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*Review*

# White Mustard, Sweet Alyssum, and Coriander as Insectary Plants in Agricultural Systems: Impacts on Ecosystem Services and Yield of Crops

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**Abstract:** The main reason for adding plants to accompany the main crop is to protect it from pests and diseases. We reviewed the effectiveness of white mustard (*Sinapis alba* L.), sweet alyssum (*Lobularia maritima* L.), and coriander (*Coriandrum sativum* L.) in this regard. White mustard proximity had a strong positive influence on the occurrence of Syrphidae, parasitoids, Coccinellidae, and Carabidae, as well as on the fertility of Syrphidae and the longevity of parasitoids—all of which are essential for biological pest control. It also reduced many pests and diseases. The influence of *S. alba* on yield depends on the spacing used and the species of protected plant. Sweet alyssum positively affected the occurrence of Syrphidae, Coccinellidae, Anthocoridae, epigeal, and soil fauna, as well as the longevity of parasitoids and Anthocoridae. Its effect on the crop yield is variable, depending on the references consulted. The sensitivity of *L. maritima* to *Phyllotreta* spp. excludes it as a companion plant for hosts of these pests. Coriander positively affected the occurrence of Chrysopidae, Coccinellidae, Staphylinidae, and Aranea, as well as the longevity of parasitoids and the egg-laying of Syrphidae. It also reduced some crop pests. Introduction of the reviewed plants can improve the biodiversity of beneficial entomofauna that can help control pests and reduce diseases, with benefits to crop and yield. The use of synthetic insecticides can thus be greatly reduced, though it is not always possible to avoid them completely.

**Keywords:** pests and diseases; beneficial entomofauna; ecosystem services; insectary plants

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## 1. Introduction

The use of pesticides on crops has become a subject of disagreement as they have been found to be harmful to human health and the environment [1]. This practice is too intensive to be ecologically sustainable and is responsible for environmental damage and the disappearance of non-target species [2]. Farmers are concerned about the damage caused but are helpless in the face of pests developing resistance to expensive chemicals. Some farmers have opted for pesticide alternatives [3]. In particular, they want to adopt more environmentally friendly methods that allow them to reduce the use of insecticides while maintaining productivity and quality of production. The introduction of insectary plants into the cultivation of major crops, especially those that produce significant amounts of pollen, is an excellent way to increase the biodiversity of beneficial entomofauna and, consequently, to improve the stability of the ecological balance in agrocenoses [4], as well as an alternative to chemical plant protection, especially in terms of use in ecological and integrated management systems [5].

White mustard (*Sinapis alba* L.), sweet alyssum (*Lobularia maritima* L.), and coriander (*Coriandrum sativum* L.) can be intercropped, undersown with the main crop, or planted on the field margins. They are popular insectary plants, and several studies have demonstrated their: (i) speed of flowering (important for attracting beneficial insects as early as possible), which is important for synchronization with the appearance of pests; (ii) pollen quality and length of flowering (important to maintain a long-lasting luring effect); (iii) competitiveness for the main protected plant; and (iv) fast growth rate and short vegetative growth period, which are important from the point of view of terrestrial fauna that prefers the shade of the substrate in the various intercropping systems [6,7].

White mustard is an annual plant that blooms early, but for a short period of time. In contrast, sweet alyssum and coriander may take longer to bloom, but their flowers last for a longer period of time [7]. White mustard can grow to over 60 cm tall and produces bright yellow flowers with high pollen production [8]. It is a hardy plant that can withstand extreme weather conditions, including frost and heat. It grows rapidly and produces a substantial amount of biomass. The plant is not very sensitive to soil pH, and it grows best in soils with a pH level between 4.5 and 8.2 [9]. Sweet alyssum is a type of flowering plant that can grow as an annual or as a short-lived perennial [10]. The size of a mature sweet alyssum plant can range from 8 to 23 cm tall and 25 to 122 cm wide, depending on the variety. It grows best in areas with full sun to partial shade, but in warmer climates, it prefers shade from the afternoon sun. The flowering period is in the spring and lasts until fall, allowing a longer window for attracting beneficia [11]. Coriander is an annual herb with slender branching stems up to 70 cm in height and a pronounced taproot. It is an excellent melliferous plant [12]. A single plant produces an average of 80 inflorescences. Coriander is attractive to many insects due to its abundant pollen production and exposed nectar [13,14].

Several experiments evaluated the potential of white mustard, sweet alyssum, and coriander to preserve and attract natural enemies of insect pests [15–18]. The nectar and pollen they provide are crucial for the survival, development, and reproductive success of many species of natural enemies, such as hoverflies and parasitoids [7,19]. In addition, field diversification was found to increase the abundance and diversity of beneficial soil invertebrates [20–25]. However, a more comprehensive approach that considers the impact of the mentioned insectary plants on other aspects that are important in crop production is still lacking.

In this review, we investigated the ecosystem services provided by white mustard, sweet alyssum, and coriander with regards to plant protection (effects on natural enemies of pests, pests themselves, pathogens, soil, and epigeal invertebrate fauna) and productivity.

## 2. Materials and Methods

The referenced literature was found using various scientific search engines (e.g., Web of Science, Scopus, Science Direct, Google Scholar) by using the key topics: “companion planting”, “insectary plants”, “beneficial fauna”, “intercropping; mustard”, “intercropping; sweet alyssum”, and “intercropping; coriander”, among others. Published, peer-reviewed experimental studies were analyzed in this review.

## 3. White Mustard

### *3.1. Influence on Beneficial Entomofauna*

White mustard is a pollen- and nectar-giving plant. It attracts natural enemies by providing shelter and food resources. For instance, adult hoverflies (Diptera: Syrphidae), whose larvae are natural enemies of pests (mainly aphids), feed upon the nectar and pollen [16]. The flower pollen is a source of amino acids, carbohydrates, sugars, proteins, and other organic and inorganic substances that are indispensable for energy generation and egg laying. Furthermore, these compounds are necessary for the proper growth and development of other important aphid predators, such as lady beetles (Coleoptera: Coccinellidae) [26]. Several authors highlighted the influence of nectar and pollen composition and flower structure on the occurrence, fecundity, and lifespan of natural enemies of pests [27,28], and flowering white mustard was found to be one of the plants most frequently visited by beneficial insects [16,18]. Table 1 presents information about the effects of white mustard proximity on beneficial invertebrates.

The presence of white mustard in broad bean inter-rows positively impacted the abundance of hoverflies [18]. It increased the number of Syrphidae larvae on broad beans by 1-, 3-, and 5-fold in three consecutive years of study, respectively, compared to broad bean monoculture. The study also documented an increased number of eggs laid by hoverflies (by 2 eggs more/plant in the 1st year; 3 eggs more/plant in the 2nd year; and 1 more egg/plant in the 3rd year) compared to the monoculture of broad beans. Colley and Luna [16] examined a range of flowering plant species to determine which were most attractive to aphidophagous hoverflies. They found that white mustard flowers are generally as attractive to feed as the flowers of other insectary plants. At the Oregon State University vegetable research site, mustard attracted a higher number of adult aphidophagous hoverflies (4 adults per 2 min) on the second sampling date (14 July) compared to sweet alyssum (3 adults per 2 min), buckwheat (*Fagopyrum esculentum* Moench) (3 adults per 2 min), and calendula (*Calendula officinalis* L.) (2.25 adults per 2 min) in bloom, with the exception of coriander (4 adults per 2 min). However, on the other sampling dates, white mustard had an intermediate visit status (1 adult per 2 min on the 1st sampling date (7 June) at the OSU site) or was relatively undervisited (on 24th July, 30th July, 13th August, 21st August, 29th August, and 2nd September) in relation to other flowers. The reason for the effect on these later dates was that after 14th July, mustard stopped blooming. At other sites (Persephone and Denison Farm), white mustard was not visited by hoverflies. The availability of other flowers may have influenced their preference. In contrast, the use of white mustard as living mulch did not enhance predatory insect abundance in zucchini (*Cucurbita pepo* L.) [29]. There was no significant variation in the mean densities of syrphids between white mustard–zucchini and monoculture zucchini plantings. The higher density of aphids present in the monoculture may have been responsible for the lack of difference in Syrphidae density. Furthermore, mustard sown one week after transplanting broccoli (*Brassica oleracea* L.) did not significantly affect the number of Syrphid larvae that were preying on cabbage aphids, *Brevicoryne brassicae* L. (Hemiptera: Aphididae) [30], while white mustard sown simultaneously with broccoli increased the density of Syrphid larvae only by 14.2% compared to broccoli monoculture. In a laboratory experiment, Laubertie et al. [31] investigated the efficacy of flowering plant species in enhancing longevity and several fecundity-related parameters of one of the most common hoverfly species, *Episyrphus balteatus* Deg (Diptera: Syrphidae). The result showed very low-level performance of adult females of *E. balteatus* in terms of the number of females that laid eggs (3), longevity (16 days), and duration of oviposition (2.7 days), which were fed on pollen and nectar from white mustard compared to those fed on buckwheat (number of females that laid eggs = 7; longevity = 45.30 days; mean duration of oviposition = 27.50 days); alyssum (number of females that laid eggs = 4; longevity = 31.8 days; mean duration of oviposition = 17.25 days); and coriander (number of females that laid eggs = 11; longevity = 23.7 days; mean duration of oviposition = 13 days). However, oviposition rate (46.6 eggs/day) was greatly enhanced by feeding on pollen and nectar from mustard compared to feeding on buckwheat (16.91 eggs/day), phacelia (*Phacelia secunda* J.F.Gmel.) (41.30 eggs/day), coriander (19.50 eggs/day), and sweet alyssum (16.26 eggs/day).

