REVISTA DELOS DESARROLLO LOCAL SOSTENIBLE

Effect of Cabbage and Basil intercropping on conservative biological control of Aphids

Efeito do consórcio couve e manjericão no controle biológico conservativo de pulgões

DOI: 10.55905/rdelosv16.n47-009

Recebimento dos originais: 28/08/2023
Aceitação para publicação: 27/09/2023

Simone Mundstock Jahnke
PhD in Plant Science
Institution: Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul
Address: Porto Alegre - RS, Brasil
E-mail: mundstock.jahnke@ufrgs.br

Luiza Rodrigues Redaelli
PhD in Science, Ecology and Natural Resources
Institution: Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul
Address: Porto Alegre - RS, Brasil
E-mail: luredael@ufgrs.br

Viviane Falkembach Pretz
Master in Plant Science
Institution: Escola Mundo, Escola Pólo Infantil, Colégio Conhecer, Escola Projeto e Instituto Plantar Colher e Cozinhar
Address: Porto Alegre - RS, Brasil
E-mail: vivipretzagro@gmail.com

ABSTRACT
Conservative biological control seeks to preserve beneficial organisms as the natural enemies of pests through habitat management. These studies aimed to measure the potential of basil (*Ocimum basilicum* L.) in the biological control of aphids in green cabbage (*Brassica oleraceae* L. var. *acephala*); and to evaluate the influence of the intercropping on green cabbage productivity. In an organic commercial crop of green cabbage in Águas Claras, RS, basil was used as an associated border (BB) and contrasted with plants in beds with no border (WB). We compared Aphididae density and parasitism, in the spring/summer seasons of 2016 and autumn/winter of 2017. *Brevicoryne brassicae* L. and *Myzus persicae* Sulzer (Hemiptera, Aphididae) were recorded in the green cabbage, in 2016. A mean of 13.8 ± 8.72 aphids/leaf was recorded in the WB, significantly higher than in the BB, 3.4 ± 1.83 (Tukey 5% p = 0.00002). In the 2017 season, this difference was not significant at 10.3 ± 12.73 (WB) and 6.9 ± 11.34 (BB). The mean of parasitized aphids was 2.8 ± 2.84 in WB and 9.9 ± 2.87 BB (p = 0.0041) in the spring crop and 2.9 ± 4.10 (WB) and 14.25 ± 7.3 (BB) in the winter (p = 0.0039). The association of green cabbage and basil had an area equivalence index (AEI) in 2016 = 1.07 and 2017 = 0.99 indicating that basil did not affect green cabbage yield.

Keywords: *brassica oleracea*, *brevicorinae brassicae*, *myzus persicae*, *ocimum basilicum*, parasitoids.

RESUMO
O controle biológico conservativo busca preservar organismos benéficos como os inimigos naturais de pragas através do manejo do habitat explorando a diversificação vegetal. Este trabalho objetivou mensurar o potencial do manjericão (*Ocimum basilicum* L.) no controle biológico de afídeos em couve (*Brassica oleraceae* L. var. *acephala*) e avaliar a influência do consórcio na produtividade da couve. Em um plantio comercial orgânico de couve em Águas Claras, RS, o manjericão foi utilizado como bordadura em consórcio (CB) sendo contrastado com plantas em canteiros sem bordadura (SB). Foi comparada a densidade de Aphididae e o parasitismo, nas safras de primavera/verão de 2016 e outono/inverno de 2017. Foram registrados os afídeos *Brevicoryne brassicae* L. e *Myzus persicae* Sulzer na couve, obtendo-se, em 2016 uma média 13,8 ± 8,72 afídeos/folha no SB significativamente maior que no CB, 3,4 ± 1,83 (Tukey 5% p= 0,00002). Em 2017 essa diferença não foi significativa, 10,3 ± 12,73 (SB) e 6,9 ± 11,34 (CB). A média de afídeos parasitados foi de 2,8 ± 2,84 no SB e 9,9 ± 2,87 CB (p=0,0041) na safra de primavera e 2,9 ± 4,10 (SB) e 14,3 ± 7,30 (CB) na de inverno (p=0,0039). A presença do manjericão não afetou a produtividade da couve, sendo que o canteiro com o consórcio couve e manjericão apresentou índice de equivalência de área (IEA) em 2016 = 1,07 e em 2017 = 0,99.

Palavras-chave: *brassica oleracea*, *brevicorinae brassicae*, *myzus persicae*, *ocimum basilicum*, parasitoids.

1 INTRODUCTION

The manipulation of the environment in an agroecosystem seeking to increase fertility, reproductive success, and the efficiency of natural enemies (NE), with plant diversification to reduce pest insect populations (Barbosa, 1998; Wackers et al., 2007) is one of the strategies used in Conservative Biological Control (CBC). Intercropping carried out through combined drawings of two or more plants in the same area, such as border cultivation, interspersed, in mixed rows, and with vegetation cover, (Altieri et al., 2010) is one of the techniques used in CBC.

However, plant diversification must be planned, with species capable of attracting and maintaining natural enemies of interest to effectively reduce pests, without affecting the productivity of the main crop or attracting pests (Barbosa et al., 2011; da Silva et al., 2022). Afrin et al. (2017) evaluated different plants intercropped with mustard (*Brassica* spp.) and showed that mustard, onion, garlic, and coriander intercropped systems significantly reduced the aphid population in the main crop. However, some intercrops like mustard with wheat and grass reduced the productivity of the main crop by increasing the pest population.

Plants with floral resources, but also harvestable, can provide additional economic incentives for farmers since the land dedicated to floral resources is removed from agricultural production, thus, this would be a means to compensate for this loss (Bugg et al., 2008).

Basil (*Ocimum basilicum* L.) is a good option for this role in agroecosystems. It is a commercially cultivated species, being the aromatic leaves used dry or fresh as a condiment or to obtain essential oil, which high concentration of linalool, a compound used by the pharmaceutical industry, with many medicinal functions (Kakaraparthi et al., 2015) The plant can also be beneficial if cultivated in intercropped system for conservative biological control, due to its architectural and chemical structure (Vieira et al., 2012; Brito et al, 2021). Additionally, this species has extrafloral nectaries that attract various insects, including predators, parasitoids, and pollinators, which come in search of food, shelter, or reproduction sites even when the plant is not flowering (Mačukanović-Jocić et al. 2007).

Green cabbage (*Brassica oleracea* L. var. acephala) is a vegetable widely cultivated in Brazil. It has a high nutritional value, is easy to grow, and has a short cycle, with up to four harvests per year, depending on the region (Filgueira, 2012). Among the main pests of cabbage are aphids, *Brevicorinae brassicae* (L.), and *Myzus persicae* (Sulzer) (Hem. Aphididae) (Cividanes, 2002). The natural biological control of these species is carried out by predators from Coccinelidae (Coleoptera), Syrfidae (Diptera), and Chrysopidae (Neuroptera) families (Riquelme, 2007) and, mainly, by parasitoids from Braconidae and Aphelinidae families (Joschi et al, 2010).

This work aimed to identify and measure the aphids and parasitoids in two seasons (spring and winter) in the single cultivation of cabbage and in intercropping with basil, and to evaluate the productivity of cabbage in intercropping based on the area equivalence index and leaf increment index in organic cultivation, in Viamão, RS.

