

## Diversity of the arthropod fauna in organically grown garlic intercropped with fodder radish

Diversidade da artropodofauna em cultivo orgânico de alho consorciado com nabo forrageiro

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**ABSTRACT:** The cultivation of garlic faces several problems, which include pest attack, and the diversification of habitat through intercropping with attractive plants comes up as a method to pest management. The objective of this research was to verify the effect of the association of garlic with fodder radish on richness, abundance and diversity of arthropods under organic production system in Lavras, MG, Brazil. The treatments were composed of garlic in monoculture and garlic in association with fodder radish, in plots of 40 garlic plants, intercropped or not with two lines of fodder radish. Weekly, 25 samples were collected for a period of 10 weeks (n=250). Species accumulation curves, species richness, abundance, and diversity index were determined, and T or Mann-Whitney tests were used for analysis. The 250 samples collected were sufficient to register the majority of species present in garlic. Richness and abundance were higher in diversified garlic whereas diversity was higher in monoculture. Diversified system increased the overall richness of phytophagous species and parasitoids. The abundance of *T. tabaci* decreased, while increased the presence of *A. fabae*, demonstrating that the association was potentially beneficial to the culture. The possible reasons for these results are discussed, and future works should focus in the ecological mechanisms involved in crop diversification of organic garlic.

**KEY WORDS:** Conservation biological control, Parasitoids, Predators, Companion plants.

**RESUMO :** O cultivo de alho enfrenta vários problemas, incluindo o ataque de pragas, e a diversificação do habitat através de consórcio com plantas atrativas surge como um método para manejo. O objetivo desta pesquisa foi verificar o efeito da associação de alho com nabo forrageiro sobre a abundância, riqueza e diversidade de artrópodes em sistema orgânico em Lavras, MG, Brasil. Os tratamentos consistiram de alho em monocultura e em associação com o nabo forrageiro, em parcelas de 40 plantas de alho, intercaladas ou não com fileiras duplas de nabo forrageiro. Semanalmente, 25 amostras foram feitas por um período de 10 semanas (n = 250). As curvas de acumulação de espécies, riqueza, abundância e índice de diversidade foram determinados, e os testes T ou Mann-Whitney utilizados para análise. As 250 amostras foram suficientes para coletar a maioria das espécies que ocorrem em alho. A riqueza e abundância observadas no alho diversificado foram maiores do que em monocultura, mas não a diversidade. O sistema diversificado aumentou a riqueza geral de espécies fitófagas e de parasitóides, mas diminuiu a abundância de *T. tabaci*, enquanto aumentou a do pulgão *A. fabae*, demonstrando que a associação foi potencialmente benéfica para a cultura. As possíveis razões para estes resultados são discutidas, e trabalhos futuros deverão se concentrar nos mecanismos ecológicos envolvidos quando a diversificação em alho orgânico é feita.

**PALAVRAS-CHAVE:** Controle biológico conservativo; Parasitóides; Predadores; Plantas companheiras.

## Introdução

Even occupying relatively small areas, vegetables compose a significant portion of production under organic management in Brazil (ORMOND et al., 2002), which is composed basically by small family producers connected to associations and social movement groups, corresponding to 70% of the Brazilian organic production (TERRAZZAN & VALARINI, 2009).

According to the Normative Instruction No. 0007, of May 17, 1999, the organic cultivation rejects employment of pesticides and any other toxicals or transgenic input, in any of the production, storage and consumption process phases. Therefore, combating pests should be carried out with sustainable, non-pollutant techniques, which represents a challenge for farmers.

The cultivation of garlic (*Allium sativum* L.) in Brazil is virtually conventional, with 86.8 thousand tons being harvested in the 2009 crop. The main producing states are Goiás, Minas Gerais and Rio Grande do Sul, with approximately 70% of national production (CONAB, 2009).

Pest attack is a problem in organic or conventional garlic crops. The following species are considered key pests of garlic culture: Thrips, mainly *Thrips tabaci* Lindeman, 1888 (Thysanoptera: Thripidae); caterpillars as *Helicoverpa zea* (Boddie, 1850) and *Agrotis ipsilon* (Hufnagel, 1767) (Lepidoptera: Noctuidae), and the mealybug *Chrysomphalus ficus* (Ashmead, 1880) (Hemiptera: Sternorrhyncha) (MONTEIRO et al., 2001; GALLO et al., 2002).

Due to the economical damage caused by these insects, the use of safer and more sustainable methods to their manage are encouraged, such as biological control, through the use of natural enemies as the hymenopteran parasitoids, Chrysopidae (Neuroptera), predator thrips of the families Aeolothripidae and Phloeothripidae and the pirate bug, *Orius* sp. Wolff 1811 (Hemiptera: Anthocoridae), main natural

enemies of the phytophagous thrips (HODDLE et al., 2000; SAMPAIO et al., 2008).

