https://doi.org/10.17221/132/2019-PPS

Effects of strip intercropping of canola with faba bean, field pea, garlic, or wheat on control of cabbage aphid and crop yield

Mostafa Mollaei, Seyed Ali Asghar Fathi, Gadir Nouri-Ganbalani, Mehdi Hassanpour, Ali Golizadeh*

Department of Plant Protection, Faculty of Agriculture and Natural Resources, University of Mohaghegh Ardabili, Ardabil, Iran

**Corresponding author: saafathi@gmail.com*

Citation: Mollaei M., Fathi S.A.A., Nouri-Ganbalani G., Hassanpour M., Golizadeh A. (2021): Effects of strip intercropping of canola with faba bean, field pea, garlic, or wheat on control of cabbage aphid and crop yield. Plant Protect. Sci., 57: 59–65.

Abstract: The impacts of intercropping of canola (Ca) with faba beans (Fb), field peas (Fp), garlic (G), or wheat (Wh) were evaluated on the cabbage aphid, *Brevicoryne brassicae* (Linnaeus, 1758), natural enemies and canola yields in row ratios of 3Ca : 3Fb, 3Ca : Fp, 3Ca : 3G, and 3Ca : 3Wh in 2018 and 2019. In both years, the lowest aphid population was recorded in 3Ca : 3G. In 2018, the aphid population was significantly ($P < 0.05$) lower in 3Ca : 3Fp than in the monoculture, while, in 2019, it was lower in the intercrops compared to the monoculture. Furthermore, none of the intercrops, except 3Ca : 3Fb, showed a significant increase in the predator diversity and parasitism rate. The dry seed weight loss was higher in the monoculture and 3Ca : 3Wh than in the other intercrops. Based upon the obtained results, decreasing the density of the cabbage aphid and increasing the canola yield by intercropping canola with the faba bean, the field pea or garlic is possible with this system. The inferences of these outcomes, which are associated with the integrated pest management (IPM) in canola cropping systems, are discussed.

Keywords: *Brassica napus*; *Brevicoryne brassicae*; intercropping; parasitism; predators; species diversity

The cabbage aphid [*Brevicoryne brassicae* (Linnaeus, 1758)] is one of the phytophagous pest insects damaging canola (*Brassica napus* Linnaeus). Because canola has a high pest burden, farmers have a recourse to the repeated use of pesticides, resulting in the formation of resistant pests, environmental deterioration, and consequences on the health of animals or human beings. Therefore, future pest management plans should promote the application of alternate procedures to substitute for the pesticides. For instance, Intercropping (IC) is one such kind of approach. Earlier investigations documented IC systems to be associated with a decline in the cabbage aphid density and enhancement in the diversity and copiousness of natural enemies. The cabbage aphid population was reported to be more than six to seven times lower in plots containing cabbages (*Brassica oleracea* var. *acephala*) and spring onions (*Allium cepa* Linnaeus) *compared* to cabbage monocultures (Mutiga et al. 2010). The researchers assigned this finding to the confounding olfactive signals provided by the onion leading to the aphids decline in their dispersion capabilities (Baidoo et al. 2012). Besides, when nectar-providing plants were present adjacent to aphid-infested plants, a 60% increase was found in the number of aphid parasitoids, *Diaeretiella rapae* M'Intosh (Hymenoptera: Aphidiinae) and aphid "mummies" (Jamont et al. 2014). Tiroesele and Matshela (2015) demonstrated that IC cabbage with garlic (*Allium sativum* Linnaeus), basil (*Ocimum basilicum* Linnaeus) and marigolds (*Tagetes*

Supported by the University of Mohaghegh Ardabili in Iran, Grant No. 1852.

