

Effect of plant diversification on abundance of South American tomato pinworm and predators in two cropping systems

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ABSTRACT

Several studies have demonstrated that the diversification of the agroecosystem may reduce insect pest infestation using the strategy of companion planting. We studied the effect of the presence of coriander and Gallant soldier as companion plants in the tomato crop under organic and conventional management on abundance of the tomato pests and predators. The experiment was carried out under field conditions, at Distrito Federal, Brazil, from July to October, 2004. The experimental design was of randomized blocks with three replicates in a 3 x 2 factorial arrangement [Three crop diversification levels: tomato in monoculture, tomato intercropped with coriander, and tomato intercropped with coriander and Gallant soldier; and two cropping systems: organic and conventional]. Each plot had 80 plants of the tomato and the pest-insects and predaceous arthropods were collected every week in five tomato plants/plot. *Tuta absoluta* (Meyr.) was the commonest pest species in both cropping systems. The tomato intercropped with coriander and Gallant soldier in organic cropping system had lower abundance and higher diversity of pests, and higher abundance and diversity of predaceous arthropods, mainly at 80 days after the tomato transplanting, coinciding with the population peak of *T. absoluta* (eggs and adults). The more abundant predators were spiders, lady beetles and ants. The spiders were abundant and uniformly distributed in both systems. The lady beetles appeared lately in the organic system, at the flowering season of the coriander. The ants were more abundant in the conventional systems.

Keywords: *Lycopersicon esculentum*, *Coriandrum sativum*, *Galinsoga parviflora*, *Tuta absoluta*, habitat manipulation, conservation biological control.

RESUMO

Efeito da diversificação de plantas na abundância da traça-do-tomateiro e predadores em dois sistemas de cultivo

Vários estudos têm demonstrado que a diversificação do agroecossistema pode reduzir a infestação por insetos-praga pelo uso da estratégia do estabelecimento de plantas companheiras. Neste trabalho estudou-se o efeito da presença do coentro e botão-de-ouro como plantas companheiras na cultura do tomate sob manejo orgânico e convencional, na abundância das pragas do tomate e de predadores. O experimento foi conduzido em condições de campo, no Distrito Federal, de julho a outubro de 2004. O desenho experimental foi em blocos ao acaso, com três repetições e no arranjo fatorial 3 x 2 [três níveis de diversificação cultural: tomate em monocultivo, tomate consorciado com coentro, e consórcio tomate com coentro e botão-de-ouro e dois sistemas de cultivo: orgânico e convencional]. Cada parcela experimental tinha 80 plantas de tomateiro, sendo os insetos-praga e artrópodes predadores semanalmente coletados em cinco plantas/parcela. *Tuta absoluta* (Meyr.) foi a espécie-praga mais comum em ambos os sistemas de cultivo. O tomate consorciado como coentro e botão-de-ouro, no sistema de cultivo orgânico, apresentou menor abundância e maior diversidade de pragas, e maior abundância e diversidade de artrópodes predadores, principalmente aos 80 dias após o transplante do tomate, coincidindo com o pico populacional da *T. absoluta* (ovos e adultos). Os predadores mais abundantes foram aranhas, joaninhas e formigas. As aranhas foram abundantes e uniformemente distribuídas em ambos os sistemas. As joaninhas apareceram tardiamente no sistema orgânico, no período de florescimento do coentro. As formigas foram mais abundantes no sistema convencional.

Palavras-chave: *Lycopersicon esculentum*, *Coriandrum sativum*, *Galinsoga parviflora*, *Tuta absoluta*, manipulação do habitat, controle biológico conservativo.

(Recebido para publicação em 24 de novembro de 2008; aceito em 20 de agosto de 2009)

(Received in November 24, 2008; accepted in August 20, 2009)

The tomato, *Lycopersicon esculentum* (Mill.) (Solanaceae) is susceptible to several pests, such as lepidopteran leafminers and borers, aphids, whiteflies and thrips (França *et al.*, 2000; Haji *et al.*, 2002). Among them, the South American tomato pinworm (SATP) *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is a serious limiting pest of tomato in conventional and organic cropping systems in Brazil (França *et*

al., 2000; Grassi, 2005). Its distribution is restricted to countries which are producers of tomato in Latin America (França, 1993; França *et al.*, 2000).

