Trap Cropping

9

Abstract

Trap crops are plants grown before or with the main crop in a smaller area (the trap crop). They are the more preferred hosts when grown with the main crop. Trap crops can increase the efficiency of control by concentrating the pests in one location and by applying a chemical treatment without spraying the main crop, or by destroying the trap crops and associated pests through tillage or burning. It is also possible to release biological control agents into the trap crops, using it as a nursery for beneficial organisms that will then spread into the main crop. The trap crops are effectively employed for the control of several herbivores, nematodes, and weeds in several agroecosystems. Trap cropping is economical to adopt, saves on input use, and is effective against pests, resulting in increased productivity.

Keywords

Antagonist crops • Insect pests • Weeds • Nematodes • Pest management

9.1 Introduction

There is a growing interest in utilizing plant biodiversity for the control of herbivores with some cultural approaches, including trap cropping. This was one of the most common herbivore management practices adopted by farmers from ancient times before the use of chemical pesticides after the Second World War (Thurston 1991; Talekar and Shelton 1993). There is a need to revert to trap cropping in view of negative externalities of chemical control. It can be combined with other methods to enhance pest management.

Trap crops, which are more attractive than main crops, are grown in a smaller area in order to trap the pests before or with the main crop in many cases. Before the

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trap crop matures, it is uprooted and destroyed so that main crop is protected from pests (Hokkanen 1991; Shelton and Badenes-Perez 2006).

Efficiency of pest management can be enhanced by concentrating the pests in one location and destroying them by applying a chemical treatment without spraying the main crop or by destroying the trap crops and associated pests through tillage or burning. The biological control agents can also be released into the trap crops, using it as a nursery for beneficial organisms that will then spread into the main crop. Kuepper and Thomas (2002) reported that the organic farmers can employ this technology for pest management without the use of chemical pesticides. For example, Zalom et al. (2001) recommended this system for the management of Lygus bugs, *Lygus lineolaris*, in organic strawberry production.

The devastating pests which are widely distributed can be managed by using trap cropping strategy. This system is most suitable for herbivores that are fairly sedentary as compared to highly mobile ones and which are carried away by wind. Trap crops, which require a limited space relative to the main crop, are easily planted and maintained and are most economical to use in this system. The life cycle of concentrated pests on trap crops are controlled by using available management practices such as cultural approaches, biological control agents, or chemical pesticides.

9.2 Selection of Trap Crops

It is a knowledge-intensive practice which needs a clear understanding of pest's biology, host range, development and multiplication, spread and survival strategies to device management strategies. The following aspects should be kept in mind while selecting trap crops for pest management:

- They should simply become far more attractive than the main crop for feeding and oviposition.
- Trap crops should attract and contain the pests, preventing their spread to the main crop.
- The pattern of pest movement decides their planting. For example, planting trap crops around the borders of field may prevent the spread of the disease pathogen *Leptinotarsa decemlineata* in potato, while trap crops within the cash crop (maize) arrest the movement of the pathogen *Ostrinia nubilalis.*
- For economically feasible and effective pest management, the trap crops should occupy very limited area (about 10–15%) in the field (ESA 2003).
- Planting of "dead-end trap crop" such as bitter cress (*Barbarea vulgaris*) is preferable for egg-laying by diamondback moth (*Plutella xylostella*) (24–66-fold more than cabbage) and prevents pest movement to cabbage vegetable crop (Shelton and Nault 2004).

9.3 Types of Trap Cropping

9.3.1 Traditional Trap Cropping

The trap crop is normally highly receptive than the main crop with respect to feeding and egg-laying and blocks the entry of pests to the cash crop. The pests are aggregated on the trap crop, which can be easily controlled using cultural, biological, and chemical methods. For example, Godfrey and Leigh (1994) reported that the Lygus bugs (*Lygus lineolaris*) on cotton can be managed by using alfalfa in central valley, California. Similarly, Pair (1997) reported that the conventional trap crop such as squash is being used commercially to control pests such as *Anasa tristis* and *Acalymma vittatum* in cucurbits.

Srinivasan and Krishna Moorthy (1991) have developed a trap cropping strategy by using *Brassica juncea* for the management of diamondback moth (*Plutella xylostella*) and other pests of cabbage and cauliflower and to increase crop productivity. This technology was demonstrated in several farmers' fields which gave effective control of cabbage and cauliflower pests and increased the yields significantly (Table 9.1) (Khaderkhan et al. 1998; Krishna Moorthy et al. 2003).