Adding white mustard as a companion plant to broad bean plants influenced the predator–prey ratio and the number of adult lady beetles [18]. In one year (2015) of a three-year study, the mean number of adult lady beetles per broad bean plant in treatments with white mustard was twice as high as in monoculture. However, in the two other years of study, the mean abundance of lady beetles per broad bean plant was higher in monoculture (0.094 adults/plant in 2016 and 0.219 adults/plant in 2017) compared to white mustard treatments (0.022–0.087 adults/plant in 2016 and 0.044–0.104 adults/plant in 2017). In addition, the findings showed that the number of lady beetle egg clutches laid on broad bean plants grown near mustard did not differ significantly from monoculture across the years of study. The proximity of white mustard to broad beans did not influence the dynamics of lady beetle occurrence either. The analysis of lady beetle occurrences in 2015 and 2016 indicated their relatively late appearance on broad bean plants, both cultivated in the vicinity of white mustard and in the control. However, for the whole observation period in 2017, its number stayed at a low, almost stable level. In contrast, the number of aphids per one predator in the white mustard treatments compared to the monoculture was between 1.0 and 12.0 times lower for lady beetle larvae and between 3.8 and 7.2 times lower for adult lady beetles, depending on the year of the study and the treatment, meaning that the lady beetle's ability to reduce aphid populations was significantly higher in the mustard treatments. Other research on the influence of white mustard used as living mulch in zucchini on coccinellids showed that their mean population density was not significantly different between monoculture and white mustard–zucchini treatment at Waimanalo, Oahu, throughout the season [29]. White mustard was destroyed by a soil-borne pathogen, *Pythium* sp., before transplanting the zucchini, so a natural succession of weeds was allowed to occur. This might be the reason that there was no difference in lady beetle abundance. On the other hand, at a different site (Poamoho), the mean population density of coccinellids per zucchini leaf in monoculture was significantly higher than that on zucchini with white mustard used as living mulch.

Among the natural enemies of pests, a significant role is played by predatory bugs from the Anthocoridae (Hemiptera) family. In the beating samples (branch hit with a rubber stick, causing insects to fall into the plastic bag), Winkler et al. [32] observed more predatory bugs, *Anthocoris nemoralis* Fabr., in the 5th sampling week (approx. 4 more adults/40 beats) near flowering strips, which included *S. alba* in pear (*Pyrus communis* L.) orchards, compared to trees neighbored by grass strips. On other sampling weeks, the average number of adults was quite similar (1st and 6th weeks: 1 more adult/40 beats; 4th week: 1 less adult/40 beats), or they were not observed (2nd and 3rd weeks). Analogously, the authors observed more individuals of *A. nemoralis* nymphs in the 4th (approx. 11 more nymphs/40 beats) and 5th weeks (approx. 2 more nymphs/40 beats) of sampling on trees adjacent to flowering plots compared to trees neighbored by grass strips. The authors did not find any *A. nemoralis* nymphs, either in treatments with flowering strips or grass strips, on another three-sampling days. There was no difference in the density of *A. nemoralis* nymphs between the treatments in twig samples.

Quantifying the effects of various nectar sources on parasitoid survival and fecundity provided important insight into which plant species should be retained or introduced into the agroecosystem. Wild mustard (*Sinapis arvensis* L.) increased the longevity of the aphid parasitoid *Aphidius colemani* Viereck (Hymenoptera: Braconidae) (2–4 days for females and 1–2 days for males) compared to the control (1–3 for females and 1 for males) [33]. There was also a significant difference in the mean egg number laid by parasitoids between the mustard and the control (water). Mustard treatment resulted in 180 eggs per female, while the mean egg number in control was 110 eggs per female at 24 h after release. Furthermore, wild mustard inclusion resulted in an increased parasitism rate (43.3%) of green peach aphids, *Myzus persicae* Sulzer (Hemiptera: Aphididae), through an increase in *A. colemani* survival and egg load compared to the control (20.7%). In New Zealand, Tompkins et al. [34] analyzed how the nectar from white mustard can affect parasitoid fitness. They observed that the provision of nectar solutions significantly increased (female: 82–85 days and male: 51–56 days) the lifespan of the parasitoid *Diadegma semiclausum* Hellen. (Hymenoptera: Ichneumonidae) when compared to those fed with tap water (female: 69 days and male: 60 days). White mustard flower nectar had a great effect on the average number of parasitoids and parasitism of the Scolytus elm bark beetle, *Scolytus scolytus* Fabr. (Coleoptera: Curculionidae) [35]. In the catch trunks alongside the areas growing mustard, the numbers of parasitoids were higher (average of 5.53 parasitoids per $dm^2$ of bark) in the first generation than in the control (average of 2.92 parasitoids per $dm^2$ of bark). Similarly, in the second generation, the average number of parasitoids in the control catch trunks was only 1.66 parasitoids per $dm^2$ of bark, while in the catch trunks near the mustard-growing area, it was 3.12 parasitoids per $dm^2$ of bark. White mustard also positively affected the parasitism of the elm bark beetle. In the first generation, the parasitism of the pest in the vicinity of white mustard plants was 41.21%, while in the control catch trunks, it reached 23.06%. In the second generation, for the catch trunks near the mustard plants, there were 47.44% parasitized bark beetles, and in the control, only 29.02%. White mustard increased parasitism by *Aphidius* spp. on the aphids *Metopolophium dirhodum* Walker (Hemiptera: Aphididae) and *Sitobion avenae* Fabricius (Hemiptera: Aphididae) on cereal crops [36]. The results showed that the overall aphid parasitism reached 70% in cereals (wheat and barley (*Hordeum vulgare* L.)) plots close to mustard cover crops and 60% in cereal plots close to grassy margins (control). Winkler et al. [37] conducted experiments to analyze the exploitation of white mustard by *Cotesia glomerata* L. (Hymenoptera: Braconidae) and *D. semiclausum*, parasitoids of *Plutella xylostella* L. (Lepidoptera: Plutellidae) and *Pieris* spp. (Lepidoptera: Pieridae). The results indicated that when *C. glomerata* was exposed to white mustard, it survived for 8–15 days, compared to 2.1 days on average in the control (exposed to water). However, provision with white mustard flowers did not increase the longevity of *D. semiclausum*. The results of this study contradicted the findings of Tompkins et al. [34] above. The difference in the results may be due to variations in temperature and humidity during the experiments. For Winkler et al. [37], the experiment cages were placed at 22 °C with 16 h of light and 8 h of darkness and high relative humidity (90 ± 5% r.h.). On the other hand, for Tompkins et al. [34], the cages were placed at 20 ± 2 °C with 70% relative humidity and 16 h of light and 8 h of darkness. Mustard nectar did not significantly increase the longevity of *Microctonus hyperodae* Loan & Lloyd (Hymenoptera Braconidae), a parasitoid of the Argentine stem weevil, *Listronotus bonariensis* Kuschel (Coleoptera: Curculionidae), compared to the water treatment [28]. The possible reason could be that it may not be able to collect mustard nectar.

When multiple crops are grown together, crop mixtures can provide diverse plant types with easily decomposable residues that support soil biota [38]. Studies showed that white mustard increased soil fauna activity. For instance, in the first year of study, the average number of *Amara aenea* De Geer beetles (Coleoptera: Carabidae) was higher in a mustard/buckwheat/canola management system (white mustard, followed by buckwheat, followed by winter canola (*Brassica napus* L.)) (78 beetles/trap) compared to all other management systems (11 beetles/trap) (oat–pea/rye–hairy vetch: spring oat (*Avena sativa* L.) and field pea (*Pisum sativum* L.), followed by cereal rye (*Secale cereale* L.) and hairy vetch (*Vicia villosa* Roth); oat–red clover: spring oat and red clover; fallow: bare fallow where weeds were controlled with tillage and no crop was grown) [39]. The dense canopy cover of flowering mustard could serve as a good habitat in a mustard/buckwheat/canola management system. In the next year of study, *A. aenea* abundance declined to near zero ($n$ = 4 total across all the treatments). Furthermore, carabid beetles (Coleoptera: Carabidae) were found in significantly higher numbers (4–21 beetles/m$^2$) on sugar beet (*Beta vulgaris* L.) with white mustard compared to sugar beet with phacelia (2–17 beetles/m$^2$) [40]. White mustard plots may have had more predatory arthropods because this plant left more organic material on the soil surface than phacelia. Groeneveld and Klein [41] investigated the effect of a pennycress (*Thlaspi arvense* L.)–corn double-cropping (harvesting of two crops in one calendar year) system on ground beetle diversity in comparison to three commonly applied corn rotations: mustard–corn (*Zea mays* L.), green fallow (land with spontaneous natural growth)–corn and bare fallow (land remaining uncropped for a season)–corn. The results indicated that the mustard–corn rotation harbored higher ground beetle abundance in comparison with the green fallow–corn and bare fallow–corn rotation. However, the overall abundance of beetles was lower than in the pennycress–corn double cropping system.