The SATP damages are caused by the caterpillars that destroy leaves, stems and fruits, besides facilitating the contamination by pathogens (França *et al.*, 2000). In Central Brazil, this pest is present throughout the year due to favorable weather conditions, especially

the temperature, and its population peaks occur from July to September, i.e., during dry and hot periods (Haji *et al.*, 1988; Castelo Branco, 1992).

In conventional cropping system, the use of chemical insecticides is the primary method to control the SATP, although it is not always effective (Haji *et al.*, 1995; Souza *et al.*, 1992). However, these pesticides are not permitted in organic cropping system.

Due to the economic importance of this crop, other methods to control this pest have been studied by several authors, such as genetic resistance of plants (Lourenção *et al.*, 1984; Thomazini *et al.*, 2001), use of entomopathogens (Giustolin *et al.* 2001a, 2001b) and botanical insecticides (Brunherotto & Vendramim, 2001; Thomazini *et al.*, 2001). The biological control with the parasitoid *Trichogramma pretiosum* Ridley (Hymenoptera: Trichogrammatidae) is successful against the SATP, but it is susceptible to insecticides applied against the whitefly *Bemisia tabaci* (Genn.) (Hemiptera: Aleyrodidae, and is reared by specialized laboratory to be applied through augmentative biological control (Haji *et al.*, 2002).

However, another future perspective for pest control is the habitat manipulation by enhancing diversification of plant species in time and space in annual cropping habitats. This strategy is based on the companion planting, which can be described as the establishment of two or more plant species in close proximity so that some cultural benefit is derived, such as pest control (Kuepper & Dodson, 2001). Habitat manipulation may occur at the within-crop, within-farm, or landscape levels. Various techniques to restore agricultural diversity in time and space include crop rotations, cover crops, vegetation handling, intercropping (or polycultures) and more complex cropping systems, such as ecological corridors and agroforestry systems (Altieri *et al.*, 2003; Nicholls & Altieri, 2006).

Several studies carried out in the USA, Europe and Australia have demonstrated the role of crop diversification in reducing insect pest infestation, and the mechanisms accounting for reduction, such as reduced pest colonization rate, reduced pest tenure time, oviposition interference, and increased mortality due to predators and/or parasitoids (Hooks & Johnson, 2003; Ponti *et al.*, 2007). These mechanisms underlie two hypotheses to explain lower pest infestations in diversified cropping systems: the resource concentration hypothesis and the natural enemy hypothesis (Root, 1973; Ponti *et al.*, 2007).

Under the first assumption, a more diverse flora in the agroecosystem impairs the ability of insect pests to find and utilize their host plant by chemical repellence, camouflage, feeding inhibition by the presence of non-host plants and reduction of immigration that result in lower colonization and reproduction of pest (Root, 1973; Ponti *et al.*, 2007). The second hypothesis presumes that more diverse cropping systems enhance abundance and diversity of natural enemies that reduces pest numbers (Andow, 1991, Ponti *et al.*, 2007), and implied the implementation of habit manipulation of non-crop species (beneficial insectary plants) in the agroecosystem to provide vital resources for natural enemies of the crop pests, which is known as conservation biological control (Landis *et al.*, 2000). The concept of encouraging beneficial insects with insectary (flowering) plants is based on the requirement for many adult predatory and parasitic insects to feed on nectar and/or pollen, including aphidophagous hover-flies, tachinid flies, ladybird beetles, lacewings and parasitic Hymenoptera (Smith, 1960; Colley & Luna, 2000; Berndt & Wratten, 2005). The larvae of these beneficial insects are the primary feeding stage on herbivorous arthropods.

Wild or cultivated flowering plants, including weeds, in or around the field, can increase the diversity of habitats and provide shelter, suitable microclimate and alternative food sources for natural enemies and can significantly increase the residency times and thus enhance the efficacy of predators and parasitoids (Emden, 1965; Altieri & Whitcomb, 1979; Landis *et al.*, 2000; Altieri *et al.*, 2003; Berndt & Wratten, 2005).

Research is still needed to identify which companion plants have the greatest potential for reducing pest infestation of the main crops. Species of Leguminosae, Apiaceae and Asteraceae have played the role as beneficial insectary plants (Altieri *et al.*, 2003). According to Landis *et al.* (2000), the selection of plants for habitat manipulation should consider their suitability in the agricultural or horticultural regime in which they will be placed. However, as pointed out by Hooks & Johnson

(2003), the indirect role that habitat manipulation plays in the population dynamics of inset pests and natural enemies still remains unclear. Previous studies conducted in Brazil indicated that SATP could respond, in a variable way, to the plant diversification of the environment.