2 MATERIAL AND METHODS

2.1 STUDY AREA

The study was carried out in an organic vegetable production area located in the settlement “Filhos de Sepé” Rural Workers Movement Settlement, which surrounds the

Banhado dos Pachecos’ environmental protection area, municipality of Viamão (between parallels 29°57'00'' S and 30°26'30'' S and meridians 51°02'00''W and 50°47'00''W). Because they are located within an Environmental Protection Area, since 2007 all crop production has been managed with organic practices. The average monthly rainfall in the region is 119 mm and the average temperature of 19ºC (IRGA 2023).

Leafy vegetables are commercially produced in the study area, such as lettuce *(Lactuca sativa* L.) (Asteraceae), green cabbage (B. *oleracea* var. *acephala*), parsley (*Petroselinum crispum* Mill.) (Apiaceae), chives (*Allium fistulosum* L.) (Alliaceae) and mustard (*Brassica alba L*.) (Brassicaceae) among others. The total area has 2.5 hectares, divided into 165 beds of 84 m in length and 1.0 m in width, with a spacing between beds of 0.5 m. Chemical additives are not used in cultivation, following the rules of organic production in Brazil (Brasil, 2003)

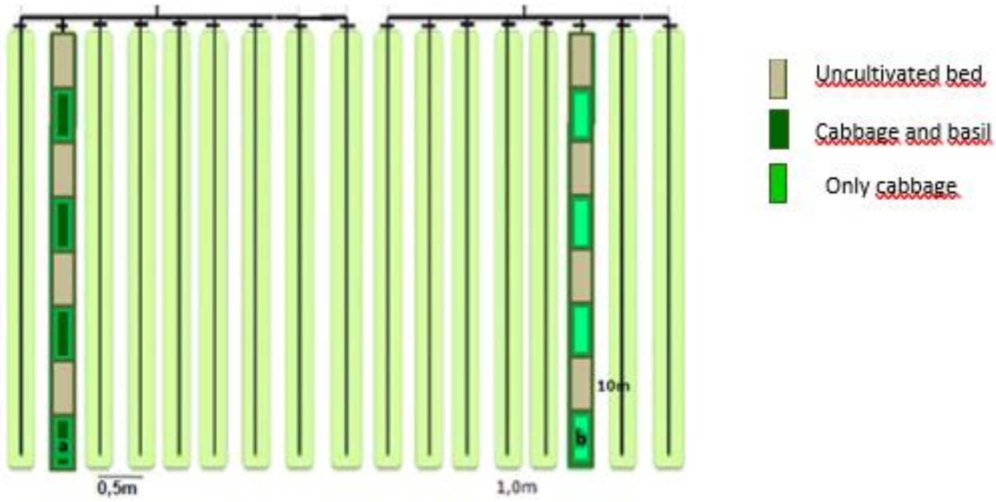
The experiment was conducted over two years. In the first year (2016) the spring crop (second annual crop) was sampled from 08/22 to 11/28. In the second year (2017), the winter crop (first crop of the year) was evaluated from 05/24 to 09/22, both crop seasons with 15 weeks of sampling.

Two beds were used, each one 80 m long and 1.0 m wide, both cultivated with green cabbage, in one of them, basil was planted in the border. Each bed was divided into eight plots 10 m in length, maintained alternately, one plot with plants and the other without any type of cultivation (Figure 1). Basil was transplanted a week before cabbage so that the seedlings could adapt to the final location. The cabbage seedlings were transplanted inside the bed forming two rows, with a spacing of 0.5 m between plants and 0.5 m between rows, with 40 plants in each plot.

Two treatments were evaluated, one plot with only cabbage, without border (WB), and the other with basil border (BB), each with four replications.

REVISTA
DELOS
DESARROLLO
LOCAL SOSTENIBLE

FIGURE 1. Draft of the crop area, showing the beds (1.0 m wide and 80 m long) and 0.5 m apart from each other and the two selected for the experiment, with the division of plots. In green, the plots with the basil and cabbage border (a); and only cabbage (b). In beige, the beds (10 m) were kept uncultivated.



2.2 INSECT SAMPLING AND SORTING

Aphid populations were monitored weekly throughout the entire cabbage crop cycle. On each sampling occasion, three cabbage plants were drawn per plot, totalizing 24 plants per collection. These were examined for the presence of aphid colonies. When the plant had aphids, a leaf with the presence of a colony was removed.

The collected leaves were individualized in identified plastic bags, deposited in styrofoam boxes, and taken to the laboratory for separation of aphids into: adults, nymphs, and "mummies", which is the name given to parasitized aphids fixed on leaves (Joschi et al, 2010). Aphid mummies were kept in a climate-controlled chamber (26 ± 2ºC, 60 ± 10% RH; photophase 12 h) until parasitoid emergence.

The emerged parasitoids were individualized in Eppendorf-type tubes containing 70% alcohol and numbered. Specialist Dr. Marcus Vinícius Sampaio, from the Federal University of Uberlândia, Minas Gerais identified the parasitoid species and confirmed the aphid species.

2.3 PLANT PRODUCTIVITY

The index of area equivalence (IAE) was calculated for the cabbage/basil intercropping, fixing a leaf increment index, that is, the average result of counting the number of leaves that the cabbage emits per week (cabbage development in leaves/week).

The index of area equivalence (IAE) used in this work was calculated using the formula:

$$IAE = \sum = (Ppi/Pmi)$$

were:

Ppi = Productivity of cultivation in consortium
Pmi = Single crop productivity

For productivity in the consortium to have an advantage over a single crop, the IEA must remain greater than or equal to 1 (Willey, 1979)

2.4 DATA ANALYSIS

Mean density and relative frequency of the species of live aphids, mummies and parasitoids, infested plants, and number of cabbage leaves, were compared between treatments using analysis of variance (ANOVA) and tested by Tukey, at a significance level of 0 .05. Population data from the two aphid species were correlated with temperature data by Person's method.

The relative frequency of each parasitoid species was calculated for the two seasons. Parasitoids alpha diversity was measured by the rarefaction method, which calculates the expected number of species in each sample. The parasitoid species composition (Beta diversity) was compared between the treatments and seasons using cluster analysis (the UPGMA algorithm with Euclidean cluster analysis).

For statistical analyses, Bioestat 5.3, Past, and R programs were used.

3 RESULTS AND DISCUSSION

3.1 APHIDS

In both seasons of this study, the aphid species found on green cabbages in both treatments were *B. brassicae* and *M. persicae*. Both are recorded for the cabbage crop and can occur together or at different times in the crop and the dominant species can vary (Sousa Silva & Ilharco, 1995). In this survey, meantime, *B. brassicae* was the dominant aphid species in the two seasons evaluated, regardless of the presence of basil, showing that the border did not influence the composition of aphid species in cabbage. The highest density of *B. brassicae* is commonly reported in Brazilian different regions, in cabbage as in a survey in Uberlândia, MG (Hubaide, 2011).