The diversification of agricultural landscape is recommended as a strategy to attract and maintain natural enemy populations in agroecosystems, through intercropping or by the maintenance of spontaneous plants and native forest fragments adjacent to the culture (NICHOLLS & ALTIERI, 2007). This diversification provides shelter and/or food for different species of entomophagous arthropods, which become effective in the control of pests population (AGRAWAL et al., 2000).

Fodder radish (*Raphanus sativus* L. var. *oleiferus* Metzg.), a rustic plant used in green manuring and oil extraction, is an option for intercropping organic garlic cultivation. This plant can be used as a natural enemy reservoir, being beneficial in diversified vegetable areas (DRIUTTI, 1999; GONÇALVES & SILVA, 2003; SAMPAIO et al., 2008; BRASIL, 2009).

Therefore, the objective of this research was to verify the association of garlic with fodder radish effect on richness, abundance and diversity of arthropods under organic production system in Lavras, MG, Brazil.

## Material and Methods

The study was developed at Department of Entomology in Lavras Federal University (Lavras, MG), from June to August of 2007. The experimental area had approximately 0.5 ha, maintained under organic cultivation system, fertilized with 250g of Bokashi per experimental plot (beds of 1.2 x 1.0 m). The organic fertilizer Bokashi was obtained through the combination of subsoil (250kg), bran wheat and soy (60kg), bone meal (50kg), phosphate arad (30kg), sulphomag (30kg), molasses (1kg), liquid solution of effective microorganisms (1L of EM-4® from Mokiti Okada Foundation) and enough water to produce a 50% RU moisture in the end. These products were

mixed and placed to ferment for a month before being used. It was also used 600g/experimental plot of quail manure before planting. In addition, two covering fertilizations (at 35 and 70 days after planting of the garlic) were conducted with the same dosage of Bokashi. Two manual weeding were done during the garlic cycle.

Experimental design was randomized in complete blocks with five replications and two treatments. The treatments were consisted of garlic in monoculture and garlic associated with fodder radish.

Garlic seedlings were prepared on trays with regular growth substrate (Plantmax®) and the fodder radish was sowed directly on the beds. Each experimental plot was composed of a 1.20m length by 1.0m width bed, the garlic was transplanted in the double row scheme (two rows of garlic spaced at 12cm from each other and with 40cm between the sets of rows) one month after the direct sown of the fodder radish. Each garlic line contained 10 plants, therefore 40 plants per experimental plot. Fodder radish was sown on the borders of the beds and an additional row in the center, between the double rows of garlic in the plots with intercropping, whose number of garlic plants was identical to the bed under monoculture.

The insect collections began four weeks after transplanting the garlic seedlings to the beds, continuing for 10 weeks. It was collected 25 samples per week, totaling 250 at the end of the experiment. Each sample was composed by a linear meter of garlic (10 plants). The samples were obtained by direct beating of plants on white trays and using a manual aspirator to collect the insects, which were preserved in 60% alcohol and identified in family, genus and species when possible, or separated by morphospecies.

The information was organized in a database. Specie richness (S) and abundance index (LAMBSHEAD et al., 1983) were determinate using the software Biodiversity Pro (MCALEECE et al.,

1997). Diversity index (H') (MAGURRAN, 2004) and species accumulation curves (GOTELLI & COLWELL, 2001) were calculated using the software EstimateS® (COLWELL, 2006).

The species were grouped according to the ecological strategy to determine the richness and abundance in each treatment. For H', and the grouped richness and abundance, the T test was performed (or Mann-Whitney U Test, according to the tests of homogeneity of variances) to show possible differences between the treatments.

All the samples and species collected were used to calculate ecological indexes, but the table with the results was summarized, omitting species with three or less individuals collected during the 10 weeks of the experiment. In those cases, they were added and identified in the table as "other taxa".

## Results and discussion

A total of 3628 arthropods was collected during the sampling period, belonging to three classes, nine orders, 40 families and 127 morphospecies. In regards to the sampling sufficiency (Figure 1, Garlic), it was observed that the general accumulation curve for species assumes a strong positive slope until the 30th sample, and declines after this, tending to reach an asymptote in the end of sampling period, thus indicating that the sampling effort (250) was sufficient to collect most of the species that could potentially occur in the garlic culture. Total individuals curve for garlic (Figure 2) resulted in a straight line, demonstrating there was no large variation in the average number of arthropods collected during the experiment. Due to this result, the sampling method was considered efficient and sufficient.

Comparing the species accumulation curve of monoculture treatment with garlic associated with fodder radish (Figure 1), it was observed that a higher richness of species was observed in the intercropped treatment (100 morphospecies,

compared to 79 in monoculture). In addition to this, it is noticeable that the accumulation curve for the intercropped treatment is farther away from its asymptote than the monoculture curve, indicating that more species could be potentially found in the association if more samples were made in this treatment. In relation to the abundance (Figure 2) it was evident that more individuals were added to the intercropped treatment during the sampling when compared with monoculture treatment. The average number of individuals collected in garlic associated with fodder radish was nearly twice if compared to monoculture (Table 1). Therefore, the association of garlic with fodder radish results in higher richness and abundance of arthropods in the plants.