In this context, the objective of this work was to study the effect of presence of the herb coriander (*Coriandrum sativum* L., Apiaceae) and the weed Gallant soldier (*Galinsoga parviflora* Cav., Asteraceae) as companion plants in tomato crop under organic and conventional managements on abundance of the tomato pests, mainly the SATP, and predators throughout the crop cycle.

MATERIAL AND METHODS

The experiment was conducted in two areas of the experimental field of Embrapa Hortaliças, located in Brasília, Brazil (15° 56'S, 48° 08'W and 997.6 m a.s.l). The soil is characterized as Dark Red Latosol (Oxisol).

The experimental design was a randomized block with three replicates in a 3 x 2 factorial arrangement: three crop diversification levels [tomato in monoculture, tomato intercropped with coriander, and tomato intercropped with coriander and Gallant soldier, a non-host of tomato pest was used to provide floral resources to natural enemies; and two cropping systems: organic and conventional.

The organic cropping system was established in a special area intended for researching on organic vegetables production system, which has been under this management since 2001. The organic and conventional areas are separated from each other at a distance of 100 m. The proximity of the areas of organic and conventional production allows comparative experiments between organic and conventional systems in a paired way, a feature which is rarely found in this type of study.

The organic area has about 250 m of a riparian forest, and is policultivated (mainly onions, carrots, broccoli, cucumber and garlic), employs crop

rotation with corn and uses corn and sorghum as green manure. It is surrounded by hedgerows of the Giant Mexican sunflower [*Tithonia diversifolia* (Hemsl.), Asteraceae] and uncultivated areas are maintained with spontaneous vegetation, which is dominated by the napier grass (*Pennisetum purpureum* Stapf., Poaceae) and brachiaria grass (*Brachiaria decumbens* Schum., Poaceae). In the hedges of the experiments, rows of corn (*Zea mays* L., Poaceae) and crotalaria (*Crotalaria juncea* L., Leguminosaceae) were established as a barrier.

The transplantation of the tomato seedlings (hybrid F1 “Durador”) took place on July 2nd 2004 in both areas, and the crop remained in the field for 101 days (end of harvested period). Each plot was formed of 80 tomato plants spaced 0.50 m between plants and 0.80 m between rows in the inverted V-shaped stake system with double rows totalizing 25.2 m² per plot, which was spaced of 2 m among themselves. The coriander and Gallant soldier were planted between the tomato lines.

The plots in both systems had the soil ploughed and flower-bedded. Fertilization in the organic system was done with manure before the cultivation and in sidedressing applications. In the conventional system, fertilization consisted of N-P-K (Makishima & Miranda, 1992). The irrigation was done by infiltration in the organic system and by sprinklers in the conventional one. All other agronomic practices, such as sprouting and conduction, followed the same technical recommendations for the crop (Makishima & Miranda, 1992). In the conventional system, a blend of insecticides, fungicides and miticides was sprayed twice a week, after planting. The following fungicides chlorothalonil (3) and metalaxil+mancozebe (1) were applied at the rates recommended by the manufacturers; The following insecticides and miticides abamectin (4), espinosade (4) and cartap (3) to control SATP and thiomethoxam (4), acephate (4) and imidacloprid (2) to control whitefly were applied at the rates recommended by the manufacturers. Bordeaux mixture was applied twice during the experiment to

control diseases and pests in the organic system. Weed control was carried out by mechanical weeding and with the herbicide glyphosate (directed spray) on post-planting in the conventional system, and with mechanical weeding in the organic system.

Delta traps containing traces of sexual SATP pheromones (isicalure *Tuta*) were distributed 1,0 m from the each experimental area not to interfere in the population samples within the areas. The traps were set up in the four corners of each area at 0.5 m above ground level. Traps were observed three times a week and the number of adult tomato pinworms captured was recorded.

The SATP population and its natural enemies were monitored in organic and conventional systems through weekly insects sampling. The number of pinworms eggs, larvae or adults were observed and counted in the field, as well as the other herbivores and natural enemies which were present from the ground to the apex, in five tomato plants/plot picked at random. The collection period lasted 84 days, starting with the first issue of floral buds (24 days after the transplant) to the end of the harvest. The insects observed were classified on the feeding habit as herbivores, predators or parasitoids. The phenology of the plant as well as the weather and cultural data were recorded.