Sesame is also being employed for attracting the herbivore *Plutella xylostella* on cruciferous crops. Similarly, cauliflower intercropped with noncrucifer host plants like sunflower, tomato, and marigold was highly effective in reducing the aphid incidence and enhancing the number of natural enemies, resulting in higher yields. Likewise, intercropping of gerbera with field bean (*Lablab purpureus*) as a trap crop is effective for the management of leaf miner.

Srinivasan et al. (1994) have developed trap cropping technology for the management of tomato fruit borer, *Helicoverpa armigera*, by using African marigold, *Tagetes erecta*, as a trap crop. The pests concentrated on marigold are managed by using a biological control agent (*Ha* NPV at 250 LE/ha) or neem products (4% NSKE or 4% pulverized NSPE, 28 and 45 DAP). The effectiveness of this technology in managing the pest and increasing the fruit yields was demonstrated in farmers' fields across three states in India (Table 9.2) (Amerika Singh et al. 2004).

Shivaramu (1999) has developed a trap cropping technology for the management of chili fruit borer *H. armigera* using marigold as a trap crop (Fig. 9.1). This strategy was found very effective in suppressing the chili fruit borer and increasing the fruit yields significantly. Similarly, trap cropping strategy has been utilized for the management of *Liriomyza trifolii* in *Lablab purpureus*, *Meloidogyne* spp. on

Table 9.1 Management of cabbage pests using Indian mustard as a trap crop

Practice	% yield increase	% increase in net returns	Cost:benefit ratio
Indian mustard trap cropping	57	591	1:2.42
Traditional method (cabbage sole crop)	–	–	1:0.83

Source: Krishna Moorthy et al. (2003)

Table 9.2 Management of tomato fruit borer using African marigold as trap crop

Location	Practice	Tomato fruit yield (tons/ha)	Net returns (Rs.)	Cost:Benefit ratio
Bangalore, Karnataka	African marigold trap cropping	74.03	249,721	1:4.82
	Sole tomato	45.05	69,704	1:0.61
Varanasi, Uttar Pradesh	African marigold trap cropping	14.25	39,917	13.30
	Sole tomato	13.00	38,167	1:2.02
Ranchi, Jharkhand	African marigold trap cropping	22.29	56,705	1:1.87
	Sole tomato	18.77	41,776	1:1.32

Source: Amerika Singh et al. (2004)

Fig. 9.1 Management of chili fruit borer using marigold as a trap crop

Solanum tuberosum, *Pomacea canaliculata* and *Pomacea maculata* on *Oryza sativa*, *Busseola fusca* on *Zea mays*, *Spilosoma obliqua* on *Vigna unguiculata*, and *Lygus hesperus* on *Gossypium* spp. and *Fragaria* × *ananassa* using *Chrysanthemum indicum, Tagetes erecta, T. patula, Sorghum vulgare, Sesamum indicum,* and *Medicago sativa* as trap crops, respectively (UC IPM 2011).

9.3.2 Dead-End Trap Cropping

The dead-end trap crops are highly receptive to crop pests which cannot survive on these crops and prevent their entry into cash crops (Shelton and Nault 2004; Badenes-Perez et al. 2005). For example, bitter cress and sun hemp act as dead-end traps against Lepidopterous pests of crucifers and French bean main crops (Shelton and Nault 2004; Lu et al. 2004; Jackai and Singh 1983). Generally, dead-end trap crops are located at crop edges and are highly receptive for egg-laying by pests belonging to Order Lepidoptera (Thompson and Pellmyr 1991).

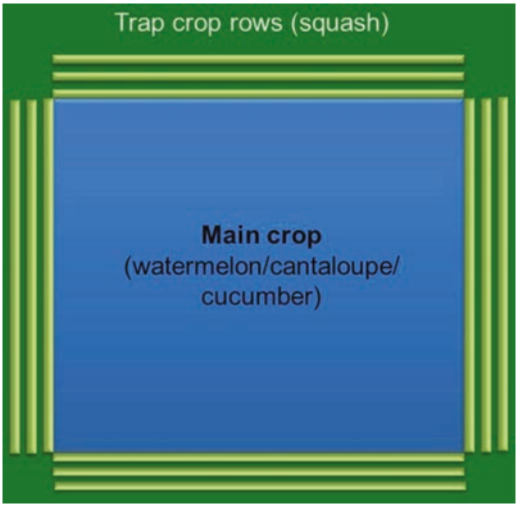

Fig. 9.2 Perimeter trap cropping for pest management

9.3.3 Genetically Engineered Trap Cropping

The deliberate gene manipulation through the use of biotechnology (genetic engineering) is the main basis on which the future trap crops are being developed for pest management. For example, Hoy (1999) reported that planting of Bt (*Bacillus thuringiensis*) potatoes early in the season acts as dead-end trap crops to attract immigrating ten-lined potato beetles to the main non-Bt potatoes planted later. Likewise, Cao et al. (2005) reported that crop pests belonging to Lepidoptera were controlled by using Bt collard green as a dead-end trap crop.