However, the monoculture diversity index of Shannon ( $H'$ ) was statistically higher ( $T = -5.68$ ;  $p < 0.0001$ ) than the intercropped treatment (Table 1). Although more species have been captured in

the fodder radish and garlic association, it was observed that some of them had quite increased abundance, leading to a numerical dominance over the other species, resulting in a decrease of  $H'$  value. It can be clearly observed when are added the taxa "Nymphs of phytophagous" (composed mainly by different aphid species) with the aphid *Aphis fabae* Scopoli, 1763 (Hemiptera, Aphididae). In the monoculture treatment this amount represents 24% of the total individuals collected and 55% in the intercropped treatment.

These results regarding the diversity are in line with the observations of Terborgh (1973), as the increase in the abundance of a certain natural resource can favor one or two species to the detriment of others, so their dominance grows and the diversity index is reduced. In this study, garlic culture in association with fodder radish resulted in a rise of 4.4 fold in the incidence of adults and nymphs of *A. fabae*, which is not a problem

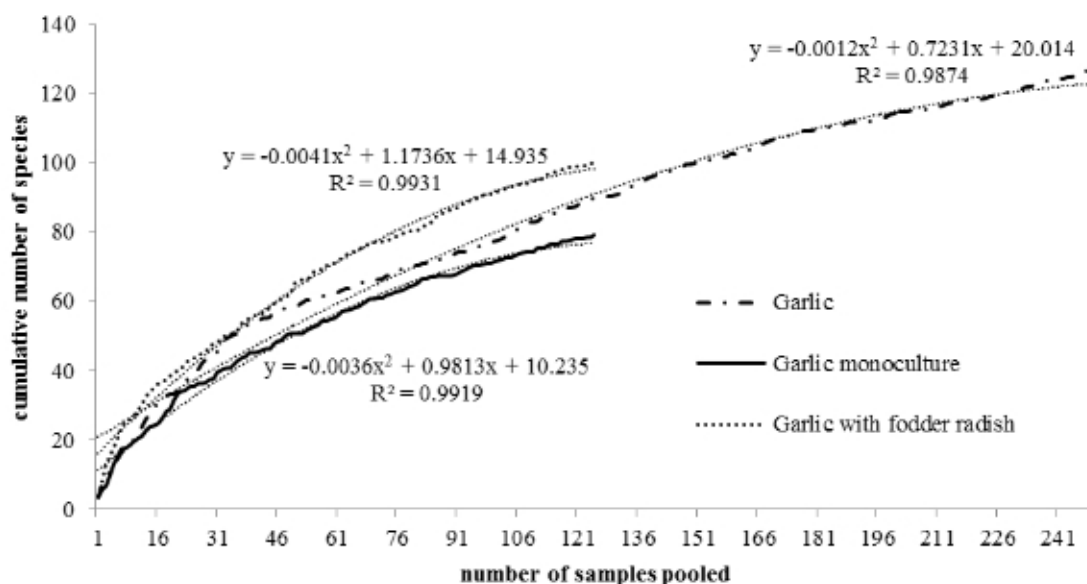


Figure 1: Collection curve (species accumulation) for garlic (all 250 samples) and for garlic monoculture and garlic associated with fodder radish (125 samples each). UFLA, Lavras, MG, June to August 2007.

Diversity of the arthropod fauna

Table 1: Taxa collected in organic garlic with and without fodder radish association, where PH = Phytophagous; PR = Predator; PA = Parasitoid and DE = Detritivorous. UFLA, Lavras, MG, June to August 2007.

