**Ecological Engineering: Sustainable Pest Management Strategy**

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Ecological engineering is the modification of agroecosystems in a way to encourage the survival, reproduction and conservation of predators and parasitoids by applying ecological principles involving habitat management (Increasing the chances of survival for the natural enemies) and habitat manipulation (Declining the chances for pest to survive). Ecological engineering provides sustainable solutions for environment which in turn promotes biodiversity, natural balance, reduces environmental pollution, suppressing pest resistance and resurgence problems. Implementation of ecological engineering requires knowledge and a detailed understanding of existing environmental factors, existing scenario of predators and parasitoids and their interaction with pest population. The ecological engineering via management of habitat offers an appropriate environment within the agroecosystem to fulfil the shelter and dietary requirements like pollen and nectar for adults of natural enemies. Odum used the term “Ecological engineering” first time, described as manipulation of environment by human beings by using low amount of additional energy to control the systems in which main energy is still coming from natural sources (Odum, 1962). It focusses on minimizing the mortality of natural enemies by offering additional resources for manipulating the host plant characters to help the bio-agents to survive and multiply, which increases the efficacy of their conservation in that particular agroecosystem.

**Ecological Engineering Techniques for IPM:**

**Selection of Appropriate Resources:** Habitat management should emphasize for the most appropriate resources which help to sustain the life cycle of natural enemies and also improve and increases their chances of survival without causing any ill effects. Number of frequent visits determine the attractiveness of a particular host plant. Fiedler and Landis (2007). Under the field conditions sugar content increases in the gut of *Diadegma insulare* which in turn improves its survival, longevity and fecundity (Lee and Heimpel, 2008). This study thus provided exceptional indication that the availability of floral resources can help to meet out the sugar need of natural enemies. If these resources are under limit the natural enemies have to meet out the dietary requirement from what is obtainable from the crop and from weed flowers and from the available flora surrounding the field. Relatively higher parasitism rates were recorded from population of rape pollen beetles nearby the field boundaries in comparison to the centre of the simple landscapes (Thies and Tscharntke, 1999). Both the studies show that availability of essential nutrient providing resources in the surroundings plays a vital role in the effective management as well as conservation of natural enemies.

**Trap croppping:** Trap crops are being used to attract or to distract or to capture insect pests in order to reduce the losses to main crop (Shelton and Badenes-Pérez 2006). As soon as the pest is gathered on trap crops, can be easily managed by application of pesticides only on trap crops or by the destruction of these trap crops along with the pest population (Pickett et al. 2014 and Reddy 2017). Even though the trap crops have been often used against one particular pest species, may be useful for more than one. For example, in cotton fields at China, velvetleaf weed (*Abutilon theophrasti* Medicus) works as trap crop for *Bemisia tabaci* Gennadius as well as for *Sylepta derogata* (Lin et al., 2015). Spraying of insecticides on the weed, velvetleaf after sufficient pest accumulation is effective to control them in fields of cotton. The host plant selection by herbivores is influenced by the species of crop and its cultivar and also by plant and pest phenology (Hokkanen 1991). The lure and the spatial coverage of the trap crop decides its role in effective pest control strategies (Gillespie et al. 2011, Sarkar et al. 2018).

**Inter-cropping**: Rising two or more diverse crop in the same area is known as inter-cropping Inter-cropping, it is a key cultural technique applied for pest management by minimising insect pest population and by enhancing ecosystem variety. Strip cropping is also type of inter-cropping in which two or more crops are grown in alternating strips over a field. Inter-cropping acts on herbivores by dividing their population load between main crop and the inter-crop, reducing pest pressure in the main crop. The chemical cues from the intercrop repel or change the insect behaviour reduces the losses caused by pests (González- Chang et al. 2017). Inter-crop also acts as a physical barrier and restricts the movement of pest within the main crop, it also provides floral resources for the associated natural enemies (Smith and McSorley, 2000). In cucumber fields inter-cropping of celery, *Apium graveolens* L. reduced the the whitefly, *Bemisia tabaci* population by its repellent and oviposition deterrent action (Tu and Qin 2017).

