

Article

Effects of Flowering Companion Plants on Black Bean Aphid (*Aphis fabae* Scop.) Abundance and Predatory Syrphid (Diptera, Syrphidae) Occurrence in Red Beetroot

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Abstract

This study aimed to determine the effect of phacelia (*Phacelia tanacetifolia*), dill (*Anethum graveolens*), and mustard (*Sinapis alba*) used as companion plants in red beetroot cultivation on the occurrence of *Aphis fabae* and predatory Syrphidae. Flowering plants were established along the edges of the beetroot crop. Aphid populations on beetroot were monitored, while syrphid larvae and pupae were collected from aphid colonies, and adult syrphids were sampled from flowers of the companion plants. The results show that beetroots grown without flowering companions had significantly higher aphid populations. The strongest aphid reduction occurred in red beetroot grown near phacelia, with aphid numbers 7.9–52.7 times lower than in control plots. Flowering strips increased the abundance of hoverfly larvae and pupae in aphid colonies, with the highest numbers recorded near dill. In total, 440 predatory syrphid larvae and pupae representing 11 species were collected from black bean aphid colonies on beetroots, whereas 3246 hoverfly adults from 46 species were observed on flowering plants, confirming their role in biological aphid control. In both cases, the eudominant group included *E. balteatus*, *S. menthastri*, and *S. scripta*. Dill flowers were the most attractive in terms of the number of captured syrphid specimens, whereas mustard showed the highest species diversity.

Keywords: beetroot; black bean aphid; companion plants; syrphids

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1. Introduction

Red beetroot, hereafter referred to as beetroot *Beta vulgaris* L. subsp. *vulgaris* (Amaranthaceae), is among the most important vegetable crops due to its considerable economic and nutritional significance. It constitutes a valuable raw material for the food-processing industry and is widely used in the production of juices, concentrates, preserved products, and pickles. In addition, beetroot represents an important component of the daily human diet. Its high nutritional value results from the presence of vitamins, minerals, dietary fiber, and numerous bioactive compounds, particularly betalains, which exhibit well-documented health-promoting properties [1,2].

The European Union is the world's largest producer of beetroot, accounting for approximately 70% of global output [3]. Within the European Union, Poland is the leading producer of this vegetable. During the period 2020–2022, Poland's share of total EU beet-

root production averaged 31.6%, while substantial contributions were also recorded for France and Germany, accounting for 21.1% and 12.7% of EU production, respectively [4]. In 2025, red beetroot was cultivated on 7867.9 ha in Poland [5].

Beetroot is attacked by numerous insect pests, among which the black bean aphid (*Aphis fabae* Scop., Hemiptera, Aphididae) is considered particularly harmful. Aphids damage host plants by feeding on their sap, leading to leaf curling, deformation, chlorosis, and reduced photosynthetic activity [6]. Severe infestations can lead to stunted growth, poor root development, and significant yield losses, potentially reaching several tens of percent. Moreover, aphids secrete honeydew, which promotes the development of sooty mold fungi, thereby decreasing the effective leaf surface available for photosynthesis. In addition, black bean aphids can act as a vector of plant viruses, further lowering crop quality and productivity [7,8]. The aphid population is regulated by predatory and parasitic insects, among which predatory hoverflies (Syrphidae, Diptera) play an important role. Adult syrphids, whose larvae are voracious aphid predators, feed on pollen and nectar, which fulfill distinct physiological needs: nectar provides energy, while pollen supports egg production [9–15]. Therefore, creating favorable conditions for the survival, development, and reproduction of syrphids is crucial for enhancing their role in biological control. The biodiversity of beneficial insects in agricultural systems can be enhanced through vegetative measures such as wildflower meadows, flowering strips, and intercropping with flowering plants, which have been shown to support biodiversity and pest control in potato, faba bean crops, apple orchards, and vineyards [16–20].

Plant-feeding insects use a combination of visual, smell-based, and touch signals to locate suitable host plants. They are attracted to host plant chemicals and often repelled by non-host plant odors [21]. The presence of non-host species can disrupt this process, either by hiding the target crop physically or by releasing chemical compounds that confuse the pest. In this way, greater plant diversity can make host plants less noticeable or “apparent” to insects [22]. The proximity of different plant species can disrupt host recognition and reduce pest activity. Effective intercropping depends on selecting compatible plant species, particularly aromatic plants whose volatile compounds can interfere with insect host-finding, feeding, and reproduction [23]. Non-host plants can disrupt pest behavior by masking plant odors, repelling pests with aromatic compounds, or attracting them away from the main crop using trap crops.

Several studies have shown that diversifying the agroecosystem through companion planting can reduce aphid infestations. A positive effect on reducing *A. fabae* populations was observed by Tingey and Lamont [24] in beans (*Phaseolus vulgaris* L., Fabaceae) mixed with winter wheat (*Triticum aestivum* L., Poaceae), by Wnuk and Wojciechowicz-Żytka [8] on broad bean intercropped with phacelia (*Phacelia tanacetifolia* Benth., Boraginaceae) and by Gospodarek [20] on broad bean mixed with *Sinapis alba* L. (Brassicaceae). According to Pobożniak and Wnuk [7], and Wnuk and Pobożniak [25], the highest densities of *A. fabae* were observed in weed-free beetroot plots, whereas the lowest densities occurred in plots where weeds (assemblage of wild dicotyledonous and monocotyledonous species, with domination of *Stellaria media* (L.), *Taraxacum officinale* F.H., *Plantago lanceolata* L., *Plantago major* L., and *Poa annua* L.) were not removed. Similar reductions were reported for cabbage aphid *Brevicoryne brassicae* L. and aphids in brussels sprouts (*Brassica oleracea* L. var. *gemmifera* (DC.) Zenker, Brassicaceae) intercropped with *Spergula arvensis* (Caryophyllaceae) [26].

Risch et al. [27] reported that populations of the European corn borer (*Ostrinia nubilalis* Hbn., Crambidae) were reduced by the predatory lady beetle *Coleomegilla maculata* (Coccinellidae) in 59% of observations from corn–bean polycultures. Likewise, Andow [28], reviewing 209 studies that compared pest and natural enemy populations in monocultures and polycultures, found that pest abundance was lower in polycultures in 52%

of the cases analyzed. Companion plants enhance conservation biological control by providing alternative food sources and shelter, which increase the abundance and effectiveness of natural enemy communities [29]. Flowering plants that provide edible pollen and suitable nectar, including spontaneous vegetation, further improve the attraction, retention, and effectiveness of natural enemies in pest suppression [30,31].

In practice, agricultural landscapes can be managed by creating habitats near fields that attract adult Syrphidae, thereby increasing the population of these predatory insects [32]. Flowering plants attract hoverflies to the crops, after which the female lay their eggs in aphid colonies, and the predatory larvae feed on pests [33]. Effective biological control through the use of flowering plants that are highly attractive to beneficial insects requires a thorough understanding of the floral resources utilized by Syrphidae, as the importance of individual plant species remains insufficiently understood. Although landscape diversification has proven effective in attracting adult syrphids, the specific flowering plant species that most effectively enhance their abundance and biological control services are still being identified.

This study aimed to evaluate the effects of phacelia (*Phacelia tanacetifolia* Benth., Boraginaceae), dill (*Anethum graveolens* L., Apiaceae), and mustard (*Sinapis alba* L., Brassicaceae), used as companion plants in red beetroot cultivation, on the occurrence of the black bean aphid and the abundance of predatory Syrphidae. An additional objective was to assess the attractiveness of phacelia, dill, and mustard flowers to adult syrphid flies.

2. Materials and Methods

2.1. Plant Material and Experimental Setup

The beetroot cultivar *Beta vulgaris* L. var. *conditiva* Czerwona Kula was used in the field experiment. The cultivar applied in this study is recommended for cultivation in central Europe and is commercially available. The seeds were obtained from Polish breeding companies, namely, PlantiCo Zielonki in Stare Babice (Poland). It is a medium-early cultivar (vegetation period approx. 100–110 days), ideal for direct consumption, juices, and long-term storage.

The experiment also utilized three species of nectar-bearing plants: the Stala variety of blue phacelia *Phacelia tanacetifolia* Benth., the Maryna variety of white mustard, *Sinapis alba* L., and the Lukullus variety of garden dill, *Anethum graveolens* L. Seeds of blue phacelia and white mustard were obtained from Polish breeding companies, namely, Granum, Wodzierany (Poland), and seeds of garden dill from Horticultural Seed and Nursery Company in Ożarów Mazowiecki (Poland). The field study was in Kozłów (southern Poland, northern part of the Małopolska district, 50°29' N, 20°03' E, 235 m above sea level).

The beetroot cultivation was conducted on a typical brown soil with a pH of 6.5 and an organic carbon content of 18 g kg⁻¹ (organic matter content of approximately 31 g kg⁻¹). All agronomic practices followed the standard recommendations for this crop type. In the spring of each experimental year, plots were fertilized according to Integrated Production guidelines for field-grown beetroot. No chemical treatments were applied on experimental plots and on surrounding fields; weed control was performed mechanically and manually.

The experiment was conducted as a randomized complete block design (RCBD) with four replications from 2010 to 2013. Each block included four treatments which differed in the species of nectar-producing plant grown near the beetroot plots. The position of treatments within each block was randomized to minimize spatial variability every year. The first combination involved growing beetroot alongside blue phacelia, hereafter referred to as phacelia; the second used garden dill, hereafter referred to as dill; the third included white mustard, hereafter referred to as mustard; and in the fourth, the beetroots

grew without neighboring plants as a control. Each beetroot plot area was 14 m² (4.5 m × 4 m), and plots were separated by 8 m wide strips covered with turf (Figure 1). Seeds were sown (14 kg/ha) in rows, 0.3 m apart, each year on 28 April. For each combination, nectar-bearing plants were cultivated on both sides of the shorter edge of the beetroot plot in strips 4.5 m long and 1.5 m wide at a distance of 1 m from the beetroot plots. Each strip was divided into 3 equal parts, each measuring 1.5 by 1.5 m. Nectar-producing plant seeds were sown every four weeks, beginning in the last week of March each year, to ensure a continuous presence of flowers. The space between beetroot plots and strips with flowering plants was 1 m. The distance between individual repetitions was 10 m (Figure 1).

