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Trap crops: A potential pest management tool in agriculture

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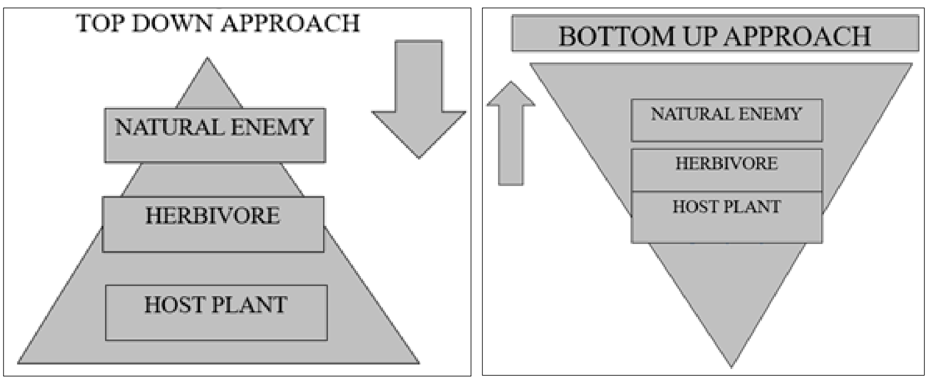
Abstract
Different pest management approaches although have been developed, yet, cultural control always remains the first priority of the farmers as it is easy to adopt. Thus, this review describes the advantages and types of trap cropping that are being followed along with the qualities of trap crops. The pest establishment, survival, development and spread is a multidimensional interaction, dependent on host plant, the environment, and the pest itself. Merely by modifying the cropping pattern, both spatially and temporally can be helpful in managing the pests in eco-friendly manner. Stem borer control in Africa has attained huge success through this trap cropping or modified trap cropping. Thus, different modalities of trap cropping such as conventional trap cropping, dead end trap cropping, genetically modified trap cropping, perimeter trap cropping, sequential trap cropping, multiple and push pull trap cropping like different methods can be adopted for diverting the pests from their main hosts and minimizing the damage caused by them.

Keywords: Trap cropping, pest management, push pull trap cropping and cultural control

Introduction
The pest establishment, survival, development and spread are a multidimensional interaction, dependent on host plant, the environment, and the pest itself. The basic difference between sole crop and trap crops can be summarised from the herbivore point of view as host quality and abiotic environmental factors of the concerned crop field. Among the host quality, plant architecture is an important factor and plant conformation and configuration, e.g. leaf shape, plant colour, branching and canopy pattern, has been reported to vary considerably depending on the interactions with neighbouring plants. It was observed that intercropping cassava with cowpea influenced cassava growth and conformation, with taller plants and larger internode lengths in the intercrop [4]. Considering the resource concentration and enemy hypothesis, the need of diversification of crops can be realised to minimise the pest incidence and intensifying the natural enemy effects. The top down and bottom up approach can be explained to describe the beneficial role of inter cropping. There are 3 trophic levels such as, host plants, herbivores and natural enemies comprise of first, second and third trophic levels respectively. Any alternation or manipulation in the trophic level structure by changing the species richness and species diversity can lead to change in herbivore composition in the crop microclimate.



The landing of herbivores on improper host plants, can lead to disruption of the entire host finding process, thus ultimately hindering the herbivory and pest biology and survival. Trap crop effects on survival and reproduction of diseases and arthropod pests by altering host plant quality which is one of the main determinants of both herbivore survival and reproduction. Otherthan this, trapcropping effects on natural enemies of herbivores.

From a pest management point of view, a system manipulation like trapcropping aims to enhance natural enemy impact on important herbivores, regardless of whether this effect is produced by increased enemy density, activity or efficiency.

The concept of trap cropping

As described before**,** the host plant selection process by insect herbivores, are regulated in 5 different steps such as, host habitat finding, host finding, host recognition, host acceptance and host suitability. To alter the host plant- insect interaction process, different non host plants can be planted which divert the insects from the main crops. In this regard, intercropping, trap cropping can be beneficial. Considering the resource concentration hypothesis, as the nutrition is the main resource provided by the host plants to the insect herbivore, alteration of plants within same field, with different types of trap crops can be beneficial in pest management. Furthermore, the enemy hypothesis, in this context explains that trap crops might act as enemy host by causing various adversities such as impairment in the life cycle of a particular insect. Thus, by simply modifying the planting type the insect pests can be managed in an eco-friendly manner. Other than, enhancing the pest control, these trap crops in some cases are also manipulating the natural enemies population in the field. Thus, the concept of trap cropping basically makes the trap crops more attractive than the main hosts, and kill the pests by manipulating the field architecture.