The average percentage of plants infested with aphids was 38.3% in the BB area and 46.6% in the WB area, in the 2016 season (spring), with no significant difference ($\chi 2$ = 2,558; gl=1; p>0, 1098). In this same season, the average number of aphids/leaf/sampling occasion was significantly lower in BB areas for both aphid species, *M. persicae* (F = 10.5253; gl+1; p < 0.005) and *B. brassicae* (F = 12.1444; gl = 1; p< 0.005) (Table 1).

Table 1. Average number (±EP) of aphids, by species, collected on cabbage leaves, in the beds without the basil border (WB) and with the border (BB), from 08/22/2016 to 11/28/ 2016 and 05/24/2017 to 09/20/2017, Viamão, RS.

	Crop season	
	2016	2017
M. persicae WB	4.4 ± 3.53 a*	2.5 ± 4.90 a
M. persicae BB	1.3 ± 0.92 b	2.4 ± 2.68 a
B. brassicae WB	9.5 ± 8.15 a	7.8 ± 6.97 a
B. brassicae BB	2.1 ± 1.33b	4.5 ± 2.73 a
Total WB	13.8± 8.72a	10.3 ± 12.73 a
Total BB	3.4 ± 1.83b	6.9 ± 11.34a

* Mean values followed by different letters in the columns differ for the same species between treatments in the same season by Tukey at 5% significance.

Smaller populations of aphids, in areas with the presence of other plants or intercropped are expected, as in the work by Resende et al. (2011) who observed significantly higher aphid populations in cabbage in single plots than in those intercropped with coriander (*Coriandrum sativum* L.) (Umbelliferae). Likewise, in a study where the occurrence of aphids and predatory insects was recorded with cabbage alone and intercropped with sorghum (*Sorghum bicolor* L.) and pigeonpea (*Cajanus cajans* L.), higher populations of *B. brassicae* and *Lipaphis erysimi* (Hemiptera: Aphididae) occurred in plots where cabbage was grown single (Ramos, 2015).

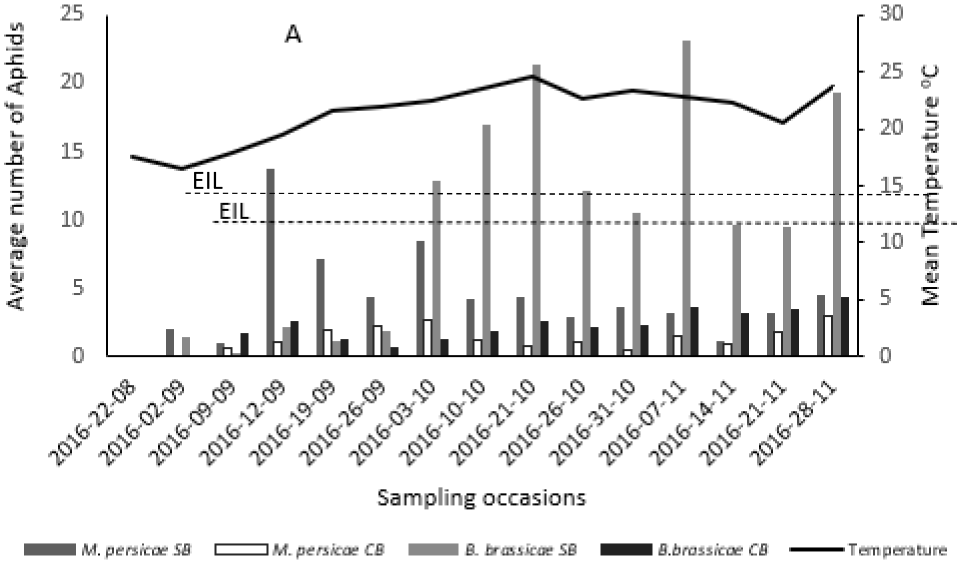
The use of plants of the genus *Ocimum* in conservative biological control in different species of *Brassica* has also been tested for lepidopterans such as *Spodoptera litura* (Noctuidae) (Kianmatee & Ranamukhaarachchi, 2007), *Plutella xylostella* L. (Plutelliidae) and *Spodoptera littoralis* (Boisduval) (Noctuidae) (Yarou et al., 2017), with a significant reduction in pest densities and damage, indicating that it is a suitable plant for reducing phytophages in the target crop. It has also been demonstrated that the spatial arrangement of basil, when intercropped with *Solanum melongena* L. (Solanaceae) increases the density and colonization rate of *Chrysopa* *pallens* (Rambur) Neuroptera: Chrysopidae) reducing the number of aphids even in the vegetative stage of crops (Fang et at., 2022)

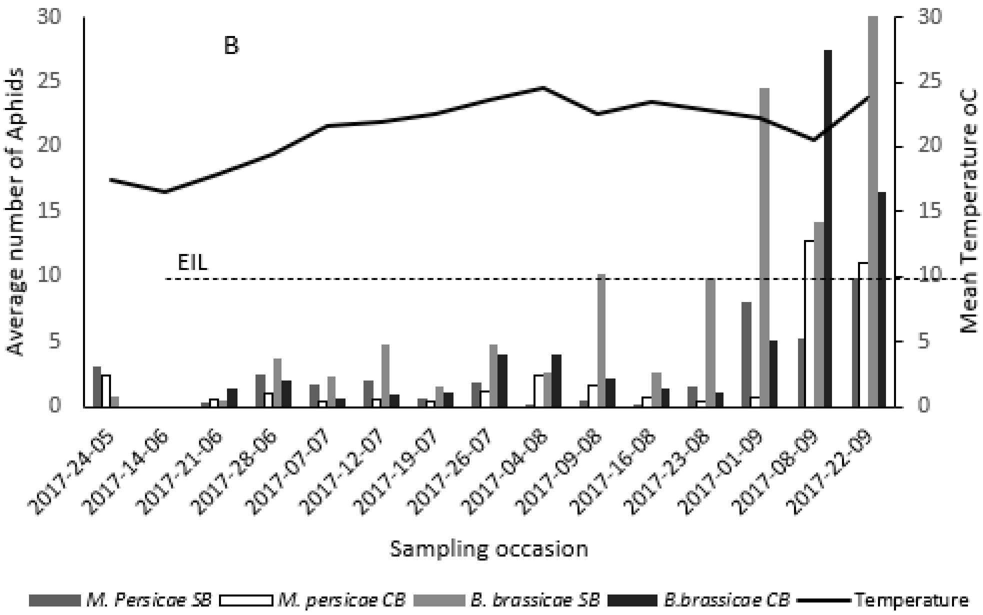
In the 2017 season (winter), however, there was no significant difference between treatments (Table 1). A possible explanation for this result is that the development of basil is favored by higher temperatures, which occurred in the 2016 harvest. But when average temperatures are lower, as in the winter season in 2017, plant development is delayed. This is confirmed because, despite being a perennial plant, it is recommended to plant basil seedlings in times of higher temperatures for better development (Costa and Filho et al., 2006) since its growth is limited in weekly thermal averages below 21°C (Costa and Filho et al. (2006). In fact, the number of leaves produced by basil in spring exceeded by 59% that of autumn, and plant height was, on average, 7.58 cm higher in spring (Ferreira et al., 2015). Thus, considering the delay in the development of plant structures, it is possible that extrafloral nectaries as well as flowers were not readily available when green cabbage was already producing.