**Table 1.** Effects of white mustard on beneficial insects in different crops. Data on other mustard species are marked with relevant superscripts [(1)].

| Crop | Exp. Type | Duration | Benefited Organisms | Effect | Notes | Ref. |
|---|---|---|---|---|---|---|
| | | | Hoverflies | | | |
| Broad bean | Field | 3 years | Syrphidae generally | Positive | Number of larval end eggs increased. | [18] |
| -- | Field | 1 year | Syrphidae generally | Positive | Higher number of adult feeding visits in comparison to alyssum, buckwheat, and calendula. | [16] |
| Broad bean | Greenhouse | 1 year | *Episyrphus balteatus* Deg. | Positive | Greater oviposition rate on mustard pollen and nectar compared to buckwheat, phacelia, coriander, and alyssum. | [31] |
| | | | | Negative | Lower longevity, number of female eggs laid, and duration of oviposition compared to buckwheat, alyssum, and coriander. | |
| Zucchini | Field | 2 years | Syrphidae generally | No effect | Densities of adult syrphids are similar in monoculture and white mustard–zucchini intercrop. | [29] |
| Broccoli | Field | 1 year | Syrphidae generally | | Number of larvae increased by 14.2%. | [30] |
| | | | Lady beetles | | | |
| Broad bean | Field | 3 years | Lady beetles generally | Positive | Higher number of adults, but only in one year of study. Lower number of aphids per one predator. | [18] |
| Zucchini | Field | 2 years | Lady beetles generally | No effect | Density of adult coccinellids is similar in monoculture and in treatment with mustard mulch at one site. | [29] |
| | | | | Negative | Lower number of adult coccinellids in treatment with mustard at a different site. | |
| | | | Anthocorids | | | |
| Pear orchard | Field | 1 year | *Anthocoris nemoralis* Fabr. | Positive | More nymphs and adults in beating samples. | [32] |
| | | | | No effect | Density of nymphs is similar in trees adjacent to flowering strips and grass strips in twig samples. | |

**Table 1.** *Cont.*

| Crop | Exp. Type | Duration | Benefited Organisms | Effect | Notes | Ref. |
|---|---|---|---|---|---|---|
| | | | Parasitoids | | | |
| -- | Laboratory | 1 year | *Aphidius colemani* Viereck | Positive | Longer lifespan, a higher number of eggs per female, and a higher parasitism rate. | [33] (1) |
| -- | Laboratory | 1 year | *Diadegma semiclausum* Hellen. (Hymenoptera: Ichneumonidae) | | Increased lifespan of adults. | [34] |
| Oak/hornbeam and elm | Field and laboratory | 1 year | *Ecphylus silesiacus* Ratz. *Coeloides scolyticida* Wesmael | | Higher number of parasitoids. Higher parasitism rate of the elm bark beetle. | [35] |
| Cereals, wheat, and barley | Field | 1 year | *Aphidius* spp. | | Higher aphid parasitism than close grassy margins. | [36] |
| -- | Field | 1 year | *Cotesia glomerata* L. | | Increased longevity. | [37] |
| -- | Laboratory | 1 year | *Microctonus hyperodae* Loan & Lloyd | No effect | No effect on longevity. | [28] |
| -- | Laboratory | 1 year | *D. semiclausum* | | No effect on longevity. | [37] |
| | | | Epigeal and soil fauna | | | |
| Multiple cover crops | Field | 2 years | *Amara aenea* De Geer | Positive | Higher number of beetles in mustard/buckwheat/canola systems of management than in other systems. | [39] |
| Sugar beet | Field | 2 years | Carabid beetles | | Higher number of beetles compared to phacelia. | [40] |
| Corn | Field | 2 years | Carabid beetles | | Higher abundance of beetles in mustard–corn rotation in comparison with green fallow–corn and bare fallow–corn (however, lower compared to the pennycress–corn double cropping). | [41] |

--: not applicable. (1) *Sinapis arvensis* L.

### 3.2. Influence on Pests

The use of insectary plants to attract natural enemies can improve pest control through biological means. Moreover, based on the "enemy hypothesis", the control of herbivores by their natural predators is predicted to be more effective in diversified crop environments compared to simplified ones. This is because natural predators may be more prevalent in habitats that provide a wider range of prey–host species and microhabitats for them to exploit [42].

White mustard found wide application as a component of mixed cultivations due to its limiting effects on insect pests (Table 2). Intercropping broad bean with white mustard increased the predation by hoverflies and lady beetles on *Aphis fabae* Scop. (Hemiptera: Aphididae) [18]. It was observed that the average number of *A. fabae* on broad beans was significantly lower in treatments where mustard was present. Specifically, the counts were 2, 9, and 7 times lower in the 1st, 2nd, and 3rd years of the study, respectively, when compared to the homogeneous broad beans. According to this report, the number of aphids per hoverfly larva was 2–11 times higher in the homogenous broad bean (control) than in the white mustard treatments, depending on the treatment and the year of study. In the case of lady beetle larvae, the aphid–lady beetle larva ratio was 1–12 times lower in the vicinity of white mustard compared to the control, depending on the year of study and treatment. Likewise, the number of aphids per lady beetle adult in mustard treatments was reduced by 3.8–7.2 times compared to the control in two out of three years of the study. Similarly, it was reported that the mean number of aphids was lower in broad bean plants accompanied by white mustard in strips (1.64 aphids/plant) and in inter-rows (6.89 aphids/plant) than for monotypic cultivation (pure stand) (11.44 aphids/plant) [43].

White mustard sown one week after transplanting broccoli tended to reduce the number of *B. brassicae* [30]. Aphid mean density in broccoli monoculture amounted to 0.31 aphids/g of fresh plant biomass, and when mustard accompanied the broccoli, it reached 0.16 aphids/g of fresh plant biomass. Mustard as living mulch can be a useful tool in controlling pests in zucchini crops [29]. In one site, the mean number of apterous melon aphids, *Aphis gossypii* Glover (Hemiptera: Aphididae), was significantly reduced in the mustard–zucchini system on specific sampling dates after zucchini transplanting, i.e., day 30 after transplanting (nearly 5 aphids/leaf), day 37 (10 aphids/leaf), day 44 (nearly 80 aphids/leaf), and day 53 (nearly 100 aphids/leaf) compared with bare ground zucchini (no mustard mulch) (nearly 15 aphids/leaf on day 30, 50 aphids/leaf on day 37, 190 aphids/leaf on day 44, and 380 aphids/leaf on day 53). White mustard had similar success in reducing the mean number of alatae aphids on the 37th day after planting (nearly 0.5 aphids/leaf), the 44th (nearly 2.5 aphids/leaf), and the 53rd (nearly 1.3 aphids/leaf) compared to bare ground zucchini (nearly 1 aphid/leaf, 3.5 aphids/leaf, and 5 aphids/leaf on the 37th, 44th, and 53rd days after planting, respectively). However, on the 30th day after planting, there was no significant difference in the density of alatae aphids between the white mustard–zucchini system and the bare ground zucchini. In other sites, the population response of apterous and alatae aphids to white mustard mulch varied.

Daniarzadeh et al. [44] examined the influence of different trap crops on the population of *P. xylostella* adults. A higher mean number of diamondback moth adults was observed in white mustard (8.74 adults/plant) compared to common cabbage (*Brassica oleracea* L.) (control treatment) (1.00 adult/plant). However, the mean total number of larvae and pupa of the diamondback moth observed was higher on the control (common cabbage) (1.34 larvae plus pupa/plant) than on white mustard (1.05 larvae plus pupa/plant) during the growing season.

White mustard was also used as a trap crop, protecting cabbage from cabbage flea beetles, *Phyllotreta* spp. (Coleoptera: Chrysomelidae) [45]. The results indicated that the average indices of feeding damage by adult *Phyllotreta* spp. were significantly higher (ranging from 2.2 to 4.0) in white mustard compared to cabbage (ranging from 1.9 to 3.0), depending on the study year and experiment site. A positive correlation was found between the content of epiprogoitrin (one of the glucosinolates occurring in different *Brassica* species), present in white mustard leaves and flowers, and the feeding intensity of cabbage flea beetles [46].

The use of white mustard caused a significant decrease in the development of *Meloidogyne* spp. in tomato crops, with an effectiveness of 46.38% compared to the control [47]. The mechanism by which white mustard suppresses nematodes is through the production of allelopathic compounds. Furthermore, white mustard caused up to a 57.9% reduction in the *Meloidogyne javanica* Treub population in tomatoes compared to the control (without white mustard) [48]. The results showed no significant difference between the effectiveness of white mustard and the nematicide Fenamiphos 40EC in this experiment.

Winkler et al. [32] found no significant difference in density of pear psylla larvae, *Cacopsylla pyri* L. (Hemiptera: Psyllidae), between trees adjacent to flowering strips with white mustard and trees adjacent to grass strips (control). In pear trees accompanied by flowering strips, the average population density of *C. pyri* larvae was highest in weeks 24 (190 larvae/20 twigs) and 25 (200 larvae/20 twigs), decreased in week 26 (115 larvae/20 twigs), and reached extremely low levels in weeks 28 and 29. In pear trees adjacent to grass strips, there were

180 larvae/20 twigs in week 24, 160 larvae/20 twigs in week 25, and 110 larvae/20 twigs in week 27. Moreover, there were no significant differences in the severity of squash silverleaf, *Bemisia argentifolii* Bellows and Perring (Hemiptera: Aleyrodidae), disorder on zucchini plants between monoculture and white mustard treatments [29].

**Table 2.** Effect of white mustard on pests in different crops.

| Crop | Exp. Type | Duration | Notes | Ref. |
|---|---|---|---|---|
| Positive effect | | | | |
| Broad bean | Field | 3 years | Reduced abundance of *Aphis fabae* Scop. Reduced aphid–hoverfly larvae/lady beetle larvae/lady beetle adult ratio. | [18] |
| Zucchini | Field | 2 years | Reduced abundance of *Aphis fabae* Scop. | [43] |
| | | 2 years | Reduced number of *Aphis gossypii* Glover. | [29] |
| Cabbage | Field | 1 year | Reduced number of *Brevicoryne brassicae* L. | [30] |
| | | 1 year | Higher number of adult *Plutella xylostella* L. compared to cabbage. | [44] |
| | | 2 years | Higher index of feeding damage by adult *Phyllotreta* spp. than on the cabbage. | [45] |
| Tomato | Greenhouse | 3 years | Reduced infestation by *Meloidogyne* spp. | [47] |
| | | 1 year | Reduced population of *Meloidogyne javanica* Treub. | [47] |
| No effect | | | | |
| Pear orchard | Field | 1 year | Density of *Cacopsylla pyri* L. larvae on trees near flowering strips, including white mustard, is similar to trees near grass strips. | [32] |
| Zucchini | Filed | 2 years | No differences in the mean ratings of silverleaf, *Bemisia argentifolii* Bellows and Perring, symptoms on zucchini among monoculture and white mustard treatments. | [29] |
| Negative effect | | | | |
| Cabbage | Field | 1 year | Higher number of larvae and pupa of *Plutella xylostella* L. on the cabbage compared to white mustard used as a trap crop. | [44] |

### *3.3. Influence on Plant Pathogens*

Introducing companion plants plays an important role in the biological control of plant pathogens. The introduced plants can affect the abundance of microbial pathogens due to the increased distance between host plant roots [49], which can reduce the severity of disease [50]. These plants also diversify soil microorganisms antagonistic to the pathogens [51]. Companion plants can reduce the likelihood of splash-dispersed and soilborne diseases [52]. The roots of a non-susceptible partner plant can act as a physical barrier, slowing the spread of pathogens to nearby susceptible host plants [53]. Furthermore, disease reduction in companion planting can occur by modifying the crop microclimate in a way that suppresses pathogen growth.