Data were statistically analyzed by multiple analysis of variance (two-way ANOVA) followed by the Student-Newman-Keuls test ($p < 0.05$) or Mann-Whitney test ($p < 0.001$) with the software Sigmatat V 3.2.

RESULTS AND DISCUSSION

The population densities of adult SATP present in the vicinities of the areas under organic and conventional management, in all samples with sex-pheromone-baited delta traps, did not differ significantly (Fig. 1) (Mann-Whitney test: $\sigma = 52,7$ organic and $\sigma = 54,4$ conventional, value of $t = 11,114$, $n=104$, $p=0,572$). It means that the population of SATP adults was uniformly distributed between the experimental areas.

However, the populations of adult

SATP sampled within the plots showed different behavior in the two systems. The number of SATP adults was lower in the organic system, mainly in the treatment with the highest level of crop diversification (tomato-coriander-Gallant soldier), which was followed by tomato-coriander and tomato single, but there were no differences among them (Fig. 2-A) ($F_{\text{week}} = 17,153$, $g.l.= 7$, $p < 0,001$; $F_{\text{treatment}} = 12,978$, $g.l.= 5$, $p < 0,001$; $F_{\text{week} \times \text{treatment}} = 2,369$, $g.l.= 35$, $p < 0,001$). However, in the conventional system, the adult population was higher, mainly at about 80 days after transplantation, when the adult numbers increased almost three-fold.

The organic cropping system showed lower numbers of SATP eggs when compared to the conventional system. In the conventional system, there were differences in the populations of eggs among weeks, among treatments within each week ($F = 22,103$, $g.l.= 7$, $p < 0,001$), among treatments, independently of the week ($F = 8,127$, $g.l.= 5$, $p < 0,001$), and there was interaction between week x treatment ($F = 1,607$, $g.l.= 35$, $p = 0,037$). Although the collection period started with the first issue of floral buds (24 days after transplant), the variable observed began to differentiate from the fifty-two days after transplantation, when the coriander and Gallant soldier started their flowering season, and tomato plants bore small fruits. The highest numbers of SATP eggs occurred in the conventional cropping system from 80 to 94 days after transplantation, for the three crop diversification levels (Table 1). The significant differences found in this period among the levels of crop diversification indicate that the oviposition behavior of SATP females was affected by complexity of vegetation around the tomato plants. In the same period, the smallest number of eggs was found in the most diverse and organic systems (Table 1, treatments 2 and 3), although organic tomato monoculture system did not differ from the three crop diversification levels in the conventional systems.

The population of SATP caterpillars showed a different pattern from adults and eggs. The mean number of total caterpillars sampled throughout the

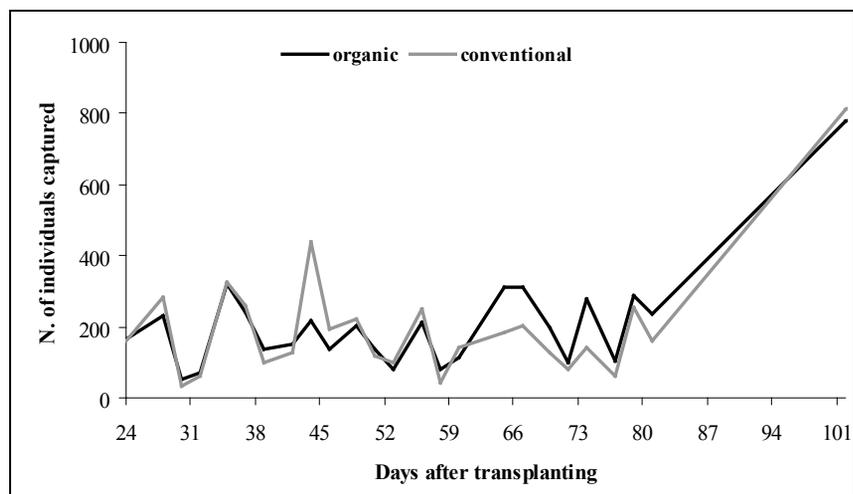


Figure 1. Adults of SATP captured by sexual pheromone traps which were placed in the edge of experimental areas under organic and conventional systems (adultos de traça-do-tomateiro coletados em armadilhas de feromônio, as quais foram instaladas nas bordas das áreas experimentais sob sistemas orgânico e convencional). Brasília, Embrapa Hortaliças, 2004.

Means did not differ from each other by Mann-Whitney test ($p < 0.001$) (médias não diferiram entre si pelo teste de Mann-Whitney ($p < 0.001$)).