Genetically engineered trap crops can also be used to manage insect vector spread stylet-borne viruses, as they remove the virus rapidly from the insect's stylet (Fereres 2000). For example, the papaya ring spot virus (PRSV) is managed by both commercially growing PRSV-resistant papaya or by using it as a trap crop (Gonsalves 1998; Gonsalves and Ferreira 2003), since PRSV is difficult to manage with insecticides.

9.3.4 Perimeter Trap Cropping

Incorporation of spatial orientation of attractive crops (to attract insect pests from the main crop), natural population regulators, and plant attributes; to redesign the system of crop production to improve pest management is called perimeter trap cropping (PTC) (Fig. 9.2) (Boucher et al. 2003). The perimeter trap crops attract pests from the main crop, which can be managed by using cultural, biological, or chemical methods. The pests that are likely to attack the crop at border area are managed effectively by this technology. The efficacy of trap cropping has been dramatically increased on a variety of crops in recent years.

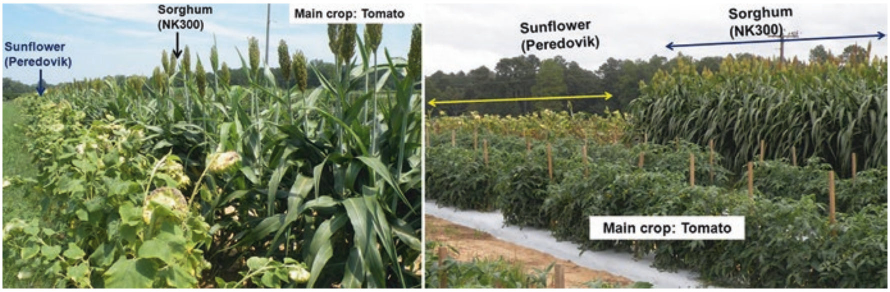

Fig. 9.3 *Left* – Perimeter trap crop design with sunflowers planted behind sorghum NK300. *Right* – Tomatoes were planted on the other side of sorghum (Majumdar et al. 2012)

Hoy et al. (2000) reported that early planting of potato plants in the perimeter was highly receptive to *Leptinotarsa decemlineata*, which can be controlled by cultural, biological, or chemical methods to prevent their entry into the main potato crop. Similarly, Bt potatoes can also be used to control *L. decemlineata* on main potato crop (Hoy 1999). Likewise, Aluja et al. (1997) suggested planting of perimeter papaya trees to reduce fruit fly, *Toxotrypana curvicauda*, damage.

Planting of early-maturing sunflowers around oilseed sunflowers gave effective and economic control of the red sunflower seed weevil, *Smicronyx fulvus* (Brewer and Schmidt 1995). This strategy can be used to control *Acalymma vittatum* and *Melittia cucurbitae* on *Cucurbita pepo* using *Cucurbita pepo* cv. Blue Hubbard on field border, which also prevented the incidence of bacterial wilt spread by *A. vittatum* (Boucher and Durgy 2003). The trap crop *Capsicum annuum* cv. Hot Cherry Pepper gave protection against *Zonosemata electa* on Capsicum, and increased the net profits by $382 per ha as compared to 15% of the fruit infested in control (Boucher et al. 2003). Commercial farmers using PTC harvested 99.99% clean capsicum fruit.

Input requirements on insecticides have been dramatically reduced by using perimeter trap cropping. Mitchell et al. (2000) reported that the diamondback moth (DBM) infestations on cruciferous vegetable crops in Florida were effectively managed by perimeter trap cropping with *Brassica oleracea*. The DBM population on the collards (*Brassica oleracea*) was reduced by a naturally occurring parasitic wasp *Diadegma insulare* and prevented its spread into cabbage crop. Pesticide cost was saved to the extent of $118 to $158 per ha in view of 56% fewer insecticide sprays to manage DBM than in conventional fields.