Taxa – ecological niche	Garlic monoculture		Garlic with fodder radish	
	Average / sample	relative %	Average / sample	relative %
<i>Thrips tabaci</i> (Thysanoptera: Thripidae) <b>PH</b>	2.22	22.13	1.81	9.53
Nymph of phytophagous (Insecta) <b>PH</b>	1.55	15.45	7.25	38.20
<i>Aphis fabae</i> (Hemiptera: Aphididae) <b>PH</b>	0.80	7.96	3.25	17.12
<i>Frankliniella</i> sp2 (Thysanoptera: Thripidae) <b>PH</b>	0.64	6.37	0.37	1.94
<i>Haplothrips gowdeyii</i> (Thysanoptera: Phloeothripidae) <b>PH</b>	0.64	6.37	1.06	5.56
Smythuridae sp1 (Collembola) <b>DE</b>	0.56	5.57	0.10	0.51
Lathridiidae sp1 (Coleoptera) <b>PH</b>	0.38	3.82	0.26	1.35
Aranea sp1 (Arachnida) <b>PR</b>	0.26	2.55	0.19	1.01
Caterpillar (Lepidoptera) <b>PH</b>	0.19	1.91	0.13	0.67
Aranea sp3 (Arachnida) <b>PR</b>	0.13	1.27	0.14	0.76
<i>Caliothrips phaseoli</i> (Thysanoptera: Thripidae) <b>PH</b>	0.13	1.27	0.13	0.67
Entomobryidae sp1 (Collembola) <b>DE</b>	0.13	1.27	0.08	0.42
<i>Franklinothrips vespiformis</i> (Thysanoptera: Aeolothripidae) <b>PR</b>	0.13	1.27	0.24	1.26
<i>Lagria villosa</i> (Coleoptera: Lagriidae) <b>PH</b>	0.13	1.27	0.21	1.10
<i>Acyrtosiphon</i> sp1 (Hemiptera: Aphididae) <b>PH</b>	0.11	1.11	0.21	1.10
Larvae of <i>Lagria villosa</i> (Coleoptera: Lagriidae) <b>PH</b>	0.10	0.96	0.14	0.76
Aranea sp2 (Arachnida) <b>PR</b>	0.06	0.64	0.02	0.08
Chrysomelidae sp2 (Coleoptera) <b>PH</b>	0.06	0.64	0.06	0.34
<i>Diabrotica speciosa</i> (Coleoptera: Chrysomelidae) <b>PH</b>	0.06	0.64	0.32	1.69
Drosophilidae sp1 (Diptera) <b>DE</b>	0.06	0.64	0.18	0.93
Figitidae sp1 (Hymenoptera) <b>PA</b>	0.06	0.64	-	-
Figitidae sp5 (Hymenoptera) <b>PA</b>	0.06	0.64	-	-
<i>Frankliniella insularis</i> (Thysanoptera: Thripidae) <b>PH</b>	0.06	0.64	0.05	0.25
Mymaridae sp1 (Hymenoptera) <b>PA</b>	0.06	0.64	0.10	0.51
<i>Neohydatothrips</i> sp1 (Thysanoptera: Thripidae) <b>PH</b>	0.06	0.64	0.03	0.17
<i>Orius insidiosus</i> (Hemiptera: Anthocoridae) <b>PR</b>	0.06	0.64	0.27	1.43
<i>Paratrechina fulva</i> (Hymenoptera: Formicidae) <b>DE</b>	0.06	0.64	0.10	0.51
Trichogrammatidae sp1 (Hymenoptera) <b>PA</b>	0.06	0.64	-	-
Mycetophilidae sp1 (Diptera) <b>DE</b>	0.05	0.48	0.02	0.08
Nymph of <i>F. vespiformis</i> (Thysanoptera: Aeolothripidae) <b>PR</b>	0.05	0.48	-	-
Phytoseiidae sp1 (Acari) <b>PR</b>	0.05	0.48	0.02	0.08
Trichogrammatidae sp2 (Hymenoptera) <b>PA</b>	0.05	0.48	0.02	0.08
Trichogrammatidae sp3 (Hymenoptera) <b>PA</b>	0.05	0.48	0.03	0.17
<i>Uroleucon ambrosiae</i> (Hemiptera: Aphididae) <b>PH</b>	0.05	0.48	0.05	0.25
Chrysomelidae sp3 (Coleoptera) <b>PH</b>	0.03	0.32	0.05	0.25