Table 1. Mean number of SATP eggs per plot sampled in tomato crop with three levels of plant diversification in the organic system (1-tomato, 2-tomato-coriander, 3-tomato-coriander-Gallant soldier) and the conventional system (4-tomato, 5-tomato-coriander, 6-tomato-coriander-Gallant soldier) (número médio de ovos da traça-do-tomateiro por parcela amostrados na cultura do tomate com três níveis de diversificação de plantas no sistema orgânico (1- tomate, 2- tomate-coentro e 3- tomate-coentro-botão-de-ouro) e no sistema convencional (4- tomate, 5- tomate-coentro e 6- tomate-coentro-botão-de-ouro). Brasília, Embrapa Hortaliças, 2004.

Sample time ¹	Organic system			Conventional system		
	1	2	3	4	5	6
52 days	4,6A ² a ³	9,0Aa	1,6Aa	9,6Aa	7,6Aab	8,3Aac
59 days	7,0Aa	6,3Aa	2,6Aa	11,3Aa	13,0Aab	14,6Aac
66 days	7,3Aa	6,3Aa	5,3Aa	4,6Aa	7,0Aab	4,0Aac
73 days	6,0Aa	1,3Aa	1,0Aa	3,0Aa	3,6Aab	3,6Aac
80 days	57,3Ab	34,6Aa	13,0Aa	59,0Bb	82,0Bbc	62,3Bbc
87 days	2,3Aa	2,0Aa	0,3Aa	33,6Bb	39,6Bac	34,5Bbc
94 days	21,0Aa	11,6Aa	3,3Aa	45,3Bb	44,6Bac	44,3Bbd
101 days	21,6Aa	13,0Aa	13,3Aa	15,6Aa	14,0Aab	17,6Aac

¹Days after transplantation (dias após o transplântio); ²Means followed by the same capital letters in the column did not differ from each other by Student–Newman-Keuls test ($p < 0.05$) (médias seguidas pelas mesmas letras maiúsculas na coluna não diferem entre si pelo teste de Student–Newman-Keuls test ($p < 0.05$)); ³Means followed by the same small letters in the line did not differ from each other by Student–Newman-Keuls test ($p < 0.05$) (médias seguidas pelas mesmas letras minúsculas na linha não diferem entre si pelo teste de Student–Newman-Keuls test ($p < 0.05$)).

tomato cycle did not differ statistically among treatments (Fig. 2-B) ($F_{\text{week}} = 27,290$, g.l.= 7, $p < 0,001$; $F_{\text{treatment}} = 2,126$, g.l.= 5, $p = 0,069$; $F_{\text{week} \times \text{treatment}} = 2,652$, g.l.= 35, $p < 0,001$). Considering that the mean number of eggs was smaller

in the more diverse and organic system, and resulted in relatively high survival of caterpillars in relation to the same levels of crop diversification in the conventional system, it is possible that the insecticides applied might be more

effective than the natural enemies, which were more abundant in the organic systems. Similar results were found by Andow (1990), who observed that the larval-pupae survival of herbivorous insects was greater in diverse habitats (with a diversity of spontaneous plants) than in simple ones.

In the conventional and organic system, other herbivorous species were found. However, higher densities of a few herbivorous species exhibited higher density in the conventional systems, such as the whitefly, besides SATP. In the organic system, the number of herbivorous species was higher than in the conventional system (Fig. 3-A) ($F_{\text{week}} = 4,380$, g.l.= 7, $p < 0,001$; $F_{\text{treatment}} = 0,576$, g.l.= 5, $p = 0,718$; $F_{\text{week} \times \text{treatment}} = 1,674$, g.l.= 35, $p = 0,026$), but they were considered as secondary tomato pests, such as *Helicoverpa zea* Boddie and *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae). Medeiros & França¹ also observed the presence of secondary pest in plantations without the interference of insecticides.

The most abundant natural enemies in the two cropping systems were predaceous arthropods, such as spiders (Araneae), ants (Formicidae) and ladybird beetles (Coccinellidae). The spiders were abundant with uniform distribution in the two systems. The ladybird beetles appeared only at the end of the cycle in the organic system, possibly attracted by the coriander inflorescences. Resende (2008) also found that higher number of ladybird beetles in the intercropping of collard with coriander than in the monoculture of collard, mainly in the flowering season of the coriander. The ants were more common in the conventional system. Other groups of predators were present, such as the bedbugs *Geocoris* sp. (Lygaeidae), *Orius* sp. (Anthocoridae), *Nabis* sp. (Nabidae), Staphylinidae, Syrphidae, Dolichopodidae, Dermaptera, the neuropteran *Chrysoperla externa* Hagen (Chrysopidae), Mantidae and Vespidae.