**Providing alternate food sources:** Free-living adults of parasitoids require nectar and pollen for longevity and reproduction. Hence, providing alternate nectar and pollen producing plants in or nearby the fields increases the abundance of parasitoids. Fava bean, greengram, lentils, marigold and cotton are rich food sources for adult parasitoids. Wildflower strips are the source of pollen, nectar, shelter, improve fitness of natural enemies and their multiplication. The effects on predators and parasitoids include increased longevity, chance of survival, and fecundity. Management of wildflower strips are also helpful in increasing the populations of some indigenous natural enemies by providing essential food elements (Briner 2002).

**Beetle Bank:** Beetle banks in agriculture or horticulture are manged on the raised ground strips of native perennial grasses or plants that provides shelter and food to the indigenous beneficial fauna. Beetle banks not only reduces the use of [insecticides](https://en.wikipedia.org/wiki/Insecticide) and can also serve as habitat for predatory birds, insect pollinators and insect predators (Carabidae , Cicindellidae, Coccinellidae, Formicidae, Sphecidae, Vespidae etc.) and parasitoids (Braconidae, Ichneumonidae, Scelionidae, Trichogrammatidae etc.). An attempt was made in England to provide a suitable habitat for the overwintering population of aphid predators within fields, researchers created ‘beetle banks’ were sown with perennial grasses such as *Dactylis glomerata* and *Holcus lanatus*. These banks when run parallel with the main crop rows, leads to a great improvement in the predator population (up to 1500 beetles/ Sq. m) can be achieved within only two years (Landis et al., 2000). Such landscapes in horticulture ecosystems enhancements at higher trophic levels effects, and can provide useful hunting lands for owls and raptors (Vickery et al., 2002).

**Chocolate-Box Ecology**: Habitat manipulation by adding floristically diverse flora to enhance pest management has been referred as “Chocolate-Box Ecology”. Floristically diverse flora provides sufficient pollen, nectar and nutrient rich diet for natural enemies, this style of habitat manipulation now needs to find out the more frequently available plant species to work out the optimal composition of species or range of selection measures to determine most suitable botanical composition (Pfiffner and Wyss, 2004). These measures reflect that the quality of the diversification (Polaszek et al., 2004) and requires the selection of right kind of diversity composition among native flora. A wide range of strategies are being establoshed by researchers and employed for the confirmation of the appropriate composition of native diversity which are being deployed for the management of pests in different agriculture and horticulture based ecosystems via ecological engineering (Gurr et al., 2004).

**Push-Pull Strategy:** Push-pull strategies works on the principle of behavioural manipulation of insect pests and their natural enemies by incorporation of stimuli that act as a protected resource, unattractive or unsuitable to the pests (push) while luring them in the direction of favoured and an attractive source (pull) from where the pests are subsequently removed (Cook et al. 2007). Push-pull strategies are based on the principle of using a combination of behaviour by modifying the stimuli to manipulate the distribution and abundance of pest and/or bio-agents for management of insect pests. These tactics are targeted against the insect pest and try to reduce their population on the protected resources or main crop. The pests are repelled away from protected resources (push) and simultaneously attracted towards (pull) attractive stimuli, such as trap crops where they are concentrated, facilitating their population suppression. The approaches involve the collective use of inter-crops and or trap crops, use of most suitable plant species for the farmers and that also exploit and conserve natural enemies. Maize stem borer, *Chilo partellus* is controlled through the use of molasses grass, *Melinis minutiflora* P.  Beauv or *Macrostomum uncinatum* (both Poaceae) as an inter-crop that attracts insect pests (push factor) and Napier grass, *Pennisetum purpureum* Schumach or Sudan grass, *Sorghum vulgare sudanese* (both Poaceae) as a trap crop (pull factor) to distract *C. partellus* females from ovipositing on maize plants (Khan et al., 2001, Khan et al., 2010). Stem borer larvae which emerged did not survive on the Napier grass because the because it produces a gummy substance that immobilizes the larvae, prevents their feeding (Khan et al., 2014). This strategy also increased the abundance and diversity of natural enemies, partly because pesticides were no longer used to control *C. partellus* (Khan et al., 2014).

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