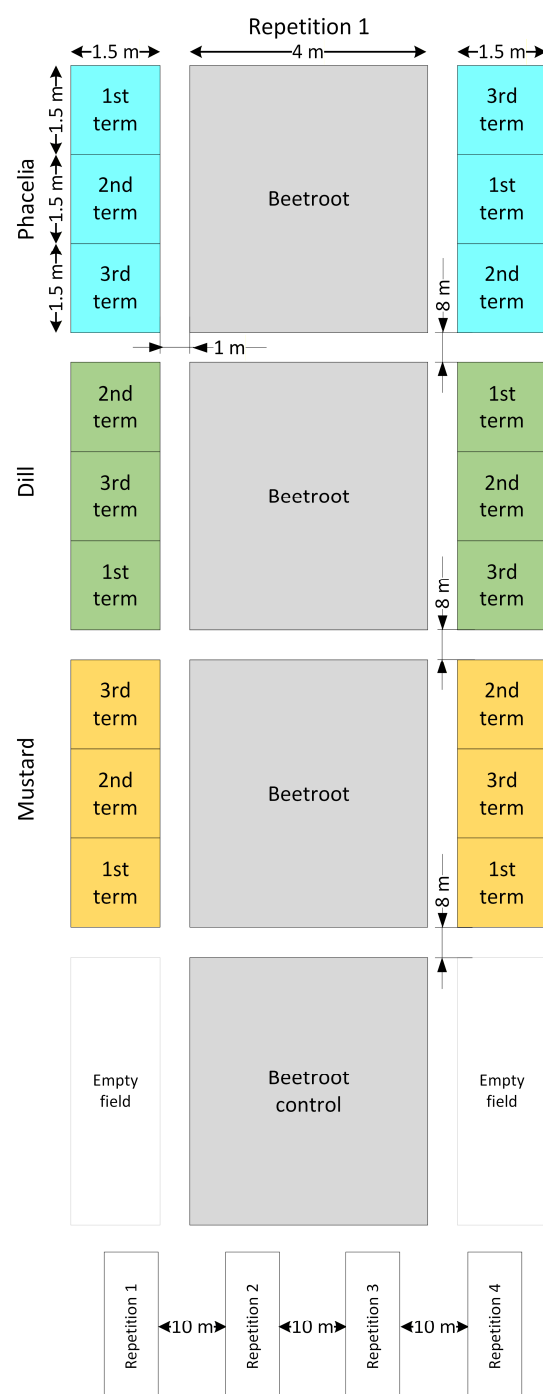


Figure 1. Graphical scheme of experiment.

2.2. Entomological Analyses

2.2.1. Black Bean Aphid Abundance

From mid-May to mid-July each year, at each sampling event, 20 randomly selected plants were examined once or twice per week for the presence of black bean aphids, *A. fabae*, within each plot. In small colonies (less than 20 specimens), all aphids, including alate and apterous forms, were counted. When their numbers were very high, an estimation was made (area-density method). Based on this data, the population dynamics of aphids were established.

2.2.2. Syrphid Abundance in the Black Bean Aphid Colony

The occurrence of syrphid larvae and pupae was assessed simultaneously with aphids on the same plants used to assess the black bean aphid. In addition, the numerical ratio of predators to prey was calculated. To determine the species composition, all syrphid larvae and pupae were picked up from aphid colonies and transferred to the laboratory. The rearing was conducted in a Petri dish at 24 ± 1 °C in $65 \pm 5\%$ relative humidity. Adults that emerged were identified to the species level.

2.2.3. Sampling the Syrphid Adults from Flowering Plants

The syrphid adults were sampled from the appearance of flowers, from the end of May until the third decade of July, marking the end of the black bean aphid's occurrence on beetroot, using a sweeping net. Sampling was conducted between 10:00 a.m. and 3:00 p.m. under clear weather conditions, with light wind and temperatures consistently above 15 °C. Each flowering plant species was surveyed for 20 min using a targeted sampling method, in which all hoverflies observed on flowers during the sampling period were collected. Species were identified in the field whenever possible and then released; if not, they were brought to the laboratory for identification using identification keys.

2.2.4. Determination of Syrphid Species

All collected syrphid adults were identified to species in the laboratory using morphological keys of van Veen [34] and Rotheray [35] under a binocular. The terminology of species was used according to Soszyński [36].

2.3. Data Analysis

Statistical analyses were performed using Statistica 13 software (Dell Inc., Round Rock, TX, USA, 2016). The experiment was conducted as a randomized complete block design (RCBD) with four replications. A block was included in the statistical analysis to account for field heterogeneity. Due to the experimental design and repeated sampling over time, data were analyzed separately for each year and sampling date using one-way ANOVA. This approach ensured independence of observations within each analysis and allowed for clear comparison of treatment effects. For all one-way ANOVA analyses, residual plots were examined to assess normality. When the assumption of normality was not met, data on the number of black bean aphids, as well as syrphid larvae and pupae collected from aphid colonies, were $\log_{10}(x + 1)$ transformed. For clarity, untransformed data are presented in the tables and figures. Multiple comparisons were performed using Tukey's multiple range test and Tukey–Kramer's test at $p < 0.05$.

To examine the relationship between the number of syrphid larvae and pupae collected from the aphid colony, Pearson's correlation coefficient (r) was calculated; significance was set to $p < 0.05$.

The dominance of syrphid species was assessed using the dominance coefficient (D) as outlined by Kasprzak and Niedbała [37]. Based on the value of this coefficient, five classes of dominance were identified:

- Eudominants (ED): $D > 10.00\%$;
- Dominants (D): $5.01\% < D < 10.00\%$;
- Subdominants (SD): $2.01\% < D < 5.00\%$;
- Recedents (R): $1.01\% < D < 2.00\%$;
- Subrecedents (SR): $D < 1.00\%$.

These classifications help in understanding the relative abundance and ecological significance of different syrphid species.

3. Results

3.1. Abundance of Black Bean Aphid

The aphid population size was larger in 2012 than in 2010–2011 and 2013. The elevated average temperatures in May, June, and July, combined with lower total rainfall, likely contributed to the increased aphid infestation observed in 2012 (Table 1; Table S1).

Table 1. Mean number ($\pm$ SEM) of *Aphis fabae* Scop. on beetroot grown with adjacent flowering strips (phacelia, dill, and mustard), and without such margins (control) in 2010–2013.

Crop	Mean Number ($\pm$ SEM) of Aphids/10 Plants			
	2010	2011	2012	2013
Beetroot with phacelia	4.36 ± 1.27 c *	14.65 ± 1.99 c	30.20 ± 4.06 c	22.45 ± 3.25 c
Beetroot with dill	124.40 ± 26.18 ab	221.7 ± 14.47 a	575.57 ± 60.16 a	79.58 ± 10.23 b
Beetroot with mustard	50.47 ± 13.55 b	73.13 ± 5.41 b	50.30 ± 7.57 b	57.73 ± 2.71 bc
Beetroot without flowering plants (control)	230.00 ± 37.81 a	256.14 ± 12.68 a	615.32 ± 33.02 a	176.56 ± 24.37 a

* Means within a column followed by the same letters are not significantly different (Tukey's Multiple Range Test, $p < 0.05$).

In the field experiment, the mean seasonal abundance of the black bean aphid infesting beetroot was significantly affected by the presence of adjacent flowering strips across four years of observation (2010–2013). In contrast, the block effect remained nonsignificant (Table S2). In all years, beetroots grown without adjacent flowering plants exhibited significantly higher mean seasonal aphid counts than those in the other cropping systems (Table 1). Beetroot grown adjacent to flowering phacelia had significantly lower aphid abundance compared to all other treatments. Phacelia cultivated adjacent to beetroot markedly reduced aphid abundance. When compared with mustard, the magnitude of reduction ranged from 1.66-fold in 2012 to 5-fold in 2011. In comparison with beetroot grown alongside flowering dill, reductions varied from 3.5-fold in 2013 to as much as 28.5-fold in 2010. Relative to the control treatment (beetroot without flowering strips), the seasonal mean aphid abundance on beetroot adjacent to phacelia was 7.9-fold lower in 2013 and up to 52.7-fold lower in 2010 (Table 1).

The weekly population dynamics of the beet aphid during the 2010–2013 growing seasons are presented in Figures 2a–d–5a–d.

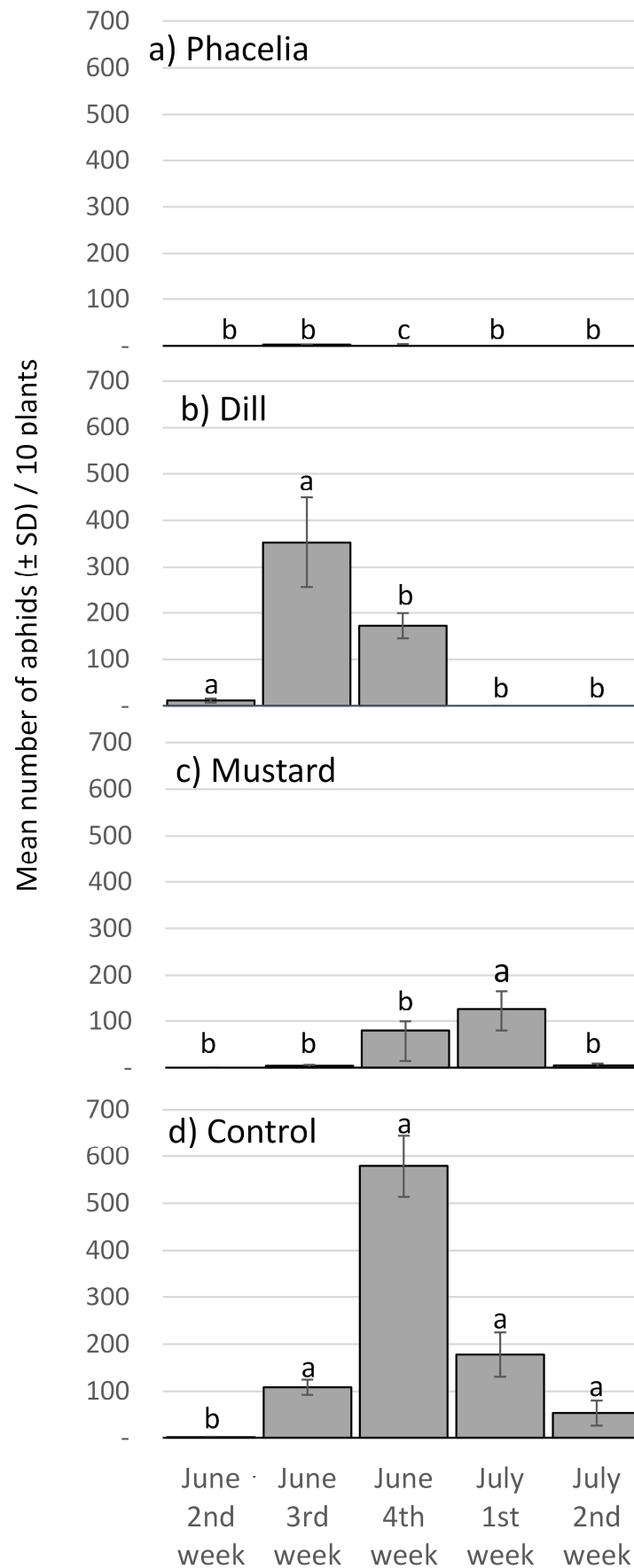


Figure 2. The mean number ($\pm$ SD) of *Aphis fabae* on beetroot surrounded with dill (a), mustard (b), and phacelia (c), and without such margins (control) (d) in the year 2010. Within each date, different letters indicate significant differences among treatments (Tukey's test, $p \leq 0.05$).