The greater abundance and diversity of predaceous species were found in the organic system. The number of predaceous in this system reached

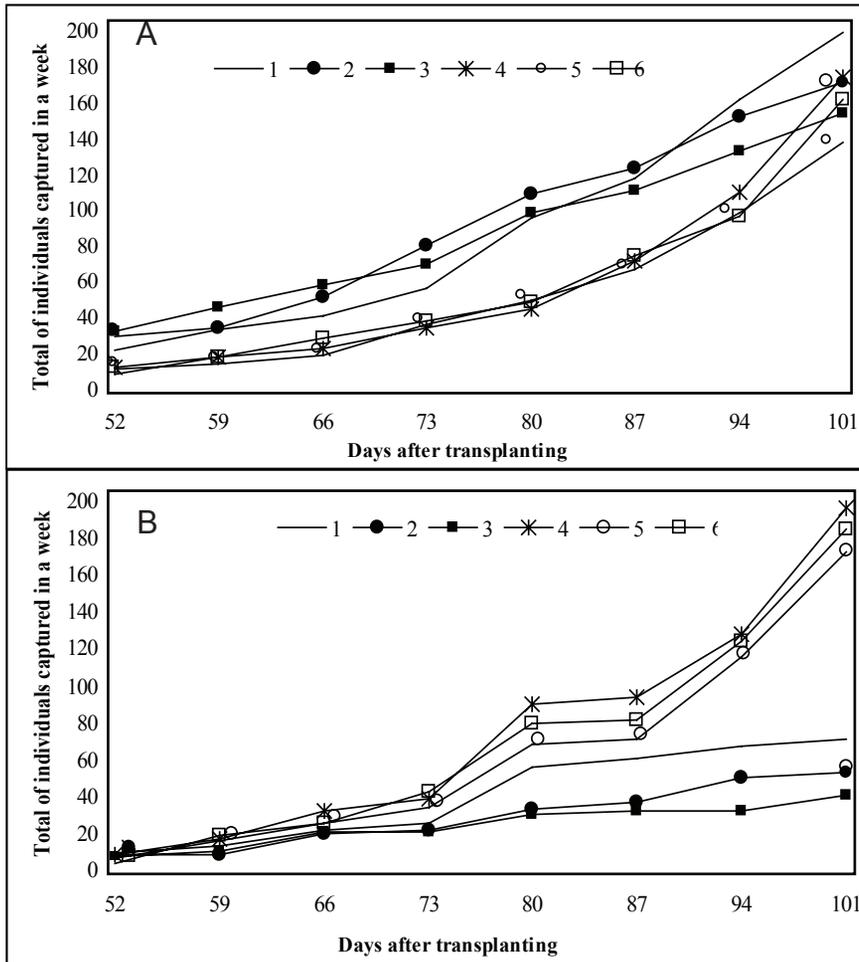


Figure 2. Accumulated number of adults (A) and caterpillar (B) of SATP sampled in tomato crop with three levels of plant diversification in the organic system (1-tomato, 2-tomato-coriander, 3-tomato-coriander-Gallant soldier) and the conventional system (4-tomato, 5-tomato-coriander, 6-tomato-coriander-Gallant soldier) (número acumulado de adultos (A) e lagartas (B) da traça-do-tomateiro amostrados na cultura do tomate com três níveis de diversificação de plantas no sistema orgânico (1- tomate, 2- tomate-coentro e 3- tomate-coentro-botão-de-ouro) e no sistema convencional (4- tomate, 5- tomate-coentro e 6- tomate-coentro-botão-de-ouro). Brasília, Embrapa Hortaliças, 2004.

Means were compared by Student-Newman-Keuls test ($p < 0.05$) (médias foram comparadas pelo teste de Student-Newman-Keuls ($p, 0.05$)). Brasília, DF, 2004.

the double of the number sampled in the conventional system at 80 days after transplanted (Fig. 3-B) ($F_{\text{week}} = 4,811$, g.l.= 7, $p < 0,001$; $F_{\text{treatment}} = 11,097$, g.l.= 5, $p < 0,001$; $F_{\text{week} \times \text{treatment}} = 1,765$, g.l.= 35, $p < 0,001$), following the increase of population density of the tomato pinworm in both cropping systems, the number of predaceous was proportionately greater with the increase of crop diversification level. Apparently the plant diversity, including weed species, is important to increase

the number of natural enemies and also confirms the hypothesis of natural enemies of Root (1973), considering the lower density of eggs and adults primarily as a result of the preying activity of generalist predaceous arthropods.