White mustard can influence the incidence of diseases in crops (Table 3). In particular, white mustard decreased the steam base and root base infection index of spring wheat, where *Fusarium* spp. and *Fusarium culmorum* (W.G. Smith) Saccardo were the predominant pathogens [54]. The value of the disease index with the incorporation of white mustard decreased by 28% compared to the control without white mustard. Similarly, white mustard reduced the *Fusarium graminearum* Schwabe infestation level of the barley grain in different tillage systems [55]. It was 21% lower in direct drilling tillage and 29% lower in deep plowing practices with the introduction of white mustard compared to the same tillage practices without white mustard.

White mustard can suppress disease-vectoring pests [56,57], which in turn reduces disease incidences. The incidence of the aphid-transmitted virus, papaya ringspot virus-watermelon strain (PRSV-W), was lowered in zucchini with white mustard used as living mulch (4%) in comparison with zucchini monoculture (no mulch) (20%) [29].

Mustard species, including white mustard, can release allelopathic compounds that affect pathogens in the surrounding environment [58–60]. The most common allelochemical found in mustard tissues is glucosinolate sinigrin, which occurs both in below- and above-ground plant parts [61].

**Table 3.** Effect of white mustard on plant pathogens in different crops.

| Crop | Exp. Type | Duration | Effect | Notes | Ref. |
|---|---|---|---|---|---|
| | | | Fungi | | |
| Wheat | Field | 3 years | Positive | Lowered steam base and root base infection. | [54] |
| Barley | Field | 5 years | | Lower infestation level by *Fusarium graminearum* Schwabe. | [55] |
| | | | Viruses | | |
| Zucchini | Field | 2 years | Positive | Reduced incidence of the papaya ringspot virus-watermelon strain. | [29] |

*3.4. Impacts on Growth Parameters and Yield of Crops*

The benefits of suppressing insect pests and pathogens using white mustard are evident. This review also summarizes the effects observed in several growth parameters, including plant height, fresh and dry aerial and root biomass, root length, and yield of diverse crops exposed to white mustard (Table 4).

An increased average mass of leaves (by 15.6%) and mass of pods (by 42.6%) was observed in a white mustard–broad bean system at a row spacing of 80 cm compared to the homogeneous broad bean (row spacing 50 cm), while seed yield increased by 21.9% at a row spacing of 65 cm across years of study compared to unprotected monocrop [18]. Biniaś et al. [62] studied the effects of white mustard on the germination capacity of broad bean seeds collected in a field experiment in which they were grown with white mustard at varying row spacings. The results indicated that the proximity of white mustard increased the average length of roots (45 mm) and length of above-ground part (18 mm) of seedlings, but only in the highest applied spacing of rows (80 cm) compared to monoculture with 50 cm spacing of rows (root length: 35 mm and length of above-ground part: 10 mm). A stimulating effect of the white mustard's proximity on the root branching of broad bean seedlings was also recorded. A higher number of lateral roots (9.5) longer than 2 mm were developed by the broad bean seedlings, which originated from seeds collected in the treatment with white mustard at a row spacing of 80 cm in relation to monoculture (4.5). In line with this, intercropping white mustard and corn with and without a root barrier (impermeable plastic sheets made of plexiglass (3 mm thick) installed into the soil between the rows to a depth of 50 cm prior to planting to stop interspecific root interactions between maize and white mustard) affected corn above-ground biomass and grain yield [63]. Corn above-ground biomass ranged between 81.8 g plant$^{-1}$ (corn monocropping, 2018, no root barrier) and 140.8 g plant$^{-1}$ (white mustard–corn intercropping, 2018, no root barrier) across years and barrier treatments. Corn grain yields ranged between 9.7 g plant$^{-1}$ (corn monocropping, 2019, root barrier) and 24.5 g plant$^{-1}$ (white mustard–corn intercropping, 2018, no root barrier) across years and barrier treatments.

Although the majority of analyses showed enhanced predator presence, herbivore suppression, and other ecosystem services in intercropping, this often did not correlate with yield gains [64,65]. This implies that, in intercropping systems, competition reduces productivity more severely than pests [66]. White mustard caused a significant decrease in early (by 34%) and total (by 17%) yields of tomatoes, as well as a decrease in the average fruit weight (by 11.1%) in relation to monocropping [47]. Romaneckas et al. [67] found a reduced (on average by 20 tons per hectare) yield of sugar beet in intercropping with white mustard compared to monocropping.

**Table 4.** Effect of white mustard on growth parameters and yield of crops.

| Crop | Exp. Type | Duration | Notes | Ref. |
|---|---|---|---|---|
| | | Positive | | |
| Broad bean | Field | 3 years | Higher seed yield at a row spacing of 65 cm. Increased mass of leaves and mass of pods with seeds at a row spacing of 80 cm | [18] |
| | Laboratory | 1 month | Increase in length of primary root and above-ground part of seedlings and higher number of lateral roots. | [62] |
| Corn | Field | 2 years | Increase in above-ground biomass. Higher grain yield. | [63] |
| | | Negative | | |
| Sugar beet | Field | 3 years | Reduced yield | [67] |
| Tomato | Greenhouse | 3 years | Reduced early yield, total yield, and average fruit weight. | [47] |

## 4. Sweet Alyssum

### *4.1. Influence on Beneficial Entomofauna*

Sweet alyssum is one of the most commonly utilized insectary plants [68]. The prolonged flowering cycle characteristic of this plant can ensure pollen and nectar sources for hoverflies and parasitic wasps throughout the entire period of crop growth [11,16,17,69]. The white color of sweet alyssum blooms is attractive to many insects, and the morphological structure of the flowers allows easy access to nutrients [69]. Sweet alyssum should be visible and easily accessible to the insects, and that can be achieved by the correct selection of row spacing [11].

A great emphasis is attached to the sweet alyssum's capacity for luring the pests' natural enemies, particularly the dipterans of the Syrphidae family [70,71] and the parasitic hymenopterans [72,73] (Table 5). The presence of sweet alyssum in field cages strongly enhanced egg production of adult female hoverflies, *Eupeodes fumipennis* (Thomson) (Diptera: Syrphidae), on lettuce plants (*Lactuca sativa* L.) [70]. It was shown that the number of hoverfly eggs remained low throughout the experiment in the control treatment (non-flower), reaching a peak of only 1.24 eggs/lettuce plant. In contrast, the number of eggs in the alyssum's presence gradually increased to a maximum of 7.59 eggs/lettuce plant on the 11th day after the release of adult female hoverflies into field cages. The results also indicated that the number of hoverfly larvae per lettuce plant was higher (0.99 larvae/plant) in the sweet alyssum treatment compared to the control (0.58 larvae/plant). The number of hoverfly larvae in the control treatment increased until day 14, then declined, whereas the number in the alyssum treatment continued to grow until day 18. Adding flowering sweet alyssum to radish (*Raphanus raphanistrum* Domin) plots increased the mean number of syrphids (1.74 adult plus larva/plot) compared to non-flowering plots (0.69 adult plus larva/plot) [74]. The attractiveness of sweet alyssum flowers for hoverflies was compared to the flowers of other plants [16]. At one experiment site, sweet alyssum received a significantly greater number of hoverfly feeding visits (3.75 adults/2 min) than rock *Aurinia saxitalis* L. Desv. (2 adults/2 min), white mustard (1 adult/2 min), and calendula (0.75 adults/2 min) on the first sampling date (7th June), with the exception of buckwheat (3.25 adults/2 min). On the three following sampling dates (14th July, 24th July, and 30th July), few adult hoverflies were observed visiting alyssum plants. At the other experiment site, sweet alyssum was less attractive (1 adult/2 min) compared to coriander (6 adults/2 min), but similarly attractive to phacelia (1 adult/2 min) on one specific date (July 16th); however, at this site, sweet alyssum was attacked by flea beetles, and it did not have enough flowers left to be evaluated across other sampling dates. Other studies showed variations in the attractiveness of sweet alyssum flowers for adult hoverflies [75]. In one year of study, *Sphaerophoria scripta* L. (Diptera: Syrphidae) and *Sphaerophoria rueppellii* Wiedemann (Diptera: Syrphidae) visited the flowers of alyssum more often (approx. 16 adults/min) than coriander (approx. 7 adults/min), whereas in the next year of the study, alyssum was excluded after comparing the attractiveness among the species and the duration of flowering in the first year.

In contrast, sweet alyssum had a worse effect on the fitness of the females of *E. balteatus* in comparison to other insectary plants [31]. The results indicated that feeding on sweet alyssum produced a lower mean oviposition rate (16.26 eggs/day) compared to buckwheat (16.91 eggs/day), phacelia (41.30 eggs/day), and coriander (19.50 eggs/day).

