**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 such as habitat management (Increasing the chances for natural enemies to survive) 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 ultimate aim of ecological engineering of habitat management is to offer a suitable environment within the agroecosystem to fulfil the shelter and dietary requirements like pollen and nectar for adults of natural enemies. Odum was the first person who used the term “Ecological engineering” which can be described as environmental manipulation by man using small amounts of supplementary energy to control systems in which the main energy drives are still coming from natural sources (Odum, 1962). It focusses on reducing the mortality of natural enemies by offering supplementary resources and manipulating host plant traits for the 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). *Diadegma insulare* in the field can lead to increased sugars content in gut which improved its longevity and fecundity (Lee and Heimpel, 2008). This study thus provided exceptional evidence that provision of floral resource subsidies 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 available within the crop i.e., honeydew, flowering weeds etc. but also on the composition of the landscape surrounding the field. Thies and Tscharntke (1999) recorded higher parasitism rates on rape pollen beetles close to the field edge compared to in the centre in structurally simple landscapes dominated by agriculture in comparison to complex landscapes. Both the studies suggest that resource availability in the surroundings also helpful in the effective conservation of natural enemies.

**Trap croppping:** Trap crops have been used to attract, divert or capture insect pests in order to reduce the losses to main crop (Shelton and Badenes-Pérez 2006). Once the pest is gathered on a trap crop, it can be managed by the use of much more localized applications of pesticides or by the physical destruction of the added vegetation and the pest along with it (Pickett et al. 2014 and Reddy 2017). Even though the trap crops have been usually used against one pest species, sometimes it can be useful against more than one. For example, in Chinese cotton fields, the weed, velvetleaf (*Abutilon theophrasti* Medicus) works as trap crop for *Bemisia tabaci* Gennadius as well as for *Sylepta derogata* F.  (Lin et al. 2015). Spraying of insecticides on the velvetleaf after sufficient pest accumulation is effective to control them in cotton fields. The selection of host plants by herbivores is influenced by crop species and cultivar and by plant and pest phenology (Hokkanen 1991). The lure of the trap crop and its spatial coverage decides its role in effective pest management schemes (Gillespie et al. 2011, Sarkar et al. 2018).

**Intercropping**: Rising two or more diverse crop in the same area is known as intercropping Intercropping, 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 intercropping in which two or more crops are grown in alternating strips over a field. Intercropping acts on herbivores by dividing their population between the main crop and the intercrop, reducing pest pressure in the main crop. The chemical cues from the intercrop repel or change the insect behaviour reduces pest damage (González-Chang et al. 2017). Intercrop plays also play a role in habitat management by creating a physical barrier, restricting inter-plant pest movement or providing floral resources for the associated natural enemies (Smith and McSorley 2000). Intercropping of celery, *Apium graveolens* L., in cucumber fields reduced the population of the whitefly, *Bemisia tabaci* by repelling the pest and deterring oviposition (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.). In England, in an attempt to provide suitable overwintering habitat within fields for aphid predators, researchers created ‘beetle banks’ sown with perennial grasses such as *Dactylis glomerata* and *Holcus lanatus*. When these banks run parallel with the crop rows, great enhancement of predators (up to 1500 beetles/ Sq. m) can be achieved in only two years (Landis et al. 2000). Such landscapes in horticulture ecosystems enhancements higher trophic level effects, and can provide useful hunting grounds 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 adequate nectar, pollen and nutritious diet for natural enemies, this approach of habitat manipulation now needs to find out the more commonly plant species to determine optimal species or use a range of selection criteria to determine appropriate botanical composition (Pfiffner and Wyss, 2004). These approaches reflect that the quality not the quantity of diversification (Polaszek et al. 2004) and requires the selection of ‘right kind’ of diversity among native flora. A wide range of approaches are being developed by researchers and employed to confirm that appropriate forms of diversity are deployed for pest management via ecological engineering (Gurr et al. 2004).

**Push-Pull Strategy:** Push-pull strategies involve the behavioural manipulation of insect pests and their natural enemies via the integration of stimuli that act to make the protected resource unattractive or unsuitable to the pests (push) while luring them toward 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 modifying stimuli to manipulate the distribution and abundance of pest and/or natural enemies for pest management. These strategies are targeted against pests and try to reduce their abundance on the protected resources. 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 elimination. The strategies involve the combined use of intercrops and trap crops, using plants that are appropriate for the farmers and that also exploit natural enemies. Maize stem borer, *Chilo partellus* is controlled through the use of molasses grass, *Melinis minutiflora* P.  Beauv or *Macrostomum uncinatum* Stapf (both Poaceae) as an intercrop that attracts the pest (push factor) and Napier grass, *Pennisetum purpureum* Schumach or Sudan grass, *Sorghum vulgare sudanese* Pers. (both Poaceae) as a trap crop (pull factor) to divert *C. partellus* females from ovipositing in maize crops (Khan et al. 2001, Khan et al. 2010). Emerging steam borer larvae did not survive on the Napier grass because the plant produces a gummy substance that immobilizes the larvae, preventing 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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