The population density of aphid species in the different sampling occasions varied from one season to the next. The population peaks of both species also occurred at different periods during the development time of the cabbage crop (Figure 2). *Myzus persicae* showed a higher population density than *B. brassicae* in the first three weeks of sampling for both treatments and was the first population observed in both seasons. According to Wellings & Dixon (1987), aphid populations can fluctuate and maintain high levels of density or, in some cases, periods of abundance are followed by periods of low density. In our work, the population density of *B. brassicae* was low at the beginning of the crop cycle and increased as it developed, in both seasons.

In the first year, it was observed that in all sampling occasions, the number of aphids of both species was higher in the treatment without borders (Figure 2 a). The economic injury level (EIL) considered for cabbages is 10 aphids per leaf/sampling, as the rapid reproduction of these insects causes rapid leaf infestation (Ahmad & Aslam, 2005). In the BB treatment, on no occasion did the average number of aphids reach 10 insects. In the WB area, however, starting in October, a number of aphids greater than the proposed EIL was recorded on all occasions.

Figure 2. The average number of aphids per leaf per week Population density over 15 weeks of sampling of *Brevicoryne brassicae* and *Myzus persicae* in the cabbage beds with border (BB) and without border (WB) of basil and average temperature (°C) in the 2016 harvest (A) and in the of 2017 (B). The dotted line indicates the crop's economic injury level (EIL).





In the 2017 season, although the average number of aphids did not differ between treatments, only on two sampling occasions the number of aphids was higher than the EIL in the beds with borders. These alternations were possibly due to variations in meteorological factors, especially the average temperature. This can be seen (Figure 2. b) as there was an increase in the average temperature in the last three samplings, followed by an increase in aphid densities. In the WB area, the density exceeded the EIL on the 10^{th}, 13^{th}, 14^{th}, and 15th weeks. Even though there was no difference in the average number of aphids, considering that in general there is a delay in the response of natural enemies to the increase in the density of their prey (Krebs, 2009), it is possible that in sequential sampling there was a reduction in aphid densities.

There was a positive correlation between the increase in average temperature and the population increase of *B. brassicae* in both seasons of this study. The average nymphal period of *B. brassicae* is 12.5 days at 15 °C and six days at 25 °C, confirming that the development of these insects is faster at higher temperatures (Satar et al., 2015). For *M. persicae*, this was only noticed in the winter season, in 2017, and in the spring of 2016, no correlation was detected, possibly because temperature variation, in this season, encompasses the thermal constant favorable to the development of the species, the from 20ºC (Afrin et al., 2017).

3.2 PARASITISM AND PARASITOIDS

The presence of mummies on the leaves indicated parasitism in the two years of sampling. In the 2016 harvest (spring) a significant difference was observed between treatments (Table 2), with a higher average of parasitized aphids when there was a basil border. In the 2017 season (winter), the BB treatment had a significantly higher number of mummies. The attraction of natural enemies in cultivated areas, with the expansion of botanical diversity, has been mentioned by other studies (Karungi et al., 2000). Intercropping cultures can increase parasitism in aphids, as described by Sturza et al. (2012) when studying the association of oats and ryegrass in increasing rates of aphid parasitism. The authors argue that this consortium makes environmental conditions more favorable for the development of parasitoid populations.

Table 2. An average number of aphids per plant (± SE) nymphs, adults, and mummies collected in green cabbage in areas with and without basil borders, in the two sampling seasons, in Viamão/RS.

	Crop season			
	2016		2017	
	WB	BB	WB	BB
Nimphs	37.1 ± 23.04 a	5.3 ± 1.97 b	66.9 ± 53.63 a	82.0 ± 62.22 a
Adults	13.9 ± 6.23 a	4.4 ± 1.93 b	56.8 ± 37.92 a	74.2 ± 44.13 a
Mummies	2.7 ± 2.84 b	9.9 ± 2.87 a	2.9 ± 4.10 b	14.2 ± 7.30 a

* Mean values followed by the same letter in the lines do not differ between treatments for the same season by the Tukey Test at 5% significance.

The greater presence of parasitoids can be related to the attractiveness exerted by basil, both in flowering and in the vegetative period, since the plant also has extrafloral nectaries (O'Leary, 2017). Also in green cabbage cultivation, the effect of extrafloral nectar of *Vicia faba* L. (Fabaceae) was evaluated on the activities of *Diaeretiella rapae* (McIntosh), having a positive effect on female longevity and increased oviposition rate (Jamont et al., 2013). Basil also acted to improve the fitness attributes of lacewing, a generalist predator, optimizing the biological control of aphids in a greenhouse (Fang et al, 2022).

Although the number of emerged parasitoids and mummies (Table 3) was higher in the BB treatment in the second season compared to the WB, there was no difference in the density of aphid nymphs and adults between treatments (Table 2). This may have occurred due to the planting time of the crops. In the 2017 season (autumn/winter), cabbage was transplanted and plant growth was favored since the best development occurs between 7ºC and 22ºC (Makishima, 1993). A milder average temperature (18 ºC) may also favor the production of glucosinolates, which are secondary metabolites produced by brassicas that attract herbivores, mainly aphids (Gols et al., 2009). On the other hand, basil has higher productive performance when planting occurs in early spring, being sensitive to cold (Messias, 2004). Thus, at the beginning of the crop cycle, the presence of basil did not reduce the aphid infestation in cabbage. The highest number of mummified aphids was observed at the end of the cycle when average temperatures were higher and basil was already more developed.

The difference may be related to the functional response of the parasitoid to host density. This was assessed by Sampaio et al. (2001), who found that the greater the density of *M. persicae* in sweet pepper plants (*Capsicum annuum* L.), the greater the rate of parasitism by *A. colemani*. A positive correlation was also demonstrated between the average number of *B. brassicae* on broccoli (*Brassica oleracea* var. itálica) and the percentage of *D. rapae* parasitism in Mexico (Salas-Araiza et al., 2016). However, parasitoid density may present a delay in response to host density (Begon, Townsend &. Harper, 2000) that could have been manifested if the sampling had advanced in time.

Six species of parasitoids were recorded in the BB and five in the WB (Table 3). In the two sampling years, only two species of parasitoids were present in both areas. *D. rapae* with frequencies above 40% in both seasons and a species of hyperparasitoid *Pachyneuron* sp. (Table 3).

Table **3.** Parasitoid species emerged from mummified aphids collected on cabbage (*Brassica oleracea* var. *acephala*), the number of individuals in treatments with (BB) and without (WB) basil border and relative frequency (%) of species, in 2016 and 2017. Viamão, RS.