Intercropping sweet alyssum with collards (*Brassica oleracea* L.) contributed to an increase in coccinellid abundance [69]. The presence of sweet alyssum alongside collards increased the mean number of Coccinellidae adults (5–17 adults/plant) and larvae (7–11 larvae/plant) on collards compared to collards alone (1–4 adults/plant and 0–7 larvae/plant). Furthermore, the mean numbers of the seven-spot ladybird *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) in radish plots with adjacent flowering sweet alyssum were significantly higher (2.03 adults/plot) than in the control plots (0.74 adults/plot) [74].

The addition of sweet alyssum to prey significantly increased the longevity of the omnivorous bug *Orius majusculus* Reuter (Hemiptera: Anthocoridae) [76]. Adult females of *O. majusculus* survived 40.60 days on sweet alyssum with prey *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae), 25.60 days on sweet alyssum without prey, and 17.40 days on green beans with prey. Females on water or prey-free green beans only survived for 7.13 days and 7.60 days, respectively. Pease and Zalom [77] evaluated the density of the predator *Jalysus wickhami* Van Duzee (Hemiptera: Berytidae) in tomatoes adjacent to a sweet alyssum border and an unplanted control border. During the first sampling period (18th–25th June), the number of *J. wickhami* was significantly greater (2.33 bugs/tomato plant) in the sweet alyssum treatment than in the control plots (0 bugs/tomato plant). However, there were no significant differences in the number of *J. wickhami* recorded in sweet alyssum and control plots in the second sampling period (6th–13th August).

Sweet alyssum significantly increased the longevity of the aphid parasitoid *Diaeretiella rapae* M'Intosh (Hymenoptera: Braconidae) compared to the control (water) [72]. The survival period for adults was 4–10 days for females and 3–7 days for males in treatment with flowering sweet alyssum, while it was 2–3 days for females and 1–3 days for males in the control group. However, adults exposed to flowering sweet alyssum survived 2–3 times shorter compared to those provided with flowering buckwheat. The survival of another parasitoid, *A. colemani*, which had access to sweet alyssum, was also longer (2–9 days for females and 1–3 days for males) compared to the control (water) (1–3 days for females and 1 day for males) [33]. However, sweet alyssum did not significantly affect survival of *A. colemani* compared to other plant treatments (*S. arvensis*, *Mentha piperita* L., *Origanum vulgare* L., *Origanum marjorana* L., and *Diplotaxis erucoides* L. DC), with the exception of buckwheat (3–11 days for females and 2–7 days for males). Johanowicz and Mitchell [17] investigated the effects of sweet alyssum flowers on the longevity of two female parasitic wasps, *Cotesia marginiventris* Cresson (Hymenoptera: Braconidae) and *Diadegma insulare* Cresson (Hymenoptera: Ichneumonidae), in a greenhouse experiment. The result revealed that *C. marginiventris* survived approx. 4.8 times longer when provisioned with sweet alyssum flowers or honey than with water, while *D. insulare* survived on average approx. 12.7 times longer in the same situation. Sweet alyssum was found to positively affect the longevity of parasitoid *D. insulare* in laboratory conditions [73]. Compared to the water control diet (2.8 days), mean longevity was significantly higher when fed on sweet alyssum flowers (22.5 days). However, the nectar of sweet alyssum had a similar effect on *D. insulare* longevity as the nectars of *Brassica napus* L., *Thlaspi arvense* L., and *S. arvensis*. Even though they were not significantly different, there was a trend toward a higher weight of insects (0.3 mg) in treatment with sweet alyssum compared to water (0.2 mg). However, body weight was higher in treatments with *S. arvensis* (0.5 mg), *T. arvense* (0.38 mg), and *B. napus* (0.32 mg) than with *L. maritima*.

**Table 5.** Effect of sweet alyssum on beneficial insects in different crops.

| Crop | Exp. Type | Duration | Benefited Organisms | Effect | Notes | Ref. |
|---|---|---|---|---|---|---|
| Hoverflies | | | | | | |
| Lettuce | Field | 1 year | *Eupeodes fumipennis* (Thomson) | | Higher number of eggs and larvae. | [70] |
| Radish | Field | 1 year | Syrphids in general | | Higher number of adults and larvae. | [74] |
| -- | Field | 1 year | Syrphids in general | Positive | More hoverfly feeding visits than *Aurinia saxitalis* L. Desv., mustard, and calendula, but only at one site and at the beginning of the observation period. At the other site, it is less attractive than coriander but similarly attractive to phacelia. | [16] |
| -- | Field | 2 years | *Sphaerophoria scripta* L. and *Sphaerophoria rueppellii* Wiedemann | | More hoverfly visits than coriander in one year of study. | [75] |
| -- | Laboratory | | *Episyrphus balteatus* Deg. | Negative | Lower oviposition rate than buckwheat, phacelia, and coriander. | [31] |
| Lady beetles | | | | | | |
| Collard greens | Field | 2 years | Coccinellids in general | Positive | Higher number of adults and larvae. | [69] |
| Radish | Field | 1 year | *Coccinella septempunctata* L. | | Higher number of adults. | [74] |
| Anthocorids | | | | | | |
| -- | Laboratory | 7 months | *Orius majusculus* Reuter | Positive | Longer survival on sweet alyssum with prey eggs, *E. kuehniella*, compared to alyssum without prey and green bean with prey. | [76] |
| Tomato | Field | 1 year | *Jalysus wickhami* Van Duzee (Hemiptera: Berytidae) | | Higher number in the 1st sampling period (end of June). | [77] |
| Parasitoids | | | | | | |
| -- | Laboratory | 1 year | *Diaeretiella rapae* M'Intosh | | Longer survival compared to the control (water), but lower than on buckwheat. | [72] |
| -- | Laboratory | 1 year | *Aphidius colemani* Viereck | | Longer survival than that of the control (water). | [33] |
| -- | Greenhouse | 1.5 year | *Cotesia marginiventris* Cresson and *Diadegma insulare* Cresson | Positive | Increased survival. | [17] |
| -- | Laboratory | 1 year | *Diadegma insulare* Cresson | No effect | Longer survival and body weight than on the water control diet. Similar longevity in relation to *B. napus*, *T. arvense*, and *S. arvensis*. | [73] |

**Table 5.** *Cont.*

| Crop | Exp. Type | Duration | Benefited Organisms | Effect | Notes | Ref. |
|---|---|---|---|---|---|---|
| | | | Epigeal and soil fauna | | | |
| Radish | Field | 1 year | Carabidae, Staphylinidae, Formicidae | Positive | Higher number of individuals. | [74] |
| Lettuce | Field | 1 year | Araneae, Cicadellidae, Carabidae | | Higher number of individuals. | [7] |
| Pumpkin | Field | 3 years | Araneae, Carabidae, Formicidae, Opiliones | No effect | Similar abundance in pumpkin next to sweet alyssum and next to grass control. | [78] |
| Vineyards | Field | 3 years | Carabidae, Nitidulidae, Opiliones, Staphylinidae, Araneae | | Similar abundance with and without sweet alyssum. | [79] |

--: not applicable.

Sweet alyssum strips in crop fields increased the abundance and diversity of epigeic and soil fauna (Table 5). For instance, sweet alyssum in common radish fields significantly increased the number of Carabidae, Staphylinidae, and Formicidae by 41.6%, 27.3%, and 26.3%, respectively, compared with the control (non-flowering) plot [74]. Sweet alyssum appeared to provide a more reliable habitat for epigeic and soil arthropods than mustard [7]. The average number of Cicadellidae (46 individuals/plot), Araneae (20 individuals/plot), and Carabidae (2 individuals/plot) across the five sample dates was higher in lettuce with sweet alyssum than with mustard (31 Cicadellidae/plot, 3 Araneae/plot, and 0 Carabidae/plot).

Phillips et al. [78] studied the influences of habitat management on predator abundance and composition in pumpkin fields. The authors reported that the average abundance of Araneae, Carabidae, Formicidae, Gryllidae, and Opiliones was not significantly different in pumpkin adjacent to alyssum compared to pumpkin adjacent to grass control. Moreover, the use of sweet alyssum in vineyards (*Vitis vinifera* L.) did not significantly affect the soil invertebrate fauna [79]. The abundance of *Pterostichus macer* Bonelli (Coleoptera: Carabidae) was even negatively affected by alyssum (0.3 adults/plot) compared to control (1.6 adults/plot), probably due to the presence of mulch derived from sweet alyssum.

### *4.2. Influence on Pests*

Sweet alyssum is widely reported to decrease aphid numbers in vegetable crops (Table 6). For instance, sweet alyssum reduced densities of woolly apple aphids, *Eriosoma lanigerum* Hausmann (Hemiptera: Aphididae), in two runs of field trials [71]. The mean number of aphids was significantly lower (550 aphids/plant in trial 1 and 560 aphids/plant in trial 2) on apple (*Malus domestica* Borkh) trees adjacent to alyssum compared to trees adjacent to mown grass with no flowers (850 aphids/plant in trial 1 and 800 aphids/plant in trial 2). Similarly, sweet alyssum covered period in lettuce had a lower density of aphids, *Nasonovia ribisnigri* Mosley (Hemiptera: Aphididae), (approx. 3–4 aphids/plant) compared to uncovered period (approx. 5–15 aphids/plant) [80].

