Review

Application of Trap Cropping as Companion Plants for the Management of Agricultural Pests: A Review

Shovon Chandra Sarkar, Endong Wang, Shengyong Wu * and Zhongren Lei *

State Key Laboratory for Biology of Plant Diseases and Insect Pests, Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing 100193, China; shovon47@gmail.com (S.C.S.); edwang@ippcaas.cn (E.W.)

* Correspondence: sywu@ippcaas.cn (S.W.); zrlei@ippcaas.cn (Z.L.)

Received: 20 August 2018; Accepted: 21 September 2018; Published: 25 September 2018

Abstract: Companion planting is a well-known strategy to manage insect pests and support a natural enemy population through vegetative diversification. Trap cropping is one such type of special companion planting strategy that is traditionally used for insect pest management through vegetative diversification used to attract insect pests away from the main crops during a critical time period by providing them an alternative preferred choice. Trap crops not only attract the insects for feeding and oviposition, but also act as a sink for any pathogen that may be a vector. Considerable research has been conducted on different trap crops as companion plant species to develop improved pest management strategies. Despite this, little consensus exists regarding optimal trap cropping systems for diverse pest management situations. An advantage of trap cropping over an artificially released natural enemy-based biological control could be an attractive remedy for natural enemies in cropping systems. Besides, many trap crop species can conserve natural enemies. This secondary effect of attracting natural enemies may be an advantage compared to the conventional means of pest control. However, this additional consideration requires a more knowledge-intensive background to designing an effective trap cropping system. We have provided information based on different trap crops as companion plant, their functions and an updated list of trap cropping applications to attract insect pests and natural enemies that should be proven as helpful in future trap cropping endeavors.

Keywords: cultural control; biological-based control; integrated pest management; natural enemy

1. Introduction

Conventional agricultural practices have detrimental effects on the environment, human health and food security, including pesticide contamination of food, insect pest resistance to insecticides and the harm of non-target organisms, including pollinators and beneficial insects [1], resulting in a shift to alternative management strategies, namely biological control for insect pests [2]. Conservation biological control through vegetative diversification is an effective strategy for pest management. Several conservation biological control practices, such as “farmscaping”, have gained popularity in pest control due to their ability to fulfill essential criteria like efficacy, predictability and cost [3–5]. Trap cropping is a means of promising conservation biological control that involves growing another non-crop species in a selected area to attract pests from target crop, preventing pests from reaching the crop and finally to control that pest in order to reduce damage to the main crop [6,7]. Since the 1930s, there have been numerous reported cases of successful trap cropping for managing various insect pests, ultimately resulting in a substantial reduction in the use of pesticides in developing countries [6]. However, with high densities of pests on these new trap plants placed within agricultural fields, preventing insect pest dispersal from the trap plants back on to the focal crop is essential for trap cropping to provide meaningful pest control [8]. In fact, every successful trap cropping example
at a commercial scale has included some method to either reduce this dispersal by either increasing trap crop retention of pests or increasing pest mortality on the trap crop [8]. Biological control is one especially promising way to increase pest mortality on the trap crop, without having to spray the trap crop with pesticides. Fortunately, trap crops can potentially attract natural enemies of insect pests [9–11], and through predation and parasitism, these natural enemies reduce the ability of trap crops to act as pest breeding grounds to disperse back into the main crop.

Therefore, understanding the interactions between trap cropping and natural enemies may be essential to the future success of trap cropping systems. In this paper, we have reviewed the trap cropping literature with a focus on its potential to enhance biological control.

2. Function of the Trap Cropping System in Agriculture

2.1. Description of the Trap Cropping System

In organic crop production, pest management relies primarily on habitat manipulation through farmscaping and other biological control practices [12]. It has been observed that polycultures of crop species often lead to less damage from pests than monocultures of crops within a given area [13,14]. One explanation for this was proposed by Root [15], that polycultures can enhance biological control by offering greater host capacity for natural enemies while simultaneously complicating the pest habitat. A habitat manipulation through trap cropping capitalizes on the strong perimeter-driven behavior in multiple cropping systems [16–19].

Trap cropping is an attractive option to reduce dependency on conventional pest management practices through insecticides. Indeed, insecticides are costly and hazardous (even the organic ones), and some insect pests have developed resistance against them [20]. An example could be the stink bug (Hemiptera: Pentatomidae), which can further be exacerbated by their long life cycle, high capacity to disperse and polyphagous nature leading to a landscape-wide agro-ecosystem threat. Trap crops have been shown to effectively manage stink bugs (Halyomorpha halys Stål (Hemiptera: Pentatomidae)) in conventional and organic crop production systems [8,19]. Sorghum (Sorghum bicolor L.) has been successfully used as trap crop in cotton fields [17]. Similarly, black mustard reduced kernel injury by 22% in sweet corn caused by Nezara viridula L. (Heteroptera: Pentatomidae) [21]. An efficient trap crop system should have at least double the pest attraction capacity of the cash crop during its vulnerable stage with an easy management strategy and should cover no more than 2%–10% of the total crop area [7,8].

2.2. Factors that Affect the Efficacy and Practicality of Trap Cropping Systems

The basic factors for a successful trap cropping system are trap crop species and their spatial arrangement. In the following sections, we have discussed existing research that may benefit the development of trap cropping systems.

Different trap crop species can release different types of volatile compounds due to a specific elicitor that can attract insects [22]. Similarly, trap crop volatiles can attract and enhance the foraging efficacy of natural enemies in an agro-ecosystem. For example, volatiles emitted by several plants can attract green lacewing (Neuroptera: Chrysopidae) [23,24]. The behavioral response of pollen beetle (Meligethes aeneus Fabricius (Coleoptera: Nitidulidae)) is enhanced by volatiles released from turnip rape (Brassica rapa L. (Brassicaceae)) and oilseed rape (Brassica napus L. (Brassicaceae)) [25]. A multi-compound blend is more attractive than a single chemical constituent because herbivorous insect pests often locate and choose hosts using a blend of chemical cues [26,27]. Therefore, pairing of trap crop species might provide a long-term effect of attracting insect pests such that the host plants often vary in their chemical profiles through time [28,29]. For example, pestiferous beetles and bugs can be intercepted and arrested by highly attractive squash varieties for controlling herbivores and thus largely restrict pest damage for cucumber, butternut squash or watermelon crop production [1,30–32].
Successful reduction of noctuid moth’s (Lepidoptera: Noctuidae) infestation is possible when corn attracts them from vegetable crops and retains them as a trap crop [33,34].

Trap crop species are highly attractive to pests species and are inter-planted with susceptible crops, which can attract and divert pests from the main crop. This practice relies on the exploitation of insect preferences for certain host plants, based on visual, tactile or olfactory cues [35,36]. Therefore, in both long- and short-range host identification, pairing of a chemically attractive trap crop species with a second trap species that provides visual or tactile cues might more effectively draw in pests than either species alone [37]. Many different plant species have been tested to develop trap cropping systems. It is necessary that trap crop species have the same horticultural requirements of the crop with which they are grown, including similar light and temperature demands. For example, mung bean (Vigna radiata (L.) R. Wilczek (Fabaceae)) has been shown to be an effective trap crop for Apolygus lucorum Meyer-Dür (Hemiptera: Miridae) and is gradually being adopted for control of this pest in cotton fields in northern China [38]. Resistant cultivars of trap crops to improve health and longevity that can grow rapidly and inexpensively are also important factors. Sunflowers Helianthus spp. (Asteraceae) are a particularly pest-resistant trap crop option, as they have been used with success as attractive plants for coleopteran, lepidopteran and hemipteran pests [7,8].