Delphacidae sp3 (Hemiptera) <b>PH</b>	0.03	0.32	0.02	0.08
Encyrtidae sp1 (Hymenoptera) <b>PA</b>	0.03	0.32	0.03	0.17
<i>Frankliniella gemina</i> (Thysanoptera: Thripidae) <b>PH</b>	0.03	0.32	0.03	0.17
<i>Hippodamia convergens</i> (Coleoptera: Coccinellidae) <b>PR</b>	0.03	0.32	0.18	0.93
Larvae of Chrysopidae <b>PR</b>	0.03	0.32	-	-
Larvae of Coccinellidae (Coleoptera) <b>PR</b>	0.03	0.32	0.08	0.42
<i>Myzus persicae</i> (Hemiptera: Aphididae) <b>PH</b>	0.03	0.32	0.18	0.93
<i>Nabis</i> sp1 (Hemiptera: Nabidae) <b>PR</b>	0.03	0.32	0.03	0.17
<i>Stomatothrips angustipennis</i> (Thysanoptera: Aeolothripidae) <b>PR</b>	0.03	0.32	0.05	0.25
Trichogrammatidae sp6 (Hymenoptera) <b>PA</b>	0.03	0.32	-	-
Trichogrammatidae sp7 (Hymenoptera) <b>PA</b>	0.03	0.32	-	-
Encyrtidae sp2 (Hymenoptera) <b>PA</b>	0.02	0.16	0.03	0.17
Eulophidae sp2 (Hymenoptera) <b>PA</b>	0.02	0.16	0.03	0.17
<i>Neohydatothrips</i> sp2 (Thysanoptera: Thripidae) <b>PH</b>	0.02	0.16	0.03	0.17
Nitidulidae sp2 (Coleoptera) <b>DE</b>	0.02	0.16	0.08	0.42
Nitidulidae sp3 (Coleoptera) <b>DE</b>	0.02	0.16	0.05	0.25
<i>Pemphigus</i> sp1 (Hemiptera: Aphididae) <b>PH</b>	0.02	0.16	0.03	0.17
Psocidae sp1 (Psocoptera) <b>DE</b>	0.02	0.16	0.05	0.25
Aranea sp4 (Arachnida) <b>PR</b>	-	-	0.05	0.25
<i>Brachymyrmex</i> sp1 (Hymenoptera: Formicidae) <b>DE</b>	-	-	0.02	0.08
<i>Braconidae</i> sp1 (Hymenoptera) <b>PA</b>	-	-	0.16	0.84
Delphacidae sp1 (Hemiptera) <b>PH</b>	-	-	0.05	0.25
Figitidae sp3(Hymenoptera) <b>PA</b>	-	-	0.06	0.34
Miridae sp1 (Hemiptera) <b>PH</b>	-	-	0.03	0.17
<i>Misumenops</i> sp1 (Aranea: Thomisidae) <b>PR</b>	-	-	0.03	0.17
Nymph of Cicadellidae (Hemiptera) <b>PH</b>	-	-	0.03	0.17
Nitidulidae sp1 (Coleoptera) <b>DE</b>	-	-	0.03	0.17
Trichogrammatidae sp4 (Hymenoptera) <b>PA</b>	-	-	0.03	0.17
Trichogrammatidae sp5 (Hymenoptera) <b>PA</b>	-	-	0.05	0.25
Trichogrammatidae sp8 (Hymenoptera) <b>PA</b>	-	-	0.03	0.17
Other taxa (average less than 0.03 individuals/sample)	0.40	3.98	0.66	3.46
<b>Abundance per sample</b>	<b>10.05</b>	<b>100.0</b>	<b>18.98</b>	<b>100.0</b>
		<b>0</b>		<b>0</b>
<b>Richness (S)</b>	<b>79</b>		<b>100</b>	
<b>H' (T = -5.68; p&lt;0.0001)</b>	<b>2.88±0.</b>		<b>2.46±0.</b>	
	<b>05</b>		<b>0 5</b>	

because this species is not a pest that causes economic damage to the garlic culture. On the other hand, the association with fodder radish led to a 2.3 fold reduction in abundance of *T. tabaci* compared to the abundance in the monoculture (Table 1). In this sense, the association was positive for garlic, because the presence of a significant phytophagous species was altered, decreasing the proportion of a key pest (*T. tabaci*), and increasing a phytophagous insect without economic importance for the culture (*A. fabae*).

One possible reason for these changes in species composition between treatments is the associational resistance, proposed by Tahvanainen & Root (1972), according to which one crop, associated to another taxonomically diverse plant species, would suffer less damage than plants not associated, since the herbivores would be repelled or would have difficulties in finding the crop. Therefore the differences in the abundances of *A.*

*fabae* and *T. tabaci* could have been caused by the presence of fodder radish plants growing together with garlic. Also, these differences could be driven by “plant quality”, as stated by Uvah & Coker (1984), according to which the physiological changes in the metabolism of the culture, when associated with another plant, can be responsible for important changes in herbivore species composition. It is necessary to address that neither the quality of the plants or the insect movements from one to another (garlic or fodder radish) were measured in the present work, but it was observed that the final production of garlic crop in monoculture or in association were statistically similar (data not shown). This suggests that garlic plants in association with fodder radish were not sufficiently stressed or nutritionally affected to reduce production. For onion crop, for example, the association with fodder radish also did not affect the bulbs production, being recommended as a