https://doi.org/10.17221/132/2019-PPS

patula Linnaeus) decreased cabbage aphid infestations. The population ranged from 4.44 (cabbage-basil treatment) to 31.17 (cabbage monoculture) aphid per plant between the treatments. It was established that broccoli (*Brassica oleracea* Linnaeus var. *italica*) and alyssum (*Lobularia maritima* Linnaeus Desv.) IC increases the population of the generalist predators, thereby reducing some pests, particularly aphids (Brennan 2016). Akbar et al. (2017) studied the impacts of IC of canola with different crops on the number of aphids and the crop yield in canola. They expressed that the minimum aphid population (49.5 aphids per plant) was observed in canola-garlic IC and gave an enhanced grain yield of 2 222.22 kg/ha, whereas canola-barley (*Hordeum vulgare* Linnaeus) IC showed significantly higher numbers of aphids (299.83 aphids per plant) with a lower canola grain yield of 648.14 kg/ha, while canola alone produced 787.02 kg/ha harbouring 243.17 aphids per plant. As a successful IC for pest control is dependent upon the selection of the accompanying crops, the present research aim was to choose the best companion crop in canola production by the following approaches: (*i*) evaluating the IC impacts of canola with the faba bean, the field pea (*Pisum sativum* Linnaeus), garlic (*A. sativum*), or wheat (*Triticum aestivum* Linnaeus) on the cabbage aphid density; (*ii*) studying the influences of the four aforementioned plants on the abundance and biodiversity for predators of cabbage aphids and the parasitism rate in canola; (*iii*) calculating the canola yield in each treatment.

MATERIAL AND METHODS

Study area and experimental design. The study was carried out in an experimental farm (48°56' E; 36°56' N, 638 m a.s.l.) in Iran in 2017 and 2018. Canola seeds were sown either as a monoculture or in a strip intercropped with faba beans, field peas, garlic, or wheat in alternate rows of these four plants (3Ca : 3Fb, 3Ca : 3Fp, 3Ca : 3G, and 3Ca : 3Wh). Hereinafter, this is referred to as the treatment (Figure 1). A sole crop of canola sprayed with pirimicarb (Pirimor® WG 50%, Syngenta Crop Protection A.G., Switzerland) at the recommended dose of 250 g/ha against the cabbage aphid was utilised to assess the yield loss initiated from the cabbage aphid populations in each treatment. The experiment was arranged in a randomised block design having four replicates. The experimental plot size ranged from 9.3 to 13.2 m^2 in the different treatments to help the practical operation in the field. Each plot had nine rows (the length of each row was 5 m), surrounded by a 3 m border of bare ground, to minimise the impact of the cropping systems. The plots were managed under low input field conditions.

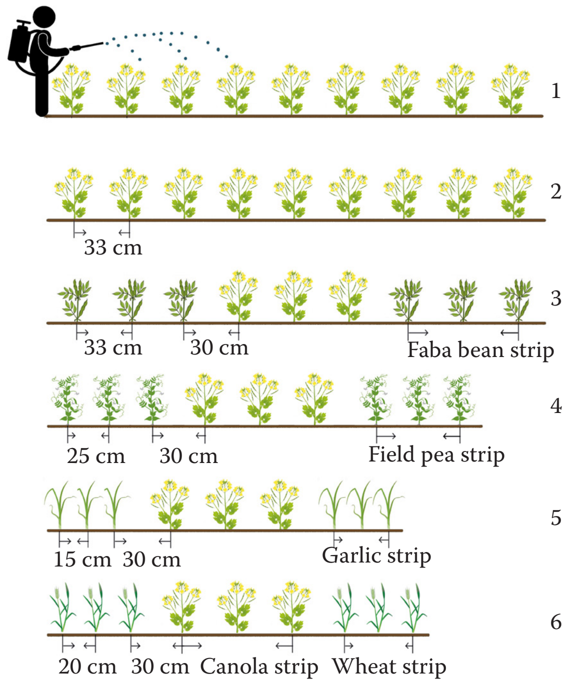

Figure 1. Schematic showing the five treatments and the control

1– monoculture of canola sprayed with pirimicarb; 2 – monoculture of canola; 3 – 3Ca : 3Fb (three canola rows intercropped with three faba bean rows); 4 – 3Ca : 3Fp (three canola rows intercropped with three field pea rows); 5 – 3Ca : 3G (three canola rows intercropped with three garlic rows); 6 – 3Ca : 3Wh (three canola rows intercropped with three wheat rows)