The spatio-temporal arrangement of trap crop around the main crop is one of the vital factors for its effectiveness. There are many strategies for arranging a trap crop system. For example, Smyth et al. [39] recommended planting trap crops sequentially with main crops so that the attractive phenological stage of both crops can be presented at the same time. On the other hand, Potting et al. [34] reported that a trap crop with a border arrangement is the best arrangement. Field margin manipulation using a more attractive plant is quite common in integrated pest management programs. The strong perimeter-driven behavior of the brown marmorated stink bug (H. halys) and the brown stink bug (Euschistus servus Say (Hemiptera: Pentatomidae)) could potentially be increased by raising a highly attractive trap crop border in a perimeter surrounding the cash crop [7,15–17]. However, this practice does not always provide the best results [40]. In a previous study, Heliothis zea Boddie (Lepidoptera: Noctuidae) infestation was substantially reduced when an upwind corn border with fresh silks was used as a trap crop compared to fields with no corn border in a tomato (Solanum lycopersicum L. (Solanaceae)) field [41]. Sequential trap crops are cultivated prior to or after the main crop [7]. For example, trap crop planted before planting sugar beets on more than 40% of the German sugar beet cropping areas primarily to reduce the nematode population leads to improve yield [42]. In Finland, multiple trap crop species (Chinese cabbage (Brassica oleracea), marigolds (Asteraceae), rapes (Brassicaceae) and sunflower (Asteraceae)) have been used in cauliflower (Brassica oleracea L. (Brassicaceae)) fields for successful control of rape blossom beetle (Meligethes aeneus Fabricius (Coleoptera: Nitidulidae)) [43]. Trap crop (perimeter) also can be combined with a repellent intercrop to develop a push-pull strategy for insect pests management. In Kenya, Khan et al. [44] reported that maize stem borer (Busseola fusca Fuller (Lepidoptera: Noctuidae)) can effectively be controlled by using a push-pull strategy, when Desmodium grasses (Fabaceae) are intercropped with Napier grass (Pennisetum purpureum Schumach (Poaceae)) planted as a perimeter trap crop.
3. Trap Cropping in Insect Pest Attraction and Repulsion

3.1. Trap Cropping in Insect Pest Management

A trap crop system is usually designed to attract agricultural pests, usually insects, away from the main crop (Figure 1). For example, in an onion (Allium cepa L. (Amaryllidaceae)) field, populations of Thrips tabaci Lindeman (Thysanoptera: Thripidae), a major pest of onion, can be suppressed by trap crop buckwheat (Fagopyrum esculentum Moench (Polygonaceae)) [45]. Furthermore, a combination of two trap crop species can attract insect pests more effectively, such as sunflower (Asteraceae) and grain sorghum (Poaceae) planted to attract the brown marmorated stink bug (H. halys) from bell peppers [16,46] (Table 1). Indeed, the successive planting of second trap crops can extend the period of attractiveness for insect pests [47].

Several cruciferous crops have been tested as trap crops. Srinivasan and Moorthy [48] tested Indian mustard (Brassica juncea L.) as a trap crop to aid in managing the major lepidopterous pests Plutella xylostella L. (Lepidoptera: Plutellidae) and Crocidolomia binotalis Zeller (Lepidoptera: Crambidae) on cabbage, and Charleston and Kfir [49] also reported that, as a trap crop, Indian mustard (B. juncea) can attract diamondback moths (Plutella xylostella L. (Lepidoptera: Plutellidae)) from several economically important cruciferous crops. A similar outcome was found in recent trap crop research, when Indian mustard (B. juncea) was protected by Ethiopian mustard (Brassica carinata A. Braun (Brassicaceae)) as a trap crop to control Pieris brassicae L. (Lepidoptera: Pieridae) [50]. Furthermore, to suppress flea beetle Phyllotreta spp. (Coleoptera: Chrysomelidae) infestation, Chinese cabbage was planted with white cabbage as trap crop [51]. All studies resulted in pest populations being reduced when trap crops were present compared to those without trap crops.

Only a few successful cases of trap crop application have been conducted at the commercial level targeting mainly Coleoptera, Hemiptera and Lepidoptera species. These cases involved insects that directed their movement and tended to aggregate on a highly attractive trap crop [7]. In addition, trap cropping is mostly effective against flying insects. Development of trap crop systems that require only plants to provide pollen or another resource may simplify implementation and maintenance. For example, eggs and larvae of the imported cabbage worm (Pieris rapae L. (Lepidoptera: Pieridae)),

Figure 1. Role of trap crop to attract insect pests and natural enemies in a farming system.
larvae of the diamondback moth (*P. xylostella*) and larvae of the cabbage looper (*Trichoplusia ni* Hübner (Lepidoptera: Noctuidae)) were more abundant in nectar-producing plants inter-planted with broccoli (*Brassica oleracea* L. (Brassicaceae)) [52]. According to Banks and Ekbom [53], for a successful trap cropping system, a very important factor is the attractiveness of the trap crop and its proportion in the field. Even the use of a highly attractive trap crop may not be successful if their percentage is too low to be effective. The proportion of these two factors is critical in deploying a successful and effective trap cropping system. However, crop species have not been systematically evaluated for their effect on the growth of alternative hosts and natural enemies. Crop species of low quality for herbivores due to low nutritional values or high defenses can reduce herbivore development and reproduction [54].

Usually, trap crop efficiency greatly depends on the additional pest management practices, and not all insects can be controlled with trap cropping. Application of trap cropping is not a foolproof solution to all pest problems because it does require additional pest management skills and a thorough understanding of insect behavior. The effectiveness of trap crops can be increased by supplemental use of other control methods, such as targeted insecticide sprays and vacuuming [7,8]. Castle [55] suggested to apply insecticides to control *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) on a cantaloupe (*Cucumis melo* var. *cantalupo* Ser. (Cucurbitaceae)) trap crop, thereby preventing adult dispersal into the main cotton crop. However, researchers exploring wider ecological functions, such as simultaneously controlling multiple pests, protecting natural enemies and enhancing their biological effectiveness, may help to accelerate the use of trap cropping in insect pest management.
Table 1. Research and demonstration projects that have implemented trap cropping systems to attract insect pests in ornamental and food crops.