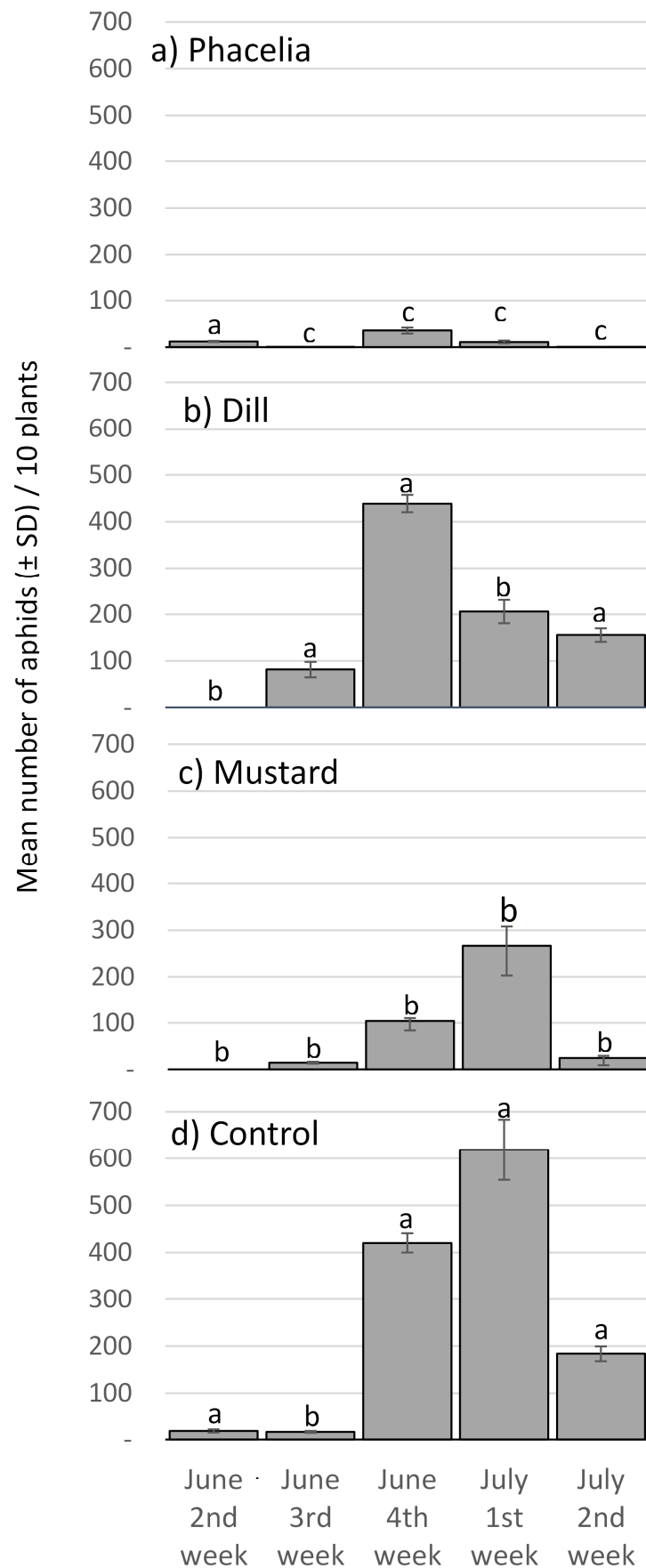


Figure 3. The mean number ($\pm$ SD) of *Aphis fabae* on beetroot surrounded with dill (a), mustard (b), and phacelia (c), and without such margins (control) (d) in the year 2011. Within each date, different letters indicate significant differences among treatments (Tukey's test, $p \leq 0.05$).

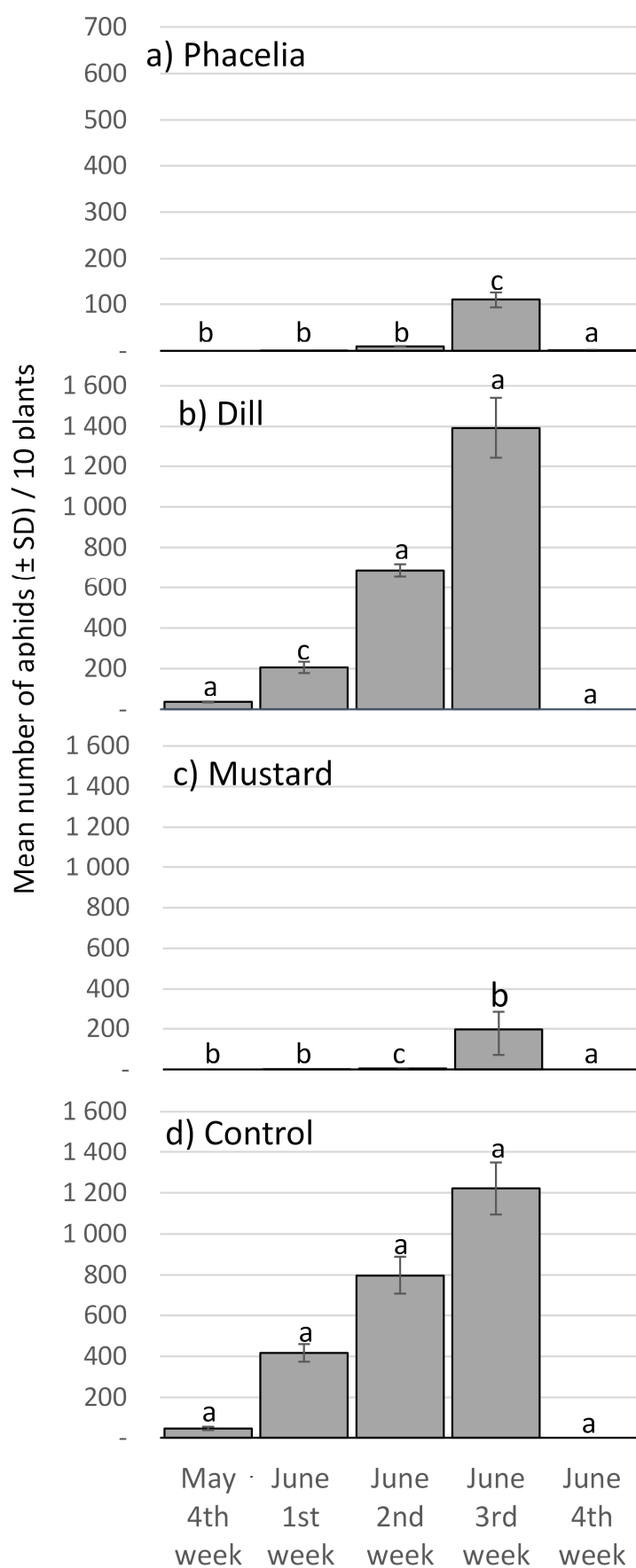


Figure 4. The mean number ($\pm$ SD) of *Aphis fabae* on beetroot surrounded with dill (a), mustard (b), and phacelia (c), and without such margins (control) (d) in the year 2012. Within each date, different letters indicate significant differences among treatments (Tukey's test, $p \leq 0.05$).

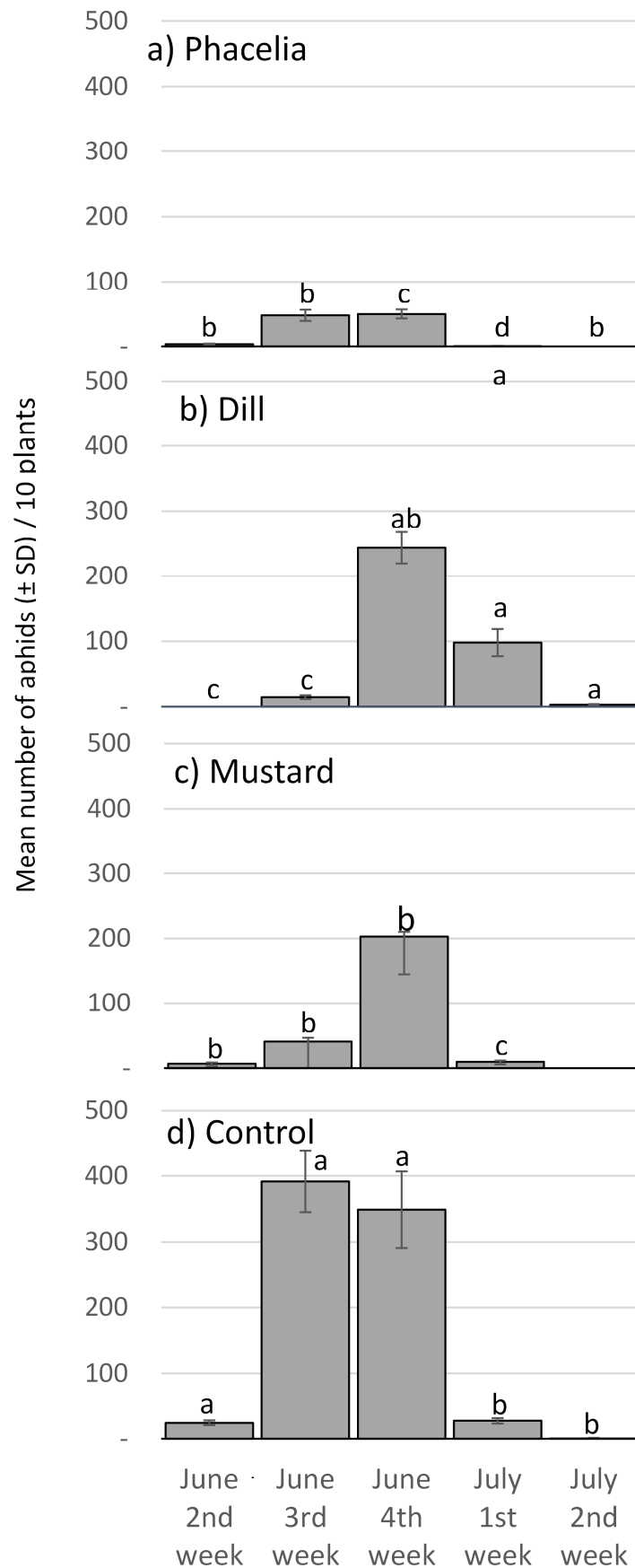


Figure 5. The mean number ($\pm$ SD) of *Aphis fabae* on beetroot surrounded with dill (a), mustard (b), and phacelia (c), and without such margins (control) (d) in the year 2013. Within each date, different letters indicate significant differences among treatments (Tukey's test, $p \leq 0.05$).

The black bean aphid was first detected in the fourth week of May 2012 on beetroots grown near dill and on the control plants (Figure 4b,d). In all other study years, the aphid was first observed in the second week of June (Figures 2,a–d 3a–d and 5a–d). Across all cropping systems, aphid populations generally peaked during the third or fourth week of June. The only exceptions were beetroots grown alongside mustard in 2010–2011 (Figures 2c and 3c) and plants in the control plots in 2011, where peak abundance occurred in the first week of July (Figure 3d).

