Impact of insecticides on non-target arthropods in watermelon crop

Impacto de inseticidas em artrópodes não-alvo associados à cultura da melancia

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Abstract

Watermelon *Citrullus lunatus* (Thunberg, Matsumura & Nakai) is an ecosystem having a variety of arthropods, each one playing a specific role. Although some of them are considered pest to crops, some others are responsible for soil aeration, nutrient release and predation of pest species and are, therefore, considered beneficial to crops. The intensive farming practiced for watermelon cultivation in Brazil is based on the use of tiamethoxam and deltamethrin, which may not only kill target but also non-target organisms such as beneficial arthropods. Research data regarding the influence of insecticides on arthropods in watermelon cropping is scarce. This study aimed to evaluate the effect of the insecticides deltamethrin and thiamethoxam on soil surface and watermelon canopy arthropod community. The study was carried out in the State of Tocantins, Brazil. Although the application of thiamethoxam and deltamethrin was efficient in controlling populations of *Aphis gossypii* (Glover), as we expected, they negatively affected non-target arthropods such as detritivores insects in the canopy and soil surface. Ecological implications of the impact of such pesticides on beneficial arthropod species are discussed.
Key words: *Citrullus lanatus*, neonicotinoids, pyrethroids, non-target arthropods

Resumo

A cultura da melancia *Citrullus lunatus* (Thunberg, Matsumura & Nakai) abriga uma grande diversidade de artrópodes, cada um desempenhando um papel específico. Apesar de alguns desses artrópodes serem considerados pragas, outros são responsáveis pela aeração do solo, liberação de nutrientes e predação das espécies-praga, sendo, dessa forma, considerados benéficos às culturas. A agricultura intensiva praticada no Brasil para o cultivo da melancia é baseada no uso dos inseticidas como tiamethoxam e deltametrina, que pode não só matar as pragas, mas também organismos não-alvo. Pesquisas relacionadas à influência de inseticidas sobre artrópodes benéficos na cultura da melancia são escassas. Este estudo foi realizado com o objetivo de avaliar o efeito dos inseticidas deltametrina e thiamethoxam na comunidade de artrópodes existentes na superfície do solo, bem como naqueles artropópodes que habitam o dossel das plantas na cultura da melancia. Este estudo foi realizado no Estado do Tocantins, Brasil. Embora as aplicações de thiamethoxam e deltametrina foram eficientes no controle de populações de *Aphis gossypii*, como era esperado, os inseticidas afetaram negativamente artrópodes não-alvo como insetos detritívoros, insetos de dossel e da superfície do solo. Implicações ecológicas do impacto dos pesticidas sobre as espécies de artrópodes benéficos são discutidos.
Palavras-chave: *Citrullus lanatus,* neonicotenóides, piretróides, artrópodes benéficos

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Introduction

Watermelon, *Citrullus lunatus* (Thunberg, Matsumura & Nakai), is an important crop in the Midwest and North regions of Brazil. Specifically, approximately 5,000 ha are grown in the State of Tocantins (SANTOS et al., 2011b). Several key pests, such as *Diaphania nitidalis* (Cramer), *Diaphania hyalinata* L., *Aphis gossypii* (Glover), *Frankliniella* sp., *Thrips* sp. and *Bemisia tabaci* (Gennadius) are responsible for yield loss and represent a threat to watermelon production (MOREIRA, 2002; BACCI et al., 2007; RUSSO et al., 1997; SOUZA et al., 2011).

Because of high vulnerability of watermelon plants, the intensive farming practiced has been based on the use of the broad spectrum synthetic insecticides. Deltamethrin and thiamethoxam are the most common insecticides in watermelon production in Tocantins (personal observation). The first is used mainly for *D. nitidalis* and *D. hyalinata* control and the second for control of *A. gossypii* and *B. tabaci* (AGROFIT, 2012). Deltamethrin is a synthetic pyrethroid, which is highly toxic to a wide range of organisms. It is obtained from pyrethrins and its action on insects is based on an acute toxicity causing immediate paralysis and consequently death (FERNANDES, 2000; SILVA et al., 2006). The impact of deltamethrin on arthropods in some crops have been accessed. For instance, Badji et al. (2004) found that on maize fields under no-tillage cultivation, the system was able to buffer the impact of the insecticide on the arthropod assemblage, minimizing its effect, but this did not occur in the conventional cultivation system where deltamethrin significantly decreased arthropod abundance, including predatory species.

