

## MARIGOLD (*Tagetes erecta* L.) AS AN ATTRACTIVE CROP TO NATURAL ENEMIES IN ONION FIELDS

Luís Cláudio Paterno Silveira<sup>1</sup>; Evoneo Berti Filho<sup>2\*</sup>; Leonardo Santa Rosa Pierre<sup>2</sup>; Fernanda Salles Cunha Peres<sup>3</sup>; Julio Neil Cassa Louzada<sup>4</sup>

<sup>1</sup>UFLA - Depto. de Entomologia, C.P. 37 - 37200-000 - Lavras, MG - Brasil.

<sup>2</sup>USP/ESALQ - Depto. de Entomologia e Acarologia, C.P. 09 - 13418-900 - Piracicaba, SP - Brasil.

<sup>3</sup>UNESP/FCAV - Depto. de Fitossanidade - 14884-900 - Jaboticabal, SP - Brasil.

<sup>4</sup>UFLA - Depto. de Biologia.

\*Corresponding author <eberti@esalq.usp.br>

**ABSTRACT:** Onion is the third most grown vegetable crop in São Paulo state, Brazil. Organic onion farming is expected to increase in the state due to the increasing demand. Pest management in organic onion farming is based on plant extracts with insecticide effects. However, the efficacy of such plant extracts has not been proved yet, and it was observed that they do negatively affect natural enemies. Plants surrounding onion fields, and that are attractive to natural enemies, may be a good option to farmers, since they may lead to increased diversity of arthropod species and, consequently, the natural control of pest populations. This study deals with the effect of marigold plants as a resource plant to natural enemies in onion fields. The experiment was set in a certified organic farm using marigold rows at a center of an onion field. Samples were taken from marigold and the onion plants 5 m (near) and 30 m (far) from the flowering strips. Higher numbers of arthropod pests were observed in onion plants 30 m from the marigold strip, while higher numbers of predators and parasitoids were found at 5 m distance. Species richness and Shannon's diversity index were higher at 5 m from marigold. Therefore, marigold rows next to onion fields resulted in higher number of entomophagous species, potentially enhancing the natural control of onion pests. In the study field, marigold strips may be an alternative to crop sprays for organic control of onion pests.

Key words: natural control, conservation, predator, parasitoid

## CRAVO-DE-DEFUNTO (*Tagetes erecta* L.) COMO CULTURA ATRATIVA PARA INIMIGOS NATURAIS EM CULTIVO DE CEBOLA

**RESUMO:** A cebola é a terceira hortaliça mais cultivada em São Paulo, cujo cultivo orgânico tende a crescer devido ao grande mercado consumidor existente. O manejo das pragas na cebolicultura orgânica baseia-se nos extratos de plantas inseticidas que, além de terem eficiência não comprovada, podem afetar negativamente os inimigos naturais. A utilização de plantas atrativas a inimigos naturais no entorno dos cultivos de cebola pode ser uma boa opção para os produtores, pois potencialmente aumentam a diversidade da artropodofauna e podem regular naturalmente as populações de espécies pragas. Verificou-se o efeito de linhas de cravo-de-defunto (*Tagetes erecta* L.) como cultura atrativa a inimigos naturais em campos de cebola. O experimento foi realizado em propriedade orgânica certificada, instalando-se linhas de cravo-de-defunto nas bordaduras de dois campos de cebola. Os tratamentos foram definidos coletando-se amostras nas plantas de cebola próximas às linhas da atrativa (5m) e distante das linhas (30 m). De maneira geral, observou-se maior quantidade de artrópodes fitófagos nas plantas de cebola longe da faixa atrativa e, inversamente, maior quantidade de inimigos naturais próximos à faixa. A riqueza de espécies também foi maior nas coletas próximas, o mesmo valendo para o índice de diversidade de Shannon. Portanto, a manutenção de linhas de cravo-de-defunto próximas ao cultivo de cebola promoveu maior riqueza e diversidade de artrópodes, bem como maior número de entomófagos, resultando em menor presença de fitófagos nas plantas, auxiliando na regulação natural das pragas da cultura.