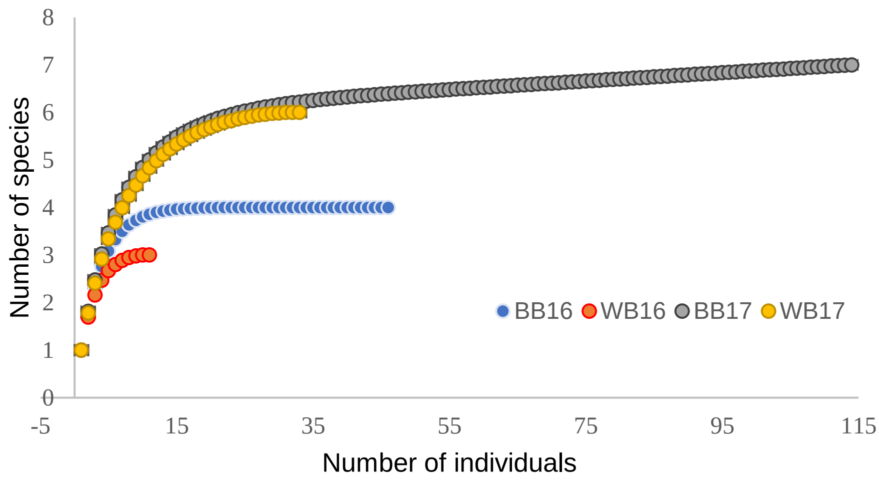
		2016 season				2017 season			
Taxa		BB	WB	Total	FR (%)	BB	WB	Total	FR(%)
Parasitoids	**Family**								
Diaretiella rapae	Braconidae	12	4	16	42.1	32	6	38	55.8
Aphidius colemani	Braconidae	12	2	14	36.8	0	0	0	0
Lipolexis scutellaris	Braconidae	8	0	8	21.1	0	0	0	0
Aphidius platensis	Braconidae	0	0	0	0	15	2	17	25
Binodoxys brevicornis	Braconidae	0	0	0	0	10	2	12	17.7
Total		32	6	38	100	58	10	68	100
Hyperparasitoids									
Pachyneuron sp.	Pteromalidae	14	5	19	100%	25	13	38	48.12
Alloxysta fuscicornis	Figitidae	0	0	0	0	22	5	27	34.1%
Syrphophagus aphidivorus	Encyrtidae	0	0	0	0	9	5	14	17.7%
Total		14	5	19	100%	56	23	79	100%

The greater presence of parasitoids must be related to the attractiveness of basil, both in flowering and in the vegetative period, since the plant has extrafloral nectaries. The extrafloral nectaries of *Vicia faba* L. (Fabaceae) when associated with *B. oleracea* also have a positive effect on the longevity and oviposition rate of the parasitoid *D. rapae* (Jamont et al., 2013). Thus, the presence of botanical species with extrafloral nectaries associated with other crops can be an important way to reinforce biological control by parasitoids.

The rarefaction curve, which allows estimating the species richness of the smallest sample (Magurran, 2011), shows greater differences between the harvests, indicating that, in the second year, the species richness of parasitoids was greater in both areas (Figure 3). On the other hand, in both seasons, the richness was higher in the treatment with the edge.

REVISTA DELOS DESARROLLO LOCAL SOSTENIBLE

Figure 3. Comparative richness rarefaction curves of hymenopteran parasitoids morphospecies collected in organic green cabbage cultivation with (BB) or without basil (WB) border in the 2016 and 2017 seasons. Viamão, RS.

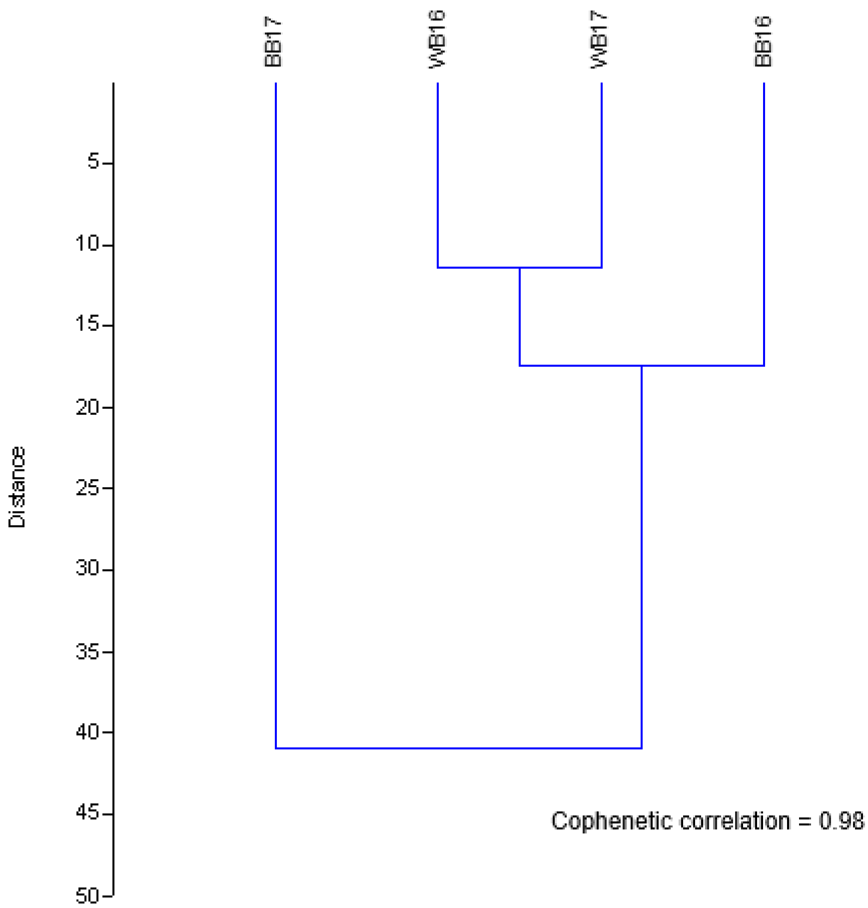


The Euclidean cluster analysis, which uses indices to describe the dissimilarity of the areas (Hammer and Harper, 2001), shows a closer cluster, that is, with little difference between the diversities of the WB areas for the two seasons. The greatest distance occurs in the BB area for the 2017 crop (Figure 4), which is certainly related to the greater number of species of parasitoids present.

In this work, the mummies collected were not identified at a specific level, thus there is no record of the specificity between the parasitoids and their hosts. However, some works report the preference of species for specific aphids, such as Silva (2011) who found a parasitism rate of *D. rapae* of 66.5% on *M. persicae* and 48.2% on *B. brassicae*, both in the cultivation of cabbage. Similarly, in broccoli cultivation, Salas-Araiza et al. (2016) verified a rate of parasitism of *D. rapae* in *B. brassicae* of 35.7%.

Diaretiella rapae is known to parasitize *B. brassicae* in cabbage, broccoli, mustard, and other brassica crops with a relative frequency above 50% (Vaz et al., 2004; Agbogba & Powell, 2007; Jamont et al.; 2013, Neuville et al.; 2016, Navasse et al.; 2017) in the same way as observed in the present work. This parasitoid, however, does not show specificity for *B. brassicae*, as Lara et al. (1999) found it on *M. persicae* in potato crops in Jaboticabal (SP) and Resende et al. (2006), recorded the species parasitizing the aphid, *Lipaphis pseudobrassicae* (Davis) in organic cabbage intercropped with showy rattlepod (*Crotalaria spectabilis* Roth*)*. The frequency of *D. rapae* in this study corroborates Silva's statement (2011), that this parasitoid has the potential to be used in biological control programs for aphids, mainly in brassica cultivation areas.