The insecticide thiamethoxam is a neonicotinoid insecticide that is rapidly absorbed by plant roots and sucking insects as well as (TOMIZAWA; CASIDA, 2005). Its high activity is brought about by binding to nicotinergic acetylcholine receptors in the nervous system of insects, which interferes with chemical signal transmission (ABBINK, 1991; TOMIZAWA et al., 1995a, 1995b; MATSUDA et al., 2001). The effect of thiamethoxam on arthropod assemblage in field conditions has not been studied. For other neonicotinoids there are field studies that show positive and negative effects on some arthropod taxa abundance (MARQUINI et al., 2002; PECK, 2009).

Thus, the insecticides used for pest control on watermelon crop may not only kill the target organisms but also non-target beneficial organisms (ARMENTA et al., 2003; JAMES, 2003, TORRES; RUBERSON, 2004; KOSS et al., 2005; ROCHA et al., 2006). Although the insecticides mentioned above are officially registered to be used against pests in watermelon cropping in Brazil (AGROFIT, 2012), their effects on non-target organisms present on this cropping systems, such as beneficial arthropods have not yet been investigated.

Although some arthropods are considered pest to crops, others are responsible for soil aeration and nutrient release and, therefore, are considered beneficial to crops. Additionally, the population of soil arthropods may have a positive correlation with soil properties. For example, insects of the family Staphylinidae have positive correlation with the availability of K and P in the soil (DANXIAO et al., 1999).

The diversity of beneficial arthropods associated with watermelon crop may be affected by the applied agricultural practices based on broad range insecticide applications. Even though, there are no studies on the impact of such insecticides on them. This impairs producers to achieve the proper management of pests or makes it ineffective. Studies on impact of pesticides on arthropod community become, therefore, fundamental to the improvement of alternatives to ensure crop productivity. This study evaluated the impact of the insecticides thiamethoxam and deltamethrin on the arthropods associated with canopy and ground surface of watermelon cropping.

Material and Methods

Experimental area

Experiment was carried out from August to November 2009, at the Experimental Area of the Federal University of Tocantins (11º45'47"S, 49º02'57"W), Gurupi-TO, Brazil. The soil type of the area is "Typic Hapludox" (EMBRAPA, 1999). An analysis of soil was done, tillage operations were carried out (SANTOS et al., 2011a), and cultural practices were followed (FILGUEIRA, 2000; SANTOS et al., 2011a).

Arthropod sampling

The experiment was conducted in an area consisting of 3,600m^2 that was divided in three sub-areas of 1,200 m^2. Each sub-area received one treatment; for sampling, each sub-area was divided into 20 points and they were sampling over time. Due to logistic reasons and field size limitations we did not repeat the experiment. Instead, care was taken to use large plots that would not limit arthropod movements (BOMMARCO, 2003). The following treatments were applied: Sub-area 1 – No pesticide application; Sub-area 2 – Four applications of thiamethoxam (Actara 250 WG, Syngenta Proteção de Cultivos LTDA) at a dosage of 60g/100L water; and Sub-area 3 – Four applications of deltamethrin (Decis 25 EC, Bayer S/A) at a dosage of 100mL/100L. The applications were, monthly, carried out by spraying using a spray volume of 200L/ha. Plants were sprayed with a costal sprayer Jacto® PJH model with a capacity of 20 L. The control of naturally occurring plants on the three areas was done through weeding (FILGUEIRA, 2000; SANTOS et al., 2011b).

Arthropods were sampled by scoring 20 points to 144 m^2 (12 x 12 m), which corresponded to the surface area of each plot. Each point was separated from the other by a border of 2 m wide. One week after seed germination the arthropod populations sampling started and were weekly assessed throughout the crop cycle. To evaluate the number of arthropods found in the canopy of watermelon plants it was used a direct counting technique (LEITE et al., 2002), where all leaves of each plot were examined, without foliage disturbance, and the arthropods were counted and registered.

Arthropods from the soil surface were sampled using pitfall traps (LUFF, 1975), installed in 10 out of the 20 plots of each treatment in the same areas mentioned above. Samples collected in the field were kept in plastic pots containing 70% alcohol. In laboratory, they were transferred to Petri dishes and the number of arthropods was counted using a stereoscopic microscope with a 12x increase fixed. Samples were collected from the pitfall traps at 60, 70 and 80 days after planting. Subsequently, the collected arthropods were identified at family level and, the most occurring morphospecies were identified by a taxonomist at genus and species level.