Palavras-chave: controle natural, conservação, predador, parasitóide

### INTRODUCTION

Onion (*Allium cepa* L.) is the third most grown vegetable crop and the sixteenth most important or-

ganic vegetable crop in São Paulo state, occupying an area of 10,000 hectares (Camargo et al., 2006). It is largely used for food and medicinal purposes and chemical free bulbs therefore have greater value

(Alonso, 1998). Because of the high market value of these products, the Brazilian growers are increasing the area of onion crops (Martins et al., 2006).

Among the insect pests causing yield losses in onion production in Brazil, the onion thrips, *Thrips tabaci* Lind. (Thysanoptera: Thripidae) is responsible for 45% of onion yield losses in the country (Boiça Júnior & Domingues, 1987; Sato, 1989; Gonçalves, 1996). One of the main recommendations for organic farming is the recovery of functional biodiversity, which is lost or very reduced in conventionally grown monocultures. Through polycultivation, maintenance of volunteer plant species and use of attractive plants the diversity of beneficial insects can be recovered in agroecosystems (Gliessman, 2001; Altieri et al., 2003). This diversity may lead to increased pest control in onion, reducing the use of plant extracts that have been shown to be detrimental to natural enemy populations.

A plant that is potentially useful to maintain arthropod biodiversity, including certain species of predator thrips, is the marigold (*Tagetes erecta* L.). According to Sampaio et al. (2008) this plant hostages species of *Orius* (Hemiptera: Anthocoridae), which is the main thrips predator around the world, including Brazil (Silveira et al., 2003a,b, 2004). Additionally, marigold plants in-between rows of onion crop have been shown to promote the reduction of aphid, nematode and whitefly populations and virus diseased plants (Martowo & Rohama, 1987; Abid & Magbool, 1990; Zavaleta-Mejia & Gomes, 1995). Moreover marigold plants host other phytophagous species that are alternative prey for entomophagous species. Some organic growers seed marigold for its pollen and nectar, which increase natural enemy fecundity and survival (Baggen, 1999). Therefore it is important to know the richness, abundance and diversity of arthropod species found in this plant, and on the surroundings of a strip, for example, once it may lead to important differences in species composition of a culture crop near or far from the marigold strips.

The use of this plant may contribute to management of onion pests, mainly the thrips, because the increase of the number of predators would promote lowering costs in pest control, thus, turning the organic onion crop more sustainable. Moreover, this study contributes to the identification of insect species occurring on both plants, providing basic information for further researches.

The aim of this study was to determine the effect of marigold plants near or far from organic onion cultivation for maintenance of natural enemies, and study the arthropod composition and its abundance on onion and marigold fields.

## MATERIAL AND METHODS

The experiment was set in an organic onion field of 5,000 square meters, in a certified organic farm (certified by 'Mokiti Okada Foundation', FMO), in Fernando Prestes, state of São Paulo, Brazil (21°14'0.29"S; 48°40'15.61"W), from August to October 2004. Seedlings, compost and biofertilizer were produced at the farm, and an irrigation system was used. Marigold seed was obtained directly from field collection on the organic farm selected and because the grower has cultivated it for years, there is no way to determine the cultivar.

The onion field has 50  $\Delta$  100 m and was divided in two similar areas by a 4 m wide path. Along the borders of this path, on both sides, there was a 50 m long and 0.5 m wide row of marigold plants. Such arrangement allowed the collection of onion samples at varying distances from marigold plants. We sampled onion plants at 5 m (near) 30 m (far) and in the marigold plant strip. Sampling began two weeks after transplanting when seedlings were 30 day-old, and continued for the following seven weeks. Ten random samples on onion according to each distance were taken weekly for seven weeks (n = 140), each sample corresponding to 1 m<sup>2</sup> of the onion field.