From the fourth week of June in 2012 (Figure 4a–d) and from the first week of July in all other years, aphid populations began to decline markedly (Figures 2a–d, 3a–d and 5a–d). By the second week of July, aphids had completely disappeared from all plots (Figures 2a–d, 3a–d and 5a–d), except in 2012, when the last individuals were recorded as early as the fourth week of June (Figure 4a–d).

Factorial analyses showed significant differences in aphid populations across crops in all sampling weeks, except for the fourth week of June in 2012. The blocking effect was not significant except for the fourth week of June in 2011 and 2013 and the first week of July in 2013 (Table S3).

The average number of aphids on beetroot cultivated alongside strips of flowering phacelia and mustard was consistently lower than that on beetroot grown near dill and on control plots during most of the weeks each study year (Figures 2a–d–5a–d). Only in some weeks did the aphid numbers on beetroot grown near mustard show a significant increase compared to those grown near phacelia (Figures 2a,c–5a,c). In contrast, aphid abundance on beetroot grown without adjacent flowering strips and near flowering dill was significantly higher compared with most other treatments during most weeks of the study period (Figures 2a–d–5a–d). Across the 2010–2013 seasons, the average aphid numbers on beetroot grown near dill were significantly lower than those recorded on control plants (Figures 2b,d–5b,d), with exceptions: the second week of June 2010 (Figure 2b,d), the third week of June 2011 (Figure 3b,d) and the first week of July 2013 (Figure 5b,d).

3.2. Abundance of Syrphids in the Aphid Colony

Syrphid population size was larger in 2012 than in 2010–2011 and 2013, when the population of black bean aphid was the highest (Tables 1 and 2).

Table 2. Mean number of syrphid larvae and pupae collected in the *Aphis fabae* Scop. colony on beetroot grown with adjacent flowering strips (phacelia, dill, and mustard), and without such margins (control) in 2010–2013.

Year	Mean Number ($\pm$ SEM) of Syrphid Larvae and Pupae/10 Plants			
	2010	2011	2012	2013
Beetroot with phacelia	0.00 $\pm$ 0.00 a *	0.12 $\pm$ 0.06 c	1.00 $\pm$ 0.24 b	0.08 $\pm$ 0.05 b
Beetroot with dill	0.25 $\pm$ 0.13 a	2.50 $\pm$ 0.12 a	4.83 $\pm$ 0.71 a	1.02 $\pm$ 0.21 a
Beetroot with mustard	0.34 $\pm$ 0.14 a	0.23 $\pm$ 0.06 c	0.12 $\pm$ 0.08 c	0.15 $\pm$ 0.06 b
Beetroot without flowering plants (control)	0.31 $\pm$ 0.11 a	0.62 $\pm$ 0.15 b	3.08 $\pm$ 0.34 a	0.65 $\pm$ 0.28 a

* Means within a column followed by the same letter(s) are not significantly different (Tukey's Multiple Range Test, $p < 0.05$).

The presence of flowering plant strips near beetroot significantly affected the number of hoverflies in beet aphid colonies during 2011–2012, while the block effect was only significant in 2013 (Table S4).

A significantly higher mean seasonal number of syrphids within aphid colonies was recorded on beetroots grown adjacent to flowering dill compared with all other cropping systems in 2011, and with beetroots grown near mustard and phacelia in 2012–2013 (Table

2). The mean seasonal number of syrphids in aphid colonies on beetroot growing adjacent to dill increased from 4.8-fold in 2011 to 20.8-fold in 2012, compared to beetroot growing adjacent to phacelia, and from 6.8-fold in 2013 to 10.8-fold in 2011, higher compared to beetroot growing adjacent to mustard (Table 2).

To determine when and how the presence of flowering strips influenced the number of predatory syrphids within aphid colonies, we analyzed the weekly dynamics of their abundance throughout the observation period (Figures 6a–d–9a–d).

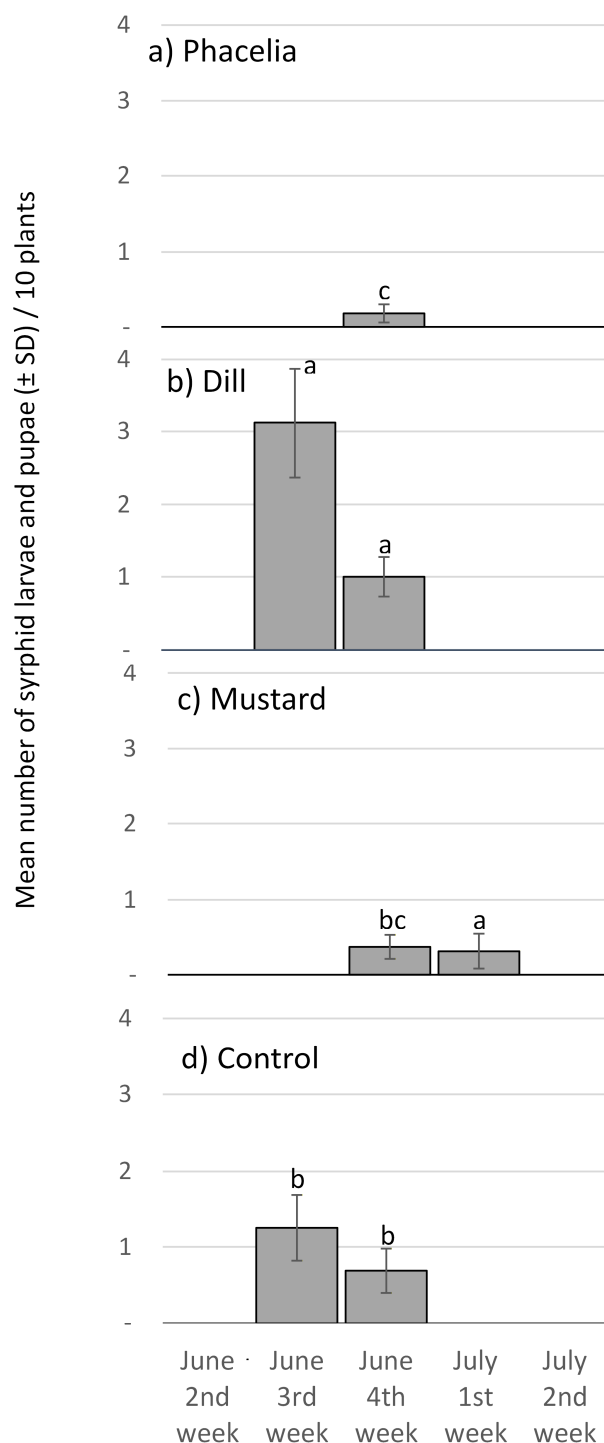


Figure 6. The mean number ($\pm$ SD) of syrphid larvae and pupae on beetroot surrounded with dill (a), mustard (b), and phacelia (c), and without such margins (control) (d) in the year 2010. Within each date, different letters indicate significant differences among treatments (Tukey–Kramer’s test, $p \leq 0.05$).

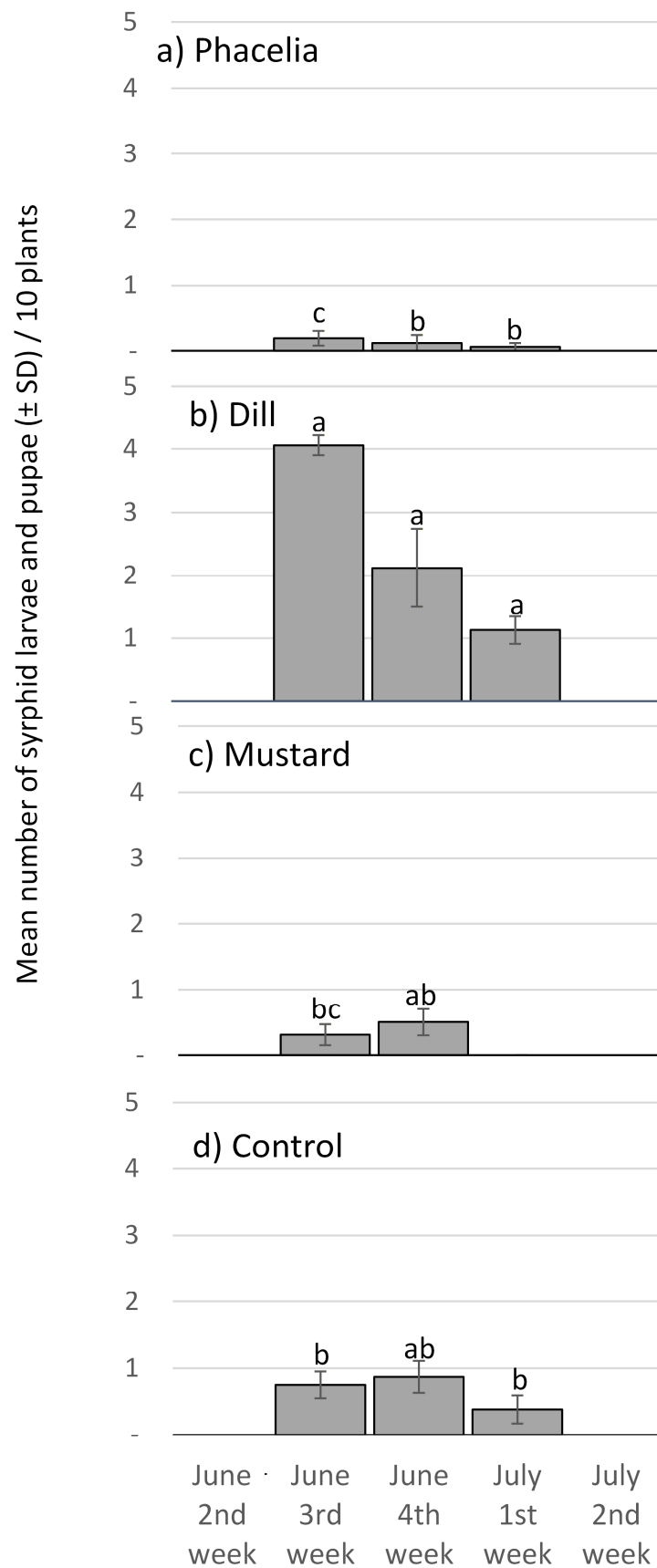


Figure 7. The mean number ($\pm$ SD) of syrphid larvae and pupae on beetroot surrounded with dill (a), mustard (b), and phacelia (c), and without such margins (control) (d) in the year 2011. Within each date, different letters indicate significant differences among treatments (Tukey–Kramer’s test, $p \leq 0.05$).