Figure 4. Cluster analysis of dissimilarity (Euclidean cluster analysis). Relation between abundance distribution in each species, season, and treatment. Cophenetic correlation = 0.98.
With (BB) or without basil (WB) border in the 2016 and 2017 seasons. Viamão, RS.



There was a record of three hyperparasitoids in both treatments. The emergence of hyperparasitoids in our study confirms the presence of the "Top-Down" system (Leroux & Loreau, 2015), occurring in the agricultural environment. In this case, a high relative frequency of hyperparasitoids may cause an imbalance in the next generation of parasitoids, reducing these populations, and thus reducing the natural biological control (Ferreira et al., 2009). On the other hand, greater complexity of interactions in the agroecosystem indicates greater functional diversity, which can enhance ecological processes (Gliessman, 2001). The presence of hyperparasitoids in an agricultural area implies the existence of a fourth trophic level in the food chain, resulting in greater complexity of ecological niches (Sulivan & Volk, 1999). According to Bueno & Sampaio (2009), the occurrence of hyperparasitism in agricultural areas not disturbed with chemical pesticides is common and can reach rates of up to 80% in relation to the number of parasitized aphids.

The three species of hyperparasitoids found in this work had already been recorded by Vaz et al. (2004) in cabbage grown without intercropping. The hyperparasitoid species *A. fuscicornis* occurred only in the winter season and may be related to milder temperatures, or because there was a greater density and diversity of parasitoids in 2017. This species is considered more almost specific for the parasitoid *D. rapae*, causing a great reduction of its population (Cividanes, 2002).

The higher population density of the fourth trophic level found in the present work in the 2017 season may be associated not only with the parasitoids present but also with the aphids. This is because, the more herbivores available, the greater the population growth of parasitoids, consequently the higher the growth rate of hyperparasitoids (Ferreira et al., 2009).

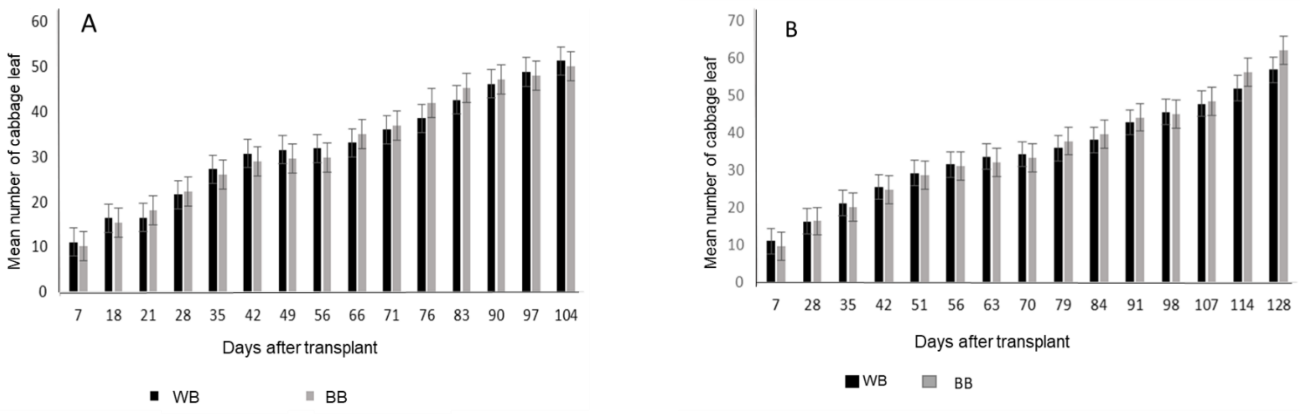
3.3 CABBAGE DEVELOPMENT WITH OR WITHOUT INTERCROPPING

No significant difference was observed in plant development based on the increase in the average number of cabbage leaves between treatments with and without basil borders over the 15 weeks of sampling, both in the 2016 harvest ($F = 0.3769$; $gl = 1$; $p > 0.005$) (Figure 5 a) and in 2017 ($F = 0.0932$; $gl = 1$; $p > 0.005$) (Figure.5 b).

The bed with the intercrop between cabbage and basil showed an index of area equivalence IAE 2016 = 1.07 and IAE 2017 = 0.99. These results show that the cabbage leaf increment was not affected by intercropping with basil, keeping the index close to 1.0. This index expresses the balance of growth in the two crops, with no nutritional or production disadvantage for either of them (Willey, 1979), indicating efficiency in land use. The evaluation of basil intercropped with lettuce has already been carried out and no negative interference of the aromatic plant was observed in the development of the main crop (Vieira et al., 2012; Pereira et al., 2015).

There is an increase in productivity per unit area, diversifying food production (Cecílio Filho & May, 2002), especially when it comes to family farming. This aspect of diversification was also observed in our work, since basil can also be sold (personal information from producer Mr. Nei D'avila), adding value to horticultural production.

Figure 5. The average number of leaves of *Brassica oleracea* v. acephala in days after transplanting (DAT) (A) in the first season (08/22/2016 to 11/28/2016) and (B) in the second season (05/24/2017 to 09/22/2017) in the beds with basil borders (BB) and without border (WB), in Viamão, RS.



In works that intercropped brassicas with a second crop, the highest agronomic indices were always absent from the intercropped treatments. In an intercropping of cabbage with coriander, the IAE was equal to 1.92, which means that the area occupied by the monoculture would need to be 92% larger than the area of the consortium to match the production obtained (Resende et al., 2011). In the present study, the IEA for the 2016 season was 8% more effective than that for the 2017 season. In this context, it is again observed that this plant responds differently to environmental conditions. Oliveira et al. (2005) discussed results like these, showing that the introduction of cultures of different cycles in the same area can increase the productive efficiency of the intercropping agroecosystem.

4 CONCLUSIONS

There was a difference in the effects of bordering for biological control purposes in each of the harvests. Thus, the border of basil grown under optimal conditions of development (ideal temperature) can help reduce the infestation of various insects in Brassicaceae, proving to be a plant suitable for use in intercropping for purposes of conservative biological control. The consortium used in this study proved to be efficient in terms of production, in addition to vegetation diversification factors to attract natural enemies and reduce pests.

REFERENCES

Afrin, S., Latif, A., Banu, N.M.A., Kabir, M.M.M., Haque, S.S., Emam Ahmed, M.M., Tonu, N.N. & Ali, M.P. (2017) Intercropping empower reduces insect pests and increases biodiversity in agro-ecosystem. *Agricultural Sciences*, 8, 1120-1134. DOI: https://doi.org/10.4236/as.2017.810082

Agbogba, B. C. & Powell, W. (2007) Effect of the presence of a nonhost herbivore on the response of the aphid parasitoid *Diaeretiella rapae* to host-infested cabbage plants. *Journal of Chemical Ecology*, 33 (12), 2229-2235.

Ahmad, M. & Aslam, M. (2005) Resistance of cabbage aphid, *Brevicoryne brassicae* (Linnaeus) to endosulfan, organophosphates, and synthetic pyrethroids. *Pakistan Journal of Zoology*, 37, 293-295.

Altieri, M., Silva, E.N. & Nicholls, C.I. (2003) *O papel da biodiversidade no manejo de pragas***.** Holos, 226p.

Barbosa, P. (1998) *Conservation Biological Control*. San Diego: Academic Press, 396p.