| Trap Crop                        | Crop                                      | Insect Pest                                      | Country  | Implementation | References                  |
|----------------------------------|-------------------------------------------|--------------------------------------------------|----------|----------------|-----------------------------|
| African marigold, *Tagetes erecta* L. (Asteraceae) | Tomato, *Solanum lycopersicum* L. (Solanaceae) | *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae) | India    | Field          | Srinivasan et al. [56]      |
| Alfalfa, *Medicago sativa* L. (Fabaceae) | Lettuce, *Lactuca sativa* L. (Asteraceae) | *Lygus rugulipennis* Hahn (Hemiptera: Miridae) | Italy    | Field          | Accinelli et al. [57]       |
| Arugula, *Eruca sativa* Mill. (Brassicaceae); | Tomato, *S. lycopersicum* | *Lygus spp.* (Hemiptera: Miridae) | United States | Field | Swezey et al. [58] |
| Buckwheat, *Fagopyrum esculentum* Moench (Polygonaceae) | Onion, *Allium cepa* L. (Amaryllidaceae) | *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) | United States | Field | Buckland et al. [45] |
| Buttercup squash, *Cucurbita maxima* Duchesne (Cucurbitaceae) | *Acalypha vittata* | (Coleoptera: Chrysomelidae); *Diabrotica undecimpunctata* L. (Coleoptera: Chrysomelidae) | United States | Field | Cavanagh et al. [59] |
| Carrot, *Daucus carota* Hoffm. (Apiaceae) | Onion, *A. cepa* | *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) | United States | Field | Buckland et al. [45] |
| Chinese cabbage, *Brassica rapa* L. (Brassicaceae) | White cabbage, *Brassica oleracea* L. (Brassicaceae) | *Phyloptera spp.* (Coleoptera: Chrysomelidae) | Slovenia | Field | Trdan et al. [51] |
| Collard cabbage, *Brassica oleracea* viridis (Brassicaceae) | Cabbage, *B. oleracea* | *Plutella xylostella* L. (Lepidoptera: Plutellidae) | United States | Field | Mitchell et al. [60] Shelton and Nault [61] |
| Eggplant, *Solanum melongena* L. (Solanaceae); | Common bean, *Phaseolus vulgaris* L. (Fabaceae) | *Bemisia argentifolii* Gennadius (Hemiptera: Aleyrodidae) | United States | Field | Smith and Mcsorley [62] |
| Ethiopian mustard, *Brassica carinata* A.Braun (Brassicaceae) | Indian mustard, *Brassica juncea* (L.) Czern. (Brassicaceae) | *Pieris brassicae* L. (Lepidoptera: Pieridae) | India | Laboratory and field | Kumar [50] |
| Indian mustard, *B. juncea* | Cabbage, *B. oleracea* | *Plutella xylostella* L. (Lepidoptera: Plutellidae); *Crocidoloma biotitis* Fabricius (Lepidoptera: Crambidae) | India | Laboratory and field | Srinivasan and Moorthy [48] |
| Marigold, *Calendula officinalis* L. (Asteraceae) | Tomato, *S. lycopersicum* | *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae) | India | Laboratory and field | Kumar et al. [63] |
| Trap Crop | Crop                          | Insect Pest                        | Country | Implementation | References          |
|-----------|-------------------------------|------------------------------------|---------|----------------|---------------------|
| Mung bean, *Vigna radiata* L. (Fabaceae) | *Bacillus thuringiensis* (Bt) cotton, (Bt) *Gossypium hirsutum* L. (Malvaceae) | *Apoxygus lucorum* Meyer-Dür (Hemiptera: Heteroptera) | China | Field | Lu et al. [38] |
| Napier grass, *Pennisetum purpureum* Schumach (Poaceae) | *Sorghum, Sorghum bicolor* L. (Poaceae) | *Busseola fusca* Fuller (Lepidoptera: Noctuidae) | United States | Field | Khan et al. [64] |
| Non-flowering *Barbara*, *Barbara* spp. (Brassicaceae) | Cabbage, *B. oleracea* | *Plutella xylostella* L. (Lepidoptera: Plutellidae) | Spain | Field | Badenes-Pérez et al. [65] |
| Sorghum, *S. bicolor* | Maize, *Zea mays* L. (Poaceae) | *Chilo partellus* Swinhoe (Lepidoptera: Crambidae) | Kenya | Field | Midega et al. [66] |
| Non-flowering *Barbara*, *Barbara* spp. (Brassicaceae) | Cotton, *G. hirsutum* | *Nezara viridula* L. (Hemiptera: Pentatomidae) | United States | Field | Tillman [67] |
| Summer squash, *Cucurbita pepo* L. (Cucurbitaceae) | Bean, *P. vulgaris* | *Bemisia argentifolii* Gennadius (Hemiptera: Aleyrodidae) | United States | Field | Smith et al. [68] |
| Sunflower, *Helianthus annuus* L. (Asteraceae); grain sorghum, *S. bicolor* | Bell peppers, *Capsicum annuum* L. (Solanaceae) | *Halyomorpha halys* Stål (Hemiptera: Pentatomidae) | United States | Field | Blaauw et al. [16,46] |
| Yellow rocket, *Barbara vulgaris* W. T. Aiton (Brassicaceae) | Cabbage, *B. oleracea* | *Plutella xylostella* L. (Lepidoptera: Plutellidae) | United States | Field | Badenes-Pérez et al. [69] |
| Indian mustard, *B. juncea*; white mustard, *Sinapis alba* L. (Brassicaceae) | Chinese Cabbage, *B. rapa*; Oilseed rape, *Brassica napus* L. (Brassicaceae) | *Ceutorhynchus obstrictus* Marsham (Coleoptera: Curculionidae) | Estonia | Field | Kovács et al. [70] |
| Black mustard, *Brassica nigra* L. (Brassicaceae); radish, *Raphanus sativus* Pers. (Brassicaceae); arugula, *E. sativa* | Oilseed rape, *B. napus* | *Meligethes aeneus* Fabricius (Coleoptera: Nitidulidae) | Estonia | Field | Kaasik et al. [71] |
| Oilseed rape, *B. napus*; Chinese cabbage, *B. rapa*; black mustard, *B. nigra*; Indian mustard, *B. juncea* | White mustard, *S. alba*; Radish, *R. sativus* | *M. aeneus* | Estonia | Field | Veromann et al. [72,73] |
3.2. Trap Cropping in Natural Enemy Attraction

Conservation of natural enemies is one of the attractive biological control tactics used in most agro-ecosystems; though, in most of the cropping systems, natural enemies are usually one step behind the pests [74–76]. In the case of annual crops, the most useful mechanism for conservation biological control is spatial attraction of natural enemies resulting in a near linear decline in pest density [77], and trap crop could be an attractive option to attract them.

A plant species able to attract simultaneously both pests and their natural enemies can be used in a trap cropping system (Figure 1) for conservation biological control program. For example, trap plant Borage *Borago officinalis* L. (Boraginaceae) has been found to be attractive to the herbivorous Aphididae and two aphid-controlling bio-agents, parasitoid *Aphidius colemani* Viereck (Hymenoptera: Braconidae) and Chrysopidae predator species [78,79]. Indeed the complementary effect suggests that multiple natural enemies would strengthen pest control (e.g., Williams et al. [80] found that the combination of two generalist natural enemies, such as green lacewings (Neuroptera: Chrysopidae) and lady beetles (Coleoptera: Coccinellidae), which are attracted to a plant volatile (methyl jasmonate) in cotton fields, was found to lead to the complementary control of insect pests). Moreover, a potential secondary trap plant might help to improve the efficacy of natural enemies. For example, the average infestation rate of pods by *Ceutorhynchus obstrictus* Marsham (Coleoptera: Curculionidae) was below 10% for plants in the cruciferous family: *B. rapa*; *Sinapis alba* L. (Brassicaceae) and *B. juncea* when planted with *B. napus* [81]. Furthermore, integration of additional technological tools can play an important role in pest suppression by attracting natural enemy species.