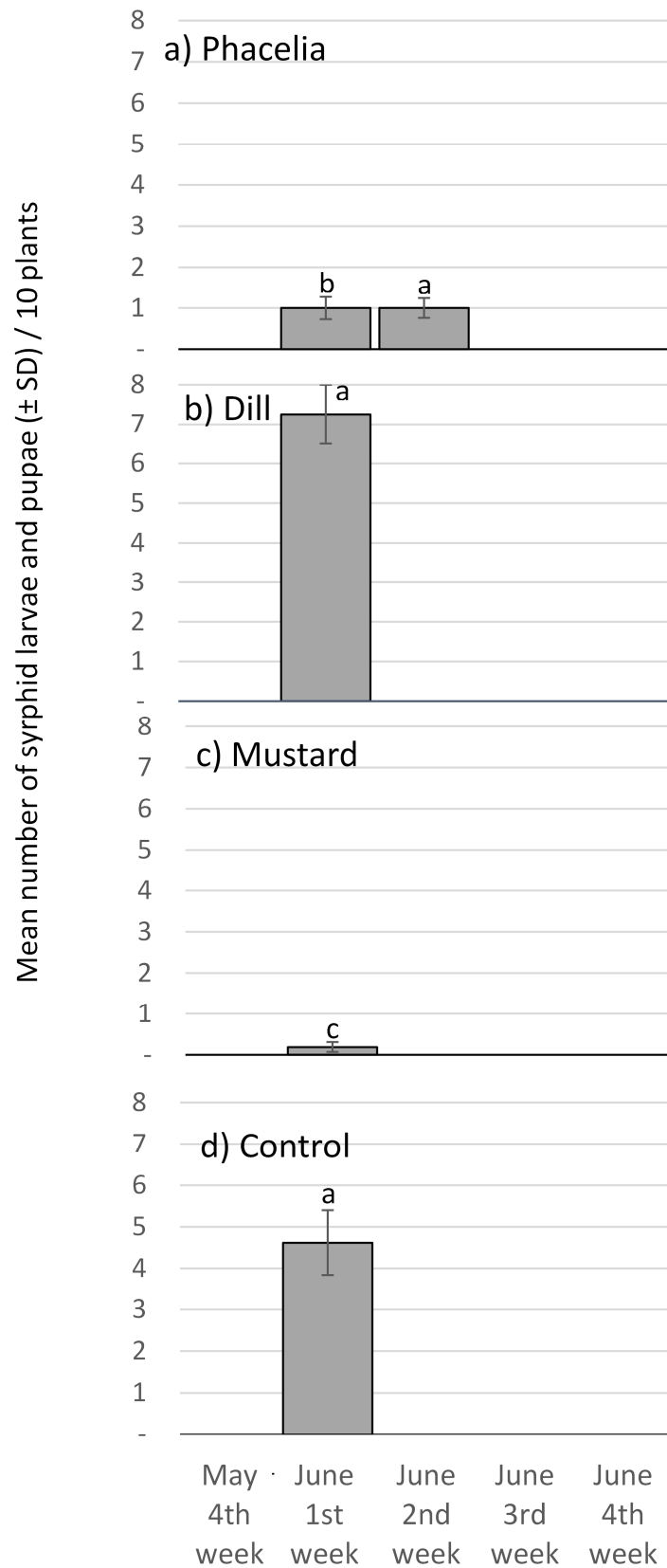


Figure 8. The mean number ($\pm$ SD) of syrphid larvae and pupae on beetroot surrounded with dill (a), mustard (b), and phacelia (c), and without such margins (control) (d) in the year 2012. Within each date, different letters indicate significant differences among treatments (Tukey–Kramer's test, $p \leq 0.05$).

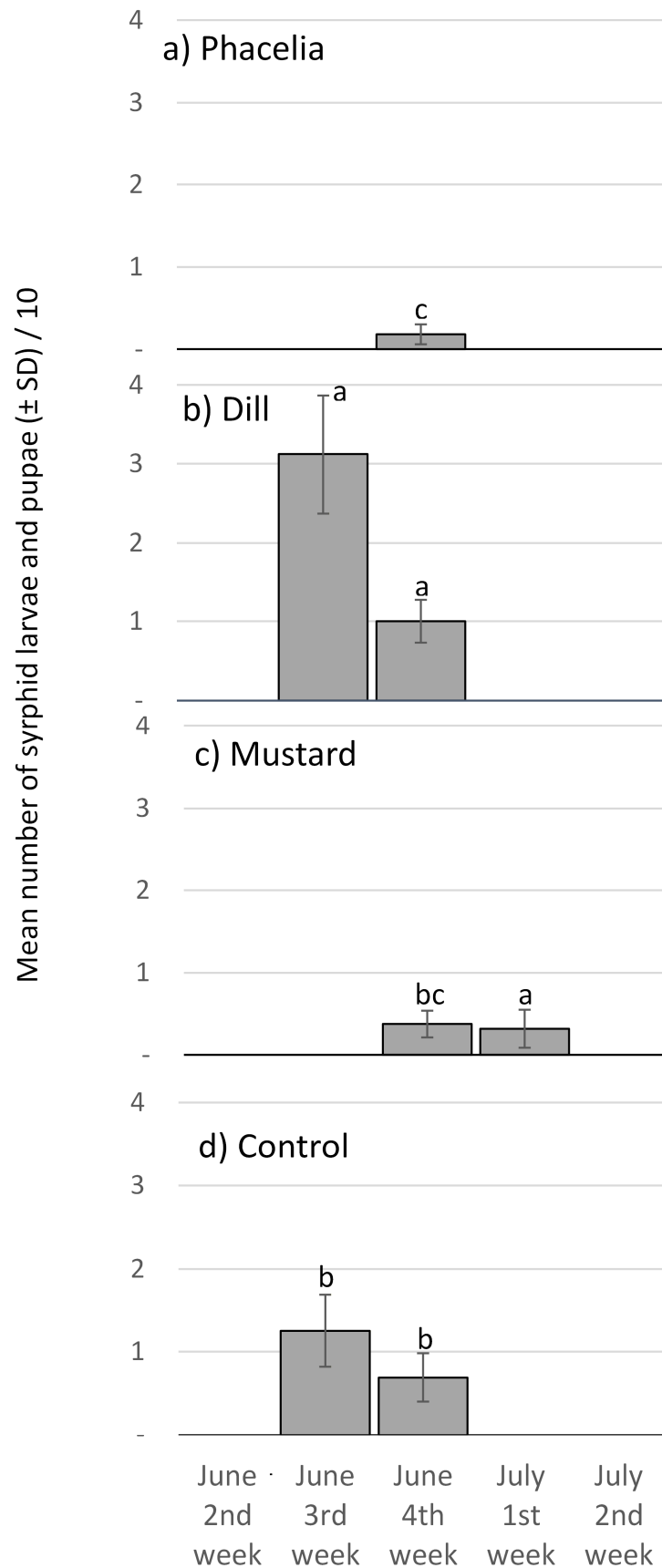


Figure 9. The mean number ($\pm$ SD) of syrphid larvae and pupae on beetroot surrounded with dill (a), mustard (b), and phacelia (c), and without such margins (control) (d) in the year 2013. Within each date, different letters indicate significant differences among treatments (Tukey–Kramer's test, $p \leq 0.05$).

Syrphids were first recorded within aphid colonies in the fourth week of June in 2010 and 2011 (Figures 6a–d and 7a–d), and one week earlier in both 2012 and 2013 (Figures 8a–d and 9a–d). The development of syrphids within the colonies lasted between two and three weeks, depending on the year (Figures 6a–d–9a–d).

Factorial analyses revealed significant differences in syrphid populations across all cropping systems during all sampling weeks, except the fourth week of June in 2010 and the first week of July in 2013. The block effect was not significant in all years and weeks, except the second week of July in 2011 and the fourth week of June in 2013 (Table S5).

In 2010, syrphid abundance was the lowest recorded across all study years. During this season, hoverflies were present within aphid colonies for only two weeks: the fourth week of June and the first week of July. In both sampling weeks, syrphids were absent from beetroot plots adjacent to phacelia. In the first week of July, they were also not detected in plots situated near dill (Figure 6a–c). In most weeks from 2011 to 2013, the average number of syrphids within aphid colonies on beetroot grown adjacent to flowering dill was significantly higher than on beetroot cultivated near mustard and phacelia (Figures 7a–c–9a–c). Moreover, syrphid abundance on beetroot grown alongside dill also significantly exceeded that recorded in the control plots in the fourth week of June and the first week of July in 2011, as well as in the third week of June in 2013 (Figures 7b,d and 9b,d).

3.3. Correlation, Predator–Prey Ratio, and Species Composition of Predators

In all years of the field experiment, the correlation coefficient indicated a positive relationship between the average number of black bean aphids and the average number of syrphid larvae and pupae within their colonies; this association was strong in 2011–2012, whereas in the remaining years it was moderate (Table 3).

Table 3. Pearson’s correlation between the mean number of aphids *Aphis fabae* Scop. and the mean number of syrphid larvae and pupae collected from the aphid colony during 2010–2013.

Parameter/Year	Mean No. of Aphids/10 Plants							
	2010		2011		2012		2013	
Mean no. of syrphid larvae and pupae/10 plants	r	p	r	p	r	p	r	p
	0.445	0.002	0.625	0.000	0.516	0.000	0.320	0.004
n	48		80		48		80	

Note: r coefficient values indicate non-significance at $p < 0.05$; n indicates the number of observations used in the correlation analysis.

Predator–prey ratio was significantly affected by the presence of adjacent flowering strips in all years of observation, while the block effect was significant only in 2011 (Table S6).

A significantly lower mean seasonal number of aphids per syrphid larva, approximately six-fold, was recorded on beetroot grown adjacent to phacelia and dill compared with beetroot cultivated near mustard and with the control in 2011. In 2012, the most favorable predator–prey ratio (i.e., the lowest number of aphids per hoverfly) occurred in beetroot grown next to phacelia, where values were approximately 3.6-fold lower than on beetroot adjacent to dill and mustard, and about six-fold lower than on control plants (Table 4). In 2010 and 2013, the predator–prey ratio was also significantly more favorable on beetroot grown alongside mustard (approximately five-fold lower) and dill (approximately seven-fold lower), respectively, compared with control plots.

Table 4. Mean number ($\pm$ SEM) of aphids *Aphis fabae* Scop per predatory Syrphid larva and pupa (predator–prey ratio) on beetroot grown with adjacent flowering strips (phacelia, dill, and mustard), and without such margins (control) in 2010–2013.

Year	Mean Number ($\pm$ SEM) of Aphids/Predatory Syrphid Larva and Pupa (Predator–Prey Ratio)			
	Beetroot Cultivated with Flowering Plants			Beetroot Cultivated without Flowering Plants
	Phacelia	Dill	Mustard	Control
2010	-	446.62 $\pm$ 195.84 ab	175.40 $\pm$ 36.89 b	883.74 $\pm$ 166.98 a*
2011	74.29 $\pm$ 35.13 b	71.43 $\pm$ 7.61 b	446.41 $\pm$ 122.75 a	487.36 $\pm$ 124.49 a
2012	33.77 $\pm$ 6.69 c	121.09 $\pm$ 5.69 b	126.89 $\pm$ 74.94 a	204.22 $\pm$ 15.84 a
2013	94.83 $\pm$ 56.27 ab	35.16 $\pm$ 13.85 b	84.69 $\pm$ 35.76 ab	250.09 $\pm$ 103.52 a

* Means within a row followed by the same letter(s) are not significantly different (Tukey–Kramer’s Multiple Range Test, $p < 0.05$).