Barbosa, F.S., Aguiar-Menezes, E. L., Arruda, L. N., Santos, C. L. R. & Pereira, M. B. (2011) Potencial das flores na otimização do controle biológico de pragas para uma agricultura sustentável**.** *Revista Brasileira de Agroecologia***,** 6 (2), 101-110.

Begon, M.; Townsend, C.R. & Harper, J.L. (2007) *Ecologia de indivíduos e ecossistemas***.** 4. ed. Porto Alegre: Artmed, 740 p.

BRASIL (2003) Lei nº 10.831, de 23 de dezembro de 2003. Dispõe sobre a agricultura orgânica e dá outras providências. Diário Oficial da União Brasília, DF. p. 8, 24 dez. 2003. Disponível em: https://www.planalto.gov.br/ccivil_03/leis/2003/l10.831.htm. Acesso em: 08/12/2022.

Brito, E. A. S.; Togni, P. H. B. & Venzon, M. (2021) Aromatic plants and chili pepper intercropping as a pest management strategy. *Revista Verde de Agroecologia e Desenvolvimento Sustentável*, 16 (4), 345–350. doi: 10.18378/rvads.v16i4.8439. Disponível em: https://www.gvaa.com.br/revista/index.php/RVADS/article/view/8439. Accesso em: 14 feb. 2023.

Bueno, V. H. P.& Sampaio, M. V. (2009) *Desenvolvimento e multiplicação de parasitoides de pulgões*. In: Bueno, V. H. P. (Org.). Controle biológico de pragas: produção massal e controle de qualidade. 2 ed. Lavras: Editora UFLA, 117-168.

Bugg, R. L, Colfer, R. G, Chaney, W. E, Smith, H. A, & Cannon, J. (2008) Flower Flies (Syrphidae) and Other Biological Control Agents for Aphids in Vegetable Crops. http://dx.doi.org/10.3733/ucanr.8285

Cecílio Filho, A.B. & May, A. (2002) Produtividade das culturas de alface e rabanete em função da época de estabelecimento do consórcio**.** *Horticultura Brasileira*, 20 (3), 501-504.

Cividanes, F.J. (2002) Impacto de inimigos naturais e de fatores meteorológicos sobre uma população de *Brevicoryne brassicae* (L.) (Hemiptera: Aphididae) em couve. *Neotropical Entomology*, 31(2), 249-255.

Costa-Filho, L.O., Encarnação, C.R.F.& Oliveira, A.F.M. (2006) Influência hídrica e térmica no crescimento e desenvolvimento de *Ocimum gratissimum L*. *Revista Brasileira de Plantas Medicinais*, 8 (1), 8-13.

Da Silva, V. F., Dos Santos, A. S., Paterno, L. C., Tomazella, V. B.& Ferraz, R. M. (2022) Push-pull cropping system reduces pests and promotes the abundance and richness of natural enemies in brassica vegetable crops. *Biological Control*, 166, 104832.
Fang, Y., Shu L., Qingxuan X., Jie W., Yajie Y., Yingying M., Zhenyu J., Desneux, N. & Wang, S. (2022) Optimizing the Use of Basil as a Functional Plant for the Biological Control of Aphids by *Chrysopa Pallens* (Neuroptera: Chrysopidae) in Greenhouses. *Insects*, 13 (6), 552.

Ferreira, S. E., Arantes, S. O., Bortoletto, D., Oliveira, R. S., Hubaide, J. E. A. & Sampaio, M. V. (2009) Espécies e flutuação populacional de hiperparasitóides (Hymenoptera: Figitidae) de pulgões. In: IX Encontro Interno e XIII Seminário de Iniciação Científica, 2009, Uberlândia-MG. IX Encontro Interno e XIII Seminário de Iniciação Científica.

Ferreira, S. D., Echer, M. M., Bulegon, L. G., Pastório, M. A., Egewarth, V. A., Yassue, R. M., & Achre, D. (2015) Influência da adubação nitrogenada na produção do manjericão Toscano folha de alface (*Ocimum basilicum* L.) em duas épocas, para fins medicinais. *Revista Cubana de Plantas Medicinales*, 20(4) 389-396.

Filgueira, F.A.R. (2012) *Novo manual e olericultura: agrotecnologia moderna na produção e comercialização de hortaliças*. Viçosa: UFV, 402p.

Gliessman, S. R. (2001) *Agroecologia: processos ecológicos em agricultura sustentável*. Porto Alegre: Ed. UFRGS, 653p.

Gols, R., van Dam, N. M., Raaijmakers, C. E., Dicke, M. & Harvey, J. E. (2009) Are population differences in plant quality reflected in the preference and performance of two endoparasitoid wasps? *Oikos*, 118, (5), 733-743.

Hammer, O., Harper, D.A.T. & Ryan, P.D. (2001) PAST: paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, vol. 4, no. 1, pp. 1-9.

Hubaide, J.E.A. (2011) *Distribuição na planta, fatores climáticos e parasitismo na dinâmica populacional dos pulgões (Hemiptera: Aphididae) em Couve*. Dissertação: Pós-graduação em Agronomia/ Fitotecnia, Universidade Federal de Uberlândia

IRGA (2022) Serviços, previsão do tempo, médias climatológicas. https://irga.rs.gov.br/medias-climatologicas . Acesso em outubro de 2022.

Jahnke S. M. & Da Silva, G. S. (2021) Challenges in the applied use of parasitoids to control agricultural pests. Awasthi LP. Recent Advances; CRC Press, Biopesticides in Organic Farming, pp 261–266.

Jamont, M., Crépellière,S. & Jaloux, B. (2013) Effect of extrafloral nectar provisioning on the performance of the adult parasitoid *Diaeretiella rapae*. *Biological Control*, 65 (2), 271-277.

Joshi,S., Rabindra, R. J. & Ranjendran, T.P. (2010) Biological control of aphids. Journal of Biological Control, 24 (3): 185-202, 2010.

Kakaraparthi, P.S., Satya Srinivas, K.V.N, Kotesh Kumar, J. Niranjana Kumar, A. & Kumar, A. (2015) Composition of herb and seed oil and antimicrobial activity of the essential oil of two varieties of *Ocimum basilicum* harvested at short time intervals. *Journal of Plant Development*, 22, 59-76.

Karungi, J., Adipala, E., Ogenga-Latigo, M. W., Kyamanywa, S.& Oyoboe N. (2000) Pest management in cowpea. Influence of planting time and plant density on cowpea field pests infestation in eastern Uganda. *Crop Protection*, 19, 231-236.

Kianmatee S. & Ranamukhaarachchi S. L. (2007) Pest repellent plants for management of insect pests of chinese green cabbage, *Brassica oleracea* L. International *Journal of Agricultural and Biology*, 9 (1), 64– 67.

Mačukanović-Jocić, M.P., Dragana, R. & Dajic Stevanovic, Z. (2007) Floral nectaries of basil (*Ocimum basilicum*): Morphology, anatomy and possible mode of secretion. *South African Journal of Botany*. 73. 636-641. doi: 10.1016/j.sajb.2007.06.008.

Leroux, S. J. & Loreau, M. (2012) Dynamics of reciprocal pulsed subsidies in local and meta-ecosystems. *Ecosystems*, 15, 48–59.