The Gallant soldier is a weed that might have a good potential as beneficial insectary plant, attracting natural enemies, since the more diversified treatments (3 and 6) had the greatest amount of predaceous arthropods (Fig. 3-B). Botelho *et al.* (1994)

observed that Gallant soldier was very attractive to beneficial insects foraging in its flowers. However, Nascente (1998) studied the fauna of arthropods in tomato crops intercropped with four weed species, including Gallant soldier, and observed that the combination tomato/Gallant soldier attracted more herbivores, mainly Lygaeidae bugs associated with this weed. The most attracted combinations to predators and parasitoids were tomato/Nightshade (*Solanum americanum* Mill.) (Solanaceae), and tomato/brachiaria grass (*Brachiaria plantaginea* (Link.) (Poaceae).

Letourneau & Goldstein (2001) observed that the damage to leaves and fruits of tomato caused by arthropods was similar among organic and conventional farms in California, USA, but the arthropod fauna was more diverse and the natural enemies were more abundant on organic farms. According to these authors, organic practices promote greater wealth of herbivores, so that the community is less dominated by a main pest. Additionally, the organic system methods promote the conservation of species of arthropods in all functional groups, which increases the abundance of natural enemies, compared to the conventional system.

The role of coriander in the system is still not clear, but at first glance, it may hinder the location of the plants by insects (Hilje, 2001). According to Andow (1990), non-host plants may interfere physically in the settlement of adults, and non-host plants reduced immigration and increased emigration of the herbivorous beetle *Epilachna varivestis* Mulsant (Coccinellidae), clearly affecting its behavior. The coriander also may cause repellence because of the chemical that they give off, as pointed out by Andow (1993), to mustard intercropped with beans. The chemicals of the mustard act as antifeedants for *E. varivestis* and contribute to the suppression of its populations in the intercropping of bean with mustard (Andow, 1993). However, the actions of the coriander on the system seem to be broader, once in the tenth week of the experiment, the coriander in bloom showed large amounts of