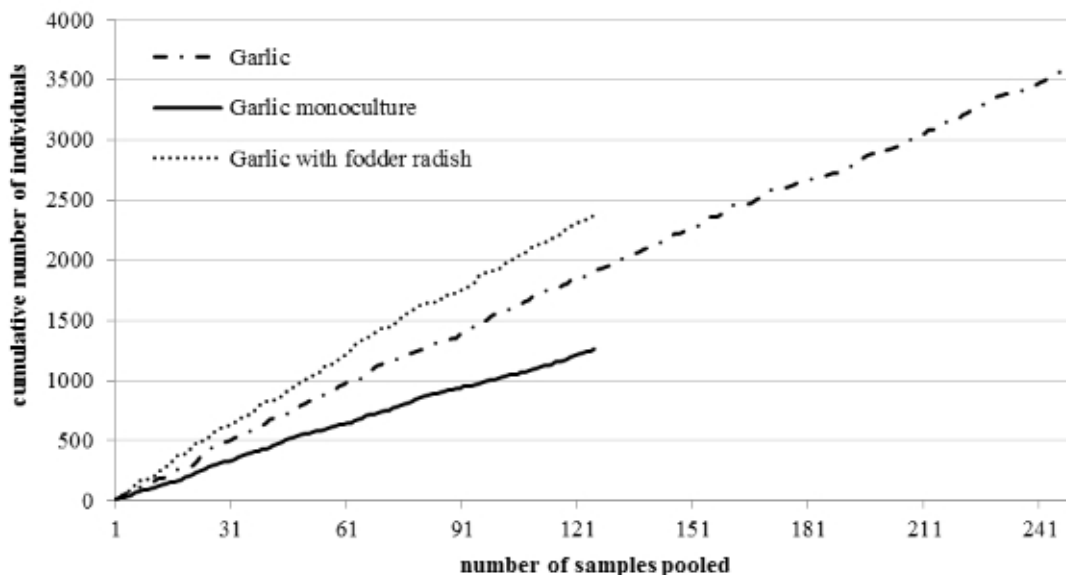


Figure 2: Cumulative number of individuals caught for garlic (all 250 samples) and for garlic monoculture and garlic associated with fodder radish (125 samples each). UFLA, Lavras, MG, June to August 2007.

positive association (DRIUTTI, 1999; GONÇALVES & SILVA, 2003).

Another reason that could explain the thrips population decrease in the intercropped treatment is related to the natural enemy theory (ROOT, 1973), as the abundance and the natural enemy diversity tend to be higher in diversified ecosystems. That happens due to an increase in the availability of more appropriated micro habitats, refuge or rest sites, besides pollen and nectar sources, and alternative preys or hosts for natural enemies. The results obtained in this study can partly confirm this hypothesis, because it was verified that several predators were more abundant when the garlic was associated to the fodder radish. For example, there was a fourfold increase in the abundance of the pirate bug *Orius insidiosus* (SAY, 1932) (Hemiptera: Anthocoridae) in the treatment associated with fodder radish compared to the garlic monoculture (Table 1). This anthocorid is the main thrips predator in various regions of the world, in several ecosystems and conditions, being widely used in biological control (BUENO, 2000;

SILVEIRA et al., 2003a, 2003b, 2004, 2009), hence this is a positive aspect of the association tested in this paper. Other predator that had higher abundance in the diversified treatment was the species *Franklinothrips vespiformis* (Crawford, 1909) (Thysanoptera: Aeolothripidae), predator of phytophagous thrips and small arthropods (HODDLE et al., 2000). The population of this species, on average, doubled in the presence of fodder radish.

Notwithstanding the abundance of these and other natural enemies in the treatment garlic with fodder radish, it was observed (Table 1) that the thrips populations in both treatments were below the economic injury level for the crop, which is 20 thrips/plant (VILLAS-BOAS et al., 1995). For the whole period the average number of thrips ranged from 1.81 to 2.22 individuals per sample of 10 plants in the association and monoculture, respectively, much less than the injury level. Consequently it is evident that the association promoted a positive impact on the populations of natural enemies of thrips and other phytophagous

Table 2: Proportions among the different ecological strategies found in organic garlic in monoculture (GM) and associated with fodder radish (GFR), where PH = Phytophagous; PR = Predator; PA = Parasitoid and DE = Detritivorous. Lavras, MG, June to August 2007.

Parameter	Treatm.	Ecological niche				Total
		PH	PR n.s	PA n.s	DE n.s	
Abundance/sample	GM	7.47**	1.01	0.58	0.99	<b>10.05</b>
	GFR	15.97	1.55	0.78	0.69	<b>18.98</b>
Relative abundance (%)	GM	74.31	10.05	5.77	9.87	<b>100.0</b>
	GFR	84.13	8.16	4.09	3.62	<b>100.0</b>
Richness (S)	GM	30**	17	20	12	<b>79</b>
	GFR	38	19	31	12	<b>100</b>
Relative richness (%)	GM	37.97	21.52	25.32	15.19	<b>100.00</b>
	GFR	38.00	19.00	31.00	12.00	<b>100.00</b>

n.s no statistical significance;

\*\* Statistically significant (Mann-Whitney U Test,  $p < 0.01$ ).



insects, but is not clear to what extent this could be considered as pest control in this paper, since the monoculture also showed low levels of thrips populations with fewer predators, as discussed earlier. In onion, Driutti (1999) concluded that the association with fodder radish promoted biological control of *T. tabaci* by the syrphid *Toxomerus* sp. Macquart, 1855 (Diptera: Syrphidae), but this species was not registered in the current experiment.

Grouping all arthropods taxa according to their ecological function in the community as a whole, it was observed that the phytophagous functional group was the most abundant, over 74% (Table 2). This result was expected, since this ecological niche is the first in the trophic web to use the accumulated energy in the plants and, therefore, it is the most abundant (ODUM, 1963).

The predators abundances varied from eight to 10% of total individuals collected in the different treatments, while the parasitoids varied from four to almost six percent of the relative abundance, but without numerical statistical significance. The entomophagous ecological niche (predators plus parasitoids) ranged from 12 to 16% of the total, a proportion that could potentially contribute to biological control, since each individual has the capacity to attack certain number of phytophagous daily. However, in spite of higher general richness and abundance of individual species, as already discussed, the association did not result in significant differences in the general abundance of natural enemies (Table 2).