Trap crops are within the scope of intercropping and are defined as plant stands which are used for the purpose of attracting; diverting, intercepting and/or retaining targeted insects in order to reduce damage to the main cash crop [20]. Related to trap cropping is mixed cropping, planting two or more different crops in the same field that have a reciprocal interaction. Mixed cropping systems have advantages additional to those given by trap crops, including repelling insect pests, increasing natural enemies in the field, suppression of weeds by shading with mixed canopies or allelopathy and improved productivity of land [1]. Improved land use is achieved by employing plants that have uses additional to attracting natural enemies or repelling pest species, usually as a fodder crop. By introducing these plants into the crop fields, areas of open ground for weeds are reduced and thereby competition with the cash crop is reduced [1]. Work on maize involved planting native African grasses that are highly attractive to ovipositing female stem borers, around maize fields to decrease pest populations [17]. Intercropping cassava with maize in Nigeria was found to reduce larval numbers of *E. saccharina*, *B. fusca* and *S. calamistis* by approximately 50% when compared with monocrop maize [11]. It was found that intercropping maize with molasses grass, *Melinis minutiflora* Beauv. (Poaceae) caused a decrease in damage to the maize plants by *Chilo partellus* Swinhoe (Lepidoptera: Crambidae) from 39.2% to 4.6% [13]. Intact *M. minutiflora* releases volatile components containing (E)-4, 8-dimethyl 1, 3, 7 nonatriene, [14], which has been implicated as a plant distress signal which recruits predators and parasitoids to the damaged plant and surrounding crop. Nonatriene is also released by stemborer damaged maize [12]. When choosing a plant species to intercrop for pest control benefits, and yield advantages, a plant that is repellent to ovipositing females of the pest is ideally required. If the pest is repelled by these plants they will not lay their eggs on the cash crop associated with them [10]. Another benefit of intercropping is that female insects will spend more time searching for a suitable host plant amongst the intercrops and so oviposit fewer eggs on the actual host [22]. At the next level of intercrop selection, if the intercropped plants stimulate the pest larvae to feed on them and not disperse off onto neighbouring plants [10], then they will act as a sink for the pest. Plants that act as sinks for pests or reduce larval survival are termed dead end crops [20].

Modalities of trap cropping

The main modalities of trap cropping can be conveniently classified according to the plant characteristics or how the plants are deployed in space or time. Other modalities, such as biological control–assisted and semiochemicals assisted trap cropping, may not easily lend themselves to such dichotomous classifications but can provide important contributions to trap cropping

A. Based on characteristics of trap crop

1. **Conventional trap crop:** It is very general practice of trap cropping, in which growing of more attractive crop in vicinity of the main crop, thus diverting the pest load from the main host and blocking the survival and development of the insect on the trap crops [9]. e.g. use of highly attractive varieties of squash to manage squash bugs and cucumber beetles in several cucurbitaceous crops, Castor and Marigold in Ground nut crop and use of Alfalfa as a trap crop for Lygus bugs in Cotton [5].
2. **Dead end Trap cropping:** This modality of trap crop is highly attractive to insects but they or their offspring's can't survive. This basically made the plants unsuitable for multiplication, in other words, it can be said that, through antibiosis, dead-end trap crops serve as a sink for pests, preventing their movement from the trap crop to the main crop later in the season. Ex: Indian mustard for Cabbage diamond back moth and Sun hemp for Bean pod borer [21].
3. **Genetically modified trap cropping:** This modality of trap cropping is not a unique. Certain crops having genetically modified traits towards insect resistance can be deployed to control the pest population. For example, genetically engineered potatoes express proteins from *Bacillus thuringiensis* (Bt) have been used as trap crops to manage Colorado potato beetle (*Leptinotarsa decemlineata*) populations [8].

B. Based on the deployment of the trap crop

1. **Perimeter trap cropping:** Trap crops planted around the borders of the main crop. The use of field margin manipulation for insect control is becoming common in IPM programs and is similar in practice to the early use of traditional trap cropping using borders of more attractive plants. For example borders of early-planted potatoes have been used as a trap crop for Colorado potato beetle, which moves to potato fields from overwintering sites next to the crop, becoming concentrated in the outer rows, where it can be treated with insecticides, cultural practices and papaya trees planted 10 m around the main papaya grooves as a trap crop to reduce fly damage [7].
2. **Sequential trap cropping:** This trap crops modality involves that trap crops are planted earlier or later than the main crop to attract the pest. Ex. Indian mustard as a trap crop for diamond back month in Cabbage. Which requires planting mustard two or three times through the

cabbage season because Indian mustard has a shorter crop cycle than cabbage and other cole crops [18].