Data collection. Samples were taken weekly from March to May each year. This two-month period included four phases of the canola growth stages. The bolting, flowering, pod-fill, and maturity stages were sampled one time, three times, four times, and once, respectively. The sampling unit was a whole plant of canola that was randomly selected from each plot at each sampling time and transferred to the laboratory in a plastic bag. Then, the number of cabbage aphids (nymph and adult stages) per plant were counted using a 20 × hand lens. The identification of *B. brassicae* was based on the identification key (Liu & Sparks 2001). The number of the individual predator species was also counted in each sample. The immature stages of the predators were kept in cup cages with a grid cap at room temperature

https://doi.org/10.17221/132/2019-PPS

until the complete development and transformation to mature predatory insects. The predator species were identified using valid keys, especially Gordon (1985), Garland (1985) and Stubbs and Falk (2002). The relative frequency of each predator species was determined by the data on their number and frequency. The Shannon Diversity Index (H') was calculated by Equation (1) (Magurran 2004):

$$H' = -\sum Pi \ln Pi$$

where: H' – the Shannon Diversity Index; Pi – the proportion of the individuals present in the i^{th} (n_i/N) species.

At every single sampling time, a canola plant per plot was transferred to the laboratory and the apparent parasitism (%) was calculated through dividing the number of mummified aphids by the total number of aphids. In order to release the parasitoids, the samples containing the mummified aphids were placed inside ventilated containers under controlled germinator conditions for 14 days to identify the adult parasitoids after emergence using a key developed by Lotfalizadeh (2002). To determine the loss percentage of the canola yield by Equation (2), five canola plants per plot were used:

$$DWL(\%) = -\frac{W_t - W_c}{W_c} \times 100$$

where: DWL – dry weight loss of seeds per canola plant; W_t – dry weight of the infected plant seeds per IC system; W_c – dry weight of the intact plant seeds in the control treatment.

Statistical analysis. Prior to the data analysis, all the data were tested using the Kolmogorov-Smirnov test for statistical normality and then, if needed, they were transferred to a logarithm scale or arcsine transformation in order to homogenise the variance. Next, the data from the cabbage aphid population and percentage of parasitism were subjected to the general linear model (GLM) analysis as a repeated measures ANOVA based on a randomised complete block design consisting of four blocks and five treatments (including four intercrops and the unsprayed canola monoculture). The average values were compared by Duncan's Multiple Range Test at $P < 0.05$ using SAS (version 9.0) (SAS INSTITUTE 2002). The Shannon Diversity Index (H') was estimated for the species abundance of predators in every plot using PAST software (version 3.15) (Hammer et al. 2001).

RESULTS

Cabbage aphid population and biodiversity of its predators. The cropping system had a significant effect on the abundance of cabbage aphids in 2018 (F = 5.053, P = 0.009), but not in 2019 (F = 2.53, P = 0.084) (Table 1). The effect of the canola growth stage was significant in both years (F = 203.26, P = 0.000 in 2018 and F = 216.89, P = 0.000 in 2019; Table 1). However, the interaction between the cropping system and the canola growth stage did not meaningfully affect the number of aphids in both 2018 and 2019 (F = 0.950, P = 0.509 in 2018 and F = 1.37, P = 0.215 in 2019) (Table 1). In 2018, the number of aphids per plant was lower in 3Ca : 3G and 3Ca : 3Fp compared to the monoculture, despite the fact it was the highest in the monoculture in 2019, and, amongst the intercrops, was significantly lower in 3Ca : 3G in contrast with 3Ca : 3Fb, 3Ca : 3Fp, and 3Ca : 3Wh (Table 2). In both years, the lowest number of aphids per plant was recorded in 3Ca : 3G. The ladybirds *Coccinella septempunctata* Linnaeus, 1758, and *Exochomus nigromaculatus* (Goeze, 1777), the common green lacewing, *Chrysoperla carnea* (Stephens, 1836) and the hoverfly, *Eupeodes corollae* (Fabricus, 1794) (Table 3) were the most abundant predators. The Adonis ladybird, *Hippodamia variegate* (Goeze, 1777) and the hoverflies *Sphaerophoria rueppellii* (Wiedmann, 1830)