Sweet alyssum incorporated in collard greens resulted in a reduction in the population of the whitefly *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) and *B. brassicae* due to an increase in generalist predator numbers [69]. It reduced the number of adult *B. tabaci* and *B. brassicae* by 69.6% and 87.5%, respectively, compared to collards alone. Hogg et al. [70] studied the efficacy of sweet alyssum in the suppression of aphids by the hoverfly *Eupeodes fumipennis* Thomson (Diptera: Syrphidae) in lettuce fields in California. As a result, the presence of sweet alyssum significantly lowered the number of aphids (approx. 100 aphids per one lettuce) compared to the control (approx. 600 aphids per one lettuce). The potential of sweet alyssum to enhance biological control of *M. persicae* using *A. colemani* under laboratory conditions was evaluated by Jado et al. [33]. The results indicated higher (83.3%) green peach aphid parasitism in the treatment with sweet alyssum compared to the control (20.7%). Similarly, the mean number of *M. persicae* was significantly lower in the radish plots with flowering sweet alyssum (0.7 aphids/plot) than in the control (non-flowering) plots (1.4 aphids/plot) [74]. Tiwari et al. [81] conducted a series of tests to evaluate the preferences of the wheat bug, *Nysius huttoni* L. (Hemiptera: Lygaeidae), on kale seedlings (used as a potentially susceptible control) and other non-kale plants as potential trap species. The results showed that sweet alyssum was significantly more favored (1.4 bugs per plant of alyssum over 120 h) than kale (*Brassica oleracea* L.) (0.8 bugs per plant of kale over 120 h), except for wheat (1.3 bugs per plant of wheat over 120 h) and phacelia (1.2 bugs per plant of phacelia over 120 h) in no-choice tests. In choice tests, sweet alyssum was also more suitable (1.6 bugs per plant of sweet alyssum over 120 h) than kale (1.1 bugs per plant of kale over 120 h), but still less suitable than wheat (1.8 bugs per plant of wheat over 120 h).

Sweet alyssum significantly influenced the rate of aphid parasitism by *D. rapae* under laboratory conditions [73]. As a result, the mean number of parasitized aphids exposed to sweet alyssum flowers was higher (186.1 aphids per *D. rapae* female) than in the control (water only) (49.4 aphids per *D. rapae* female). Pease and Zalom [77] evaluated the stink bug, *Euschistus conspersus* Uhler (Hemiptera: Pentatomidae), egg parasitism in tomatoes adjacent to a sweet alyssum border and an unplanted control border. They reported that the mean egg parasitism rate of *E. conspersus* sentinel eggs was higher (4.3–53.3%) in the sweet alyssum border than in the control (4.1–45.6%) throughout the sampling period. Furthermore, the addition of sweet alyssum increased egg predation of the spotted cucumber beetle, *Diabrotica undecimpunctata* Mannerheim (Coleoptera: Chrysomelidae), (75.69%) compared to grass control (63.66%) in the cucumber crop [78]. The presence of *L. maritima* also limited the eggs of the squash bug, *Anasa tristis* De Geer (Hemiptera: Coreidae)—egg predation was higher in the alyssum treatment (7.92%) than in the grass control (6.13%). In contrast, sweet alyssum did not seem to have a significant effect on any of the vineyard pests [79].

The presence of flowering plants in an agroecosystem is not always a guarantee of biocontrol service [82]. Some studies reported a negative effect of introducing insectary plants. Intercropping cabbage with sweet alyssum had a positive effect on flea beetle *Phyllotreta* spp. Chevrolat (Coleoptera: Chrysomelidae) infestation of cabbage plants (a maximum of 40 flea beetles per plant in the first experimental site and 1.0 flea beetles per plant in the other site in the alyssum treatment, and a maximum of 15 flea beetles per plant in the first site and 0.3 flea beetles per plant in the other site in the non-insecticide control) [83].

There was no information in the available literature on the effect of sweet alyssum on pathogens.

**Table 6.** Effect of sweet alyssum on pests in different crops.

| Crop | Exp. | Duration | Notes | Ref. |
|---|---|---|---|---|
| | | Positive effect | | |
| Lettuce | Field | 1 year | Reduced aphid numbers. | [70] |
| | | 1 year | Lower number of *Nasonovia ribisnigri* Mosley. | [80] |
| Apples trees | Field | 1 year | Lower number of aphids on trees near sweet alyssum than on trees adjacent to mown grass without flowers. | [71] |
| -- | Laboratory | 1 year | Higher green peach aphid parasitism. | [33] |
| Radish | Field | 1 year | Lower number of *Myzus persicae* Sulzer. | [74] |
| Collard greens | Field | 2 years | Reduced number of adult *Bemisia tabaci* Gennadius and *Brevicoryne brassicae* L. | [69] |
| -- | Greenhouse | 1 year | Higher number of *Nysius huttoni* L. on sweet alyssum than on kale plants. | [81] |
| Tomato | Field | 1 year | Higher parasitism rate of sentinel egg masses of *Euschistus conspersus* Uhler in the alyssum border than in the bare ground border. | [77] |
| -- | Laboratory | 1 year | Higher number of aphids parasitized by *Diaeretiella rapae* M'Intosh. | [72] |
| Cucumber | Field | 3 years | Higher *Diabrotica undecimpunctata* Mannerheim and *Anasa tristis* De Geer eggs predation than in grass control. | [78] |
| | | No effect | | |
| Vineyards | Field | 3 years | No significant effect on any of the vineyard pests. | [79] |
| | | Negative effect | | |
| Cabbage | Field | 1 year | Higher number of *Phyllotreta* spp. Chevrolat. | [83] |

--: not applicable.

### *4.3. Impacts on Growth Parameters and Yield of Crops*

Several studies have evaluated the influence of sweet alyssum occurrence on the productivity of various crops (Table 7). Sweet alyssum used as a companion plant to broccoli increased shoot dry matter by 31–67% compared to broccoli monoculture [11].

Köneke et al. [83] conducted a field experiment to estimate the possible effects of a wheat undersowing system with additional intercropping of sweet alyssum on cabbage. The results indicated that neither the wheat nor sweet alyssum intercropping significantly affected the weight of the cabbage crop. Similarly, the presence of sweet alyssum had no significant effect on the length of the primary root and the above-ground part of the broad bean seedlings, nor on the number of lateral roots [62]. Cucumber yield was not affected by alyssum flowers, with one exception: in 2015, cucumber yield was higher in sweet alyssum plots than in plots without alyssum flowers [84].

In contrast, intercropping with sweet alyssum can reduce lettuce yield [85]. The result indicated that lettuce head dry matter was 25% lower in the highest density intercropping treatment (65,333 lettuce transplants per ha (L100) plus additional sweet alyssum transplants at 5333 per ha) than in monoculture (65,333 lettuce transplants per ha (L100)). Dry matter of lettuce heads on intercropped plots was also slightly reduced compared to monoculture lettuce in the L50A50 replacement treatment (50% lettuce and 50% sweet alyssum ratio on intercropped plot) (by 9.5–23%) and in the L25A75 replacement treatment (25% lettuce and 75% sweet alyssum ratio) (by 11.6%).

**Table 7.** Effect of sweet alyssum on growth parameters and yield of crops.

| Crop | Exp. Type | Duration | Effect | Notes | Ref. |
| --- | --- | --- | --- | --- | --- |
| Broccoli | Field | 3 years | Positive | Higher shoot dry matter. | [11] |
| Broad bean | Laboratory | 6 months | No effect | No influence on the length of the primary root, above-ground part, or the number of lateral roots. | [62] |
| Cabbage | Field | 1 year | | No influence on harvest weight. | [83] |
| Cucumber | Field | 2 years | | No effect on the yield. | [84] |
| Lettuce | Field | 1 year | Negative | Lower dry matter content of heads in the highest density intercrop (monoculture lettuce plus additional 5333 sweet alyssum transplants per ha). | [85] |

## 5. Coriander

### *5.1. Influence on Beneficial Entomofauna*

Introducing coriander increases beneficial organism survival, fecundity, and abundance in agroecosystems (Table 8). In particular, coriander is widely known to attract adult hoverflies [86–89]. It was preferred to other flowers. Its shallow corolla allows access to both pollen and nectar [16]. At one test location, it received more hoverfly feeding visits on two sampling dates—16 July (6 adults per 2 min) and 25 July (13 adults/2 min)—than sweet alyssum (1 adult/2 min on 16 July and no visit on 25 July) and phacelia (1 adult/2 min on 16 July and 2 adults/2 min on 25 July). After 1 August (1 adult/2 min), coriander stopped blooming, and insignificant differences in feeding preferences were observed compared to sweet alyssum and phacelia. At the other site, it was also the most attractive plant on 24 and 30 July, attracting a mean of 9 adults/2 min and 2.67 adults/2 min, respectively. Coriander stopped flowering after these dates. Furthermore, coriander was a more suitable flower for female *E. balteatus* in terms of mean oviposition duration (13 days) than marigold (*Calendula arvensis* L.) (10.50 days) and white mustard (2.70 days) [31]. However, it was less suitable compared to buckwheat (27.50 days) and sweet alyssum (17.25 days). Coriander intercropped with carrot (*Daucus carota* (Hoffm.) Schübl. & G. Martens) was found to be attractive to Syrphidae [89]. As a result, significantly higher numbers of syrphids were recorded on the leaves of carrots (0.33 larvae plus pupae/plant in 2010 and 1.13 larvae plus pupae/plant in 2011) sown in intercropping with coriander compared to the homogenous carrot crop (0.22 larvae plus pupae/plant in 2010 and 0.38 larvae plus pupae/plant in 2011).

There was no significant difference in the average number of hoverfly larvae (2.84 larvae/plot in the first study year, 0.98 larvae/plot in the second study year) on cabbage plants in the plots with coriander and in the control plots (1.14 larvae/plot in the first year of study, and 0.84 larvae/plot in the second year of study) [88]. Similarly, no significant difference in the number of hoverfly visits was found between coriander (5.3 hoverfly/min), perennial wall-rocket (*Diplotaxis tenuifolia* L. DC.) (4.8 hoverfly/min), buchanweed (*Hirschfeldia incana* (L.) Lagr.-Foss.) (4.5 hoverfly/min), and marigold (5.9 hoverfly/min) in one year of study [90]. However, in the other year of the study, coriander showed a significantly higher number of visits (3.5 hoverfly/min) compared to perennial wall-rocket (2.4 hoverfly/min) and buchanweed (1.5 hoverfly/min), with the exception of marigold (3.6 hoverfly/min).

