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# Trap Cropping

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**Abstract:** *Managing crop pests on a farm can be challenging, especially for organic growers or those who simply choose to use fewer insecticides or no chemical applications at all. One proven practice of cultural pest control is trap cropping, an Integrated Pest Management (IPM) technique that uses plants attractive to insect pests to lure them away from the cash crop. Trap crops provide many benefits, including increasing crop quality, attracting beneficial insects, enhancing biodiversity and reducing insecticide use. Trap crops can be planted around field perimeters or inter-planted with the cash crop. A trap crop's effectiveness depends on what pest you are trying to manage and how desirable the host is for those pests. Trap cropping may offer a means of reducing reliance on chemical applications for pest management, and it has been shown to have potential for the control of numerous Brassica pests and it can be difficult to tackle through the use of pesticides (due to the resistance issues described above) and responds relatively weakly to some other IPM strategies such as the use of under-sowing with non-host plants. Thus, there is a need to investigate alternative methods of management for this pest.*

**Keywords:** *agriculture, effects, trap crops*

## 1. Introduction

*Phelipanche*and *Orobanche* (broomrapes) are root parasites of several crops in Iran (Minbashi& Mazaheri, 2002). Egyptian broomrape (*Phelipancheaegyptiaca*.) is an obligate parasite plant species widespread in Mediterranean areas, Asia and Southern and Eastern Europe (Hershenhorn et al., 2009). They act by attaching themselves to the roots of many plant species with haustorium and obtain nutrients and water from their host. This parasitic plant causes economic damage in field crop and vegetable production worldwide (Joel, 2000; Press et al., 2001; Eizenberget al., 2004; Lopez-Raez et al., 2008). Control with herbicides or other approaches are not successful for broomrape because these parasites cause greatest damage prior to their shoot emergence and flowering (Ross et al., 2004).

Scientific interest in trap cropping, as well as other integrated pest management (IPM) strategies, has increased in recent years. A major driver for this is that stricter pesticide safety standards have resulted in the withdrawal of many products used previously in pest management. Furthermore, the use of products still permitted for application may be hampered, as pest insects commonly develop resistance to the pesticides used against them (Wyman, 2003). Resistance to one or more insecticides has now been reported in over 500 pest insect species (Altieri, 2004).

In a recent review, only ten examples of trap cropping systems that are being used commercially worldwide were identified, despite numerous examples of experimental trap crops being given (Shelton &Badenes-Perez, 2006). More research is needed to understand how trap crops work and how they can be most efficiently deployed before this method can be adopted more widely in pest management. One way of maximizing trap crop effectiveness is to ensure that the trap crop species itself is optimally acceptable to the pest when compared with the main crop (Hannunen, 2005).

## 2. 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 semiochemically assisted trap cropping, may not easily lend themselves to such dichotomous classifications but can provide important contributions to trap cropping.

## 3. Modalities Based on the Trap Crop Plant Characteristics

Conventional trap cropping**,** we use this term to define the most general practice of trap cropping, in which a trap crop planted next to a higher value crop is naturally more attractive to a pest as either a food source or ovi position site than is the main crop, thus preventing or making less likely the arrival of the pest to the main crop and/or concentrating it in the trap crop where it can be economically destroyed. This modality was the primary focus of the two previous reviews (Javaid & Joshi, 1995). One of the most widely cited examples of successful conventional trap cropping, which served as a major contributor to the development of IPM in the central valley of California in the 1960s, is the use of alfalfa as a trap crop for lygus bugs in cotton (Godfrey & Leigh, 1994).

Genetically engineered trap cropping, this modality of trap cropping may not be considered unique in and of itself because it can produce plant characteristics that fit other modalities we describe. However, because of its present importance and growing potential, we believe it bears special consideration. There are already examples of genetic engineering (i.e., the deliberate manipulation of genes through the use of biotechnology) in trap cropping, and its importance in the development and improvement of trap crops is likely to increase in the future. For example, potatoes that have been genetically engineered to express proteins from *Bacillus thuringiensis* (Bt) have been used as trap crops to manage Colorado potato beetle (*Leptinotarsadecemlineata*) populations. If Bt potatoes are planted early in the season to attract immigrating Colorado potato beetle, they can act as an early season, dead-end trap crop and prevent colonization of the interior of the field that is planted to non-Bt potatoes (Hoy, 1999).

## 4. Modalities Based on the Deployment of the Trap Crop

Trap cropping should be viewed in the larger context of landscape ecology. Within any agro ecosystem there is a changing mosaic of habitats that vary through time in their attractiveness and suitability to insect pests and/or their natural enemies (Kennedy & Storer, 2000). From the standpoint of trap cropping, the most relevant parameters of the land scape structure are those that refer to the spatial pattern of vegetation patches, including their distribution, size, shape, configuration, number, and type. Insects and their host plants interact and become influenced by size, fragmentation, and connectivity of host patches (Tscharntke & Brandl, 2004).