Onion plants were shaken against a white plastic tray to dislodge arthropods, which were immediately transferred to plastic containers and kept in 60% ethanol for later identification. Arthropods were identified to the lowest possible level and grouped as phytophagous or entomophagous. We performed an ANOVA with the average calculated over seven weeks of sampling, showing patterns of weekly abundance but performed statistical analysis for the whole period of the experiment. We used the software Statistica<sup>®</sup> for the analysis and SigmaPlot<sup>®</sup> for graphics.

The marigold strips were also sampled during the period of onion cultivation, and each sample corresponding to one square meter of crop coverage, using the same methodology as for onion plants. These marigold samples were taken randomly and at three developmental stages during the experiment: a) onset flowering, when up to 10% of plants were flowering (25 August and 7 September), plants were in full vegetative growth with few flowers (N = 8); b) peak flowering stage (N = 8), when more than 80% of the plants were flowering (8 and 15 September); c) late flowering, when flowers were senescent and losing their attractiveness (29 September and 6 October), and the number of plants were lower, since they were dying (N = 6).

The following ecological parameters were determined for onion and marigold using the software

Biodiversity Pro<sup>®</sup> (McAleece, 1997): (i) Richness of species (the total number of species and morph species collected); abundance index (Lambshhead et al., 1983), calculated from the mean of the entire 7-week sampling season of each species; (ii) Diversity index  $H'$  (Shannon & Weaver, 1949), which considers the quantitative uniformity of each species in relation to the others; (iii) Similarity index, calculated through cluster analysis (Pielou, 1984), which indicates how similar two substrates can be in relation to the species found. In this case the data were separated in two groups, phytophagous or entomophagous, and the whole sampling periods were considered for each substrate; and (iv) Correlation index ( $R^2$ ) (Sokal & Rohlf, 1969), which shows the dependence between two groups of data obtained from different plants.

Besides these indices, collection curves were calculated for onion samples (Magurran, 1988). These curves may indicate whether sampling was regular and enough to potentially collect all species that may be present in the crop (for the whole experimental period, independently of the sampling week).

For the determination of these parameters, arthropods presenting very low occurrence (one or two individuals) during the entire sampling period were not included in analysis.

## RESULTS AND DISCUSSION

First of all, the calculated collection curve indicated that the 140 samples taken from onion crop were enough to collect the majority of species present in the crop during the experiment. After the sampling 134 the collection curve reaches the asymptotic position, indicating that no new species were collected from this point on.

Data from onion samples were taken at 5 m and 30 m from the marigold strip (Figure 1). Arthropods were grouped in two main ecological groups: phytophagous and entomophagous, considering all specimens found on samples, regardless of their higher or lower abundance. There was a higher number of phytophagous arthropods  $m^{-2}$  in onion plants far from marigold (30 m). Despite the higher variation, the number of entomophagous arthropods  $m^{-2}$  may explain this result, as the number of natural enemies was lower in plants localized far from marigold row, therefore resulting in higher amounts of herbivores. In this field there is a positive effect of marigold rows on natural enemy abundance and negative effect on pest insect abundance. Similar results were reported by Driutti (1998) using several plant species in surrounding rows and within organic onion fields, who found that the number of phytophagous insects, especially thrips, which

account for more than 86% of the herbivores, was significantly lower near the attractive plants.

Another possible explanation for this result is that marigold plants could produce repellent volatiles to thrips, including *T. tabaci*. So, there would be less thrips near marigold strips because of its repellence, not by natural enemy predation. As stated by Visser (1986), phytophagous insects respond to a complex mixture of plant odors to recognize their hosts. Four plant essential oils to repel *T. tabaci* were tested by Tol et al. (2007), who conclude that *Origanum majorana* L. (Labiatae) is a promising thrips repellent which could be used for further testing in a push-pull system. Similar tests should be performed to identify this possibility in relation to *T. erecta*.

The analysis of ecological indices on grouped data from onion (5 m and 30 m from the marigold strip,  $N = 70$  for each) and marigold rows ( $N = 8$  for onset flowering stage and peak flowering stage and  $N = 6$  for late flowering stage) (Table 1) showed higher richness in samples near the marigold strip, with 37 taxa or morphospecies, and 24 species in samples far from the marigold strip. The diversity index ( $H'$ ) was higher at 5 m from the marigold strip, indicating that dominance of species is slightly lower than at 30 m from the marigold strip. This is due to a higher number of *T. tabaci* individuals observed at 30 m than at 5 m from marigold.