3. **Multiple trap cropping:** Planting of several species simultaneously as trap crops with the purpose of either managing several insect pests at the same time or enhancing the control of one insect pest by combining plants for attracting pests. For ex. use of a mixture of castor, millet, and soybean to control Groundnut leaf miner and the use of corn and potato plants combined as a trap crop to control wireworms in sweet potato fields [16].
4. **Push - Pull trap cropping:** One method of pest management utilises plant volatiles in a habitat management system by planting non-crops that are attractive, and or plants that are repellent to the pests, in or near the crop fields. This strategy known as push-pull‖, has been used successfully by cotton farmers [19]. Miller and Cowles [15] coined the term stimulo-deterrent diversion', (SDD) for push-pull plants and used SDD to protect onions from onion flies by attracting (pulling) gravid, female onion flies away from the onion crops using onion culls while at the same time adding an additional push pressure using a feeding deterrent and a toxin [15]. The push-pull technique is also known as "stimulo-deterrent diversion" strategy is based on a combination of a trap crop (pull component) with a repellent intercrop (push component). The trap crop attracts the insect pest and, combined with the repellent intercrop, diverts the insect pest away from the main crop [14]. A push-pull strategy based on using either Napier or Sudan grass as a trap crop planted around the main crop, and either desmodium or molasses grass planted within the field as a repellent intercrop, has greatly increased the effectiveness of trap cropping for stem borers in several countries in Africa [15]. This is achieved by introducing volatiles, which make the host organism, in case of cotton, unattractive so that the pest, *Heliothis spp* (Lepidoptera: Noctuidae), will leave the crop to find an alternative host, which emits a more attractive volatile than the cotton field. Often this alternative is a killing lure which may prevent full development of the pest species on it [19].

Additional trap cropping modalities

1. **Biological Control- Assisted Trap Cropping:** A part from diverting the insect pests away from the main crop, trap crops can also reduce insect pest populations by enhancing populations of natural enemies. For example, a sorghum trap crop used to manage cotton bollworm, *Helicoverpa armigera*, also increases rates of parasitism by *Trichogramma chilonis* [23].
2. **Semiochemically Assisted Trap Cropping:** Semiochemically assisted trap crops are either trap crops whose attractiveness is enhanced by the application of semiochemicals or regular crops that can act as trap crops after the application of semio-chemicals [2]. One of the most successful examples of this trap crop modality is the use of pheromone-baited trees that attract bark beetles to facilitate their control [3].

Advantages and disadvantages

Advantages of trap cropping includes it enhances the crop quality, by protecting the crops from pests and providing the safeguard through natural enemies. It has also been observed to conserve soil and environment, thus it is an environment friendly approach. It increases the productivity and enhances the biological diversity in the cropping system. It also reduces the pest incidence along with reducing the overuse or inadequate use of insecticides and conserves and augments the existing natural enemy population. As it is a modified cultural management approach, grower must have adequate knowledge for the proper selection of trap crops suitable to the main crop regarding insect behaviour, life cycle and migration. It needs proper and early planning such as early planting and resources like land, labour, capital, seeds. In some cases, insecticides are still needed as immediate curative control measures. It necessitates the need of adoption of timely control measures.

Increasing the effectiveness of trap crops

Adopting only trap cropping is nor suitable neither advisable, in the existing pest management methods. IPM always focusses on the use of diverse control measures in a suitable manner to control the pest population below the injury level. Thus various other control measures such as, biological and/or insecticidal control measures can supplement the efficacies of trap crops in obtaining sustainable pest management. Considering the inherent characteristics of a trap plant, the spatial and temporal alteration of plants in main crops can also effectively manage the target pest. Certain semiochemicals can be used to attract insects towards the trap crops, thus insect behaviour can be used to manage insect itself. Furthermore, advanced breeding approaches can be used to alter the genetic composition of plants to make them more attractive towards pests, natural enemies and morphologically make them inadequate for survival and development of insects. Enhancing the effectiveness of the trap crop is vital to minimize the land sacrificed to production when using trap cropping. General guidelines for trap cropping recommend that about 10% of the total crop area be planted with the trap crop [6], although the percentage of trap crop in different cases vary among plants and depending on the pest targeted. For example, to reduce diamondback moth populations, between 5 and 13% of the crop area should be reserved for the trap crop. Cultural control methods can also be used to increase the effectiveness of trap crops. Water stress can also increase the attractiveness to certain insect pests in some plants but not others, indicating that some trap cropping systems could benefit by controlling water stress. The spatial arrangement of the trap crop alongwith the temporal dynamics is also important in changing the main crop micro climate and thus can influence the host selection process by the insect.

Conclusion

The insect stage targeted by the trap crop and the insect's ability to direct its movement, its migratory behavior and its host-finding behaviour determine the selection of suitable trap crops. The insect stage to be controlled by the trap crop is of critical importance in designing an effective trap crop strategy. Usually, the attractiveness of the trap crop and the proportion of trap crops in the field are important factors in the arrestment of the insect and the success of a trap cropping system. Trap cropping has provided sustainable and long-term management solutions to control difficult pests in an eco-friendly and economically feasible manner. This approach has been successful in both developed (e.g., Lygus bugs on cotton) and developing countries (e.g., use of push-pull trap cropping to control stem borers in corn). With the advent of advance biotechnology and improved breeding methodologies, new opportunities for trap cropping have arisen, for examples of *Bt* potatoes. Organic growers and those farmers interested in trap cropping; thus, this method has widespread illustrations in controlling pests by simply manipulating the insect behaviour and the spatial and temporal planting pattern.

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