Statistical analysis

The mean and the standard error of number of taxa per treatment as well as the total frequency of arthropods were calculated. The normality and homogeneity of variances were analyzed using the univariate procedure (SAS INSTITUTE, 2001). Abundance data were transformed by $\log_{10} (x + 2)$ and arthropods were excluded when the occurrence frequency was below 15%, due to their low importance for the crop. The data were submitted to a selection process that determines which taxa can better explain the observed variance (PROC STEPWISE STEPDISC with selection, SAS INSTITUTE, 2001). Those were selected from the previously analyze and were submitted to a canonical variate analysis (CVA). This analysis is a widely used method for analyzing group structure in multivariate data (KRZANOWSKI; RADLEY, 1989). It reduces the dimensionality of the original data set of variables and can be used to graphically illustrate the relative positions and

orientations of the mean assemblage responses to the treatments under comparison (KEDWARDS et al., 1999 cited by BADJI et al., 2004). The significant difference (indicated by ordination) among groups due to treatment was determined by comparing the treatments using the F test (p < 0.05). The Mahalanobis distance between the respective classes of canonical means was used. Analyses were performed using the procedure CANDISC statistical package SAS (SAS INSTITUTE, 2001).

The arthropods that had the highest canonical coefficients were selected and subjected to multivariate analysis due to repeated measurements. Subsequently, graphics were made using the means and standard errors of abundance of arthropods over time. Since the sampling of arthropods was conducted in the same location several times, the analysis of variance due to repeated measures was done to avoid pseudo-replication in time (GREEN, 1993; PAINE, 1996).

Results

Arthropods associated with canopy of watermelon plants

Among the collected taxa, seven with frequency superior than 15% were selected as a group that allowed to better explain the observed variation in the treatments (Table 1 and 2): *A. gossypii* (Hemiptera: Aphididae), Chrysomelidae (Coleoptera), Staphylinidae (Coleoptera), *Frankliniella schultzei* (Trybom) (Thysanoptera: Thripidae), Pentatomidae (Hemiptera), Pyralidae (Lepidoptera) and *Cycloneda sanguinea* (Coleoptera: Coccinellidae).

The ordination diagram derived from the CVA showed significant difference among treatments (Figure 1A). The diagram was constructed with the first two canonical axes, which together explain 77% of the observed differences. All treatments differed by the F test based on Mahalanobis distance between classes of means. Thus, it was observed a significant effect of insecticides, especially the impact of the insecticide thiamethoxam on the canopy arthropod community of watermelon plants (Figure 1 and 2). The taxa found on the canopy of watermelon cropping that positively contributed to the divergence in the first canonical axis were *A. gossypii*, Chrysomelidae (Coleoptera), Staphylinidae, *C. sanguinea* and Pentatomidae, whereas *F. schultzei* and Pyralidae (Lepidoptera) negatively contributed to this divergence (Table 3).

In the second canonical axis, *A. gossypii*, Chrysomelidae, *C. sanguinea* and Pyralidae positively contributed while Staphylinidae, *F. schultzei* and Pentatomidae negatively contributed to the difference between treatments in the explanation of all the data (Table 3). The taxa that most contributed to differences between treatments in the canopy according to the canonical coefficients were *A. gossypii*, Pyralidae, *F. schultzei* and Staphylinidae (Table 2). The repeated-measure analysis showed that the main taxa affected by insecticides applications on watermelon canopy were: *F. schultzei* (F = 5.48, p = 0.01), *A. gossypii* (F = 17.68, p = 0.01), Pyralidae (F = 13.21, p = 0.01) and Staphylinidae (F = 13.99, p = 0.01).

Table 1. Abundance (mean ± standard error), frequency (F) (%) and guild of arthropods associated with the canopy and the soil surface in watermelon crop treated with insecticides (Gurupi, TO, 2009). Abundance is referred as average number of taxa collected per plot and each plot was represented by 20 points scored in an area of 144 m^2 (12 x 12 m).