Perimeter trap cropping, perimeter trap cropping can be defined as the use of a trap crop planted around the border 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 (Boucher et al., 2003).

Sequential trap cropping**,** this modality involves trap crops that are planted earlier and/or later than the main crop to enhance the attractiveness of the trap crop to the targeted insect pest. An example of this is the use of an early-season trap crop of potatoes to manage Colorado potato beetles, which we described also as a perimeter trap cropping example (Hoy et al., 2000).

Multiple trap cropping, multiple trap cropping involves planting several plant 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 whose growth stages enhance attractiveness to the pest at different times. All the multiple trap cropping cases that we found in the literature belong to the latter category. For example, a mixture of Chinese cabbage, marigolds, rapes, and sunflower has been successfully used as a trap crop for the pollen beetle, *Melighetesaeneus*, in cauliflower fields in Finland (Hokkanen, 1989).

Push-pull trap cropping, push-pull (Pyke et al., 1987. Khan et al., 2001) or “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 insectpest and, combined with the repellent intercrop, diverts the insect pest away from the main crop (Miller & Cowles, 1990).

## 5. Additional Trap Cropping Modalities

Biological control-assisted trap cropping**,** our definition of trap cropping focuses on the interactions between the plant and the pest rather than on the natural enemies of the insect pest. We chose this delineation to preserve the distinction between habitat manipulation for enhanced biological control and the various examples of what we suggest constitute trap cropping (Landis et al., 2000). Semiochemically assisted trap cropping, principles underlying the effects of trap cropping on insect behavior are similar to those behind semiochemicals and other behavior-based methods for pest management (Foster & Harris, 1997). In conventional trap cropping, attraction to the plant may be due to semio chemicals naturally produced by the trap crop. 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 semiochemicals. 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 (Borden & Greenwood, 2000).

## 6. CHARACTERISTICS OF A TRAP-CROP PLANT

Shelton & Badenes-Perez (2006); Majumdar (2010) described conventional trap cropping as a practice whereby a trap crop is planted or sown next to the main crop (a higher-value crop or a crop to be protected) which is more attractive than the main crop. Therefore, the trap crop will serve as a food source or ovi position. The trap crop will then divert the pest from the main crop so that, it can be destroyed in the trap crop if necessary. Alfalfa has been used as a trap crop for Lygus bugs in cotton. The highly attractive varieties of squash have also been used as a trap crop to manage squash bugs and cucumber beetles in several cucurbitaceous crops.

A dead-end trap crop attracts insects highly, but the offspring cannot survive on the same plant. This plant serves as a sink for pests, thereby preventing them from migrating from the trap crop to the main crop later in the season. Sun hemp has been suggested as a dead-end trap crop for the bean pod borer. Shelton et al.,(2006) suggest that dead-end trap crops should be planted at the borders of the main crop, where they can intercept insect pests and reduce pest damage in the field.

Shelton & Badenes-Perez, (2006) confirm that genetically engineered trap-crop genes are intentionally manipulated through the use of biotechnology. The potatoes which have been used as a trap crop to manage Colorado potato beetle (*Leptinotarsadecemlineata*) populations were genetically engineered to express proteins from *Bacillus thuringiensis*(Bt). Genetically engineered trap cropping can also be used as an early season trap crop for Colorado potato beetle.

## 7. TRAP CROP DEPLOYMENT

The main distinguishable modalities of trap cropping, based on their deployment, are perimeter, sequential, multiple and push-pull trap cropping (Shelton et al., 2000). The more attractive trap crops are planted at the field margin, where they protect the main crop from insect pests Majumdar, (2012), planted potatoes early and they were used as a border trap for Colorado potato beetles (Cook et al., 2007) The Colorado potato beetles passed through from 11 Over wintering sites close to the main crop and became concentrated on the outside rows. They could then be easily treated mechanically, culturally or chemically.

Sequential trap cropping was practised by Shelton & Badenes-Perez (2006) when they used Indian mustard as a trap crop for diamond-back moths. They indicate that Indian mustard needs to be planted two or three times before the cabbage season because they have a short crop cycle. They further indicate that sequential trap cropping improves the attractiveness of the trap crop.