Table 1. Repeated measures ANOVA parameters for the effects of the cropping system, canola growth stage, and interactions on the number of aphids

Source	*df*	2018		2019	
		F	*P*-values	*F*	*P*-values
Cropping system	4	5.053	**0.009**	2.53	0.084
Canola growth stage	3	203.26	**0.000**	216.89	**0.000**
Cropping system × canola growth stage	12	0.950	0.509	1.37	0.215

The bold P values indicate significant treatment effects ($P < 0.05$)

https://doi.org/10.17221/132/2019-PPS

Table 2. Mean (± SE) population of the cabbage aphid in the five cropping systems

Cropping systems	Number of aphids per plant	
	2018	2019
Canola monoculture	27.82 ± 4.77[a]	16.27 ± 4.17[a]
Intercrop 3Ca : 3Fb	25.37 ± 4.78[a]	12.86 ± 3.24[ab]
Intercrop 3Ca : 3Fp	24.24 ± 4.59[ab]	14.60 ± 3.55[ab]
Intercrop 3Ca : 3G	19.61 ± 3.68[b]	11.03 ± 2.73[b]
Intercrop 3Ca : 3Wh	29.68 ± 4.82[a]	15.05 ± 3.54[ab]

The same letters in each column show a non-significant difference at $P \leq 0.05$ by Duncan's test

Sphaerophoria turkmenica Bankoska, 1964 and *Episyrphus balteatus* (De Geer, 1776) (Table 3) were less abundant. In 2018, the lowest *H*' value was recorded in 3Ca : 3G. The *H'* value was lower in 3Ca : 3Fp and 3Ca:3Wh than in 3Ca : 3Fb and the canola monoculture, but no significant difference was observed between 3Ca : 3Fp and 3Ca : 3Wh or 3Ca : 3Fb and the canola monoculture (Table 4).

Table 4. Mean (± SE) values of the Shannon Diversity Index for the species composition of the cabbage aphid predators in the five cropping systems

Cropping systems	Shannon Diversity Index (*H*')	
	2018	2019
Canola monoculture	1.95 ± 0.04[a]	1.89 ± 0.07[a]
Intercrop 3Ca : 3Fb	1.98 ± 0.02[a]	1.89 ± 0.05[a]
Intercrop 3Ca: 3Fp	1.75 ± 0.14[ab]	1.61 ± 0.19[a]
Intercrop3Ca : 3G	1.46 ± 0.15[b]	0.50 ± 0.31[b]
Intercrop 3Ca : 3Wh	1.74 ± 0.07[ab]	0.44 ± 0.27[b]

The same letters in each column show a non-significant difference at $P \leq 0.05$ by Duncan's test

During 2019, the *H*' value was lower in 3Ca : 3G and 3Ca : 3Wh than in 3Ca : 3Fb, 3Ca : 3Fp, and the canola monoculture, but no significant difference was recorded among 3Ca : 3Fb, 3Ca : 3Fp, and the canola monoculture (Table 4).

Parasitism of cabbage aphid. The cropping system had significant effect on the percentage of parasitised

Table 3. Predators of the cabbage aphid (*Brevicoryne brassicae* L.) on the canola (*Brassica napus* L.) and the percentage of their relative abundance in the five cropping systems in the Tarom region of Zanjan, Iran