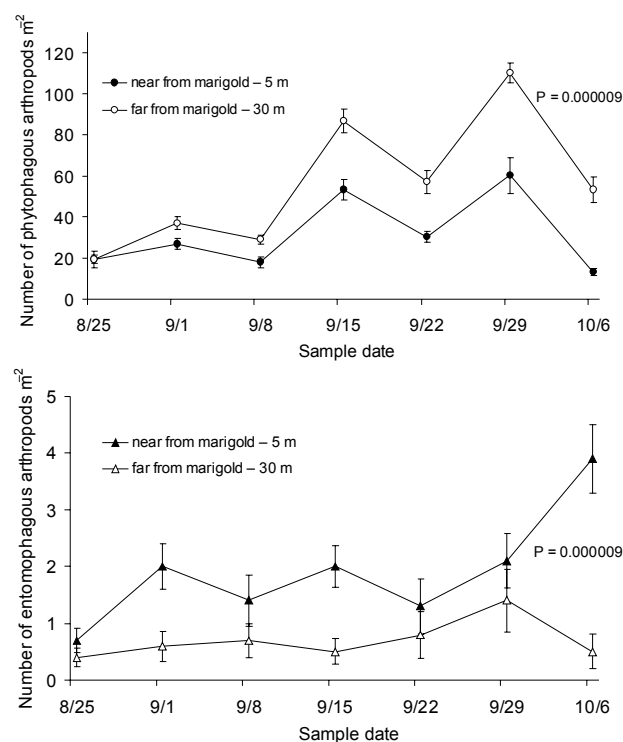


Figure 1 - Number of phytophagous and entomophagous arthropods  $m^{-2}$  in an onion organic field with marigold rows at distances of 5 m (near) and 30 m (far).

Table 1 - Average number of arthropods in each taxon collected/m<sup>2</sup> sample, Richness, Abundance and Diversity (H') in onion or marigold plants under organic farming.