Badenes-Perez et al., (2005) implemented multiple trap cropping with the purpose of controlling several insect pests or improving the control of one pest by combining plants’ growth stages to promote attractiveness to the pest. Shelton et al., (2000) indicate that a mixture of Chinese cabbage, marigold, rape and sunflower have been used successfully as trap crops for pollen beetles (*Melighetesaeneus)* in cauliflower fields in Finland. Castor, millet and soya beans were also used to control ground nut leaf miner (*Aproaremamedicella*) by Shelton et al., (2000) as multiple trap crops. They further implemented a combination of corn and potato plants in fields of sweet potato as trap crops to control wireworm.

Push-pull trap cropping, as practiced by Shelton et al., (2000) ; Cook et al., (2007), entails planting a pull component (the trap crop) in order to attract the insect pest and a push component (a repellent intercrop) to distract them away from the main crop. They confirmed the planting of Napier and Sudan grass as a push-pull trap crop around the main crop and plant desmodium or molasses grass within the field as a repellent intercrop to control stem borer for corn production. They encouraged the use of molasses grass as a repellent intercrop because it promotes and improves stem borer parasitoid abundance and control in the fields.

## 8. Applications of Trap Cropping in Insect Pest Management.

**Table1.** *Recent and most relevant attempts to use trap cropping in insect pest management*

| Insect pest species | Country | Crop | Trap crop (modality)a | Reference(s) (Level of implementation)b |
|---|---|---|---|---|
| Order Coleoptera: beetles and weevils *Acalymmavittatum*(F.)<br>Striped cucumber beetle | United States | Cucurbitaceae<br>Cucumber<br>Cucurbitaceae | Cucurbitaceae (C, S)<br>Squash (C)<br>Squash (C, S, SA) | (48) (F)<br>(100) (F)<br>(90, 91, 125) (F, S) |
| *Agriotesobscurus*(L.)<br>Dusky wireworm | Canada | Strawberry | Wheat and other grains (M, S, SA) | (137, 138) (F) |
| *Anthonomusgrandisgrandis*<br>Boheman Boll weevil | United States | Cotton | Cotton (SA) | (63) (U) |
| *Ceutorhynchusassimilis*(Paykull)<br>Cabbage seedpod weevil | United States | Oilseed rape | Oilseed rape (S) | (22) (E, U) |
| *Conoderus*spp. Wireworm | United States | Sweetpotato | Corn and wheat (M, S) | (113) (F) |
| *Dendroctonusponderosae*<br>Hopkins | Canada | Coniferae | Coniferae logs and trees (SA) | (18, 19) (S) |
| *Dryocoetesconfusus*Swaine<br>*Dendroctonusrufipennis*Kirby<br>Bark beetles | United States | | | |
| *Diabroticaundecimpunctata howardi*Barber | United States | Peanuts | Squash (S) | (16) (F) |
| Southern corn rootworm | | Cucurbitaceae | Cucurbitaceae (C, S) | (48) (F) |
| *Leptinotarsadecemlineata* (Say) | United States | Potato | Potato (S, SA) | (52, 53, 80, 81, 140) (P, F) |
| Colorado potato beetle | Canada | Tomato | Potato (S) | (54) (F) |
| *Melighetesaeneus*F. | Finland | Cauliflower | Chinese cabbage, marigolds, rapes, and sunflower (M) | (49) (S) |

*A Modalities include conventional (C), multiple (M), biological control–assisted (E), dead-end (D), genetically modified (G), sequential, early, and/or late planting (S), semio chemically assisted (SA), push-pull (PP), and perimeter (P) trap cropping. bLevels of implementation include unsuccessful, no potential shown in preliminary studies in the field and/or the laboratory (U); behavioral observation (BO); good potential shown in preliminary studies in the laboratory, greenhouse, and/or screen house (P); good potential shown in preliminary studies in the field (F); and successfully used by growers in commercial fields (S).*

Attempts to use trap cropping in insect pest management have been common in entomological research. Table 1 summarizes recent and relevant references on trap cropping and is organized by insect order and species, location of testing, crop, and modality of trap crop used. It also includes the level of implementation of the trap crop and our interpretation of whether it was successful. Success in preliminary laboratory, greenhouse, screen house, or field studies may not necessarily result in a successful use at the commercial level, where additional variables and different environmental conditions may affect insect behavior. Adoption of trap cropping is also dependent on the potential economic return to the grower in a particular situation. In those cases in which we classify a particular trap cropping system as successfully used in commercial fields, we could not find reliable data on the actual area in which it is grown

## 9. Increasing the Effectiveness of Trap Crops

In general, combining biological and/or insecticidal control to supplement the effects of the trap crop can increase the effectiveness of a trap crop. In addition to the inherent characteristics of a particular plant used as a trap crop, insect preference can be altered in time and space to enhance further the effectiveness of a trap crop. Plant breeding can be used to develop trap crop cultivars with enhanced attractiveness to the insect pest and/or low larval survival, such as glossy wax traits (Eigen brode et al., 1991), or attractiveness to natural enemies (Loughrin et al., 1995; Poppy & Sutherland, 2004). Enhancing the effectiveness of the trap crop is vital to minimize the land sacrificed to production when using trap cropping (Badenes-Perez et al., 2005).