Western flower thrips in pepper fields were managed by planting sunflower on the perimeter, which encouraged the buildup of predatory minute pirate bugs (*Orius* spp.) in Florida (Funderburk et al. 2011).

Perimeter trap cropping system incorporating sorghum (NK 300) and Peredovik sunflower provided significant reduction of leaf-footed bugs in tomato, resulting in significant reduction in pesticide usage (Fig. 9.3). Treatment of sorghum at peak leaf-footed bug activity with insecticide gave 78–100% control of the pest without the need for treating the main crop (Majumdar et al. 2012).

Fig. 9.4 Stimulo-deterrent diversion trap crop strategy for pest management

9.3.5 Sequential Trap Cropping

In this system, the attractive crop is grown before or after the cash crop. The sequential trap cropping has been utilized for the management of the herbivores such as *Leptinotarsa decemlineata* on *Solanum tuberosum*, *Plutella xylostella* on *Brassica oleracea* var. *capitata* and *Agriotes obscures* on *Fragaria* × *ananassa* by early planting with trap cops like *Solanum tuberosum*, *Brassica oleracea* and *Triticum vulgare*, respectively (Hoy et al. 2000; Pawar and Lawande 1999; Vernon et al. 2000).

9.3.6 Multiple Trap Cropping

In this system, various trap crops are grown simultaneously to improve the management of multiple crop pests. For example, Hokkanen (1989) reported that simultaneous planting of trap crops such as *Brassica rapa*, sub spp. *Pekinensis* and *chinensis*, *Tagetes erecta*, *Brassica napus*, and *Helianthus annuus* for the management of beetles feeding on pollen of *Brassica oleracea.* Similarly, the groundnut leaf miner, *Aproarema medicella*, can be managed by planting several attractive trap crops such as *Ricinus communis*, *Pennisetum glaucum*, and *Glycine max* (Muthiah 2003). Likewise, Seal et al. (1992) found that wireworms in sweet potato fields can be managed by simultaneously growing of *Solanum tuberosum* and *Zea mays* as attractive crops.

9.3.7 Push-Pull Trap Cropping

The "stimulo-deterrent diversion trap crop strategy" can be employed to manage stem borers and *Striga* weed on maize and sorghum. In this strategy, repellent intercrops are used for driving stem borers away ('push'), and attractive trap crops are used in the crop border to attract female moths ('pull') to lay eggs (Fig. 9.4). Besides controlling stem borers, Molasses grass enhances natural enemy population (*Cotesia* sp.), when intercropped with maize (Khan et al. 1997). The intercrop *Pennisetum* *purpureum* secretes gummy substance which restricts larval development, causing few to survive (Khan et al. 2006).

Push-pull trap crop strategy can also be adopted to control Old World (African) bollworm of cotton (Duraimurugan and Regupathy 2005), pea leaf weevil, *Sitona lineatus* in beans (winter peas as trap crop) (Smart et al. 1994), *Leptinotarsa decemlineata* on *Solanum tuberosum* (Martel et al. 2005), beetle that feeds on field mustard (Potting et al. 2005), maggot, *Delia antigua* on onions (onion culls as trap crop) (Miller and Cowles 1990), and thrips, *Frankliniella occidentalis* on chrysanthemums (chrysanthemum cv. Springtime as trap plants that are most attractive) (Bennison et al. 2001) (for further details on push-pull strategy, see Chap. 12).

9.3.8 Biological Control-Assisted Trap Cropping

In this strategy, attractive crops increase population of biological control agents to manage crop pests. Virk et al. (2004) found that the rates of parasitism of cotton bollworm, *Helicoverpa armigera* by *Trichogramma chilonis* increased when the sorghum was used as a trap crop. Besides controlling stem borers, the trap crop Molasses grass enhance the population of biocontrol agent *Cotesia* sp. when intercropped with maize (Khan and Pickett 2004).

Planting of cowpea as a bund crop attracts *Cheilomenes* spp.; maize as intercrop is known to encourage *Chrysoperla carnea*; growing cowpea as trap crop increases the parasitization of *H. armigera* larvae and predation of eggs by coccinellids; growing *Tagetes* spp. as border crop attracts heavy egg-laying by *H. armigera* which in turn attracts parasitization by *Trichogramma* spp.