Taxa	Abundance (mean ± standard error)			F (%)	Guild*
	No insecticides	Thiamethoxam	Deltamethrin		
Cycloneda sanguinea (Coccinellidae)	0.25 ± 0.04	0.29 ± 0.05	0.23 ± 0.04	19.26	P
Staphylinidae (Coleoptera)	0.35 ± 0.06	0.03 ± 0.02	0.28 ± 0.05	15.00	P
Aphis gossypii (Aphididae)	11.13 ± 2.10	0.11 ± 0.04	1.01 ± 0.19	27.22	H
Diabrotica speciosa (Chrysomelidae)	1.21 ± 0.11	0.54 ± 0.08	0.77 ± 0.09	42.96	H
Frankliniella schultzei (Thripidae)	5.04 ± 0.50	3.64 ± 0.43	4.86 ± 0.45	53.15	H
Pentatomidae (Hemiptera)	0.62 ± 0.10	0,07 ± 0.03	0.30 ± 0.05	15.74	
Pyralidae (Lepidoptera)	0.24 ± 0.05	0.61 ± 0.11	0.27 ± 0.05	19.07	H
Soil surface					
Acrididae (Orthoptera)	8.43 ± 1.59	3.30 ± 0.73	3,37 ± 0.55	58.9	H
Araneae (Arachnida)	5.10 ± 1.03	2.43 ± 0.33	0.10 ± 0.03	43.3	P
Bostrichidae (Coleoptera)	12.43 ± 2.36	2.53 ± 0.79	2.23 ± 1.29	30.0	H
Carabidae (Coleoptera)	2.30 ± 0.36	2.47 ± 0.35	0.77 ± 0.17	47.78	P
Chrysomelidae (Coleoptera)	1.17 ± 0.24	0.80 ± 0.18	0.07 ± 0.03	28.9	H
Curculionidae (Coleoptera)	0.30 ± 0.05	0.57 ± 0.23	0.00 ± 0.00	16.0	H
Entomobryidae (Collembola)	9.67 ± 2.30	3.53 ± 0.86	0.83 ± 0.48	21.1	D
Formicidae (Hymenoptera)	144.07 ± 23.10	16.27 ± 3.73	5.47 ± 2.33	65.6	P
Gryllidae (Orthoptera)	6.33 ± 0.63	3.83 ± 0.45	5.87 ± 0.71	77.8	H
Isotomidae (Collembola)	7.20 ± 2.81	4.13 ± 1.13	1.33 ± 0.77	21.1	D
Lagriidae (Coleoptera)	1.50 ± 0.35	1.27 ± 0.32	0.00 ± 0.00	23.3	H/D
Coleoptera larvae	34.90 ± 3.70	18.03 ± 3.18	4.73 ± 2.54	46.7	H
Noctuidae (Lepidoptera)	0.43 ± 0.09	1.45 ± 0.22	0.80 ± 0.16	35.6	H
Nitidulidae (Coleoptera)	37.20 ± 4.44	15.50 ± 2.55	3.00 ± 1.73	44.4	P
Reduviidae (Hemiptera)	2.33 ± 0.62	0.07 ± 0.04	0.07 ± 0.03	15.6	P
Scarabidae (Coleoptera)	1.17 ± 0.36	0.47 ± 0.13	0.27 ± 0.07	21.1	D
Staphylinidae (Coleoptera)	3.30 ± 0.52	1.20 ± 0.26	0.20 ± 0.08	32.2	P
Tenebrionidae (Coleoptera)	12.37 ± 2.19	11.83 ± 3.61	5.70 ± 1.07	62.2	H

* H = Herbivore; P= Predator; D = Detritivore
Source: Elaboration of the authors.

Table 2. Summary of the stepwise selection method to select the taxa to be included in the canonical variate analysis and obtain the maximum discrimination between treatments.

Taxa	Test F – Analysis of covariance			Partial squared correlation	
	Partial R^2	F	P	Squared canonical correlation	P
			Canopy		
Cycloneda sanguinea	0.03	7.35	<0.01	0.17	<0.01
Staphylinidae	0.03	9.21	<0.01	0.15	<0.01
Aphis gossypii	0.26	95.17	<0.01	0.13	<0.01
Frankliniella shcultzei	0.01	3.83	0.02	0.17	<0.01
Pentatomidae	0.01	2.70	0.07	0.18	<0.01
Pyralidae	0.03	7.47	<0.01	0.16	<0.01
			Soil surface		
Acrididae	0.12	5.34	0.01	0.35	<0.01
Aranea	0.06	2.47	0.09	0.31	<0.01
Formicidae	0.37	25.68	<0.01	0.19	<0.01
Gryllidae	0.08	3.50	0.03	0.38	<0.01
Isotomidae	0.06	2.59	0.08	0.43	<0.01
Lagriidae	0.07	3.35	0.04	0.26	<0.01
Nitidulidae	0.09	3.92	0.02	0.41	<0.01
Noctuidae	0.11	5.12	<0.01	0.23	<0.01
Reduviidae	0.07	3.04	0.05	0.29	<0.01

Source: Elaboration of the authors.

Table 3. Canonical coefficients of axes showing the effect of thiamethoxam and deltamethrin applications on the arthropods of soil surface in watermelon cropping (Gurupi – TO, 2009).