The predator–prey ratios were significantly influenced by adjacent flowering strips over all weeks of all years of observation except for the fourth week of June in 2010, while the block effect was not significant (Table S7).

The most favorable predator–prey ratio was observed on beetroots grown near phacelia compared to beetroots grown in control plots in the fourth week of June in 2011 and 2013, and to all other crops in the first week of July in 2011, and the third week of June in 2012 (Table 5).

Table 5. Mean number ($\pm$ SEM) of aphids *Aphis fabae* Scop per predatory syrphid larva and pupa (predator–prey ratio) on beetroot grown with adjacent flowering strips (phacelia, dill, and mustard), and without such margins (control) per week from 2010 to 2013.

Year	Week	Mean Number ($\pm$ SEM) of Aphids/Predatory Syrphid Larva and Pupa (Predator–Prey Ratio)			
		Beetroot Cultivated with Flowering Plants			Beetroot Cultivated Without Flowering Plants (Control)
		Phacelia	Dill	Mustard	
2010	June 4th week	-	302.80 $\pm$ 137.50	167.00 $\pm$ 131.21	1430.50 $\pm$ 290.04
	July 1st week	-	-	199.00 $\pm$ 154.94 b	441.25 $\pm$ 284.81 a*
2011	June 4th week	47.92 $\pm$ 37.177 b	108.84 $\pm$ 8.13 b	250.44 $\pm$ 105.56 ab	798.47 $\pm$ 332.60 a
	July 1st week	6.25 $\pm$ 6.25 b	159.01 $\pm$ 75.09 a	332.00 $\pm$ 143.28 a	863.50 $\pm$ 225.54 a
	July 2nd week	-	176.69 $\pm$ 67.50 b	-	417.63 $\pm$ 177.33 a
2012	June 3rd week	123.57 $\pm$ 21.34 c	191.69 $\pm$ 7.84 b	329.87 $\pm$ 194.54 a	259.94 $\pm$ 14.40 b
	June 4th week	1.25 $\pm$ 0.94	-	-	-
	June 3rd week	-	5.89 $\pm$ 1.75 b	-	407.68 $\pm$ 241.92 a
2013	June 4th week	71.75 $\pm$ 39.44 c	277.57 $\pm$ 41.39 bc	363.71 $\pm$ 153.22 ab	731.45 $\pm$ 195.22 a
	July 1st week	-	-	-	38.93 $\pm$ 27.55

* Means within a row followed by the same letter(s) are not significantly different (Tukey–Kramer’s Multiple Range Test, $p < 0.05$).

In turn, in all weeks of each year, the least favorable predator–prey ratio (i.e., the highest number of aphids per hoverfly larva) was observed on beetroots grown in control plots and on beetroots grown near flowering mustard (Table 5).

A total of 440 predatory syrphid specimens representing 11 species of the subfamily Syrphinae were collected from black bean aphid-infested beetroot across all plots during the 2010–2013 seasons (Table 6). *Episyrphus balteatus*, *Sphaerophoria scripta*, and *Sphaerophoria menthastri* were the most numerous and eudominant species, while *Syrphus vitripennis* was classified as dominant (Table 6).

Table 6. Species composition of predatory Syrphidae collected from *Aphis fabae* Scop. colonies on beetroot grown alongside flowering plants (phacelia, dill, and mustard), and cultivated without adjacent plants (control) in 2010–2013.

Species	Beetroot Cultivated with Flowering Plants and Without (Control)								Total	
	Phacelia		Dill		Mustard		Control			
	No.	%	No.	%	No.	%	No.	%	No.	%
<i>Episyrphus balteatus</i> [Deg.]	3	20.00 Eu	101	37.55	6	28.57	60	44.44	170	38.64 Eu
<i>Eupeodes corollae</i> [Fabr.]	-		66	24.54	-	-	4	2.96	70	15.91 Eu
<i>Melanostoma mellinum</i> [L.]	1	6.67	-	-	-	-	1	0.74	2	0.45 Sr
<i>Melanostoma scalare</i> [Fabr.]	1	6.67	-	-	-	-	1	0.74	2	0.45 Sr
<i>Scaeva pyrastris</i> [L.]	-	-	-	-	1	4.76	-		1	0.23 Sr
<i>Sphaerophoria menhastri</i> [L]	1	6.67	32	11.9	-	-	22	16.3	55	12.5 Eu
<i>Sphaerophoria rueppelli</i> [Wied.]	1	6.67	1	0.37	-	-	-	-	2	0.45 Sr
<i>Sphaerophoria scripta</i> [L.]	6	40.0	47	17.47	2	9.52	35	25.93	90	20.45 Eu
<i>Platycheirus peltatus</i> [Meig.]	1	6.67	1	0.37	-	-	-		2	0.45 Sr
<i>Syrphus ribesii</i> [L.]	1	6.67	2	0.74	3	14.29	5	3.7	11	2.5 Sd
<i>Syrphus vitripennis</i> Meig.	-	-	19	7.06	9	42.29	7	5.19	35	7.95 D
Total	15	100	269	100	21	100	135	100	440	100

Eudominants (Eu) > 10.00%, Dominants (D) 5.01–10.00%, Subdominants (Sd) 2.01–5.00%, and Subrecedents (Sr) < 1.00%. No.—number, %—percentage share.

E. balteatus and *S. scripta* were the dominant species found in aphid colonies feeding on beetroot across all plot combinations. In contrast, *S. menhastri* was particularly abundant in aphid colonies on beetroot located near flowering dill and on beetroots on control plants. *Eupeodes corollae* was dominant only in plots adjacent to dill, while *Syrphus ribesii* and *Syrphus vitripennis* were abundant in plots next to mustard (Table 6).

The composition of predatory Syrphidae collected from individual plots in subsequent years of the study aligns with the previously described trend (Table S8).

3.4. Species Composition of Adult Syrphids Collected from Flowers

Between 2010 and 2013, a total of 3246 individuals representing 46 species of predatory syrphids were collected from the flowers of plants growing adjacent to the beetroot plots (Table 7). These included representatives of all species whose larvae fed on beet aphid colonies (Table 6). The eudominant group comprised *E. balteatus*, *E. corollae*, *S. menhastri*, and *S. scripta*. *Melanostoma mellinum* and *Melanostoma scalare* were classified as subdominant species, whereas all remaining species were categorized as recedents or subrecedents (Table 7).

Table 7. Species composition of adult syrphids collected from flowering phacelia, dill, and mustard from May to the second decade of July in 2010–2013.

No.	Subfamily/Species	Phacelia	% Share Domi- nance	Dill	% Share Domi- nance	Mustard	% Share Domi- nance	Total	% Share Domi- nance
	Syrphinae	-	-	-	-	-	-	-	-
1	<i>Chrysotoxum bicinctum</i> [L.]	-	-	-	-	1	0.09 Sr	1	0.03 Sr
2	<i>Chrysotoxum cautum</i> [Harr.]	-	-	-	-	1	0.09 Sr	1	0.03 Sr
3	<i>Chrysotoxum festivum</i> [L.]	-	0.14 Sr	9	0.63 Sr	10	0.89 Sr	20	0.62 Sr
4	<i>Chrysotoxum vernale</i> [Loew.]	-	-	7	0.49 Sr	1	0.09 Sr	8	0.25 Sr
5	<i>Dasysyrphus venustus</i> [Fall.]	--	-	6	0.42 Sr	5	0.45 Sr	11	0.34 Sr
6	<i>Dasysyrphus albostrigatus</i> [Fall.]	-	-	-	-	2	0.18 Sr	2	0.06 Sr
7	<i>Epistrophe melanostoma</i> [Zett.]	-	-	-	-	2	0.18 Sr	2	0.06 Sr
8	<i>Epistrophe nitidicollis</i> [Meig.] ¹	-	-	-	-	1	0.09 Sr	1	0.03 Sr

9	<i>Epistrophe ochrostoma</i> [Zett.]	1	0.14 Sr	-	-	-	-	1	0.03 Sr
10	<i>Episyrphus balteatus</i> [Deg.] *	175	24.89 Eu	484	33.99 Eu	386	34.50 Eu	1045	32.19 Eu
11	<i>Eupeodes corollae</i> [Fabr.] *	42	5.97 D	170	11.94 Eu	160	14.30 Eu	372	11.46 Eu
12	<i>Eupeodes latifasciatus</i> [Macq.]	1	0.14 Sr	-	-	1	0.09 Sr	2	0.06 Sr
13	<i>Eupeodes lapponicus</i> [Zett.]	-	-	-	-	2	0.18 Sr	2	0.06 Sr
14	<i>Eupeodes luniger</i> [Meig.]	-	-	4	0.28 Sr	6	0.54 Sr	10	0.31 Sr
15	<i>Eupeodes nitens</i> [Zett.]	-	-	-	-	5	0.45 Sr	5	0.15 Sr
16	<i>Melangyna lasiophthalma</i> [Zett.]	-	-	-	-	1	0.09 Sr	1	0.03 Sr
17	<i>Melangyna quadrimaculata</i> [Verr.]	1	0.14 Sr	-	-	-	-	1	0.03 Sr
18	<i>Melangyna umbellatarum</i> [Fabr.]	-	-	-	-	1	0.09 Sr	1	0.03 Sr
19	<i>Melanostoma mellinum</i> [L.] *	25	3.56 Sd	32	2.25 Sd	16	1.43 R	73	2.25 Sd
20	<i>Melanostoma scalare</i> [Fabr.] *	30	4.27 Sd	32	2.25 Sd	20	1.79 R	82	2.53 Sd
21	<i>Meliscaeva auricollis</i> [Meig.]	-	-	-	-	3	0.27 Sr	3	0.09 Sr
22	<i>Meliscaeva cinctella</i> [Zett.]	-	-	-	-	2	0.18 Sr	2	0.06 Sr
23	<i>Parasyrphus annulatus</i> [Zett.]	-	-	-	-	1	0.09 Sr	1	0.03 Sr
24	<i>Parasyrphus vittiger</i> [Zett.]	-	-	-	-	7	0.63 Sr	7	0.22 Sr
25	<i>Paragus haemorrhous</i> Meig.	-	-	-	-	1	0.09 Sr	1	0.03 Sr
26	<i>Platycheirus albimanus</i> [Fabr.]	1	0.14 Sr	3	0.21 Sr	15	1.34 R	19	0.59 Sr
27	<i>Platycheirus angustatus</i> [Zett.]	-	-	-	-	10	0.89 Sr	10	0.31 Sr
28	<i>Platycheirus clypeatus</i> [Meig.]	14	1.99 R	-	-	7	0.63 Sr	21	0.65 Sr
29	<i>Platycheirus fulviventris</i> [Macq.]	-	-	-	-	2	0.18 Sr	2	0.06 Sr
30	<i>Platycheirus manicatus</i> [Meig.]	-	-	-	-	1	0.09 Sr	1	0.03 Sr
31	<i>Platycheirus melanopsis</i> [Loew.]	-	-	-	-	1	0.09 Sr	1	0.03 Sr
32	<i>Platycheirus peltatus</i> [Meig.] *	2	0.28 Sr	17	1.19 R	6	0.54 Sr	25	0.77 Sr
33	<i>Platycheirus albimanus</i> [Fabr.]	-	-	-	-	25	2.23 Sd	25	0.77 Sr
34	<i>Platycheirus scambus</i> [Staeg.]	-	-	-	-	4	0.36 Sr	4	0.12 Sr
35	<i>Platycheirus scutatus</i> [Meig.]	-	-	4	0.28 Sr	-	-	4	0.12 Sr
36	<i>Scaeva pyrastris</i> [L.] *	14	1.99 R	20	1.40 R	18	1.61 R	52	1.60 Sr
37	<i>Scaeva selenitica</i> [Meig.]	-	-	6	0.42 Sr	2	0.18 Sr	8	0.25 Sr
38	<i>Sphaerophoria taeniata</i> [Meig.]	2	0.28 Sr	-	-	-	-	2	0.06 Sr
39	<i>Sphaerophoria menhastri</i> [L.] *	70	9.96 D	223	1.66 R	106	9.47 D	399	12.29 Eu
40	<i>Sphaerophoria rueppelli</i> [Wied.] *	22	3.13 Sd	9	0.63 Sr	15	1.34 R	46	1.42 R
41	<i>Sphaerophoria scripta</i> [L.] *	296	42.11 Eu	393	27.60 Eu	216	19.30 Eu	905	27.88 Eu
42	<i>Syrphus braueri</i> Egg.	-	-	-	-	1	0.09 Sr	1	0.03 Sr
43	<i>Syrphus ribesii</i> [L.] *	5	0.71 Sr	-	-	12	1.07 Sr	17	0.52 Sr
44	<i>Syrphus vitripennis</i> Meig. *	1	0.14 Sr	5	0.35 Sr	39	3.49 Sd	45	1.39 R
45	<i>Xanthandrus comtus</i> [Harr.]	-	-	-	-	2	0.18 Sr	2	0.06 Sr
46	<i>Xanthogramma pedissequum</i> [Harr.]	-	-	-	-	2	0.18 Sr	-	0.06 Sr
Total		703	100	1424	100	1119	100	3246	100

