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Ecological Engineering: A Practice to Conserve Pollinators and Natural Enemies

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Abstract

Intensive agriculture has significantly impacted beneficial arthropods, such as natural enemies and pollinators, through practices like excessive pesticide use and habitat reduction. The disruption has led to declines in biological diversity and ecosystem services provided by organisms, undermining agroecosystem sustainability. Ecological engineering offers a promising solution by fostering balanced ecosystems through biodiversity enhancement and habitat manipulation. This approach includes methods such as trap cropping, intercropping, and the use of flower strips to manage pests and support pollinators. Trap cropping diverts pests from main crops to trap crops, reducing damage and reliance on pesticides. Intercropping reduces pest pressure by dividing pest populations and enhancing natural enemy habitats. Flower strips provide essential resources for natural enemies, boosting their effectiveness. Border crops act as physical barriers and provide additional resources for pest control. Non-cropped areas enhanced with floral resources and cover crops support pollinators. Integrating ecological engineering principles achieves sustainable pest management, benefiting agricultural productivity and pollinator conservation.

1. Introduction

Intensive agriculture has negatively impacted populations of beneficial arthropods, such as natural enemies and pollinators. This is mainly due to pesticide use and the reduction of suitable habitats for foraging and nesting sites in the agricultural landscape. As a result, there has been a decline in biological diversity and the delivery of ecosystem services like biological control and pollination. Ultimately, this undermines the sustainability of agroecosystems (Bretagnolle and Gaba, 2015). Ecological engineering is an innovative method of pest management that considers cultural practices based on environmental knowledge and natural solutions. This shift in thinking is becoming more popular in pest management because it has the potential to be

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both sustainable and effective without harming the environment. Ecological engineering is a field that aims to create a balanced ecosystem by enhancing biodiversity, promoting ecological processes, maintaining ecosystem stability and reducing synthetic inputs. The goal of this field is to create an environment that can resist pest infestation naturally. This is achieved through methods such as promoting natural enemies of pests, reducing the availability of pest food sources, and enhancing plant resistance. Implementing sustainable agronomic practices like managing field margins and mid-field strips with selected flower plants, cover crops, banker plants, uncultivated areas (set aside), headlands and hedges create favorable habitats that offer food and shelter to pollinators and natural enemies of insect pests in disturbed agro-ecosystems (Campbell et al., 2017). Companion planting, intercropping and crop rotation are some of the methods used in ecological engineering. Companion planting involves planting two or more plant species together that have a mutually beneficial relationship. This can include providing each other with nutrients, or repelling pests. Not only for pest management aspects but even for the restoration of pollinators ecological engineering, which is otherwise called habitat manipulation is necessary.

2. Ecological Engineering for Pest Management

Several studies have confirmed that pest populations were lower in polycultures of crops, in comparison to monocultures. Two potential mechanisms explain such patterns. The first is the *'resource concentration'* hypothesis, which suggests that specialist herbivores are less likely to locate and remain on host plants within a polyculture. The second is the *'enemies' hypothesis*, which suggests that natural enemies are more effective in diverse crop environments.

2.1. Trap cropping

Trap crops are used to control insect pests in the main crop. They work by luring the pests away from the main crop and into the trap crop. Once the pests are concentrated in the trap crop, they can be removed by targeted use of pesticides or by destroying the trap crop along with the pests it contains. This technique helps to minimize the damage caused by pests in the main crop.

Examples: Successful control of pests on a large scale by utilizing the trap crop method was reported in some crop ecosystems like Cotton in the US, where sesame acts as a trap crop for *Heliothis* species. Marigold acts as a trap crop for *Helicoverpa* and Castor acts as a trap crop for *Spodoptera litura.*

Trap cropping is a technique that has been used to control pests in agriculture. One of the most effective methods is called 'dead-end' trap cropping, where certain plants are selected to attract pests. However, these pests are unable to survive long on these plants, so there is no need to use pesticides to control them. The 'push-pull' system is an example of this method, which was developed in East Africa (Khan et al., 2001).

Example of Push-pull strategy: Utilizing molasses grass, *Melinis minutiflora* or *M. uncinatum* (both Poaceae) as an intercrop that draws the pest (push factor) and Napier grass, *Pennisetum purpureum* or Sudan grass, *Sorghum vulgare* (both Poaceae) as a trap crop (pull factor) to deter *Chilo partellus* females from ovipositing in maize crops are two ways to control the maize stem borer (Khan et al., 2010). Because the plant secretes a gummy material that immobilises the larvae and prevents them from feeding, emerging stem borer larvae did not survive on Napier grass. Because *C. partellus* was no longer controlled with pesticides, this tactic also led to an increase in the diversity and richness of natural enemies (Khan et al., 2014).