Predators	Canola monoculture		Intercrop 3Ca : 3Fb		Intercrop 3Ca : 3Fp		Intercrop 3Ca : 3G		Intercrop 3Ca : 3Wh	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Coleoptera										
Coccinellidae										
Coccinella septempunctata (Linnaeus, 1758)	18.53	18.87	20.77	20.83	24.11	25.81	17.32	30.00	19.23	57.14
Exochomus nigromaculatus (Goeze, 1777)	12.28	13.21	12.64	12.50	16.52	12.90	10.51	10.00	12.18	14.29
Hippodamia variegate (Goeze, 1777)	9.29	7.55	8.13	6.25	8.48	9.68	8.24	0.00	9.40	0.00
Neuroptera										
Chrysopidae										
Chrysoperla carnea (Stephens, 1836)	14.19	15.09	17.29	16.67	19.35	19.35	15.53	10.00	23.61	14.29
Diptera										
Syrphidae										
Eupeodes corolla (Fabricus, 1794)	19.97	20.75	18.51	18.75	14.73	16.13	28.32	50.00	18.48	14.29
Sphaerophoria rueppellii (Wiedmann, 1830)	14.09	15.09	11.93	12.50	4.76	6.45	10.04	0.00	6.20	0.00
Sphaerophoria turkmenica (Bankoska, 1964)	7.86	5.66	7.55	8.33	2.83	3.23	5.49	0.00	6.20	0.00
Episyrphus balteatus (De Geer, 1776)	3.80	3.77	3.18	4.17	9.23	6.45	4.53	0.00	4.70	0.00

https://doi.org/10.17221/132/2019-PPS

Table 5. Repeated measures ANOVA parameters for the effects of the cropping system, canola growth stage, and interactions on the percentage of the parasitised cabbage aphid

Source	*df*	2018		2019	
		F	*P*	*F*	*P*
Cropping system	4	9.168	**0.001**	1.275	0.323
Canola growth stage	3	9.304	**0.000**	27.531	**0.000**
Cropping system × canola growth stage	12	0.797	0.651	1.600	0.126

The bold *P*-values indicate significant treatment effects ($P < 0.05$)

cabbage aphids in 2018 (F = 9.168, P = 0.001), but not in 2019 (F = 1.275, P = 0.323) (Table 5). The effect of the canola growth stage was significant in both years (F = 9.304, P = 0.000 in 2018 and F = 27.531, P = 0.000 in 2019) (Table 5). However, the interaction between the cropping system and the canola growth stage did not significantly affect the percentage of the parasitised cabbage aphids in both 2018 and 2019 (F = 0.797, P = 0.651 in 2018 and F = 1.600, P = 0.126 in 2019) (Table 5). Only one parasitoid, *D. rapae*, was reared from the mummies of the cabbage aphids. In 2018, the percentage of parasitised cabbage aphids per plant was highest in 3Ca : 3Fb (Table 6). It was lower in 3Ca : 3G and 3Ca : 3Wh than in 3Ca : 3Fp and the canola monoculture, but no significant difference was observed between 3Ca : 3G and 3Ca : 3Wh or 3Ca : 3Fp and the canola monoculture (Table 6). During 2019, no significant difference was recorded among the cropping systems (Table 6).

Canola yield loss. The dry seed weight loss was considerably different among the five cropping systems (F = 4.97; df = 4, 12; P = 0.0135 for 2018 and F = 5.70; df = 4, 12; P = 0.0083 for 2019). In both years, the yield loss was highest in the canola monoculture and 3Ca : 3Wh. It should be noted that the yield loss substantially decreased in the three intercrops of 3Ca : 3Fb, 3Ca : 3Fp, and 3Ca : 3G (Figure 2).

Table 6. Mean (± SE) percentage of the parasitised cabbage aphids (mummies) in the five cropping systems

Cropping systems	Parasitised cabbage aphids per plant* (%)	
	2018	2019
Canola monoculture	9.16 ± 1.6[b]	6.37 ± 2.3[a]
Intercrop 3Ca : 3Fb	12.33 ± 1.8[a]	8.63 ± 2.8[a]
Intercrop 3Ca : 3Fp	8.64 ± 1.6[b]	7.04 ± 2.2[a]
Intercrop 3Ca : 3G	4.64 ± 1.1[c]	4.38 ± 2.1[a]
Intercrop 3Ca : 3Wh	5.13 ± 1.2[c]	4.05 ± 1.2[a]