Species/morphospecies - ecological niche	Means/Sample <sup>1</sup>				
	onion		marigold flowering stage		
	Near (5 m)	Far (30 m)	onset	peak	late
<b>PHYTOPHAGOUS</b>					
<i>Thrips tabaci</i> (Thysanoptera: Thripidae)	22.54	35.29	0.13	-	-
<i>Therioaphis trifolii</i> (Hemiptera: Aphidae)	2.94	3.36	3.13	-	-
Lathridiidae sp. (Insecta: Coleoptera)	0.80	0.19	0.13	0.88	
<i>Aphis fabae</i> (Hemiptera: Aphidae)	0.33	1.11	11.63	4.75	1.17
<i>Frankliniella schultzei</i> (Thysanoptera: Thripidae)	0.27	1.04	0.13	0.25	3.67
<i>Haplothrips gowdeyii</i> (Thysanoptera: Thripidae)	0.27	0.11	-	0.13	0.67
<i>Caliothrips phaseoli</i> (Thysanoptera: Thripidae)	0.07	-	-	0.38	0.50
<i>Neohydatotrips</i> sp. (Thysanoptera: Thripidae)	0.07	-	0.25	0.63	-
<i>Uroleucon ambrosiae</i> (Hemiptera: Aphidae)	0.04	-	0.25	-	-
<i>Pseudodendrothrips</i> sp. (Thysanoptera: Thripidae)	0.04	0.04	0.13	-	-
<i>Lagria villosa</i> (Coleoptera: Lagriidae)	0.04	0.03	-	0.13	-
<i>Acyrtosiphum kondoi</i> (Hemiptera: Aphidae)	0.04	-	0.25	-	-
<i>Taylorilygus pallidulus</i> (Hemiptera: Miridae)	0.03	0.06	-	0.13	-
<i>Myzus persicae</i> (Hemiptera: Aphidae)	0.03	0.03	0.25	0.13	0.33
<i>Aphis</i> sp. (Hemiptera: Aphidae)	0.01	0.41	-	-	-
<i>Corytucha</i> sp. (Hemiptera: Tingidae)	0.01	-	-	-	0.50
<i>Creontidades rubrinervis</i> (Hemiptera: Miridae)	0.01	0.19	-	-	-
<i>Frankliniella insularis</i> (Thysanoptera: Thripidae)	0.01	-	-	0.25	-
<i>Neopamera bilobata</i> (Hemiptera: Lygaeidae)	0.01	-	0.13	-	-
<i>Arorathrips</i> sp. (Thysanoptera: Thripidae)	-	0.09	-	-	0.17
<i>Macrosiphum euphorbiae</i> (Hemiptera: Aphidae)	-	0.03	0.63	-	
Miridae sp2 (Insecta: Hemiptera)	-	0.01	0.13	0.13	0.17
Psyllidae sp1 (Insecta: Hemiptera)	-	-	0.75	-	-
Psyllidae sp2 (Insecta: Hemiptera)	-	-	-	0.5	0.33
Membracidae sp. (Insecta: Hemiptera)	-	-	0.50	-	-
<i>Lipaphis erysimi</i> (Hemiptera: Aphidae)	-	-	0.50	-	-
<i>Diabrotica speciosa</i> (Coleoptera: Chrysomelidae)	-	-	0.38	0.38	-
<i>Aconophora</i> sp. (Hemiptera: Membracidae)	-	-	0.25	-	-
<i>Cerotoma arcuata</i> (Coleoptera: Chrysomelidae)	-	-	0.13	0.13	-
<i>Liothrips</i> sp1 (Thysanoptera: Phlaeothripidae)	-	-	0.13	-	-
Miridae sp3 (Insecta: Hemiptera)	-	-	0.13	0.13	-
<i>Sonesimia grossa</i> (Hemiptera: Cicadellidae)	-	-	0.13	-	-
<i>Frankliniella gemina</i> (Thysanoptera: Thripidae)	-	-	-	4.38	23.33
<i>Frankliniella rodeos</i> (Thysanoptera: Thripidae)	-	-	-	2.25	2.50
<i>Frankliniella gardeniae</i> (Thysanoptera: Thripidae)	-	-	-	0.25	18.33
<i>Frankliniella</i> sp1 (Thysanoptera: Thripidae)	-	-	-	0.25	
<i>Harmostes</i> sp1 (Hemiptera: Rhopalidae)	-	-	-	0.25	1.33
<i>Acrosternum</i> sp1 (Hemiptera: Pentatomidae)	-	-	-	0.13	-
Miridae sp1 (Insecta: Hemiptera)	-	-	-	0.13	-
<i>Nysius</i> sp. (Hemiptera: Lygaeidae)	-	-	-	-	27.00

Continue...

Table 1 - Continuation.