3.3. Technological Tool for Trap Cropping to Improve Natural Enemy Attraction

Attraction of natural enemies by behavioral manipulation is not a new topic [82–86]. To monitor major pests in agriculture and forest environment, commonly, sex pheromone has been used as an attractant for a long period of time. Another option is to make the plant more attractive to pests and natural enemies. Different volatiles can play important roles in attracting natural enemy species. Male and female *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae) adults will respond to several semiochemicals produced by corn (*Zea mays* L. (Poaceae)), as well as a prey species of aphid (*Acrithosiphon pisum* Harris (Homoptera: Aphididae)) [24]. Rhino et al. [41] used corn as a potential trap crop for *Helicoverpa zea* Boddie (Lepidoptera: Noctuidae). Therefore, semiochemicals emitted from trap plant and pest species could be attractive for natural enemies. Moreover, herbivore-induced trap crops can emit herbivore-induced plant volatiles (HIPVs) and use a catalyst to control agricultural pests by attracting natural enemies [87–94]. For example, an aphid infested borage plant can attract *Aphidius colemani* Viereck (Hymenoptera: Braconidae) [60]. A plant volatile or a mixture of plant volatiles can also improve natural enemy attraction capacity in a trap cropping system. For instance, methyl salicylate is used as a common attractant for natural enemies and insect pests. Both synthesized and methyl salicylate released from herbivore-induced plant volatile has been shown to be attractive to green lacewings [64,95,96]. Alfalfa could be an example, which can release attractive plant volatiles for natural enemies. Zhu et al. [97] observed a high abundance of green lacewing adults in early summer in alfalfa (*Medicago sativa* L. (Fabales: Fabaceae)) fields (Table 2). However, the value of using plant volatiles to manipulate natural enemies is still unclear [98].

A sugar-rich food source is needed for the egg parasitoid *Telenomus laeviceps* Förster (Hymenoptera: Scelionidae) to increase their parasitization performance and female offspring abundance [99]. In that case, artificial food-spray could be an additional resource for beneficial insects. Thereafter, the use of an artificial food spray remains a possibility in conservation biological control [100], because it can attract and intercept natural enemies in an area [101,102]. More than 50 years ago, the first documented field usages of artificial food sprays occurred with sucrose solutions [103,104]. Many natural enemies are attracted to plant-derived foods such as pollen, nectar, extra-floral nectar or honeydew in their immature and adult diets [105–107]. However, artificial food spray in trap crop to attract natural enemies is necessary to improve through a better understanding of the ecological basis.
Table 2. Research and demonstration projects that have implemented cropping systems to attract natural enemies in ornamental and food crops.

| Trap Crop                     | Crop                      | Natural Enemy                  | Country          | Implementation | Reference                  |
|-------------------------------|---------------------------|--------------------------------|------------------|----------------|----------------------------|
| Alfalfa, *M. sativa* L.       | Maize, Z. *mays*          | *Chrysopidae*                  | United States    | Field          | Zhu et al. [97]            |
| Borage, *Borago officinalis* L. (Boraginaceae) | Tomatoes, S. *lycopersicum* | *A. colemani*; *Syrphidae*; *Chrysopidae* | Japan, United States | Greenhouse, field | Fujinuma et al. [78]; Hogg et al. [108] |
| Coriander, *Coriandrum sativum* L. (Apiaceae); | Banana, *Musa balbisiana* L. (Musaceae) | *Chrysopidae*; *Coleomegilla maculata* De Geer (Coleoptera: Coccinellidae) | Brazil | Greenhouse | Salamanca et al. [109] |
| Cornflower, *Centaurea cyanus* L. (Asteraceae) | Squash, C. *pepo* | Spiders; *Carabidae* | United States | Field | Fair and Braman [110] |
| Maize, Z. *mays*              | Cucumber, C. *sativus*     | *A. colemani*                  | United States    | Field          | Bennison and Corless [111] |
| Sunflower, *H. annuus*        | Banana, *M. balbisiana*   | *Chrysopidae*                  | United States    | Field          | Zhu et al. [97]            |
| Sunflower, *H. annuus*        | Cotton, G. *hirsutum*     | *Chrysopidae*; *Coccinellidae* | United States | Field | Williams et al. [80] |
| Sunn hemp, *Crotalaria juncea* L. (Fabaceae) | Tobacco, *Nicotiana tabacum* L. (Solanaceae) | *Crocothemis servilia* Drury (Odonata: Libellulidae); *OrthetrumSabina* Drury (Odonata: Libellulidae) | Indonesia | Field | Trisnawati and Azis [112] |
| Sweet alyssum, *Lobularia maritime* L. (Brassicaceae) | Cruciferous vegetables, *Brassica* spp. (Brassicaceae) | *Syrphidae* | United States | Field | Hogg et al. [79] |
| Wheat, *Triticum aestivum* L. (Poaceae) | Cucumber, C. *sativus*     | *A. colemani*                  | United Kingdom   | Greenhouse     | Jacobson and Croft [113]  |
While trap crop is an attractive option for organic crop production through attraction of natural enemies, it also has many limitations. Depending on target insect pests and the cropping system, only a few programs involve trap crops to attract natural enemies [7]. Besides, some programs introduced new species of natural enemies in trap crops, which often disrupts the ecosystem by competing with native natural enemy species, and only a few of them are known to switch their target insect host [114].

Trap cropping to attract natural enemies is knowledge intensive to maximize its effectiveness. Many crops are infested by multiple arthropod pest species, often making it impossible to control with one natural enemy within a given ecosystem. Moreover, the process of actually developing a successful trap crop system is costly and, in most cases, involves a secondary product with little, if any, market value [10]. Although biocontrol with natural enemies may ultimately have a desirable long-term effect, achieving the desired results is usually a slow process requiring considerably more time than simply applying pesticides on trap crops.

4. Conclusions

It is true that there has been a long history of research involving trap crops, with researchers investigating many pest species (Table 1) and natural enemy species that are attracted to prospective trap crops (Table 2); still, little consensus exists regarding an optimal trap cropping system. There is no specific recommendation of attractive plant to a specific pest, as well as their natural enemy.