Cowpea varieties CO-2 and CO-4 harbored the highest population of legume aphid, *Aphis craccivora*, and whiteflies which are attracted by predatory ladybird beetles in large numbers. Similarly, cowpea cultivars CO-2, CO-4, and C-152 harbored aphids and leafhopper *Empoasca kerri*, which are attracted by ladybird and spider predators which fed on aphids and nymphs of leafhoppers.

9.3.9 Semiochemically Assisted Trap Cropping

The attraction of insect pests to the trap crop involves the production of pheromones by the trap crops to enhance their effectiveness. For example, Borden and Greenwood (2000) employed baiting of trees with semiochemical traps to manage the spruce and bark beetles (*Dendroctonus rufipennis* and *Dryocoetes confusus*). The fruit flies in papaya orchards can be managed by baiting trees in the border with semiochemical traps (Aluja et al. 1997). Vernon et al. (2000) found that the effectiveness of traps can be enhanced by treating border winter pea plants with the aggregation pheromone to enhance the concentration of pea leaf weevils (Smart et al. 1994). *Leptinotarsa decemlineata* on *Solanum tuberosum* is managed by using semiochemicals that can enhance attraction (Dickens et al. 2002).

9.4 Advantages and Benefits

9.4.1 Advantages

The advantages of perimeter trap cropping are as follows:

- Complement current pest management program.
- Difficult to control pest's damage but can be restricted to border plants.
- Savings in pesticide costs and improvement in crop quality.
  - Development of pesticide resistance is delayed.
  - Less environmental and safety concerns.
  - Lower pesticide costs and reduce pesticide residues.
- Negative externalities of chemical pesticides can be reduced.
- Biological control agents are encouraged.

9.4.2 Benefits

Trap cropping offers several benefits in pest management systems, which include the following:

- Pests of cash crops are reduced.
- Cash crops need not be sprayed with chemical pesticides.
- Cost of maintaining trap crops is compensated by economizing on input costs.
- Increase in marketable yield.
- Naturally occurring biocontrol is enhanced by increased concentration of insect pests on trap crops which may attract natural enemies.
- Synergistic effects due to integration of multiple trap crops (Martel et al. 2005).
- Semiochemicals are effectively utilized to enhance concentration of insect pests on trap crops (Raffa and Frazier 1988).
- Chances of pests developing resistance to pesticides is limited, since noninsecticidal components/reduced amounts of pesticides are used (Foster et al. 2005).

In summary, use of trap crops for the management of various insect pests on several crop plants is presented in Table 9.3.

9.5 Nematode Management

Vigna unguiculata and *Crotalaria* species act as trap crops for the management of root-knot nematodes (*Meloidogyne* species). Planting of *V. unguiculata* early in the season helps to trap the root-knot nematodes in their root system, which are destroyed earlier to nematode reproduction, before taking up the main crop. Similarly, early-season planting of *Crotalaria* species attracts the root-knot

Table 9.3 Effect of trap crops for the management of various insect pests on several crops

Main crop/s	Trap crop/s	Insects managed
Cotton	Lucerne	*Lygus hesperus*
	Castor, Bengal gram, corn, tobacco, cowpea, sunflower	*Helicoverpa* spp.
	Okra	Flower weevil
	Cotton	Cotton boll weevil, *Anthonomus grandis*
Garlic	Basil, marigold	Thrips
Vegetables, ornamentals	Chervil	Slugs
Cabbage	Collards	Diamondback moth
	Brassica rapa sub sp. *chinensis, Brassica juncea, Raphanus raphanistrum* sub sp. *sativus*	*Hellula undalis, Halticus tibialis, Lipaphis erysimi*
Corn	*Phaseolus vulgaris*	*Liriomyza trifolii*, *Cerotoma trifurcata*, *Ophiomyia phaseoli*, *Spodoptera frugiperda*
	Sudan grass	Stem borer
	Glycine max	*Helicoverpa* spp.
	Vetiver	Corn stalk borer
Corn, cowpea, millet, sorghum	Desmodium	*Chilo partellus*
Tomato	*Anethum graveolens, Levisticum officinale*	*Manduca quinquemaculata*
Potato	Tansy, horse radish	Colorado potato beetle
	Potato	*Leptinotarsa decemlineata*
Bell pepper	Hot cherry pepper	*Zonosemata electa*
Vegetables (Solanaceae, Brassicaceae, Leguminosae, Cucurbitaceae)	Marigold (French & African)	*Meloidogyne* spp.
Carrot	Medick	*Chamaepsila rosae*
	Onion, garlic	*Chamaepsila rosae, Thrips tabaci*
Brassica oleracea	Nasturtium	Aphids, *Phyllotreta cruciferae*, cucumber beetle, squash vine borer
	Brassica juncea	*Crocidolomia binotalis*
	Tomato	*Plutella xylostella*
Brassicaceae (Cruciferae)	Radish	*Phyllotreta cruciferae*, *Delia radicum*

