacing and irrigation practices) as well as other factors such as phylloplane chemistry (pH etc) enhances the pathogen levels of arthropods. Watering can increase efficacy of *Verticillium lecanii* in green house for aphids.

Crop Residue Management: Sometimes the predators and parasitoids harboured in the residues of the crops are destroyed by burning or destruction of the crop residues. Several

parasitoids, *Epiricania melanoleuca*, *Parachrysocharis javensis* and Sugar cane leafhopper (*Pyrilla perpusilla*) could be conserved if crop residues of sugarcane were left unburnt. Retention of live post harvest plants in Cole crops enhances the conserving of *Cotesia rubecula* which attacks larvae of *Pieris rapae*.

Strip Harvesting: Strips harvesting in Lucerne was found to enhance predator or parasitoid population. Strips with taller growth had greater natural enemies population than in more recently harvested strips¹⁰. It showed that the egg parasitism by *Trichogramma* spp. on *Helicoverpa armigera* is greater in unharvested strips with dense parasitoid population.

Minimum Tillage: Population of predacious ground beetle are significantly higher in no-tillage fields than in conventionally tilled fields.

Cover Crops: Cover crops, when compared to areas of bare tilled soil, were seen to lower soil temperature, raise the relative humidity (RH) and make free water more readily available (figure 2).

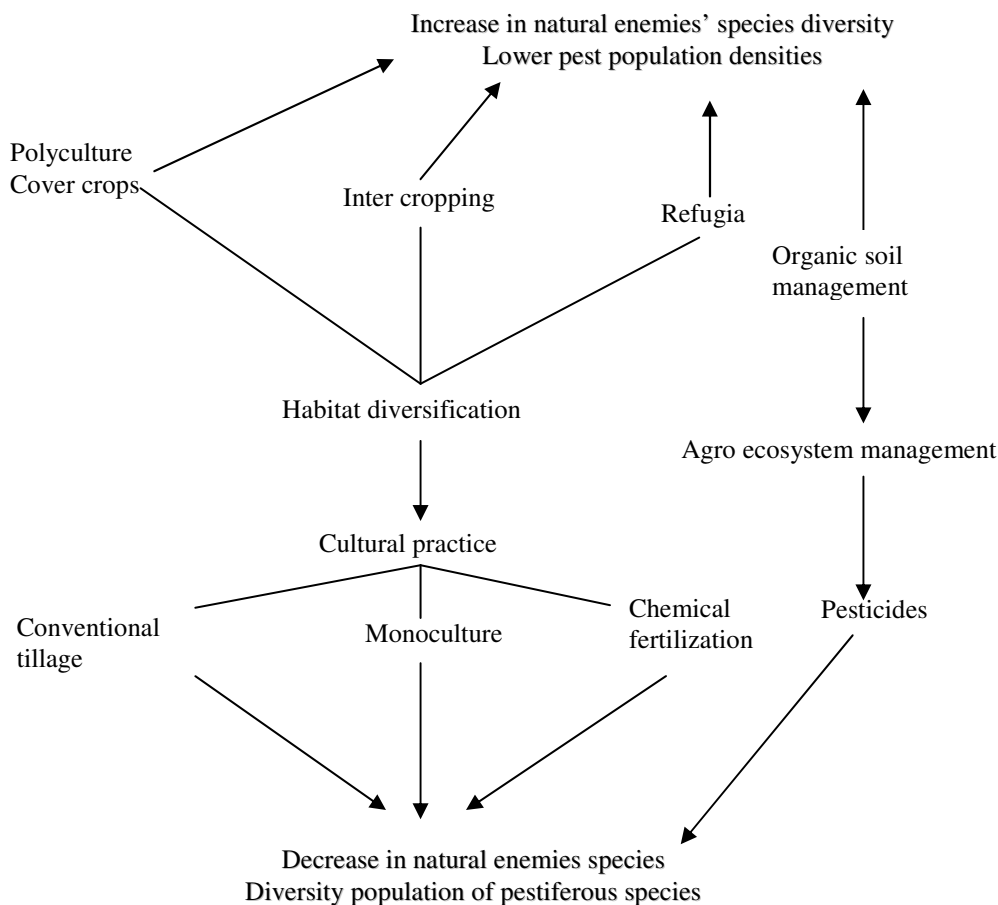


Figure-2
 Effect of cultural practices on biodiversity of natural enemies and abundance of insect pests

Constraints and Future Prospects

There is basic need to strengthen the research on defining the role of the tritrophic interactions, cultural practices and other practices in improving the efficiency of the natural enemies for important species of natural enemies used in India. Integration of the conservation and manipulation techniques in the IPM modules should be done and be tested for proper pest management practices for different crop pests.

A concerted research effort between different disciplines such as Plant Breeders, Agronomist, Soil Scientists, and Chemists and Entomologists is necessary to develop viable technologies with consideration to the conserving of the natural enemies or increasing the efficiency of the natural enemies.

Removing the extension gap between the researcher and the farmer is pivotal for the success of the conservation and manipulation techniques. Some of the farmers still believe in 'clean cultivation' by burning the residual crops, deep ploughing etc. as the right way of control without being aware of the damage caused to the natural enemies. Periodical training is necessary to educate the extension workers and farmers on biological control incorporating the conservation and manipulation methods.

Most of the experiments especially on the use of semiochemicals were conducted in smaller area or in semi field conditions and thus make difficult to draw any conclusions. Studies should be conducted in larger areas so as to generate good amount of data on the use of the semiochemicals.

Conclusion

Habitat manipulation is another form of augmentation and conservation of natural enemies in which cropping system altered successfully to augment and enhance the effectiveness of the natural enemies. Adult parasitoids and predators significantly benefited from source of nectar and the protection provided by refuge (hedge rows, cover crops and weedy borders). Mixed planting increase the diversity of habitats and provide more effective shelter and alternative food source to predators and parasites.

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