Intercropping carrot with coriander increased the number of Coccinellidae on the carrot (0.92 adults plus larvae/plant in 2010 and 1.59 adults plus larvae/plant in 2011) compared to a homogeneous carrot crop (0.58 adults plus larvae/plant in 2010 and 0.46 adults plus larvae/plant in 2011) [89]. Incorporating coriander in rows of strawberries increased the number of lacewing eggs laid on aphid-infested strawberry plants by fourfold compared to the control (monoculture) [91].

The effect of coriander flowers on the longevity of two parasitoids, *Aphidius ervi* Haliday (Hymenoptera: Braconidae) and *Dendrocerus aphidum* Rondani (Hymenoptera: Megaspilidae), was investigated in a laboratory experiment [92]. The result revealed that *A. ervi* exposed to coriander flowers survived 3–4 times longer than those in the control (water), but not as long as those in the buckwheat treatment, which survived 4–5 times longer than in the control. *D. aphidum* exposed to coriander flowers survived 3–5 times longer than those in the control but, similarly to *A. ervi*, not as long as those on buckwheat (5–6 times longer than in the control).

Introducing coriander into cropping systems can affect the abundance and diversity of predaceous soil surface arthropods [93]. Coriander intercropped with kale positively affected the overall abundance (increased by a factor of 2.0) and species richness (increased by a factor of 2.7) of Staphylinidae and Araneae compared to kale grown alone [94]. In contrast, coriander strips did not increase ecosystem service levels in mixed orchards in Portugal [95]. The result also revealed that the rate of seed predation on weed seeds by epigeic fauna showed no difference in the coriander and control plots.

**Table 8.** Effect of coriander on beneficial insects in different crops.

| Crop | Exp. Type | Duration | Benefited Natural Enemies | Effect | Notes | Ref. |
|---|---|---|---|---|---|---|
| Hoverflies | | | | | | |
| -- | Field | 1 year | Syrphids in general | Positive | More adults visit than on sweet alyssum. | [16] |
| -- | Laboratory | 1.8 year | *Episyrphus balteatus* De Geer | | Higher duration of oviposition when fed on nectar from coriander than in the case of marigold and white mustard. | [31] |
| Carrot | Field | 2 years | Syrphids in general | | Higher number of larvae plus pupae. | [89] |
| Cabbage | Field | 2 years | Syrphids in general | No effect | Insignificant difference in hoverfly counts. | [88] |
| -- | Field | 2 years | Syrphids in general | | The same number of visits compared to perennial wall-rocket and buchanweed in one year of study. | [90] |
| | | | | Positive | Significantly larger number of visits than on perennial wall-rocket and buchanweed, with the exception of marigold, in the other study year. | |
| Lady beetles | | | | | | |
| Carrot | Field | 2 years | Coccinellids in general | Positive | Higher number of adults plus larvae. | [89] |
| Lacewings | | | | | | |
| Strawberry | Under polythene-clad Spanish tunnels | 1 year | Lacewings in general | Positive | More eggs laid compared to monoculture. | [91] |
| Parasitoids | | | | | | |
| -- | Laboratory | 1 year | *Aphidius ervi* Haliday and *Dendrocerus aphidum* Rondani | Positive | Longer survival in comparison to water control. | [92] |
| Epigeal and soil fauna | | | | | | |
| Kale | Field | 1 year | Staphylinidae and Araneae | Positive | Higher number and species richness. | [94] |
| Mixed orchards | Field | 1 year | -- | No effect | No increase in ecosystem services from epigeic fauna. | [95] |

--: not applicable.

### 5.2. Influence on Pests

Several experiments assessed the potential of coriander in biological pest management (Table 9). Coriander as an intercrop in broad bean affected the feeding of pea leaf weevils, *Sitona* spp. (Coleoptera: Curculionidae), on broad bean [96]. *Sitona* spp. beetles damaged approximately 28% to about 75% of the leaves in the intercrop and 59% to about 86% in the homogeneous crop (control), depending on the year of study. However, the proximity of coriander did not significantly affect the degree of root nodule damage caused by *Sitona* spp. larvae (33.7% in 2011 and 8.1% in 2012) compared to monoculture (38.9% in 2011 and 11.6% in 2012).

Many legume crops are attacked by the pod borer *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae). In Bangladesh, coriander as an intercrop in chickpea (*Cicer arietinum* L.) helped control chickpea pod borer infestation [97]. As the finding showed, intercropping coriander reduced pod borer infestation by 3.71% to 10.06%, depending on the ratio of coriander within chickpea plants. Bickerton and Hamilton [98] investigated the effect of intercropping pepper (*Capsicum annuum* L.) with flowering plants to improve the biological control provided by the natural enemies of the European borer, *Ostrinia nubilalis* Hübner (Lepidoptera: Crambidae). As a result, intercropping pepper with coriander may lead to a higher percentage of predation on *O. nubilalis* eggs by *Orius insidiosus* Say (Hemiptera: Anthocoridae) (ranged from 4.7% to 15.2%) and *Coleomegilla maculata* DeGeer (Coleoptera: Coccinellidae) (ranged from 5.9% to 10.8%) than non-intercropped control plots (ranged from 2.6% to 10.1% by *O. insidiosus* and ranged from 5.0% to 8.5% by *C. maculate*) over the three years of the study.

Introducing coriander with carrot plants significantly reduced the aphid complex: *Cavariella aegopodii* Scop. (Hemiptera: Aphididae), *Semiaphis dauci* Fabr. (Hemiptera: Aphididae), and *A. fabae*, as well as Carrot psyllid, *Trioza viridula* Zett (Hemiptera: Triozidae) by 40% to 62.5% and 100%, respectively, to levels that did not require chemical control [89]. The authors reported that the reduction in pest incidence was correlated with the presence of the lady beetle, *Coccinella undecimpunctata* L. In addition, coriander introduction reduced root-knot nematode-infested carrot roots by 30.0% to 30.4% compared to homogeneous crops over the two-year study period.

Coriander ground cover reduced the number of incoming adults of *B. tabaci* on tomato crops by 79.7% compared to the control (bare soil) [99]. Coriander strips reduced the abundance of sucking bugs, *Lygus* sp. and *Nezara viridula* L. (Hemiptera: Pentatomidae), in tomato plants (1–6 bugs/plot) and lowered fruit damage by these sucking bugs (11–70%) compared to an uncovered edge (abundance: 5–37 bugs/plot; percent of damage: 18–75) throughout the crop cycle [100]. In another study, tomatoes intercropped with coriander had a lower abundance of *T. absoluta* by 34% compared with homogeneous tomatoes [93]. The reduction in *T. absluta* infestation was due to the increased diversity of predaceous arthropods, such as spiders, ants, and ladybird beetles.

However, incorporating coriander in rows of strawberries did not differentiate aphid numbers from control plants (an average of 113.7 aphids per plot), although there was a significant increase in the number of lacewing eggs laid on aphid-infested strawberry plants [91].

**Table 9.** Effect of coriander on pests in different crops.

| Crop | Exp. Type | Duration | Notes | Ref. |
|---|---|---|---|---|
| | | Positive effect | | |
| Broad bean | Field | 2 years | Reduced feeding of adult *Sitona* spp. | [96] |
| Chickpea | Field | 2 years | Reduced infestation with *Helicoverpa armigera* Hubner. | [97] |
| Pepper | Field | 3 years | Higher percent of *Ostrinia nubilalis* Hübner eggs predation by *Orius insidiosus* Say and *Coleomegilla maculata* DeGeer. | [98] |
| Carrot | Field | 2 years | Reduced number of *Cavariella aegopodii* Scop., *Semiaphis dauci* Fabr., *Aphis fabae* L., and *Trioza viridula* Zett. Reduced carrot root damage by root-knot nematodes. | [89] |
| Tomato | Field | 2 years | Reduced abundance and decreased fruit damage by *Nezara viridula* L. and *Lygus* spp. | [100] |
| | | 1 year | Reduced number of eggs of *Tuta absoluta* Meyrick. | [93] |
| | | 2 years | Reduced number of incoming whitefly adults. | [99] |

**Table 9.** *Cont.*

| Crop | Exp. Type | Duration | Notes | Ref. |
|---|---|---|---|---|
| | | No effect | | |
| Broad bean | Field | 2 years | No effect on damage caused to root nodules by *Sitona* spp. larvae | [96] |
| Strawberry | Polythene-clad tunnels | 1 year | Aphid population did not differ between control and intercropping. | [91] |

### 5.3. Influence on Plant Pathogens

Companion plants can directly prevent plant diseases by reducing pathogen spore dispersal and by altering environmental conditions to make them less favorable for pathogens. The effects of coriander proximity on plant pathogens are presented in Table 10. Boligłowa et al. [101] reported that introducing coriander into broad bean significantly reduced pod infection by Chocolate spot, *Botrytis fabae* Sardiña, (by 7.8%) compared to the homogeneous broad bean crop (control). A similar response was also noted for Ascochyta blight, *Ascochyta fabae* Speg. infection in broad beans. Furthermore, intercropping broad bean with coriander significantly reduced broad bean pod rust, *Uromyces viciae-fabae* (Pers.) J. Schröt, and Grey mold, *Botrytis cinerea* Pers., by 17.1% and 9.8%, respectively, in relation to the control.

In contrast, planting broad beans with coriander favored seed colonization by pathogenic, saprotrophic fungi [102]. It was reported that the average number of fungal isolates obtained in seeds from an alternating row crop of broad bean with coriander (546 isolates) was higher than in seeds from the control (501 isolates) (without protection) over the three years of the study. Likewise, intercropping coriander with tomatoes increased the severity of late blight in tomato plants (7.4%) compared to a single tomato crop (5.5% severity) [103]. The severity of powdery mildew was also positively influenced by intercropping tomatoes with coriander (25.1% in intercropping and 23.0% in monoculture).