<i>Frankliniella</i> sp2 (Thysanoptera: Thripidae)	-	-	-	-	10.00
<i>Frankliniella condei</i> (Thysanoptera: Thripidae)	-	-	-	-	5.00
<i>Utheteisa ornatrix</i> (Lepidoptera: Arctiidae)	-	-	-	-	0.83
Bruchidae sp1 (Insecta: Coleoptera)	-	-	-	-	0.50
<i>Paranapiacaba significata</i> (Coleoptera: Chrysomelidae)	-	-	-	-	0.33
Bruchidae sp2 (Insecta: Coleoptera)	-	-	-	-	0.17
Curculionidae sp1 (Insecta: Coleoptera)	-	-	-	-	0.17
Curculionidae sp2 (Insecta: Coleoptera)	-	-	-	-	0.17
Miridae sp4 (Insecta: Hemiptera)	-	-	-	-	0.17
Total phytophagous/sample	27.56	41.99	20.07	16.7	97.34
<b>PREDATORS</b>					
<i>Stomatothrips angustipennis</i> (Thysan.: Aeolothripidae)	0.21	0.1	-	-	-
<i>Stomatothrips rotundus</i> (Thysan.: Aeolothripidae)	0.2	0.14	0.25	-	-
<i>Franklinothrips vespiformis</i> (Thysan.: Aeolothripidae)	0.07	0.04	-	0.13	-
<i>Orius insidiosus</i> (Hemiptera: Anthocoridae)	0.07	-	5.38	4.88	10.83
Thomisidae (Araneae)	0.07	0.03	0.25	0.75	0.17
<i>Nabis</i> sp. (Hemiptera: Nabidae)	0.07	0.01	-	0.25	-
Coccinellidae sp1 (Insecta: Coleoptera)	0.03	-	-	-	-
<i>Hippodamia convergens</i> (Coleoptera: Coccinellidae)	0.03	-	0.13	0.25	-
Coccinellidae sp2 (Insecta: Coleoptera)	0.01	-	0.13	0.25	-
<i>Cycloneda sanguinea</i> (Coleoptera: Coccinellidae)	0.01	0.09	0.13	-	0.50
<i>Geocoris</i> sp. (Hemiptera: Lygaeidae)	0.01	-	0.13	0.13	1.00
<i>Scymnus</i> sp. (Coleoptera: Coccinellidae)	0.01	-	0.25	0.63	2.00
Staphylinidae sp2 (Insecta: Coleoptera)	0.01	-	-	-	0.17
Staphylinidae sp1 (Insecta: Coleoptera)	-	-	0.13	-	-
Reduviidae sp2 (Insecta: Hemiptera)	-	-	0.13	-	-
<i>Lebia</i> sp1 (Coleoptera: Carabidae)	-	-	-	0.25	-
Coccinellidae sp3 (Insecta: Coleoptera)	-	-	-	0.13	-
<i>Doru luteipes</i> (Dermaptera: Forficulidae)	-	-	-	0.13	-
Elateridae sp1 (Insecta: Coleoptera)	-	-	-	0.13	-
Reduviidae sp1 (Insecta: Hemiptera)	-	-	-	0.13	-
<i>Orius perpunctatus</i> (Hemiptera: Anthocoridae)	-	-	-	-	1.17
<i>Misumenops pallidus</i> (Araneae: Thomisidae)	-	-	-	-	0.17
<i>Misumenops pallens</i> (Araneae: Thomisidae)	-	-	-	-	0.17
Total predators/sample	0.8	0.41	6.91	8.04	16.18
<b>PARASITOIDS</b>					
Mymaridae sp2 (Insecta: Hymenoptera)	0.03	-	-	-	-
Figitidae sp2 (Insecta: Hymenoptera)	0.03	-	-	-	0.17
Trichogrammatidae sp2 (Insecta: Hymenoptera)	0.03	-	-	-	-
Mymaridae sp1 (Insecta: Hymenoptera)	0.01	0.01	-	0.25	0.17
Trichogrammatidae sp1 (Insecta: Hymenoptera)	0.01	0.01	-	-	-
Figitidae sp1 (Insecta: Hymenoptera)	-	0.03	-	-	-
<i>Aprostocetus</i> sp. (Hymenoptera: Eulophidae)	-	-	0.25	0.25	-
<i>Opius</i> sp1 (Hymenoptera: Braconidae)	-	-	0.25	-	-
Bethylidae sp (Insecta: Hymenoptera)	-	-	0.13	-	0.17

Continue...



Table 1 - Continuation.

<i>Baryscapus</i> sp1 (Hymenoptera: Eulophidae)	-	-	0.13	-	-
<i>Galeopsomyia</i> sp1 (Hymenoptera: Eulophidae)	-	-	0.13	-	-
<i>Lysiphlebus testaceipes</i> (Hymenoptera: Braconidae)	-	-	0.13	-	-
Mymaridae sp3 (Insecta: Hymenoptera)	-	-	0.13	-	-
Scelionidae sp4 (Insecta: Hymenoptera)	-	-	0.13	0.13	-
Trichogrammatidae sp3 (Insecta: Hymenoptera)	-	-	-	0.25	-
Scelionidae sp1 (Insecta: Hymenoptera)	-	-	-	-	1.17
Figitidae sp3 (Insecta: Hymenoptera)	-	-	-	-	0.67
Scelionidae sp3 (Insecta: Hymenoptera)	-	-	-	-	0.50
Scelionidae sp2 (Insecta: Hymenoptera)	-	-	-	-	0.17
Total parasitoids/sample	0.11	0.05	1.28	0.88	3.02
Richness	37	24	40	40	40
Total/sample	28.47	42.45	28.26	25.62	116.54
H'	0.453	0.325	0.996	1.231	1.069