Eudominants (Eu) > 10.00%, Dominants (D) 5.01–10.00%, Subdominants (Sd) 2.01–5.00%, Recedents (R) 1.01–2.00%, and Subrecedents (Sr) < 1.00%. * Syrphid species collected from *Aphis fabae* colonies.

A total of 1424 specimens of predatory syrphids representing 17 species were collected from dill flowers, while 1119 individuals belonging to 42 species were recorded on mustard flowers. The smallest collection of 703 specimens from 18 species was gathered from phacelia flowers. The most abundant species observed on mustard and dill flowers were *E. balteatus*, *E. corollae*, and *S. scripta*. Additionally, *E. balteatus* and *S. scripta* were dominant on phacelia flowers. *Sphaerophoria menhastri* was also identified as a dominant species on both phacelia and mustard flowers. *Melanostoma mellinum* and *M. scalare* were classified as subdominant species on phacelia and dill flowers (Table 7).

In 2011 and 2012, 1128 and 1149 individuals were captured, respectively, whereas in 2010 and 2013, only 460 and 508 adults were collected (Table S9). In all years, the highest number of adult hoverflies was collected from dill flowers. The only exception was in 2012, when the greatest number of individuals was recorded on mustard flowers. *Episyrphus balteatus*, *Eupeodes corollae*, *Melanostoma mellinum*, *Scaeva pyrastris*, *Sphaerophoria men-*

hastri, *Sphaerophoria rueppelli*, and *Sphaerophoria scripta* were collected from all flower species in every year of the study. *Melanostoma scalare* was absent only in 2013 on phacelia flowers (Table S9).

4. Discussion

In our experiment, we observed differences in the abundance of aphids on beetroot between years, especially in 2010 compared to 2011–2013. These differences may be attributed to environmental conditions. In 2010, lower mean temperatures, particularly in May, and higher rainfall during May and June likely influenced the development of aphid populations and the activity of syrphids.

In all study years, the highest black bean aphid populations were observed on beetroot cultivated without adjacent flowering plants. Consistently, the proximity of flowering phacelia and mustard significantly reduced seasonal aphid populations on beetroot, with the effect of phacelia being significantly greater than that of mustard. A significant effect of dill on mean seasonal aphid abundance was observed only in 2013.

The results of the present study indicate that the occurrence of phacelia, mustard, and dill in the vicinity of beetroot fields created ecological conditions less favorable for the development of *Aphis fabae* populations. This pattern suggests that increased habitat heterogeneity, disruption of aphid host-location mechanisms, and enhanced activity of natural enemies collectively contributed to aphid suppression, in accordance with the principles of conservation biological control.

In particular, the presence of phacelia was associated with increased activity of beneficial insects. Its high attractiveness to adult syrphids likely promoted the occurrence of their larvae, which are effective aphid predators and may have played a significant role in reducing *A. fabae* abundance. Similarly, the presence of dill appeared to support the abundance and effectiveness of natural enemies within the beet agroecosystem. In contrast, mustard exhibited a more complex effect on *A. fabae* populations. The observed patterns may be linked to the production of volatile organic compounds by Brassicaceae plants, which can interfere with insect orientation and behavior. These compounds may have exerted a masking effect, reducing the attractiveness of sugar beet plants to migrating aphids and thereby limiting their colonization. Twardowski et al. [38] discovered that increasing landscape diversity around sugar beet fields by incorporating strips of flowering plants like mustards, phacelia, and coriander (*Coriandrum sativum* L.), along with natural weedy margins, significantly reduced black bean aphid populations compared to bare soil borders. Gospodarek [20] also highlighted the importance of intercropping mustard with broad bean, which effectively reduced black bean aphid abundance and provided pest suppression comparable to that of chemical control. In studies on the effect of intercropping broad bean with phacelia on the population of black bean aphid [8,39], the authors noted a reduction in aphid colonies, which was associated both with reduced ability to locate and access host plants by them, as well as with the attraction of predatory insects by the flowers of phacelia, which forage within aphid colonies. According to Pobożniak [40], a weedy background significantly reduces the colonization and population density of the black bean aphid on beetroot crops, whereas the highest aphid abundance was in plots kept weed-free throughout the growing season. Cited authors [20,39,40] suggested that weeds, as well as phacelia and mustard, may act as a physical barrier, reducing aphid colonization and dispersal. According to Finch et al. [21], companion plants may visually or physically camouflage host plants, reducing pest landing and colonization, as proposed by the appropriate/inappropriate landing theory. Finch and Edmonds [41] reported that cabbage aphid numbers decreased significantly only when clover provided complete ground cover.

In this study, we observed that the presence of phacelia and mustard reduced aphid numbers starting from the first or second week of their appearance on beetroots. This effect generally continued throughout the subsequent weeks until the aphid population eventually died out. In the presence of dill, reduced aphid abundance on beetroot compared with the control was observed only in selected weeks of 2010 and 2011, after the population peak. During aphid colonization, strips included well-developed phacelia and mustard reaching 70–100 cm, potentially acting as a physical barrier, particularly along the prevailing wind direction. In contrast, beetroot was only 15–30 cm tall; thus, dill, at 50 cm, could not provide a comparable mechanical barrier, likely resulting in a weaker effect on aphid landing and movement.

In our experiment, the plants used to create flower strips were selected to provide a constant source of food and shelter for predatory syrphid insects. Their flowering periods were consecutive, allowing them to maintain a food base for beneficial insects throughout the growing season. Larvae of predatory hoverflies were observed in aphid colonies for several to approximately a dozen days following aphid colonization. A similar pattern has been reported in recent studies, where larvae of predatory hoverflies were recorded in aphid colonies shortly after their establishment [39,42,43].

In the study, the development of Syrphidae within the colonies lasted between two and three weeks, depending on the year. The highest seasonal abundance of syrphids we observed on beetroot grown adjacent to flowering dill suggests that dill may have been particularly effective in attracting and retaining these natural enemies within aphid colonies. Between 2011 and 2013, this effect was pronounced compared to other cropping systems. In 2010, strips of flowering mustard had a similar impact. This conclusion is further supported by the results, which show that predatory hoverflies were more numerous on dill and mustard flowers than on phacelia. According to Almohamad et al. [42], Laubertie et al. [44], and Dunn et al. [45], flowers of dill provide highly accessible, nectar-rich floral resources that strongly attract adult hoverflies. The small, shallow flowers arranged in flat umbels enhance hoverfly survival and fecundity and promote oviposition near aphid colonies, thereby supporting biological aphid control. Mena and Gospodarek [46] indicate that the proximity of white mustard had a strong positive influence on the occurrence and the fertility of Syrphidae. Gospodarek [20] found that broad bean grown in the presence of white mustard supported greater numbers of hoverflies, promoting hoverfly oviposition early in aphid infestation development despite limited prey abundance. Although phacelia is generally regarded as an effective insectary plant attracting hoverflies and supporting aphid biological control [9,39], the response of syrphid populations appears to be context-dependent. While earlier studies reported increased syrphid larval densities in cropping systems incorporating flowering phacelia, in the present study, syrphid abundance within aphid colonies on beetroot was consistently and significantly lower when grown near phacelia across all years. This result is likely associated with the oviposition behavior of syrphid females, which appears to be primarily driven by aphid colony size [47–49]. In the present study, aphid colonies were largest on beetroots grown in the control plots and in plots adjacent to dill. Accordingly, no statistically significant differences in the abundance of syrphid larvae within beet aphid colonies were observed between the control treatment and dill-adjacent plots in 2010 and 2012–2013, suggesting that prey availability played a stronger role in shaping syrphid oviposition patterns than the presence of flowering companion plants. This is further supported by our study, in which syrphid larval abundance was positively correlated with black bean aphid density, with a strong association in 2011–2012 and a moderate one in the remaining years. The observed differences among flowering plant treatments may not solely reflect their direct effects on syrphid attraction but could also result from their influence on aphid populations. In particular, phacelia may have contributed to lower aphid abundance through

plant-mediated mechanisms, such as disrupting aphid host-finding behavior or reducing host plant apparency. Such effects could limit aphid colonization independently of predator activity. Conversely, dill plots supported higher aphid densities, potentially providing a more abundant and reliable resource for ovipositing syrphid females. Because aphid colonies constitute both a food source for larvae and an important cue for adult hoverflies, increased aphid abundance may have enhanced syrphid recruitment and oviposition in these treatments.