General guidelines for trap cropping recommend that about 10% of the total crop area be planted with the trap crop (Hokkanen, 1991), although the percentage of trap crop needed for each particular system has to be determined for each case. For example, to reduce diamondback moth populations, between 5 and 13% of the crop area should be reserved for the trap crop (Srinivasan & Krishna Moorthy, 1991). Cultural control methods can also be used to increase the effectiveness of trap crops. Host utilization by most insect herbivores, particularly specialists, is consistent with the resource concentration hypothesis in that they are more likely to find and remain in hosts that are concentrated (Root, 1973). For example, diamondback moth adults were more attracted to large groups of collard plants than to small groups (Maguire, 1983), as well as to larger plants and higher planting densities (Badenes-Perez et al., 2005).Water stress can also increase the attractiveness to certain insect pests in some plants (Rubberson, 1996.Showler& Moran, 2003) but not others (Slosser, 1980), indicating that some trap cropping systems could benefit by controlling water stress. The spatial arrangement of the trap crop is also important and is discussed in more detail below.

## 10. Factors Determining the Success of Trap Cropping Systems

The most important insect characteristics that determine whether an insect may be subject to management by trap crops are the insect stage targeted by the trap crop and the insect's ability to direct its movement, its migratory behavior (mobility and mode of colonization), and its host-finding behavior (pre-alighting versus post-alighting). The insect stage to be controlled by the trap crop is of critical importance in designing an effective trap crop strategy. For example, adult female Lepidoptera select plants for ovi position but it is the larvae, which typically have limited mobility, that are the damaging stage (Renwick, 1989). On the other hand, it is the mobile adult crucifer flea beetle, *Phyllotreta*spp. that selects host plants and causes injury. To select a successful trap crop in the first case requires knowledge of the ovipositional preference; in the second case knowledge of adult feeding preference is required. The ability of insects to direct their movements as a result of the presence of the trap crop should also be considered in the deployment of trap crops (Potting et al., 2005).

In simulation models, Potting et al. (2005) concluded that small insects with limited ability to detect hosts and move to them would be unsuitable for trap cropping, citing studies conducted with the hop aphid, *Phorodonhumuli* (Losel et al., 1996),and the whitefly, *Bemisiaargentifolii*, as evidence (Smith and McSorley, 2000). Colonization patterns of these insects are largely due to passive, random, high-altitude aerial dispersal. However, trap crops taller than the main crop and planted in the borders could act as barrier crops (Fereres, 2000). On the other hand, larger insects in the orders Coleoptera and Lepidoptera generally have an enhanced capacity for directional flight that makes them more amenable for trap cropping (Potting et al., 2005). For example, some trap crops elicit aggregation and partial inhibition of flight (arrestment) in diamondback moth, reducing its movement and colonization of the main crop (Badenes-Perez et al., 2005). The spatial arrangement of the trap crop should be reflective of the patterns of field colonization by the insect. For insects that move into the field (e.g., Colorado potato beetle) rather than emerge from the field (e.g., Southern corn rootworm) after over wintering, a high perimeter-to-area ratio may increase the chances of a perimeter trap crop intercepting the insect pest (Hannunen, 2005). Regarding host-finding behavior, the strength of arrestment seems to be the most important parameter influencing the effectiveness of a trap crop in insects with post-alighting host-recognition behavior (Bukovinsky et al., 2005,Potting et al., 2005). However, in insects that use olfactory or visual cues to find plants, the actual aggregation in the trap crop was a combination of attraction and arrestment.

## 11. Conclusions and Recommendations

The perimeter and inside-row trap-cropping methods were conventionally implemented. The trap crops attracted high numbers of pentatomid bugs at the flowering and seed-formation stage. All these substantiate the contention that stinkbugs are insects that have the potential to be managed with trap crops. If the right trap crops can be found and applied correctly, it could lead to ecologically and environmentally sustainable management techniques that could be considered in future agricultural ecosystems. Trap crops should be sown earlier or on the same day as the commercial crop, so that the flowering or 34 fruit set will coincide with the commercial crop fruit development. The trap crop should be irrigated and fertilized, so that it will grow well, which in turn will promote its ability to intercept the insect pest. The trap crops need to be sown at least 1 m away from the main crop to avoid shading. Alternatively, one could practice strip trap-cropping, with rows of trap crops adjacent to the main crop around the perimeter as well as inside the field.

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