According to Gurr et al. [115], attainment through biological control can be measured as, “whether crop damage is reduced to the extent that adequate control—usually regarded as maintenance below the economic injury level—is afforded, and whether significant proportions of farmers adopt this approach to pest management”. For establishing a successful trap cropping system in different agronomic situations, primarily a thorough understanding is required of the behavior and preferences of the targeted pests, as well as the dispersal and the attraction of natural enemies for the trap crop species. There still exists a need for basic biological and ecological research on the specific host plants involved, along with their pests, appropriate trap crops and their natural enemies, especially their interactions with each other, to improve and implement successful biological control programs using trap crop systems. Further study is also needed on the effective application of trap crops, including cropping pattern (e.g., perimeter, sequential, multiple and push-pull planting schemes), the total percentages compared to the cash crop, as well as maintenance details.

This review has highlighted several potential advantages of using trap cropping systems that may make them more important and economical. The success and implementation of biological control with trap crop will be increased, if future research demonstrates the long-term, preventive and economically efficient way to control insect pests. However, in the present situation, attraction of natural enemies by the trap crop and continuous production of them may be counter-acted by more cost effectiveness. In our opinion, trap crop species that have natural enemy attracting capacity will be greatly enhanced if future research works are conducted with diverse concepts and modalities.

Author Contributions: Conceptualization, S.C.S., S.W. and Z.L. Writing, original draft preparation, S.C.S. and S.W. Writing, review and editing, S.C.S., S.W., E.W. and Z.L.

Funding: This work was supported by the National key Research & Developments (R&D) plan (Grant No. 2016YFD0201002, 2017YFD0200900) and the China Agriculture Research System (CARS-23-D-08).

Acknowledgments: We wish to thank Cecil L. Smith, University of Georgia, USA, for help with the language editing of the revised manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.
References

1. Adler, L.S.; Hazzard, R.V. Comparison of perimeter trap crop varieties: Effects on herbivory, pollination, and yield in butternut squash. *Environ. Entomol.* 2009, 38, 207–215. [CrossRef] [PubMed]

2. McCaffery, A.R. Resistance to insecticides in heliothine Lepidoptera: A global view. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 1998, 353, 1735–1750. [CrossRef]

3. Heinz, K.M.; Van Driesche, R.G.; Parella, M.P. *Biocontrol in Protected Culture*; Ball Publishing: Batavia, IL, USA, 2004.

4. Gurr, G.M.; Wratten, S.D.; Landis, D.A.; You, M. Habitat management to suppress pest populations: Progress and prospects. *Annu. Rev. Entomol.* 2017, 62, 91–109. [CrossRef] [PubMed]

5. Hatt, S.; Boerave, F.; Artru, S.; Dufrène, M.; Francis, F. Spatial diversification of agroecosystems to enhance biological control and other regulating services: An agroecological perspective. *Sci. Total Environ.* 2018, 621, 600–611. [CrossRef]

6. Hokkanen, H.M. Trap cropping in pest management. *Annu. Rev. Entomol.* 1991, 36, 119–138. [CrossRef]

7. Shelton, A.M.; Badenes-Perez, F.R. Concepts and applications of trap cropping in pest management. *Annu. Rev. Entomol.* 2006, 51, 285–308. [CrossRef] [PubMed]

8. Holden, M.H.; Ellner, S.P.; Lee, D.H.; Nyrop, J.P.; Sanderson, J.P. Designing an effective trap cropping strategy: The effects of attraction, retention and plant spatial distribution. *J. Appl. Ecol.* 2012, 49, 715–722.

9. Parolin, P.; Bresch, C.; Desneux, N.; Brun, R.; Boll, R.; Poncet, C. Secondary plants used in biological control: A review. *Int. J. Pest Manag.* 2012, 58, 91–100. [CrossRef]

10. Parker, J.E.; Snyder, W.E.; Hamilton, G.C.; Rodriguez-Saona, C. Companion planting and insect pest control. In *Weed and Pest Control Conventional and New Challenges*; Soloneski, S., Larramendy, M., Eds.; InTech: Rijeka, Croatia, 2013; pp. 1–30.

11. Naranjo, S.E.; Ellsworth, P.C.; Fiservold, G.B. Economic value of biological control in integrated pest management of managed plant systems. *Annu. Rev. Entomol.* 2015, 60, 621–645. [CrossRef] [PubMed]

12. Zehnder, G.; Gurr, G.M.; Kühlne, S.; Wade, M.R.; Wratten, S.D.; Wyss, E. Arthropod pest management in organic crops. *Annu. Rev. Entomol.* 2007, 52, 57–80. [CrossRef] [PubMed]

13. Andow, D.A. Vegetational diversity and arthropod population response. *Annu. Rev. Entomol.* 1991, 36, 561–586. [CrossRef]

14. Letourneau, D.K.; Armbrrecht, I.; Rivera, B.S.; Lerma, J.M.; Carmona, E.J.; Daza, M.C.; Escobar, S.; Galindo, V.; Gutiérrez, C.; López, S.D.; et al. Does plant diversity benefit agroecosystems? A synthetic review. *Ecol. Appl.* 2011, 21, 9–21. [CrossRef] [PubMed]

15. Root, R.B. Organization of a plant-arthropod association in simple and diverse habitats: The fauna of collards (*Brassica oleracea*). *Ecol. Monogr.* 1973, 43, 95–124. [CrossRef]

16. Blaauw, B.R.; Morrison, W.R.; Mathews, C.; Leskey, T.C.; Nielsen, A.L. Measuring host plant selection and retention of *Halyomorpha halys* by a trap crop. *Entomol. Exp. Appl.* 2017, 163, 197–208. [CrossRef]

17. Tillman, P.G.; Northfield, T.D.; Mizell, R.F.; Riddle, T.C. Spatiotemporal patterns and dispersal of stink bugs (Heteroptera: Pentatomidae) in peanut-cotton farmscapes. *Environ. Entomol.* 2009, 38, 1038–1052. [CrossRef] [PubMed]

18. Venugopal, P.D.; Martinson, H.M.; Bergmann, E.J.; Shrewsbury, P.M.; Raupp, M.J. Edge effects influence the abundance of the invasive *Halyomorpha halys* (Hemiptera: Pentatomidae) in woody plant nurseries. *Environ. Entomol.* 2015, 44, 474–479. [CrossRef] [PubMed]

19. Nielsen, J.K.; Larsen, L.M.; Sørensen, H. Host plant selection of the horseradish flea beetle *Phyllotreta armoraciae* (Coleoptera: Chrysomelidae): Identification of two flavonol glycosides stimulating feeding in combination with glucosinolates. *Entomol. Exp. Appl.* 1979, 26, 40–48. [CrossRef]

20. Gao, Y.L.; Lei, Z.R.; Reitz, S.R. Western flower thrips resistance to insecticides: Detection, mechanisms, and management strategies. *Pest Manag. Sci.* 2012, 68, 1111–1121. [CrossRef] [PubMed]

21. Rea, J.H.; Wratten, S.D.; Sedcole, R.; Cameron, P.J.; Davis, S.I.; Chapman, R.B. Trap cropping to manage green vegetable bug *Nezara viridula* (L.) (Heteroptera: Pentatomidae) in sweet corn in New Zealand. *Agric. Forest Entomol.* 2002, 4, 101–107. [CrossRef]