Regarding the richness of species within each ecological strategy, it was observed that significantly more phytophagous taxa were obtained from the diversified treatment (Table 2). The parasitoids richness increased about 1.5 fold in absolute numbers in the presence of fodder radish, while the predators showed a small increase (but with no significance for both) and the detritivorous were not changed. Therefore, with the

diversification, there is a tendency for the increase of natural enemy's richness, but mainly parasitoids. According to several authors (ROOT, 1973; ANDOW, 1991; BAGGEN et al., 1999), the supply of food resources for adult parasitoids, such as pollen and nectar, increases specially their longevity and fecundity, leading to higher populations in diversified environments. In this study it was observed that parasitoids experienced a certain increase in richness when there was an increase in plant diversity, which could be driven by the supply of pollen and nectar via the presence of the fodder radish. In second place, the parasitoid enhancement in the diversified garlic could be associated to the increase of alternative hosts, as in the case of the aphids discussed previously, but also other species, if it is considered that significantly more phytophagous were found in the association treatment in this paper (Table 1 and 2). This is in agreement with Aguiar-Menezes (2004) and Landis et al. (2000), who stated that the presence of non-pest species for a certain culture can sustain higher populations of natural enemies in diversified areas, mainly for predators and generalist parasitoids.

Therefore, the changes in the arthropod species and functional strategies observed in the present paper lend support to the diversification theories. The association of garlic culture with fodder radish led to important modifications, as the numerical substitution of the main phytophagous garlic pest *T. tabaci*, by the aphid *A. fabae* which is not a pest for garlic, but the mechanisms that driven to this remain to be determined. Is also important to highlight that *A. fabae* is a potential insect pest to other horticultural plants, such as lettuce and rocket, for instance the use of fodder radish as an intercropping option should not be recommended in those cultures without more specific tests. Future work should investigate if organic garlic is naturally resistant to pests attack, due to the intrinsic stability and resilience of organic management system

(GLIESSMAN, 2001; SCHOWALTER, 2006), where the treatments were installed. This may have omitted the real reasons of having fewer pest species in the garlic associated to the fodder radish than in monoculture.

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### Referências Bibliográficas

- AGRAWAL, A.A. et al. How leaf domatia and induced plant resistance affect herbivores, natural enemies and plant performance. *Oikos*, v. 89, n. 1, p. 70-80, 2000.
- AGUIAR-MENEZES, E.L. **Diversidade vegetal: uma estratégia para o manejo de pragas em sistemas sustentáveis de produção agrícola**. Seropédica: Embrapa Agrobiologia, 177, 2004. p. 68.
- ANDOW, D.A. Vegetational diversity and arthropod population response. *Annual Review of Entomology*, v. 36, p.561-586, 1991.
- BAGGEN, L.R. et al. Flowers in tri-trophic systems: mechanisms allowing selective exploitation by insect natural enemies for conservation biological control. *Entomologia Experimentalis et Applicata*, v.91, p.155-161, 1999.
- BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. **Instrução Normativa nº 7, de 17 de maio de 1999**. Capturado em 15 agosto 2009. Online. Disponível na Internet <http://www.agricultura.gov.br/>.
- BUENO, V.H.P. Desenvolvimento e multiplicação de percevejos predadores do gênero *Orius* Wolff, p.69-85. In V.H.P. Bueno (ed.), **Controle biológico de pragas: Produção massal e controle de qualidade**. Lavras: UFLA, 2000. 192p,
- COLWELL, R.K. **EstimateS: Statistical estimation of species richness and shared species from samples**. Version 8, 2006. Capturado em 10 agosto 2009. Online. Disponível na Internet <http://viceroy.eeb.uconn.edu/EstimateS>.
- CONAB, Companhia Nacional de Abastecimento. **Conjuntura Mensal**. Ministério da Agricultura, Pecuária e Abastecimento. 2009. Capturado em 15 setembro de 2009. Online. Disponível na Internet <http://www.anapa.com.br/principal/images/stories/conjunturaconab/alhooutubro2009.pdf>.
- DRIUTTI, A. Control biológico natural de trips, *Thrips tabaci* Lindeman 1888 (Thysanoptera: Thripidae) por sírfidos predadores en cultivo de cebolla (*Allium cepa* L.) por el cultivo de borduras y/o entrelineas, 1. **Agrotecnia**. v.5, p.3-15, 1999.
- GALLO, D. et al. **Manual de Entomologia Agrícola**. São Paulo: Agronômica Ceres, 2002. 649p.
- GLIESSMAN, S.R. **Agroecologia: processos ecológicos em agricultura sustentável**. Porto Alegre: Ed. Universidade/UFRGS, 2001, p. 653.
- GONÇALVES, P.A.S.; SOUZA-SILVA, C.R. Efeito de espécies vegetais em bordadura em cebola sobre a densidade populacional de trips e sírfidos predadores. **Horticultura Brasileira**, Brasília, v. 21, n. 4, p. 731-734, 2003.
- GOTELLI, N., COLWELL, R.K. Quantifying biodiversity: Procedures and pitfalls in the measurement and comparison of species richness. **Ecology Letters**, v.4, p.379-391, 2001.
- HODDLE, M.S. et al. Developmental and reproductive biology of a predatory *Franklinothrips n.* sp. (Thysanoptera: Aeolothripidae). **Biological Control**, v.18, p.27-38, 2000.
- LAMBSHEAD, P.J.D. et al. Detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. **Journal of Natural History**, v. 17, p. 859-874, 1983.
- LANDIS, D.A.; WRATTEN, S.D.; GURR, G.M. Habitat management to conserve natural enemies of arthropod pests in agriculture. **Annual Review of Entomology**, v. 45, p. 175-201, 2000.
- MAGURRAN, A.E. 2004. **Measuring biological diversity**. Oxford, Blackwell Publishing, 258p.
- MCALEECE, N. et al. **BioDiversity Pro** (version 2). Londres, The Natural History Museum & The Scottish Association for Marine Science. 1997. Capturado em 05 de maio de 2007. Online. Disponível na Internet [http://gcmd.nasa.gov/records/NHML\\_Biopro.html](http://gcmd.nasa.gov/records/NHML_Biopro.html).
- MONTEIRO, R.C.; MOUND, L.A.; ZUCCHI, R.A. Espécies de Thrips (Thysanoptera: Thripidae)