<sup>1</sup>Means/sample less than 0.03 in onion and marigold samples were disregarded.

In general, there was high similarity for phythophagous (75.98 through cluster analysis, Table 2) and correlation ( $R^2 = 0.9985$ ) between species collected in onions at 5 m and at 30 m from the marigold strip, thus indicating high relation between the amount of each species in different distances. For natural enemies these values are low (51.84% similarity, Table 2, and  $R^2 = 0.9063$ ). In spite of these similarities, the main phythophagous species collected, *T. tabaci*, was 57% more abundant far from marigold than near it. A similar result was found for the second most abundant species, *Therioaphis trifolii* (Hemiptera: Aphidae), which was 15% more abundant far from the marigold strip. The opposite was observed with predators, especially *Stomatothrips angustipennis*, *Stomatothrips rotundus* and *Franklinothrips vespiformis* (Thysanoptera: Aeolothripidae), which were twice as abundant in onion plants near the marigold strip. Parasitoid abundance, in general, was very low in onion plants, but much lower far from the marigold strip (Table 1). Regarding marigold plants (Table 1) we found more richness and abundance of parasitoids compared to onion plants, since those plants produce pollen and nectar that potentially can sustain parasitoid populations (Baggen, 1999).

Very low percentages of similarity were observed between phythophagous and entomophagous on onion compared to marigold (Table 2). For herbivores the values are similar in relation to the distance from marigold, but become lower as the flowering stage advance. That was expected since the main herbivore species, *T. tabaci*, was not observed on marigold at peak and late flowering stage. For natural enemies the similarity was even lower compared to herbivores, but

the distance to marigold strip affect the values, since they were higher if compared onion at 5 m with onion at 30 m from the attractive plants. So these low natural enemies' similarities between marigold and onion indicate that not the same but different species were found on onion near attractive plants. Therefore, the main phythophagous species were more abundant in onion plants 30 m from marigold, while the main predators were more abundant in plants close to the attractive species. However, Gonçalves & Souza-Silva (2003), studying only *T. tabaci* and *Toxomerus* spp. (Diptera: Syrphidae) populations in relation to different plant species in rows surrounding the onion field, observed no population decrease of the pest species. This study, however, only included abundance of thrips nymphs and syrphid larvae, and there may have been differences in the abundance of other phythophagous and predatory species.

Higher herbivore species richness but lower abundance were detected in plots near marigold than in plots far from marigold. Nineteen taxa 5 m from marigold and 15 taxa 30 m from onion plants were found. Phythophagous insect abundance, however, was greater far from than near to marigold strips, 41.99 and 27.57 herbivores / sample, respectively. Both greater abundance and higher species richness of entomophagous species (predators and parasitoids) were found in plots near marigold than in plots far from marigold. Eighteen taxa 5 m from marigold and only ten 30 m from marigold plants were found, as well as nearly twice as many natural enemies near to as far from marigold strips, 0.91 and 0.46 insects / sample, respectively. Hence, we found higher diversity of both phythophagous and entomophagous species on onion plants close to mari-

Table 2 - Cluster analysis (% similarity) for phytophagous and entomophagous among the different treatments for onion and marigold under organic farming.