2.2. Intercropping

Intercropping involves planting two or more crops in the same field. This method helps to control herbivores by dividing their population between the main crop and the intercrop. This reduces pest pressure in the main crop. Additionally, non-crop visual and chemical cues in the intercrop can change insect behavior, thus reducing pest damage. Intercropping also creates a physical barrier that restricts the movement of inter-plant pests and provides floral resources for their natural enemies, which helps in managing the habitat effectively. Smith and McSorley (2000) have also mentioned similar benefits of intercropping in their research.

Examples: In central and southern India, farmers have reported that intercropping cotton with black gram, green gram, onion and cowpeas can help reduce the population of sucking pests and American bollworms that often harm cotton crops. Additionally, intercropping groundnut with pearl millet may help reduce the incidence of thrips, jassid and leafminer. Pearl millet in groundnut has been found to increase the activity of parasitic wasps, such as *Goniozus* sp.

2.3. Flower strips or insectary plants

The establishment of flower strips is a common technique used to promote conservation biological control, along with other ecosystem services. Diversifying the landscape through selective floral habitats that provide nectar and pollen to natural enemies can enhance the efficiency of biological control agents such as predators and parasitoids. This enhancement occurs by improving the pest's fitness to a lesser extent. Studies have shown that maintaining such habitats can be highly effective (Shields et al., 2019).

2.4. Border crops

Soft-bodied insects such as aphids, thrips, mites and whiteflies can be easily carried by wind currents to different locations. However, if border and barrier crops are grown around and within the main crop, the thick plant canopy can physically prevent the dispersal of these insects and thus reduce the spread of sucking pests. Furthermore, border and barrier crops can provide sufficient food such as nectar and pollen for natural enemies, which can help decrease the pest population on the main crop.

Example: Sowing of tall crops like maize, sorghum and other fodder grass around the border of chilli fields acts as a barrier for pests like chilli, thus protecting the main crop from pest incidence (Sujay et al., 2015). The reduced activity of fruit borers in chilli plants was also observed due to the planting of border crops, which may be due to the release of certain volatile substances by border and barrier crop plants. These substances can limit the colonization of the main crop by the fruit borers. Additionally, adopting border and barrier cropping systems can help in manipulating the habitat to maintain the eco-balance and provide favorable conditions for the natural enemies of fruit borers.

3. Landscape Enhancement of Floral Resources to Enhance Pollinators

Annual cropping systems have caused crop rotations to become simpler, resulting in monocultures, reduced plant diversity and large areas of wind-pollinated or self-pollinated crops. This practice can cause a lack of pollen and nectar resources for bees, even in bee-pollinated crops that may have a short period of abundant bloom. To fill the gap, the flora in non-cropped areas could provide additional forage resources during the bloom time of cultivated plants. However, these non-cropped areas are often scarce in the most intensively farmed areas. To solve this issue, creating and protecting additional non-cropped areas could be a solution. By maintaining large strips (6–12 m wide) of native or non-native melliferous plants between crop fields, also known as "bee pastures," we can help support pollinators in agricultural landscapes.

3.1. Cover crops

Some plants are sown as cover crops, which have short, rapid flowering life cycles. They can provide early honey bee forage in the spring when planted before the primary crop. Similarly, these plants can follow the primary crop in rotation in the fall to provide late-season bee forage. Some of the potentially suitable plants for this purpose are scorpion weeds (*Phacelia* spp.), annual clovers (*Trifolium* spp.), Brassicaceae-like radishes (*Raphanus* spp.) and mustards (*Brassica* spp.).

In other systems, longer-lived or even perennial cover crop plants are preferred. For example, a cover crop rotation between two Gramineae crops such as barley and corn might last as long as 9 months.

3.2. Field margins

Field margins are strips of land along the borders of crop fields and can also be vegetative strips adjacent to roads, paths, railways, hedgerows and forest boundaries. These areas serve multiple agro-environmental purposes, such as stabilizing riparian areas, capturing soil via grassed waterways, and buffer zones for pesticide drift. Field margins represent a large and important global surface area, and by making simple management modifications, critical ecological and environmental services can be provided, including the availability of food for honey bees (Decourtye et al., 2010).

4. Conclusion

Ecological engineering employs innovative solutions for managing pests and conserving pollinators by utilizing natural processes and relationships within ecosystems. A comprehensive understanding of the habitat of pests, their natural enemies, and pollinators and their interaction with the ecosystem is crucial in developing effective habitat manipulation strategies. By integrating these ecological engineering principles into agricultural and land management practices, we can promote sustainable pest management while protecting vital pollinator populations and the ecosystems they support.

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