*the percentage of the parasitised cabbage aphids per plant is a cumulative measure for the entire cropping season by the aphid parasitoid Diaeretiella rapae M'Intosh; the same letters in each column show a non-significant difference at $P \leq 0.05$ by Duncan's test

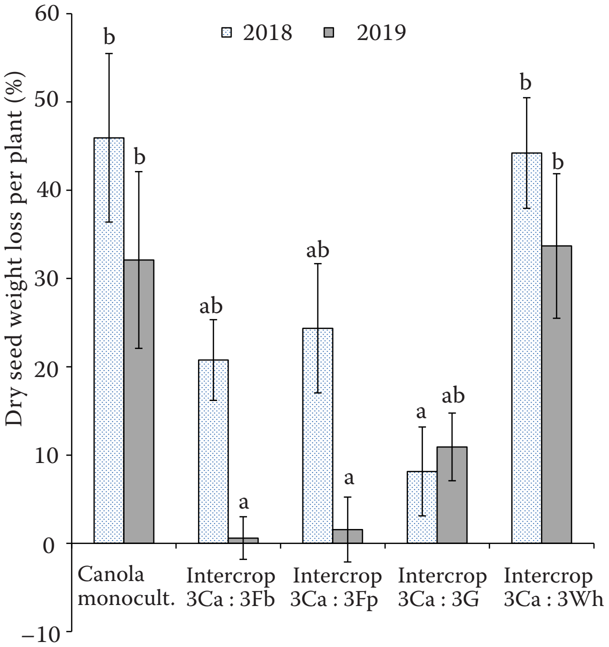

Figure 2. Mean (± SE) of the percentage of the dry seed weight loss in the five cropping systems

The bars in each year with the same letter are not significantly different ($P \leq 0.05$)

DISCUSSION

The reduced population of the cabbage aphids detected in 3Ca : 3G can be attributed to the repellent effect of garlic (Zhou et al. 2013a; Debra & Misheck 2014; Tiroesele & Matshela 2015; Afrin et al. 2017; Akbar et al. 2017). Concerning 3Ca : 3Fp, the reduced population probably initiates from the fact that the displacement of the insect pests is physically hindered by a non-host crop acting as a barrier plant. Moreover, peas can be introduced as a widely used barricade due to having a high potential in acting (Zhou et al. 2013b; Lopes et al. 2016). Likewise,

https://doi.org/10.17221/132/2019-PPS

the reduced population of the cabbage aphids in 3Ca : 3Fb is explained through the faba bean strips in the role of natural enemies, which are supported through providing sufficient alternative sources of food and shelter, as well as breeding and nesting sites (Cahenzli et al. 2017; Gurr et al. 2017; Palsson 2019). In this way, the highest proportion of parasitised cabbage aphids was reported in 3Ca : 3Fb during the 2-year period. This observation is attributable to the extrafloral nectar from the faba bean as a potential food source for female *D. rapae*, which is in agreement with Jamont et al. (2014).

The *H*' values showed that the predators of the cabbage aphid were not attracted and supported by the IC. This could occur because canola is excellent for both nectar and pollen (Carruthers et al. 2017). Hence, canola itself serves as an insectary plant for the predators of cabbage aphids and provides both nectar and pollen together with a landing platform of yellow petals. The low yield loss detected for 3Ca : 3G can result from the low aphid population (due to the deterrent impact of the garlic); this could have occurred with a high percentage of parasitism in 3Ca : 3Fb that might positively affect the suppression of the aphid population. Besides, it has been shown that IC with legumes can supply a nitrogen input through nitrogen fixation (Génard et al. 2017; Couëdel et al. 2018) with a subsequent reduction in the yield loss. On the other hand, the parasitism rate of the cabbage aphid is interrelated to the soil nitrogen content by *D. rapae* (Ponti et al. 2007). Moreover, a crucifer-legume IC can provide better resource use efficacy because of the niche complementarity in the utilisation of abiotic resources including light, water, and nutrients (Couëdel et al. 2019). Accordingly, a successful IC system should not be determined on the basis of controlling a single target pest, or on some other single representative of the system, but rather based on the cropping system as a whole. Otherwise stated, the IC can influence the cropping systems via other advantageous means consisting of an improvement in the soil quality and health (Lian et al. 2019), raising nutrient and water use efficiency (Ma et al. 2019), and inhibiting weed growth (Elsalahy et al. 2019). Therefore, future investigations should address the impacts of the IC on multiple factors possibly affecting the crop yield.