Phytophagous	Onion 30 m	Marigold - onset	Marigold - peak	Marigold - late
Onion 5 m	75.9827	16.5648	8.4939	1.6795
Onion 30 m	-	15.2823	6.2235	3.6454
Marigold - onset	-	-	34.6388	3.0578
Marigold - peak	-	-	-	17.6041
Entomophagous	Onion 30 m	Marigold - onset	Marigold - peak	Marigold - late
Onion 5 m	51.844	9.6322	7.7457	2.3976
Onion 30 m	-	3.934	2.0913	0.4386
Marigold - onset	-	-	67.4854	46.1857
Marigold - peak	-	-	-	42.5552

gold rows, but increased herbivore abundance and decreased natural enemy abundance on onion plants at greater distances from marigold. For the samples on marigold strips, species dynamics varied depending on the developmental stage, abundance and similarity (Tables 1 and 2), but not for richness: the same number of taxa (40) was collected considering all arthropod categories. While no numerical difference was observed, species composition varied greatly between flowering stages. The analysis of similarity indices between marigold developmental stages (Table 2) indicated that there is greater similarity between the onset and peak flowering periods for phytophagous (34.6%) than between the late flowering and the other stages (3.05 to 17.6%). For the entomophagous the similarities is bigger (Table 2) ranging between 42 and 67.5% depending on the flowering stage. This indicates that a major number of natural enemy species uses the marigold strip during more time than the herbivores do, which is interesting for biological control.

The higher diversity index was observed in marigold during full bloom ( $H'$ , Table 1), when the predator *Orius insidiosus* was most abundant, as well as herbivore *Aphis fabae* Scopoli (Hemiptera: Aphididae). This is in accordance with previous observations. There was a slight dominance of phytophagous species at the beginning and at the end of flowering periods (the aphid *A. fabae* and the Lygaeidae *Nysius* sp., respectively), resulting in lower diversity indices at these stages. The marigold at the onset of flowering was more attractive to sucking phytophagous species, e.g. Hemiptera from the families Aphidae, Psyllidae and Membracidae, which combined represented over 60% of the collected individuals. This was expected because plants were still undergoing vegetative growth, i.e. sprouting and producing flowers, which were attractive to these species. At full flowering period, Aphidae represented only 29% of phytophagous species, when thrips (Thysanoptera) became dominant, with over 52%

of the phytophagous and 34% of the entire arthropod abundance at this stage. This tendency was confirmed at the end of the flowering period, when thrips abundance increased to 55% of the total arthropods. Besides these phytophagous species, the sucking hemipteran *Nysius* sp. became very abundant in marigold flowers at this stage.

This dominance of phytophagous taxa in the beginning and the end of marigold flowering periods, however, did not produce a great impact on the onion field, because insects using marigold as a host plant (e.g. aphids, thrips or other phytophagous bugs) are not the same as those that attack onion plants, especially *T. tabaci*, the primary onion pest (Table 1). This is confirmed by the similarity index between onion and marigold collections (Table 2), which reached 16.56% between onion near marigold and the initial marigold development stage. This is an indication that few phytophagous species were found at both plant species, except for *A. fabae* and *T. trifolii*, which were collected in marigold and onion.

This study was set in a particular situation and therefore the data would probably not fit the expectations of other people working on organic agriculture in other conditions. Thus, further tests could be necessary to clarify the role of marigold plants near the onion crop in other areas. Anyway the data of the association of marigold plants and onion crops will certainly help organic onion growers mainly in reducing the production costs.

We found evidence that marigold strip is supporting alternative prey and hosts, mainly from full blossom to the end of the flowering period, which are key components of conservation biological control. This fact is very important to maintain local populations of generalist predators and parasitoids (Landis et al., 2000). For example, *O. insidiosus* abundance was higher during late flowering, possibly in response to the increase in thrips number at that time. Since the

phytophagous species involved are not potential pests to onion plants, their population maintenance in the system is not likely to have the associated negative impact of increasing crop herbivore.

Therefore, keeping marigold rows close to the onion field results in higher diversity and abundance of natural enemies than when the attractive species is kept far from onion plants. This indicates a beneficial effect of marigold on the onion field, especially on the dynamics of the arthropod species, which varies as onion plants are collected from more distant marigold plants. Additional studies are necessary to determine the least distance between onion crop and the marigold rows and what is the best width of these rows.

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