22. Dicke, M.; Hilker, M. Induced plant defences: From molecular biology to evolutionary ecology. *Basic Appl. Ecol.* 2003, 4, 3–14. [CrossRef]
23. Reddy, G.V.P. Plant volatiles mediate orientation and plant preference by the predator *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae). *Biol. Control* 2002, 25, 49–55. [CrossRef]

24. Zhu, J.; Cossé, A.A.; Obrzycki, J.J.; Boo, K.S.; Baker, T.C. Olfactory reactions of the twelve-spotted lady beetle, *Coleomegilla maculata* and the green lacewing, *Chrysoperla carnea* to semiochemicals released from their prey and host plant: Electroantennogram and behavioral responses. *J. Chem. Ecol.* 1999, 25, 1163–1177. [CrossRef]

25. Cook, S.M.; Rasmussen, H.B.; Birkett, M.A.; Murray, D.A.; Pye, B.J.; Watts, N.P.; Williams, I.H. Behavioural and chemical ecology underlying the success of turnip rape (*Brassica rapa*) trap crops in protecting oilseed rape (*Brassica napus*) from the pollen beetle (*Meligethes aeneus*). *Arthropod Plant Interact.* 2007, 1, 57. [CrossRef]

26. Nielsen, A.L.; Dively, G.; Pote, J.M.; Zinati, G.; Mathews, C. Identifying a potential trap crop for a novel insect pest, *Halyomorpha halys* (Hemiptera: Pentatomidae), in organic farms. *Environ. Entomol.* 2016, 45, 472–478. [CrossRef] [PubMed]

27. Webster, B.; Bruce, T.; Pickett, J.; Hardie, J. Volatiles functioning as host cues in a blend become nonhost cues when presented alone to the black bean aphid. *Anim. Behav.* 2010, 79, 451–457. [CrossRef]

28. Lambdon, P.W.; Hassall, M.; Boar, R.R.; Mithen, R. Asynchrony in the nitrogen and glucosinolate leaf-age profiles of *Brassica*: Is this a defensive strategy against generalist herbivores? *Agric. Ecosyst. Environ.* 2003, 97, 205–214. [CrossRef]

29. Wallace, S.K.; Eigenbrode, S.D. Changes in the glucosinolate–myrosinase defense system in *Brassica juncea* cotyledons during seedling development. *J. Chem. Ecol.* 2002, 28, 243–256. [CrossRef] [PubMed]

30. Dogramaci, M.; Shrefler, J.W.; Roberts, B.W.; Pair, S.; Edelson, J.V. Comparison of management strategies for squash bugs (Hemiptera: Coreidae) in watermelon. *J. Econ. Entomol.* 2004, 97, 1999–2005. [CrossRef] [PubMed]

31. Pair, S.D. Evaluation of systemically treated squash trap plants and attracticidal baits for early-season control of striped and spotted cucumber beetles (Coleoptera: Chrysomelidae) and squash bug (Hemiptera: Coreidae) in cucurbit crops. *J. Econ. Entomol.* 1997, 90, 1307–1314. [CrossRef]

32. Radin, A.M.; Drummond, F.A. Patterns of initial colonization of cucurbits, reproductive activity, and dispersion of striped cucumber beetle, *Acalymma vittata* (E) (Coleoptera: Chrysomelidae). *J. Agric. Entomol.* 1994, 11, 115–123.

33. Abate, T. Experiments with trap crops against African bollworm, *Heliothis armigera*, in Ethiopia. *Entomol. Exp. Appl.* 1988, 48, 135–140. [CrossRef]

34. Potting, R.P.J.; Perry, J.N.; Powell, W. Insect behavioral ecology and other factors affecting the control efficacy of agro-ecosystem diversification strategies. *Ecol. Model.* 2005, 182, 199–216. [CrossRef]

35. Yan, F.M. *Chemical Ecology*; China Science Press: Beijing, China, 2003. (In Chinese)

36. Schoonhoven, L.M.; Van Loon, J.J.; Dicke, M. *Insect-Plant Biology*, 2nd ed.; Oxford University Press: Oxford, UK, 2005.

37. Eigenbrode, S.D.; Birch, A.N.; Lindzey, S.; Meadow, R.; Snyder, W.E. A mechanistic framework to improve understanding and applications of push-pull systems in pest management. *J. Appl. Ecol.* 2016, 53, 202–212. [CrossRef]

38. Lu, Y.H.; Wu, K.M.; Wyckhuys, K.A.; Guo, Y.Y. Potential of mungbean, *Vigna radiata* as a trap crop for managing *Apolygus lucorum* (Hemiptera: Miridae) on Bt cotton. *Crop. Prot.* 2009, 28, 77–81. [CrossRef]

39. Smyth, R.R.; Hoffmann, M.P.; Shelton, A.M. Effects of host plant phenology on oviposition preference of *Crocidoloma patronana* (Lepidoptera: Pyralidae). *Environ. Entomol.* 2003, 32, 756–764. [CrossRef]

40. Kumari, A.P.P.; Pasalu, I.C. Influence of planting pattern of trap crops on yellow stem borer, *Scirpophaga incertulas* (Walker), damage in rice. *Ind. J. Plant Prot.* 2003, 31, 78–83.

41. Rhino, B.; Verchère, A.; Thibaut, C.; Ratnadass, A. Field evaluation of sweet corn varieties for their potential as a trap crop for *Helicoverpa zea* under tropical conditions. *Int. J. Pest Manag.* 2016, 62, 3–10. [CrossRef]

42. Buhre, C.; Apfelbeck, R.; Hesse, F.; Van Look, M.; Mielke, C.; Ladewig, E. Survey on production technology-regional differences in sugar beet production in the field of plant protection. *Sugar Ind.* 2014, 139, 110–116.

43. Hokkanen, H.M.T. Biological and agrotechnical control of the rape blossom beetle *Meligethes aeneus* (Coleoptera: Nitidulidae). *Acta Entomol. Fenn.* 1989, 53, 25–30.

44. Khan, Z.R.; Pickett, J.A.; Wadhams, L.; Muyekho, F. Habitat management strategies for the control of cereal stemborers and striga in maize in Kenya. *Insect Sci. Appl.* 2001, 21, 375–380. [CrossRef]
55. Castle, S.J. Concentration and management of Bemisia tabaci in cantaloupe as a trap crop for cotton. Crop. Prot. 2006, 25, 574–584. [CrossRef]

56. Srinivasan, K.; Moorthy, P.K.; Raviprasad, T.N. African marigold as a trap crop for the management of the fruit borer Helicoverpa armigera on tomato. Int. J. Pest Manag. 2008, 40, 56–63. [CrossRef]

57. Accinelli, G.; Lanzoni, A.; Ramilli, F.; Dradi, D.; Burgio, G. Trap crop: An agroecological approach to the concentration and management of diamondback moth (Lepidoptera: Plutellidae) in cantaloupe as a trap crop for cotton. HorticScience 2000, 35, 875–879.