CONCLUSION

The IC of canola and faba beans, field peas or garlic was associated with a reduced cabbage aphid density and an improved canola crop yield. Accordingly, to achieve heightened savings in control programmes of cabbage aphids, these routes should be utilised, which will result in a non-toxic food and an environment in fine fettle as well. For that reason, it could be a practical technique in the integrated management of cabbage aphids in canola fields and recommendable for the extended utilisation in the production of canola.

Acknowledgement: The authors sincerely thank the management and staff of Jihad-e Agriculture in Tarom, for permission to use the experimental farm and their valuable cooperation with this research.

REFERENCES

Afrin S., Latif A., Banu N., Kabir M., Haque S., Ahmed M.E., Tonu N., Ali M. (2017): Intercropping empower reduces insect pests and increases biodiversity in Agro-Ecosystem. Agricultural Sciences, 8: 1120–1134.

Akbar W., Asif M.U., Ismail M., Bux M., Memon R.M. (2017): Management of aphids on canola (*Brassica napus* L.) through cultural practices. Pakistan Entomologist, 39: 27–31.

Baidoo P., Mochiah M., Apusiga K. (2012): Onion as a pest control intercrop in organic cabbage (*Brassica oleracea*) production system in Ghana. Sustainable Agriculture Research, 1: 36–41.

Brennan E.B. (2016): Agronomy of strip intercropping broccoli with alyssum for biological control of aphids. Biological Control, 97: 109–119.

Cahenzli F., Pfiffner L., Daniel C. (2017): Reduced crop damage by self-regulation of aphids in an ecologically enriched, insecticide-free apple orchard. Agronomy for Sustainable Development, 37: 65.

Carruthers J.M., Cook S.M., Wright G.A., Osborne J.L., Clark S.J., Swain J.L., Haughton A.J. (2017): Oilseed rape (*Brassica napus*) as a resource for farmland insect pollinators: quantifying floral traits in conventional varieties and breeding systems. GCB Bioenergy, 9: 1370–1379.

Couëdel A., Alletto L., Tribouillois H., Justes É. (2018): Cover crop crucifer-legume mixtures provide effective nitrate catch crop and nitrogen green manure ecosystem services. Agriculture, Ecosystems & Environment, 254: 50–59.

Couëdel A., Kirkegaard J., Alletto L., Justes E. (2019): Crucifer-legume cover crop mixtures for biocontrol: Toward a new multi-service paradigm. Advances in Agronomy, 157: 55–139.

Debra K.R., Misheck D. (2014): Onion (*Allium cepa*) and garlic (*Allium sativum*) as pest control intercrops in cabbage based intercrop systems in Zimbabwe. IOSR Journal of Agriculture and Veterinary Science, 7: 13–17.

https://doi.org/10.17221/132/2019-PPS

Elsalahy H., Döring T., Bellingrath-Kimura S., Arends D. (2019): Weed suppression in only-legume cover crop mixtures. Agronomy, 9: 648.

Garland J. (1985): Identification of Chrysopidae in Canada, with bionomic notes (Neuroptera). The Canadian Entomologist, 117: 737–762.

Génard T., Etienne P., Diquélou S., Yvin J.C, Revellin C., Laîné P. (2017): Rapeseed-legume intercrops: plant growth and nitrogen balance in early stages of growth and development. Heliyon 3: e00261. doi: 10.1016/j.heliyon.2017.e00261

Gordon R.D. (1985): The Coccinellidae (Coleoptera) of America north of Mexico. Journal of the New York Entomological Society, 93: 1–912.