Furthermore, the positive relationship observed between aphid abundance and syrphid larval density suggests that syrphids responded to prey availability. This pattern is consistent with the view that female hoverflies preferentially oviposit in locations where aphid densities are sufficiently high to support larval development. Consequently, the greater abundance of syrphid larvae in certain flowering plant treatments may not necessarily indicate a stronger direct attraction of adult hoverflies to floral resources alone, but rather a combined effect of floral attractiveness and increased prey availability. These findings highlight the importance of considering both bottom-up effects mediated by plants and top-down effects exerted by natural enemies when interpreting the role of flowering plants in conservation biological control. Also, according to Wnuk and Pobożniak [25], the diversity of aphidophagous Syrphidae in beetroots was not directly related to weed presence, suggesting that hoverfly oviposition increases primarily with aphid colony size rather than with vegetation structure. Sutherland et al. [47] showed that females of *Episyrphus balteatus* laid significantly more eggs on wheat plants hosting larger colonies of grain aphid *Sitobion avenae* (F.), indicating a strongly density-dependent oviposition response. Similarly, Ankersmit et al. [50] and Hickman and Wratten [9] showed that although flowering plants increased adult hoverfly abundance in cereal fields, egg deposition and larval distribution were more strongly associated with aphid colony density than with the presence of flower strips.

Aphid suppression by syrphid larvae is strongly dependent on the predator–prey ratio [42], with optimal control of black bean aphid on broad bean reported by Wojciechowicz-Żytka [51] at ratios of 1:25–1:50 for *E. balteatus* and *S. scripta* larvae. In our study, we recorded the highest number of aphids per hoverfly larva on beetroot plants in the control plots. We also found that neighboring flowering plants significantly affected the hoverfly-to-aphid ratio. This ratio was the lowest on beetroots growing next to phacelia in 2011–2012, next to dill in 2011 and 2013, and next to mustard in 2012. Also, Twardowski et al. [38] indicate that plots surrounded by diverse flowering plant mixtures exhibited the most balanced predator–prey relationships. Yang et al. [52] conducted a two-year field study in cotton, demonstrating that flower strips of another Apiaceae plant, Monnier’s snow parsley (*Cnidium monnieri* (L.)) established along field margins significantly increased the abundance of hoverflies and other predatory arthropods. The number of cotton aphids in cotton plots bordered by Monnier’s snow flower strips was reduced by 57% in 2020 and 34% in 2021 compared with cotton plots bordered by control (cotton-only) strips. In turn, Gardarin et al. [53] demonstrated, over a four-year rotation, that flower strips, abundant in nectar-rich and legume species, increase the ratio of predators, such as hoverflies, to prey, thereby effectively suppressing the aphid population. These findings reinforce the value of floral-rich strips and non-crop habitats in promoting biological control. In our study, *Episyrphus balteatus*, *Sphaerophoria scripta*, and *Sphaerophoria menthastris* were eudominant species, while *Syrphus vitripennis* was classified as dominant. *E. balteatus* and *S. scripta* were the most abundant species in aphid colonies on beetroot across all plot types, and they represented 59.09% of all syrphid larvae collected from aphid colonies in the experiment. *S. menthastris* was especially numerous in colonies on beetroot situated near flowering dill and on control plants. *Eupeodes corollae* predominated only in plots adjacent to dill, whereas *Syrphus ribesii* and *Syrphus vitripennis* were most

abundant in plots located next to mustard. According to Wnuk, Pobożniak [25], the most abundant species in the colony of black bean aphids on beetroots was *Episyrphus balteatus*, followed by *Sphaerophoria scripta*. *E. balteatus* was particularly numerous in weed-free plots, whereas species from the genus *Sphaerophoria* were relatively more common in plots where weeds were present. *Episyrphus balteatus* was regarded as one of the key predators of black bean aphids on beet crops [54–57]. However, views differ regarding the importance of other species. Among those frequently mentioned by Bombosch [54] as contributing to the control of these aphids on beets are *S. ribesii*, *S. vitripennis*, and *M. corollae*. Wnuk, Wojciechowicz-Żytka [8] and Wojciechowicz-Żytka, Wnuk [39], in a study on broad bean intercropped with phacelia, found that the dominant species were *E. balteatus*, *S. scripta*, *S. ribesii*, and *Epistrophe eligans*, with *E. balteatus* accounting for approximately 70% of individuals in phacelia-rich environments. Studies by Hurej et al. [58], Altieri [59], and Kienegger et al. [60] provide information on aphid-feeding hoverflies in aphid colonies. In several of these works, *E. balteatus* was reported as the dominant species.

In the presented study, dill flowers were the most attractive in terms of the number of captured syrphid individuals, whereas mustard showed the highest species diversity. A total of 42 species out of the 46 collected from all plant flowers were recorded on mustard flowers, including several species that are rare in our region, e.g., *Eupeodes nitens* [Zett.], *Melangyna umbellatarum* [Fabr.] and *Parasyrphus vittiger* [Zett.]

Although phacelia flowers yielded a similar number of syrphid species to dill, nearly half as many adult individuals were captured on phacelia. All species whose larvae occurred in black bean aphid colonies on beetroot were represented in the sample collected from flowers of dill, mustard, and phacelia. As with syrphid larvae from aphid colonies, *Episyrphus balteatus* and *Sphaerophoria scripta* were the most abundant, together accounting for 60.8% of individuals collected from the flowers of all studied plants. The group of the most numerous species also included *Eupeodes corollae* and *Sphaerophoria menthastri*, which together with the previous species constituted 88.55%. These results indicate that the four hoverfly species were most strongly attracted to flowering plants and subsequently dispersed into beetroot fields, where they contributed to aphid suppression. *E. balteatus*, *S. scripta*, and *S. menthastri* were most abundantly collected from dill flowers, followed by mustard and phacelia, whereas *E. corollae* showed a stronger preference for phacelia than for mustard. According to Wojciechowicz-Żytka and Wnuk [39] and Wnuk et al. [61], the syrphid species most frequently found on phacelia flowers intercropped with broad bean were *E. balteatus*, *S. scripta*, and *S. ribesii*, together accounting for more than 86% of all collected predatory hoverflies. In another study, Kelm et al. [62] reported that *S. scripta*, the dominant species on herb flowers, preferred dill and coriander over summer savory *Satureja hortensis* L. and pot marigold *Calendula officinalis* L., attributing this preference to the easy access to nectar in their umbellate inflorescences. Among the predatory syrphids collected on caraway *Carum carvi* L., dill, coriander, and garden lovage *Levisticum officinale* Koch., the most abundant and eudominant species were *Sphaerophoria scripta*, *Eupeodes corollae*, and *Syrphus vitripennis*. *Melanostoma mellinum* was identified as a dominant species, while *Scaeva pyrastris* and *Syrphus ribesii* were considered subdominant [14]. In turn, Hogg et al. [63] recommend white mustard for intercropping with lettuce or sowing along field margins due to its rapid flowering, which is important for the early attraction of predatory insects and synchronization with pest appearance. He also emphasizes the quality of its pollen as an important protein source for females during egg production. Ambrosino et al. [64] studied the attractiveness of four nectar-producing plant species sown within broccoli crops: sweet alyssum (*Lobularia maritima* L. Desv.), coriander, buckwheat *Fagopyrum esculentum* Moench, and phacelia. The findings indicated that coriander and buckwheat attracted more visits from key aphidophagous hoverflies, such as *Toxomerus* spp. and *Melanostoma mellinum* (L.). In contrast, while phacelia was visited less fre-

quently by hoverflies, it was highly attractive to bumblebees, which could potentially lead to interspecific competition. Phacelia is considered one of the most melliferous annual plants, characterized by a markedly higher nectar production and honey yield than white mustard [65–67]. Competition among hoverflies, which are smaller than bumblebees and bees, likely resulted in their lower numbers being collected from phacelia flowers than from mustard and dill.

5. Conclusions

This study concludes that flowering strips of phacelia and mustard are effective in reducing the infestation and population growth of black bean aphid in our region. Among the two, phacelia offers the most beneficial ratio of predatory syrphid larvae to aphids, leading to the lowest aphid population density on beetroots. Dill and mustard attracted adult Syrphidae more strongly than phacelia, which was reflected in a higher abundance of their larvae within aphid colonies; however, this abundance was not sufficient to suppress aphid populations to the level observed on beetroot grown in the vicinity of phacelia.

Enhancing plant diversity appears to be a promising ecological approach to pest management in vegetable cropping systems; however, its effectiveness is often species-specific and context-dependent, underscoring the need to tailor diversification strategies to crop–pest interactions. Future research should focus on evaluating predator functional responses within diversified cropping systems by quantifying syrphid oviposition, larval feeding rates, and aphid mortality. Further studies should also investigate the mechanisms underlying the different responses of pests and natural enemies to flowering plant species. This may include assessing flowering phenology, nectar and pollen availability, plant volatile emissions, and floral attractiveness. In addition, long-term studies are needed to evaluate the stability of crop yields and to identify the most effective flowering plant combinations for sustainable pest control.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/agronomy16131266/s1>, Table S1. Mean monthly air temperature and rainfall totals from 2010 to 2013 compared with the multiannual means from 1971 to 2000. Table S2. Significance of sources of variation in one-way ANOVA for the mean number ($\pm$ SEM) of aphids *Aphis fabae* Scop. on beetroot grown with adjacent flowering strips (phacelia, dill, and mustard), and without such margins (control) in 2010–2013. Table S3. Significance of sources of variation in one-way ANOVA for the mean number ($\pm$ SEM) of aphids *Aphis fabae* Scop. on beetroot grown with adjacent flowering strips (phacelia, dill, and mustard), and without such margins (control) in 2010–2013, $df = 3$. Table S4. Significance of sources of variation in one-way ANOVA for the mean number ($\pm$ SEM) of predatory Syrphid larvae and pupae on beetroot grown with adjacent flowering strips (phacelia, dill, and mustard), and without such margins (control) in 2010–2013. Table S5. Significance of sources of variation in one-way ANOVA for the mean number ($\pm$ SEM) of syrphid larvae and pupae collected from the *Aphis fabae* Scop. colony on beetroot grown with adjacent flowering strips (phacelia, dill, and mustard), and without such margins (control) in 2010–2013, $df = 3$. Table S6. Significance of sources of variation in one-way ANOVA for the mean number ($\pm$ SEM) of aphids *Aphis fabae* Scop. per predatory Syrphid larva and pupa on beetroot grown with adjacent flowering strips (phacelia, dill, and mustard), and without such margins (control) in 2010–2013. Table S7. Significance of sources of variation in one-way ANOVA for the mean number ($\pm$ SEM) of aphids *Aphis fabae* Scop. per predatory Syrphid larva and pupa on beetroot grown with adjacent flowering strips (phacelia, dill, and mustard), and without such margins (control) per week from 2010 to 2013. Table S8. Species composition of syrphids collected from *Aphis fabae* Scop. colonies on beetroot grown alongside flowering plants (phacelia, dill, and mustard), and cultivated without adjacent plants (control) from 2010 to 2013. Table S9. Species composition of zoophagous adult syrphids collected

from flowering plants, phacelia, dill, and mustard from May to the second decade of July from 2010 to 2013.

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