58. Shelton, A.M.; Nault, B.A. Dead-end trap cropping: A technique to improve management of the diamondback moth, Plutella xylostella (Lepidoptera: Plutellidae). Crop Prot. 2004, 23, 497–503. [CrossRef]

59. Smith, H.A.; McSorley, R. Potential of field corn as a barrier crop and eggplant as a trap crop for management of Bemisia argentifolii (Homoptera: Aleyrodidae) on common bean in North Florida. Fla. Entomol. 2000, 83, 145–158. [CrossRef]

60. Kumar, V.; Mahla, M.K.; Lal, J.; Singh, B. Effect of abiotic factors on the seasonal incidence of fruit borer, Helicoverpa armigera (Hub.) on tomato with and without marigold as a trap crop. J. Entomol. Zool. Stud. 2017, 5, 803–807.

61. Khan, Z.R.; James, D.G.; Midega, C.A.; Pickett, J.A. Chemical ecology and conservation biological control. Biol. Control 2008, 45, 210–224. [CrossRef]

62. Badenes-Pérez, F.R.; Márquez, B.P.; Petitpierre, E. Can flowering Barbarea spp. (Brassicaceae) be used simultaneously as a trap crop and in conservation biological control? J. Pest Sci. 2017, 90, 623–633. [CrossRef]
67. Tillman, P.G. Sorghum as a trap crop for *Nezara viridula* L. (Heteroptera: Pentatomidae) in cotton in the southern United States. *Environ. Entomol.* 2006, 35, 771–783. [CrossRef]

68. Smith, H.A.; Koenig, R.L.; McAuslane, H.J.; McSorley, R. Effect of silver reflective mulch and a summer squash trap crop on densities of immature *Bemisia argentifolii* (Homoptera: Aleyrodidae) on organic bean. *J. Econ. Entomol.* 2000, 93, 726–731. [CrossRef] [PubMed]

69. Badenes-Pérez, F.R.; Nault, B.A.; Shelton, A.M. Dynamics of diamondback moth oviposition in the presence of a highly preferred non-compatible host. *Entomol. Exp. Appl.* 2006, 120, 23–31. [CrossRef]

70. Kovács, G.; Kaasik, R.; Metspalu, L.; Williams, I.H.; Luik, A.; Veromann, E. Could *Brassica rapa*, *Brassica juncea* and *Sinapis alba* facilitate the control of the cabbage seed weevil in oilseed rape crops? *Biol. Control* 2013, 65, 124–129. [CrossRef]

71. Kaasik, R.; Kovács, G.; Kaart, T.; Metspalu, L.; Williams, I.H.; Veromann, E. *Meligethes aeneus* oviposition preferences, larval parasitism rate and species composition of parasitoids on *Brassica nigra*, *Raphanus sativus* and *Eruca sativa* compared with on *Brassica napus*. *Biol. Control* 2014, 69, 65–71. [CrossRef]

72. Veromann, E.; Metspalu, L.; Williams, I.H.; Hiiiesaar, K.; Mand, M.; Kaasik, R.; Jogar, K.; Svilponis, E.; Kivimagi, I.; et al. Relative attractiveness of *Brassica napus*, *Brassica nigra*, *Eruca sativa* and *Raphanus sativus* for pollen beetle (*Meligethes aeneus*) and their potential for use in trap cropping. *Arthropod Plant Interact.* 2012, 6, 385–394. [CrossRef]

73. Veromann, E.; Kaasik, R.; Kovács, G.; Metspalu, L.; Williams, I.H.; Mänd, M. Fatal attraction: Search for a dead-end trap crop for the pollen beetle (*Meligethes aeneus*). *Arthropod Plant Interact.* 2014, 8, 373–381. [CrossRef]

74. Ehler, L.E.; Miller, J.C. Biological control in temporary agro ecosystems. *Entomophaga* 1978, 23, 207–212. [CrossRef]

75. Wiedenmann, R.N.; Smith, J.W. Attributes of natural enemies in ephemeral crop habitats. *Biol. Control* 1997, 10, 16–22. [CrossRef]

76. Wissinger, S.A. Cyclic colonization in predictably ephemeral habitats: A template for biological control in annual crop systems. *Biol. Control* 1997, 10, 4–15. [CrossRef]

77. Kaplan, I. Attracting carnivorous arthropods with plant volatiles: The future of biocontrol or playing with fire? *Biol. Control* 2012, 60, 77–89. [CrossRef]

78. Fujinuma, M.; Kainoh, Y.; Nemoto, H. *Borago officinalis* attracts the aphid parasitoid *Aphidius colemani* (Hymenoptera: Braconidae). *Appl. Entomol. Zool.* 2010, 45, 615–620. [CrossRef]

79. Hogg, B.N.; Bugg, R.L.; Daane, K.M. Attractiveness of common insectary and harvestable floral resources to beneficial insects. *Biol. Control* 2011, 56, 76–84. [CrossRef]

80. Williams, L., III; Rodriguez-Saona, C.; Castle del Conte, S.C. Methyl jasmonate-induction of cotton: A field test of the “attract and reward” strategy of conservation biological control. *AoB Plants* 2017, 9, plx032. [CrossRef] [PubMed]

81. Kovács, G.; Kaasik, R.; Kaart, T.; Metspalu, L.; Luik, A.; Veromann, E. In search of secondary plants to enhance the efficiency of cabbage seed weevil management. *BioControl* 2017, 62, 29–38. [CrossRef]

82. Vinson, S.B. Behavioral chemicals in the augmentation of natural enemies. In *Biological Control by Augmentation of Natural Enemies*; Springer: New York, NY, USA, 1977; pp. 237–279.

83. Gross, H.R. Employment of kairomones in the management of parasitoids. In *Semiocarbons: Their Role in Pest Control*; Nordlund, D.A., Jones, R.L., Lewis, W.J., Eds.; Wiley: New York, NY, USA, 1981; pp. 137–150.

84. Nordlund, D.A.; Lewis, W.J.; Gross, H.R. Elucidation and employment of semiochemicals in the manipulation of entomophagous insects. In *Management of Insect Pests with Semiocarbons*; Springer: Boston, MA, USA, 1981; pp. 463–475.

85. Powel, W. Enhancing parasitoid activity in crops. In Proceedings of the 13th Symposia of the Royal Entomological Society of London, London, UK, 18–19 September 1985; Royal Entomological Society: London, UK, 1986.

86. Lewis, W.J.; Martin, W.R. Semiocarbons for use with parasitoids: Status and future. *J. Chem. Ecol.* 1990, 16, 3067–3089. [CrossRef] [PubMed]

87. Bottrell, D.G.; Barbosa, P.; Gould, F. Manipulating natural enemies by plant variety selection and modification: A realistic strategy? *Annu. Rev. Entomol.* 1998, 43, 347–367. [CrossRef] [PubMed]
88. Degenhardt, J.; Gershenzon, J.; Baldwin, I.T.; Kessler, A. Attracting friends to feast on foes: Engineering terpene emission to make crop plants more attractive to herbivore enemies. *Curr. Opin. Biotechnol.* 2003, 14, 169–176. [CrossRef]

89. Turlings, T.C.; Wäckers, F. Recruitment of predators and parasitoids by herbivore-injured plants. *Adv. Insect Chem. Ecol.* 2004, 2, 21–75.