(continued)

Table 9.3 (continued)

Main crop/s	Trap crop/s	Insects managed
Soybean	*Secale cereale*	*Delia platura*
	Sesbania bispinosa	*Acrosternum hilare*
	Senna obtusifolia	*Anticarsia gemmatalis*, *Acrosternum hilare*
	Green beans	Mexican bean beetle
	Snap bean	Stink bugs, Mexican bean beetle, bean leaf beetle
Rape	Rape, marigold, cauliflower	Blossom beetle, *Meligethes aeneus*
Pine trees	Pine logs	Pine shoot beetle, *Tomicus piniperda*
Spruce	Spruce tree logs	Spruce bark beetle, *Ips typographus*

nematode larvae to infect the roots, but the nematode is not able to complete the life cycle (Cook and Baker 1983).

Mohandas (2001) reported that planting of sweet potato cv. Shree Bhadra acts as a dead-end trap crop which allows the root-knot nematode larvae to enter the roots but does not allow the nematode development and reproduction, resulting in drastic reduction of *Meloidogyne* population in soil. Subsequently, crops like okra, tomato, coleus, and African yam which are susceptible to root-knot nematodes can be taken up profitably.

Growing of French marigold, *Tagetes patula* trap crop in alternate rows with potato was found effective in reducing larval population in soil, root galling and tuber infestation while the yields increased up to 123% over control.

Solanum sisymbriifolium, which is highly susceptible to cyst nematodes, acts as a trap crop for the control of *Globodera rostochiensis* and *G. pallida* on potato.

Tomato nursery beds previously planted with trap crop (marigold) effectively controlled root-knot nematodes and also increased the germination of tomato seeds and production of healthier (nematode-free) seedlings (Rangaswamy et al. 1999).

Root-knot nematodes on brinjal were managed by early planting of knol-khol as a trap crop, which was destroyed before taking up the main crop (Ayyar 1926).

9.6 Enhancing Effectiveness of Trap Crops

The efficacy of trap cropping is enhanced by integrating with other components like baiting with pheromone traps, use of sequential cropping with nonhosts, releasing natural enemies, and spraying chemical pesticides. Plant breeding can be employed in developing trap crop cultivars with glossy wax characters on leaves, or more attractiveness to natural enemies (Poppy and Sutherland 2004; Eigenbrode et al. 1991; Badenes-Perez et al. 2005).

Hokkanen (1991) recommended that in general, a small area can be utilized for planting the trap crop. About 5–13% of the crop area was employed for the management of *Plutella xylostella* on Cole crops (Badenes-Perez et al. 2005; Srinivasan and Krishna Moorthy 1991).

According to Root (1973), the specialist insect herbivores are contained within the field and prefer larger plants, higher planting densities, and enough moisture as per resource concentration hypothesis (Badenes-Perez et al. 2005; Maguire 1983; Showler and Moran 2003).

9.7 Conclusions and Recommendations

The successful implementation of trap cropping systems has provided the long-term and sustainable management of pests which are difficult to control both in developing (e.g., use of stimulo-deterrent diversion trap crop strategy to manage *Chilo partellus* in maize) and in developed countries (e.g., *Lygus hesperus* on *Gossypium* species). Genetic engineering has provided additional avenues in this strategy in case of PRSV-resistant papaya and Colorado-beetle-resistant Bt potatoes. The more traditional trap cropping systems can be implemented commercially in case of capsicum against *Zonosemata electa* (Boucher et al. 2003) and the use of *Brassica juncea* to manage *Acrosternum hilare* in maize (Rea et al. 2002).

In recent times, the interest in trap cropping strategy to manage crop pests is enhanced as indicated by the publication of more than 150 publications on the subject during the last two decades. The increased interest in trap cropping has been especially shown by organic growers, nongovernmental agencies, and State Agricultural Universities/Indian Council of Agricultural Research Institutes, particularly in underdeveloped regions. The concepts of this strategy to include the diverse modalities can be increasingly expanded by the interaction between the farmers, scientists, and extension educators.

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