The effects of several cover plants on the spread of the whitefly-borne tomato yellow mottle virus were studied in comparison with a conventional insecticide [99]. As a result, coriander reduced the accumulated disease incidence of the tomato yellow mottle virus by 61.4% compared to the bare soil control.

**Table 10.** Effect of coriander on plant pathogens in different crops.

| Crop | Exp. Type | Duration | Effect | Notes | Ref. |
|---|---|---|---|---|---|
| | | | Fungi | | |
| Broad bean | Field | 3 years | Positive | Reduced *Botrytis fabae* Sardiña, *Uromyces viciae-fabae* (Pers.) J. Schröt, and *Botrytis cinerea* Pers. pod infections. | [101] |
| | | 3 years | Negative | More fungal isolates were found in seeds obtained from plants interplanted with coriander than in seeds grown without protection. | [102] |
| Tomato | Field | 1 year | | Higher severity of late blight and powdery mildew. | [103] |
| | | | Viruses | | |
| Tomato | Field | 2 years | Positive | Reduced disease incidence of the tomato yellow mottle virus. | [99] |

### 5.4. Impacts on Growth Parameters and Yield of Crops

In addition to improved pest and disease management, intercropping coriander with other crops may have an impact on crop yield. Meta-analyses showed that the yield benefits of the intercropping system are more context-dependent [64,104]. The context dependency of yield is strongly correlated with competition between intercrops [105,106]. Overall, research suggests that intercropping coriander can be beneficial in terms of yield and system productivity (Table 11).

Intercropping coriander with chickpea at a density of 2 rows of coriander and 2 rows of chickpea produced a higher yield (1.4 t/ha), number of pods (45.67 pods/plant), 1000 seed weight (149.70 g), and height (35.00 cm/plant) of the chickpea than monoculture (1.03 t/ha (yield), 41.33 pods/plant (number of pods), 136.70 g (1000 seed weight), and 32.67 cm/plant (height) [97]. The increase in yield with intercropping could be attributed to differences in insect infestation due to the repellent nature of coriander. Using coriander as a cover crop in tomatoes increased the average yield of tomato plants (18,698 kg/ha) compared to the bare soil control (5148 kg/ha) over the years of the study [99]. The results indicated an association between increased yield in intercropping and reduced numbers of whitefly adults on tomatoes, decreased disease severity, and a reduced incidence of virus infections.

However, other studies showed that coriander as a companion plant had no significant effect on the number of root nodules produced by broad beans [96]; the fruit fresh weight and proportions of marketable fruit of strawberries [91]; or the total number of fruits, the number of marketable fruits, the total fruit yield, or the marketable yield of tomatoes [103] when compared to monoculture.

**Table 11.** Effect of coriander on growth parameters and yield of crops.

| Crop | Exp. Type | Duration | Notes | Ref. |
|---|---|---|---|---|
| | | Positive | | |
| Chickpea | Field | 2 years | Higher yield, number of pods, 1000 seed weight, and height. | [97] |
| Tomato | Field | 1 year | Increased yield. | [99] |
| | | No effect | | |
| Broad bean | Field | 2 years | Number of root nodules unaffected. | [96] |
| Tomato | Field | 1 year | Number of fruits per plant, total fruit yield, and marketable yield comparable in intercropping and monoculture. | [103] |
| Strawberry | Greenhouse/Polythene-clad tunnels | 1 year | Mean values of fruit fresh weight, percentage of marketable fruit, and fruit yield for strawberries comparable in intercropping and monoculture. | [91] |
| | | Negative | | |
| Broad bean | Field | 2 years | Lower yield. | [107] |
| Onion | Field | 2 years | Lower yield. | [108] |

Intercropping coriander with broad beans resulted in a lower yield of broad beans (708.46 kg/ha). The highest broad bean yield (880.87 kg/ha) was obtained in monoculture [107]. This may be due to the competition of coriander with broad bean plants. Similarly, Abdelkader and Mohsen [108] found that all the intercropping patterns: 1 row of coriander with 1 row of onion (1.22 t/ha and 1.17 t/ha in 1st and 2nd study years, respectively), 1 row of coriander with 2 rows of onion (1.97 t/ha and 2.06 t/ha in 1st and 2nd study years, respectively), and 1 row of coriander with 3 rows of onion (1.30 t/ha and 1.38 t/ha in 1st and 2nd study years, respectively) significantly decreased the total yield compared to the sole crop pattern (2.67 t/ha and 2.53 t/ha in the 1st and 2nd study years, respectively) across the study years.

## 6. Conclusions and Research Gaps

Current knowledge on pollen-bearing plants is primarily focused on the impact of particular species on beneficial fauna. Here we reviewed the effects of white mustard, sweet alyssum, and coriander as companion plants in crop production on the abundance and biology (longevity, fertility, and egg-laying duration) of beneficial insects, the occurrence of pests and plant pathogens, and productivity. The reviewed studies showed that white mustard, sweet alyssum, and coriander had different types and strengths of impacts on natural enemies, pest and disease outbreaks, and crop yield (Table 12). Despite some negative effects (e.g., favoring plant diseases, reduced yield), the overall benefits of their intercropping in enhancing ecosystem services outweigh these negative effects.

Thus, we concluded that the introduction of white mustard had a strong positive influence on the occurrence of Syrphidae, parasitoids, Coccinellidae, and Carabidae, as well as on the fertility of Syrphidae and the longevity of parasitoids—all of which are essential for biological pest management. It also greatly reduced pest infestations and had a positive impact on disease incidence (by limiting it). Crop yield may also be affected by *S. alba*; however, the influence depends on the spacing used and the main crop species. The disadvantages of white mustard are its relatively short flowering period and very intense and rapid growth, which may cause significant competition with the main crop. The presence of sweet alyssum had a strong positive impact on the abundance of Syrphidae, Coccinellidae, Anthocoridae, and the longevity of parasitoids and Anthocoridae; it also had a positive impact on the occurrence of epigeal and soil fauna (Carabidae, Staphylinidae, Aranea, Formicidae, and Cicadellidae). It had a positive effect on biological pest control as well. Similarly to white mustard, *L. maritima* can have a positive, negative, or no effect on yield (depending on the plant species being protected). Sweet alyssum, because of its small size, generally does not compete with the main plant and blooms early and for a long time. The disadvantage, however, is that it is susceptible to flea beetles, which excludes it as a companion plant for plants that are hosts of these pests. The introduction of coriander had a strong positive effect on the occurrence of Chrysopidae, Coccinellidae, Staphylinidae, and Aranea, as well as on the longevity of parasitoids and the egg-laying duration of Syrphidae. It also had a positive effect on the reduction of pests. In general, the yield is not significantly reduced by the proximity of the coriander. It is characterized by moderate growth and a long flowering period, although it starts to bloom quite late.

Our review suggests that the introduction of white mustard, sweet alyssum, and coriander into the cultivation of main crops can improve the biodiversity of beneficial entomofauna that can help control pests and reduce diseases, with benefits to crop and yield. The use of synthetic insecticides can thus be greatly reduced, but depending on the crop, year, and other factors that are often unknown or undervalued, it is not always possible to eradicate them from agricultural use. Moreover, there are still some research gaps, namely: the influence of white mustard, sweet alyssum, and coriander on the biology of some important beneficial insects, such as lady beetles and lacewings. The effects of sweet alyssum and coriander on parasitoid occurrence under field conditions are still not well understood. There is also little information about the influence of white mustard and coriander on epigeal and soil fauna, as well as the influence of revised insectary plants on plant pathogens. An interesting solution could also be to test the possibility of combining the positive features of these three plant species and to create a mixture that would allow an early start of the effect of attracting beneficial fauna (white mustard), would not constitute too much competition for the main plant (sweet alyssum), and would ensure the longest possible effect period (sweet alyssum and coriander).

**Table 12.** Summary of the type and strength of impacts on ecosystem services and yield.

| Parameters | White Mustard | Sweet Alyssum | Coriander |
| --- | --- | --- | --- |
| | Syrphidae | | |
| Occurrence | [++,0] | [++] | [++,0] |
| Longevity | [--] | [?] | [+] |
| Fertility | [++,-] | [-] | [?] |
| Egg lying duration | [---] | [?] | [++] |
| | Coccinellidae | | |
| Occurrence | [++,0,-] | [+++] | [+] |

**Table 12.** *Cont.*

| Parameters | White Mustard | Sweet Alyssum | Coriander |
|---|---|---|---|
| | Anthocoridae | | |
| Occurrence | [++,0] | [++] | [?] |
| Longevity | [?] | [++] | [?] |
| | Parasitoids | | |
| Occurrence | [++] | [?] | [?] |
| Longevity | [++,0] | [+++,0] | [+++] |
| Fertility | [+] | [?] | [?] |
| | Chrysopidae | | |
| Occurrence | [?] | [?] | [+++] |
| | Epigeal and soil fauna | | |
| Carabidae occurrence | [++] | [++,0] | [?] |
| Stapylinidae | [?] | [+,0] | [++] |
| Aranea | [?] | [+,0] | [++] |
| Formicidae | [?] | [+,0] | [?] |
| Cicadellidae | [?] | [+] | [?] |
| | Pests, pathogens, and yield | | |
| Pest suppression | [+++,0] | [++,0,-] | [++,0] |
| Pathogen suppression | [+] | [?] | [+,-] |
| Growth parameters and yield | [+,-] | [+,0,-] | [+,0,-] |

Type and strength of the effect: positive [+]: 1–2 times better than in control, positive [++]: 2–3 times better than in control, positive [+++]: > 3 times better than in control, negative [-]: 1–2 times less than in control, negative [--]: 2–3 times less than in control, negative [---]: <3 times less than in control, no effect [0], lack of information [?]. When more than one effect is reported on services, different signs are presented.

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