90. Pickett, J.A.; Bruce, T.J.; Chamberlain, K.E.; Hassanali, A.H.; Khan, Z.R.; Matthes, M.C.; Napier, J.A.; Smart, L.E.; Wadhams, L.J.; Woodcock, C.M. Plant volatiles yielding new ways to exploit plant defense. *Chem. Ecol. Gene Ecosyst.* 2006, 2, 161–173.

91. Turlings, T.C.; Ton, J. Exploiting scents of distress: The prospect of manipulating herbivore-induced plant odours to enhance the control of agricultural pests. *Curr. Opin. Plant Biol.* 2006, 9, 421–427. [CrossRef] [PubMed]

92. Mumm, R.; Dicke, M. Variation in natural plant products and the attraction of bodyguards involved in indirect plant defense. The present review is one in the special series of reviews on animal-plant interactions. *Can. J. Zool.* 2010, 88, 628–667. [CrossRef]

93. Hare, J.D. Ecological role of volatiles produced by plants in response to damage by herbivorous insects. *Annu. Rev. Entomol.* 2011, 56, 161–180. [CrossRef] [PubMed]

94. Simpson, M.; Gurr, G.M.; Simmons, A.T.; Wratten, S.D.; James, D.G.; Leeson, G.; Nicol, H.I. Insect attraction to synthetic herbivore-induced plant volatile-treated field crops. *Agric. Forest Entomol.* 2011, 13, 45–57. [CrossRef]

95. James, D.G. Methyl salicylate is a field attractant for the golden eyed lacewing, *Chrysopa oculata*. *Biocontrol. Sci. Technol.* 2006, 16, 107–110. [CrossRef]

96. James, D.G. Further field evaluation of synthetic herbivore-induced plant volatiles as attractants for beneficial insects. *J. Chem. Ecol.* 2005, 31, 481–495. [CrossRef] [PubMed]

97. Zhu, J.; Obrycki, J.J.; Ochieng, S.A.; Baker, T.C.; Pickett, J.A.; Smiley, D. Attraction of two lacewing species to volatiles produced by host plants and aphid prey. *Naturwissenschaften* 2005, 92, 277–281. [CrossRef] [PubMed]

98. Jones, V.P.; Horton, D.R.; Mills, N.J.; Unruh, T.R.; Baker, C.C.; Melton, T.D.; Milickzy, E.; Steffan, S.A.; Shearer, P.W.; Amarasekare, K.G. Evaluating plant volatiles for monitoring natural enemies in apple, pear and walnut orchards. *Biol. Control* 2016, 102, 53–65. [CrossRef]

99. Barloggio, G.; Tamm, L.; Nagel, P.; Luka, H. Selective flowers to attract and enhance *Telenomus laeviceps* (Hymenoptera: Scelionidae): A released biocontrol agent of *Mamestra brassicae* (Lepidoptera: Noctuidae). *Bull. Entomol. Res.* 2018, 1–9. [CrossRef] [PubMed]

100. Rogers, M.E.; Potter, D.A. Potential for sugar sprays and flowering plants to increase parasitism of white grubs (Coleoptera: Scarabaeidae) by Tiphidi wasps (Hymenoptera: Tiphidiidae). *Environ. Entomol.* 2004, 33, 619–626. [CrossRef]

101. Evans, E.W.; Swallow, J.G. Numerical responses of natural enemies to artificial honeydew in Utah alfalfa. *Environ. Entomol.* 1993, 22, 1392–1401. [CrossRef]

102. Jacob, H.S.; Evans, E.W. Effects of sugar spray and aphid honeydew on field populations of the parasitoid *Bathysphletes carculionis* (Hymenoptera: Ichneumonidae). *Environ. Entomol.* 1998, 27, 1563–1568. [CrossRef]

103. Ewert, M.A.; Chiang, H.C. Dispersal of Three Species of Coccinellids in Corn Fields. *Can. Entomol.* 1966, 98, 999–1003. [CrossRef]

104. Schiefelbein, J.W.; Chiang, H.C. Effects of spray of sucrose solution in a corn field on the populations of predatory insects and their prey. *Entomophaga* 1966, 11, 333–339. [CrossRef]

105. Hagen, K.S. Ecosystem analysis: Plant cultivars (HPR), entomophagous species and food supplements. In *Interactions of Plant Resistance and Parasitoids and Predators of Insects*; Wiley: New York, NY, USA; Ellis Horwood Limited: Chichester, UK, 1986; pp. 151–197.

106. Coll, M.; Guershon, M. Omnivory in terrestrial arthropods: Mixing plant and prey diets. *Annu. Rev. Entomol.* 2002, 47, 267–297. [CrossRef] [PubMed]

107. Wackers, F.L.; van Rijn, P.C. Food for protection: An introduction. In *Plant-Provided Food for Carnivorous Insects: A Protective Mutualism and Its Applications*; Wackers, F.L., van Rijn, P.C.J., Bruin, J., Eds.; Cambridge University Press: Cambridge, UK, 2005; pp. 1–14.

108. Hogg, B.N.; Nelson, E.H.; Mills, N.J.; Daane, K.M. Floral resources enhance aphid suppression by a hoverfly. *Entomol. Exp. Appl.* 2011, 141, 138–144. [CrossRef]
109. Salamanca, J.; Pareja, M.; Rodriguez-Saona, C.; Resende, A.L.S.; Souza, B. Behavioral responses of adult lacewings, *Chrysoperla externa*, to a rose-aphid-coriander complex. *Biol. Control* **2015**, *80*, 103–112. [CrossRef]

110. Fair, C.G.; Braman, S.K. Assessment of Habitat Modification and Varied Planting Dates to Enhance Potential Natural Enemies of *Anasa tristis* (Hemiptera: Coreidae) in Squash. *Environ. Entomol.* **2017**, *46*, 291–298. [CrossRef] [PubMed]

111. Bennison, J.A.; Corless, S.P. Biological control of aphids on cucumbers: Further development of open rearing units or “banker plants” to aid establishment of aphid natural enemies. *WPRS Bull.* **1993**, *16*, 5.

112. Trisnawati, I.; Azis, A. The effectiveness of habitat modification schemes for enhancing beneficial insects: Assessing the importance of trap cropping management approach. In *AIP Conference Proceedings*; AIP Publishing: Melville, NY, USA, 2017; Volume 1854, p. 020038.

113. Jacobson, R.J.; Croft, P. Strategies for the control of *Aphis gossypii* Glover (Hom.: Aphididae) with *Aphidius colemani* Viereck (Hym.: Braconidae) in protected cucumbers. *Biocontrol. Sci. Technol.* **1998**, *8*, 377–387. [CrossRef] [PubMed]

114. Brodeur, J. Host specificity in biological control: Insights from opportunistic pathogens. *Evol. Appl.* **2012**, *5*, 470–480. [CrossRef] [PubMed]

115. Gurr, G.M.; Wratten, S.D.; Barbosa, P. Success in conservation biological control of arthropods. *Biol. Control Meas. Success* **2000**, *30*, 105–132.

© 2018 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).