¹Personnal communication

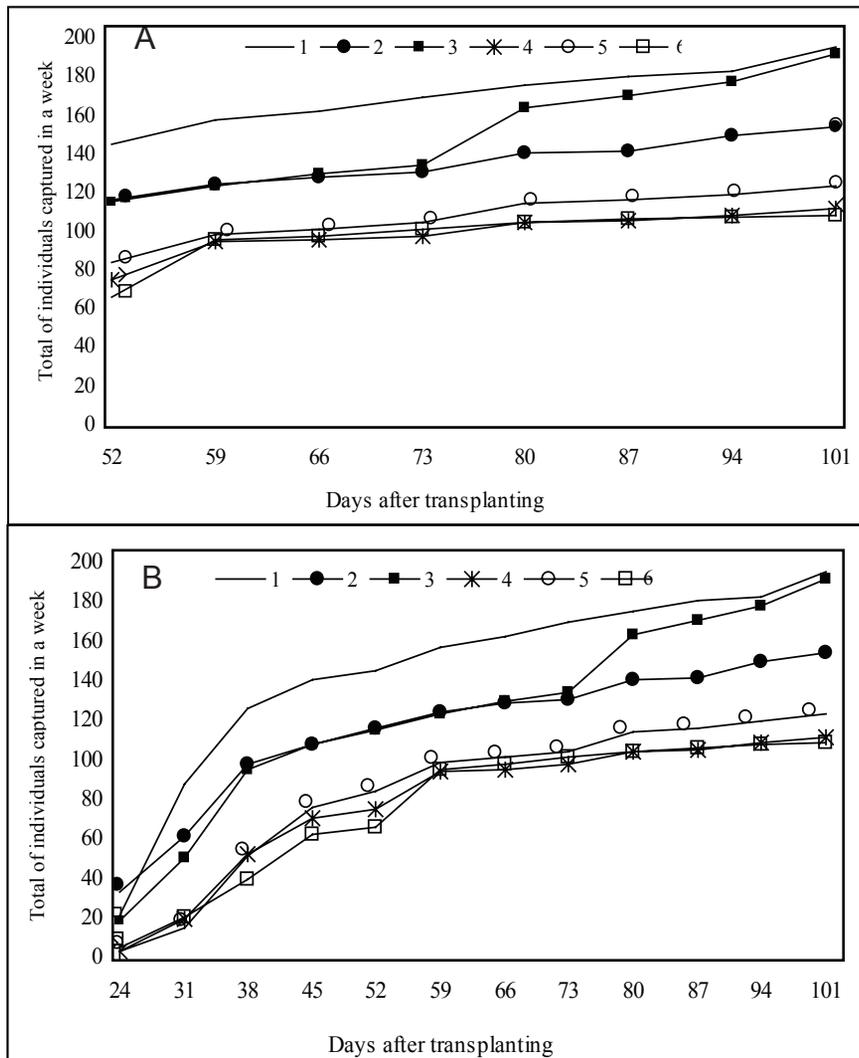


Figure 3. Acumulated number of herbivorous (A) and predaceous arthropods (B) sampled in tomato crop with three levels of plant diversification in the organic system (1-tomato, 2-tomato-coriander, 3-tomato-coriander-Gallant soldier) and the conventional system (4-tomato, 5-tomato-coriander, 6-tomato-coriander-Gallant soldier) (número acumulado de herbívoros (A) e artrópodes predadores (B) amostrados na cultura do tomate com três níveis de diversificação de plantas no sistema orgânico (1- tomate, 2- tomate-coentro e 3- tomate-coentro-botão-de-ouro) e no sistema convencional (4- tomate solteiro, 5- tomate-coentro e 6- tomate-coentro-botão-de-ouro). Brasília, Embrapa Hortaliças, 2004. Mean were compared by Student-Newman-Keuls test ($p < 0.05$) (Médias foram comparadas pelo teste de Student-Newman-Keuls ($p < 0.05$))

aphids and in turn attracted a lot of ladybird beetles, such as *Hippodamia convergens* Guérin-Ménéville, *Cycloneda sanguinea* L. and *Eriopis connexa* (Germar) (Coccinellidae), which were used as alternative preys. Resende (2008) also observed the infestation of coriander by aphid *Aphis spiraeicola* Patch. (Aphididae) at the end of the flowering season, which was used as food for *C. sanguinea*. In the present study, there were a great number of these predators during the other following

two weeks, and in the conventional system, they did not occur. A strategy for possible handling may be to cut the coriander, forcing the migration of predators for the tomato. Risch *et al.* (1982) observed that *H. convergens* were more abundant in monocultures than in policultures as a result of plant density. In the present study, ladybird beetles were attracted by the abundant food (aphids) and by the diversity of the cropping system (tomato-coriander-Gallant soldier, which occurred in

higher abundance). Andow & Risch (1985) stated that, if the diversification resulted in greater abundance of food resources or greater spatial dispersion of food, then the predators may be more abundant and effective in a diversified agroecosystem.

Besides the SATP, common diseases of tomato such as tospovirus, geminivirus, bacterial wilt and powdery mildew affected the productivity of the organic system. Competition of coriander and Gallant soldier with tomato also had a direct effect on productivity. Probably, the organic system is capable of supporting a broad arthropod community, including a percentage of pests because there are several factors working simultaneously on the environment, i.e., it is the complementarity that makes the system viable.

Coriander and Gallant soldier associated with tomato affected the population dynamics of the arthropod community. Even though there is a significant difference between the population levels achieved in each cropping system, the influence of these companion plants can be checked by various indicators, such as lower densities of eggs and adults, greater wealth and abundance of general herbivores and generalist predators on both cropping systems, organic and conventional. Further studies should emphasize the following unknown aspects: 1) the associated plants can be used in a spatial arrangement that increases and conserves natural enemies and that, at the same time, does not present any negative influences on the crop, such as competition; 2) if management of these plants will be enough to ensure the protection of the tomato, allowing the production of organic tomatoes and 3) The environmental management to minimize the problems caused by the diseases of the tomato still remains to be studied.

ACKNOWLEDGEMENTS

We thank Hozanan Pires Chaves, José Gomes Teixeira for helping during the field work, to anonymous reviewers for suggestions on manuscript. This

work is a part of the requirements from the Pos-Graduate Program of Ecology in the University of Brasilia for the achievement of Doctor in Sciences degree by Maria Alice de Medeiros.

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