Magurran A. E. (2011) Medindo a diversidade biológica. Editora UFPR. 261p.

Makishima, N. (1993) O cultivo de hortaliças, - Brasnia :EMBRAPA-CNPH : EMBRAPA-SPI, Coleção Plantar; 4116p.

Messias, U. (2004) Resposta pós-colheita à injúria por frio de três cultivares de manjericão (*Ocimum basilicum* L.). 36f. Dissertação (Mestrado em Fitotecnia) - Universidade Federal de Viçosa. Viçosa, MG.

Navasse, Y., Derocles, S.A.P., Plantegenest, M. & Le Ralec, A. (2018) Ecological specialization in *Diaeretiella rapae* (Hymenoptera: Braconidae: Aphidiinae) on aphid species from wild and cultivated plants. *Bulletin of Entomological Research*, 108 (2), 175 - 184. doi: https://doi.org/10.1017/S0007485317000657

Neuville, S., Le Ralec, A., Outreman, Y. & Jaloux, B. (2016) The delay in the arrival of the parasitoid *Diaeretiella rapae* influences the efficiency of cabbage aphid biological control. *Biological Control*, 61 (2), 115-126.

O'Leary, N. (2017) Taxonomic revision of *Ocimum* (Lamiaceae) in Argentina. *The Journal of the Torrey Botanical Society*, 144(1), 74-87.

Oliveira, F.L., Ribas, R.G.T., Junqueira, R.M., Padovan, M.P., Guerra, J.G.M., Almeida, D.L.& Ribeiro, R.L.D. (2005) Desempenho do consórcio entre repolho e rabanete com pré-cultivo de crotalária, sob manejo orgânico. *Horticultura Brasileira*, 23 (2), 184-188.

Pereira, A.L. C. Taques, T.C., Valim, J.O.S., Madureira, A. P. & Campos, W.G. (2015) The management of bee communities by intercropping with flowering basil (*Ocimum basilicum*) enhances pollination and yield of bell pepper (*Capsicum annuum*). *Journal of Insect Conservation*, 19 (3), 479-486.

Ramos, T. De O. *Couve consorciada com sorgo e feijão-guandu na ocorrência de pulgões e insetos predadores*. 58 p. Tese (doutorado) - Universidade Estadual Paulista Júlio de Mesquita Filho, Faculdade de Ciências Agrárias e Veterinárias de Jaboticabal, 2015. Disponível em: http://hdl.handle.net/11449/135960 Acesso em: 25/02/2018.

Resende, a. L. S. Silva, E. E.; Silva, V. B.; Ribeiro, R. L. D; Guerra, J. G. M & Aguiar-Menezes, E. L. (2006) Primeiro registro de *Lipaphis pseudobrassicae* Davis (Hemiptera: Aphididae) e sua associação com insetos predadores, parasitoides e formigas em couve (Cruciferae) no Brasil. *Neotropical Entomology*, 35 (4), 551-555.

Resende, A. L. S. Lixa, A. T., Santos, C. M. A. dos, Souza, S. A. da S., Guerra, J. G. M., & Aguiar-Menezes, E. de L. (2011) Comunidade de joaninhas (Coleoptera: Coccinellidae) em consórcio de couve (*Brassica oleraceae* var. *acephala*) com coentro (Coriandrum sativum) sob manejo orgânico. *Revista Brasileira de Agroecologia*, 6 (1), 81-89.

Riquelme, A.H. (2007) Control ecológico de las plagas de la huerta. Buenos Aires: INTA, 93p.

Sampaio, M. V., Bueno, V. H. P. & Maluf, R. P. (2001) Parasitism of *Aphidius colemani* Viereck (Hymenoptera: Aphidiidae) in different densities of *Myzus persicae* (Sulzer)(Hemiptera: Aphididae). *Neotropical Entomology*, 30 (1), 81-87.

Salas-Araiza, M. D. González-Márquez, M. A. & Martínez-Jaime, O. A. (2016) Relación del número de individuos de *Brevicoryne brassicae* con la temperatura y con su parasitoide *Diaretiella rapae* en brócoli en el Bajío, México. *Revista Mexicana de Ciências Agrícolas*, 7 (2), 463-69. doi: https://doi.org/10.29312/remexca.v7i2.358

Satar, S., Kersting, U. & Ulusoy, M. R. (2005) Temperature-dependent life history traits of *Brevicoryne brassicae* (L.) (Homoptera: Aphididae) on white cabbage. *Turkish Journal Agriculture and Forestry*, Ankara, v. 29, p.341- 346.

Silva, R. J. (2011) *Efeito da temperatura e de hospedeiros no desenvolvimento de Diaeretiella rapae (McIntosh) (Hymenoptera: Braconidae, Aphidiinae).* 82 f. Tese (doutorado) - Universidade Estadual Paulista, Faculdade de Ciências Agrárias e Veterinárias. Disponível em: http://hdl.handle.net/11449/102310 Acesso em: 22/02/2018.

Sousa-Silva, C.R. & Ilharco F.A. (1995) *Afídeos do Brasil e suas plantas hospedeiras (lista preliminar)*. São Carlos, EDUFSCar, 85p.

Sturza, V., Poncio, S., Santos, A. B. dos & Lopes-Da-Silva, M. (2012) Infestation and natural parasitism of aphids in single and mixed pastures of black oats and ryegrass. *Revista Brasileira de Entomologia,* 56 (3), 363-367.

Sullivan DJ, Volkl W. (1999) Hyperparasitism: multitrophic ecology and behavior. *Annual Review of Entomology,* 44, 291–315. doi: 10.1146/annurev.ento.44.1.291

Vaz, L.A.L., Tavares, M. T. & Lomônaco, C. (2004) Diversidade e tamanho de himenópteros parasitoides de *Brevicoryne brassicae* L. e *Aphis nerii* Boyer de Fonscolombe (Hemiptera: Aphididae). *Neotropical Entomology***,** 33 (2), 225-230.

Vieira, M.C., Carlesso, A., Heredia Zárate, N. A., Gonçalves, W. L. F., Tabaldi, L. A. & Melgarejo, E. (2012) Consórcio de manjericão (*Ocimum basilicum* L.) e alface sob dois arranjos de plantas. *Revista Brasileira de Plantas Medicinais*, 14 (3), 169-174.

Wackers, F.L. & Van Rijn, P.C.J. (2007) Nectar and pollen feeding by insect herbivores and implications for multitrophic interactions. *Annual Review Entomology*, 52, 301-323.

Wellings, P.W. & Dixon, A. F. G. (1987) *The role of weather and natural enemies in determining aphid outbreaks.* In: Barbosa, P. Insect outbreaks. San Diego, Academic Press, 578p.

Willey, R.W. (1979) Intercropping its importance and research needs. I. Competition and yield advantages. *Field Crop Abstracts*, 32, 1-10.

Yarou, B. B., Assogba, K. F., Tossou, E., Mensah, A., Simon, S., Verhaegen, D. & Francis, F. (2017) Efficacy of basil-cabbage intercropping to control insect pests in Benin, West Africa. *Communications in Agricultural and Applied Biological Sciences*, 82 (2), 157-166.