Gurr G.M., Wratten S.D., Landis D.A., You M. (2017): Habitat management to suppress pest populations: progress and prospects. Annual Review of Entomology, 62: 91–109.

Hammer Ø., Harper D.A., Ryan P.D. (2001): PAST: paleontological statistics software package for education and data analysis. Palaeontologia Electronica, 4: 1–9.

Jamont M., Dubois-Pot C., Jaloux B. (2014): Nectar provisioning close to host patches increases parasitoid recruitment, retention and host parasitism. Basic and Applied Ecology, 15: 151–160.

Lian T., Mu Y., Jin J., Ma Q., Cheng Y., Cai Z., Nian H. (2019): Impact of intercropping on the coupling between soil microbial community structure, activity, and nutrient-use efficiencies. PeerJ, 7: e6412. doi: 10.7717/peerj.6412

Liu T.X., Sparks Jr. A.N. (2001): Aphids on cruciferous crops: identification and management. AgriLife Extension, 6109: 1–12.

Lopes T., Hatt S., Xu Q., Chen J., Liu Y., Francis F. (2016): Wheat (*Triticum aestivum* L.)-based intercropping systems for biological pest control. Pest Management Science, 72: 2193–2202.

Lotfalizadeh H. (2002): Parasitoids of cabbage aphid, *Brevicoryne brassicae* (L.) (Hom.: Aphididae) in Moghan Region. Agricultural Science (Tabriz), 12: 15–25.

Ma L., Li Y., Wu P., Zhao X., Chen X., Gao X. (2019): Effects of varied water regimes on root development and its relations with soil water under wheat/maize intercropping system. Plant and Soil, 439: 113–130.

Magurran A.E. (2004): An index of diversity. Measuring biological diversity. Malden, Blackwell Publishing: 103–108.

Mutiga S.K., Gohole L.S., Auma E.O. (2010): Effects of integrating companion cropping and nitrogen application on the performance and infestation of collards by *Brevicoryne brassicae*. Entomologia Experimentalis et Applicata, 134: 234–244.

Palsson J. (2019): Attract, reward and disrupt: combining habitat manipulation and semiochemicals to enhance pest control in apple orchards. [Ph.D. thesis]. Alnarp, Swedish University of Agricultural Sciences: 65.

Ponti L., Altieri M.A., Gutierrez A.P. (2007): Effects of crop diversification levels and fertilization regimes on abundance of *Brevicoryne brassicae* (L.) and its parasitization by *Diaeretiella rapae* (M'Intosh) in broccoli. Agricultural and Forest Entomology, 9: 209–214.

SAS Institute (2002): SAS/Stat Version 9, SAS Institute Inc, Cary, NC, USA.

Stubbs A.E., Falk S.J. (2002): British Hoverflies: An Illustrated Identification Guide. London, British Entomological and Natural History Society.

Tiroesele B., Matshela O. (2015): The effect of companion planting on the abundance of cabbage aphid, *Brevicoryne brassicae* L., on kale (*Brassica oleracea* var. *acephala*). Journal of Plant and Pest Science, 2: 58–65.

Zhou H., Chen J., Liu Y., Francis F., Haubruge E., Bragard C., Sun J., Cheng D. (2013a): Influence of garlic intercropping or active emitted volatiles in releasers on aphid and related beneficial in wheat fields in China. Journal of Integrative Agriculture, 12: 467–473.

Zhou H., Chen L., Chen J., Francis F., Haubruge E., Liu Y., Bragard C., Cheng D. (2013b): Adaptation of wheat-pea intercropping pattern in China to reduce *Sitobion avenae* (Hemiptera: Aphididae) occurrence by promoting natural enemies. Agroecology and Sustainable Food Systems, 37: 1001–1016.

Received: December 30, 2019
Accepted: September 14, 2020
Published online: November 24, 2020