- no Brasil. **Neotropical Entomology**, Piracicaba, v. 1, p. 61-63, 2001.
- NICHOLLS, C.I.; ALTIERI, M.A. Projeção e implantação de uma estratégia de manejo de habitats para melhorar o manejo de pragas em agroecossistemas. In: ALTIERI, M.A.; NICHOLLS, C.I.; PONTI, L. (Eds). **Controle biológico de pragas através do manejo de agroecossistemas**. Brasília : MDA, 2007. p.02-16.
- ODUM, E. P. "Ecology". New York: Holt, 1963. p.623.
- ORMOND, J.G.P. et al. **Agricultura orgânica: quando o passado é futuro**. BNDES Setorial, Rio de Janeiro, n. 15, p. 3-34, 2002.
- ROOT, R. B. Organization of plant – arthropod association in simple and diverse habitats: the fauna of collards (*Brassica oleraceae*). **Ecology Monographs**, v. 43, p. 95-124, 1973.
- SAMPAIO, M. V. et al. Biological Control of Insect Pests in the Tropics. In: **International Commission on Tropical Biology and Natural Resources**. Eds. Del Claro, K. Encyclopedia of Life Support Systems (EOLSS), UNESCO, Eolss Publishers, Oxford ,UK. 2008. Capturado em 5/10/2009. Capturado em 01 dez 2008. Online. Disponível na Internet <http://www.eolss.net>.
- SCHOWALTER, T. D. **Insect ecology: An ecosystem approach**. 2nd Edition. Academic Press. Burlington, MA, 2006.
- SILVEIRA, L.C.P. et al. C. *Orius insidiosus* as biological control agent of Thrips in greenhouse chrysanthemums in the tropics. **Bulletin of Insectology**, v.57, n.2, p. 103-109, 2004.
- SILVEIRA, L.C.P. et al. Record of two species of *Orius Wolff* (Hemiptera, Anthocoridae) in Brazil. **Revista Brasileira de Entomologia**, v. 47, p. 303-306, 2003a.
- SILVEIRA, L.C.P. et al. Plantas cultivadas e invasoras como habitat para predadores do gênero *Orius* (Wolff) (Heteroptera: Anthocoridae). **Bragantia**, v.62, n.2, p.261-265, 2003b.
- SILVEIRA, L.C.P. et al. Marigold (*Tagetes erecta* L.) as an attractive crop to natural enemies in onion fields. **Scientia Agricola**, v. 66, n. 6, 2009.
- TAHVANAINEN, J.O., ROOT, R.B. The influence of vegetational diversity on the population ecology of a specialized herbivore, *Phyllotreta cruciferae* (Coleoptera: Chrysomelidae). **Oecologia**, v.10, p.321-46, 1972.
- TERBORGH, J. On the notion of favorableness in plant ecology. **American Naturalist**, n.107, p.441-561, 1973.
- TERRAZZAN, P.; VALARINI, P.J. Situação do mercado de produtos orgânicos e as formas de comercialização no Brasil. **Informações Econômicas**, São Paulo, v.39, n.11, 2009.
- UVAH, I.I.I.; COAKER, T.H. Effect of mixed cropping on some insect pests of carrots and onions. **Entomologia Experimentalis et Applicata**, v. 36, p. 159-167, 1984.
- VILLAS BÔAS, G. L. et al. Nível de danos de trips em alho cultivado no Distrito Federal e região geoeconômica. **Horticultura Brasileira**, v.13, n.1, p.22 – 27, 1995.