Taxa	Canonical axis	
	1	2
	Canopy	
Aphis gossypi	0.92	0.19
Diabrotica speciosa	0.21	0.10
Staphylinidae	0.14	-0.57
Cycloneda sanguinea	0.29	0.42
Frankliniella schultzei	-0.24	-0.59
Pentatomidae	0.20	-0.13
Pyralidae	-0.20	0.57
F	18.16	3.74
gl (numerator; denominator)	14/1062	6/532
P	<0.01	<0.01
Squared canonical correlation	0.57	0.20
	Surface soil	
Aranea	0.61	0.84
Lagriidae	-0.35	0.39
Nitidulidae	0.80	0.72
Isotomidae	-0.46	0.10
Reduviidae	0.47	-0.30
Formicidae	0.81	-0.92

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Noctuidae	-0.05	0.75
Acrididae	-0.67	-0.64
Gryllidae	-0.14	-0.58
F	6.77	4.79
gl (numerator; denominator)	18/156	8/79
P	<0.01	<0.01
Squared canonical correlation	0.53	0.33

Source: Elaboration of the authors.

Figure 1. Ordination diagram (CVA) showing the difference among treatments in the canopy arthropod community (A) and in the soil surface (B), based on Mahalanobis distance between means of classes p ≤ 0.05 (Gurupi-TO, 2009).
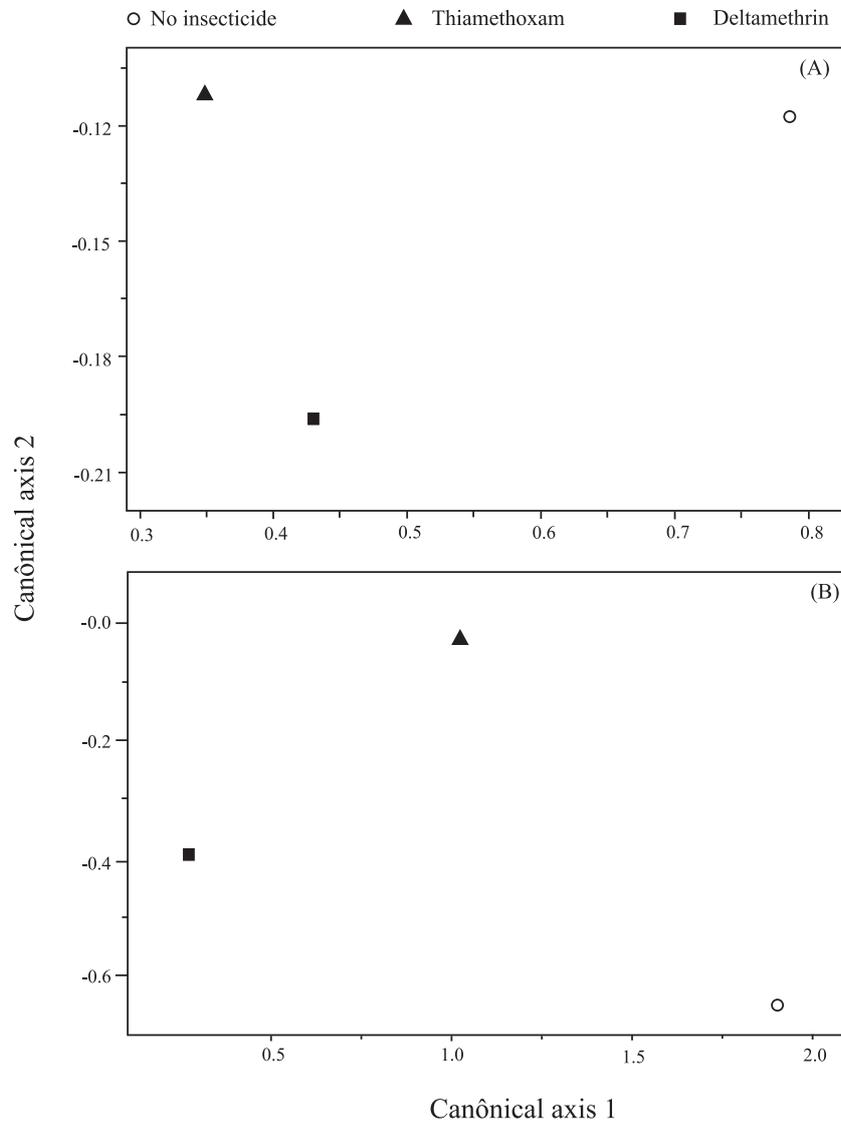
Source: Elaboration of the authors.

Figure 2. Abundance (mean ± standard error) of arthropods associated with canopy of watermelon relative to the application of deltamethrin and thiamethoxam (Gurupi – TO, 2009). A= *Aphis gossypii*; B=Pyralidae; C= *Frankliniella schultzei*; D= Staphylinidae.
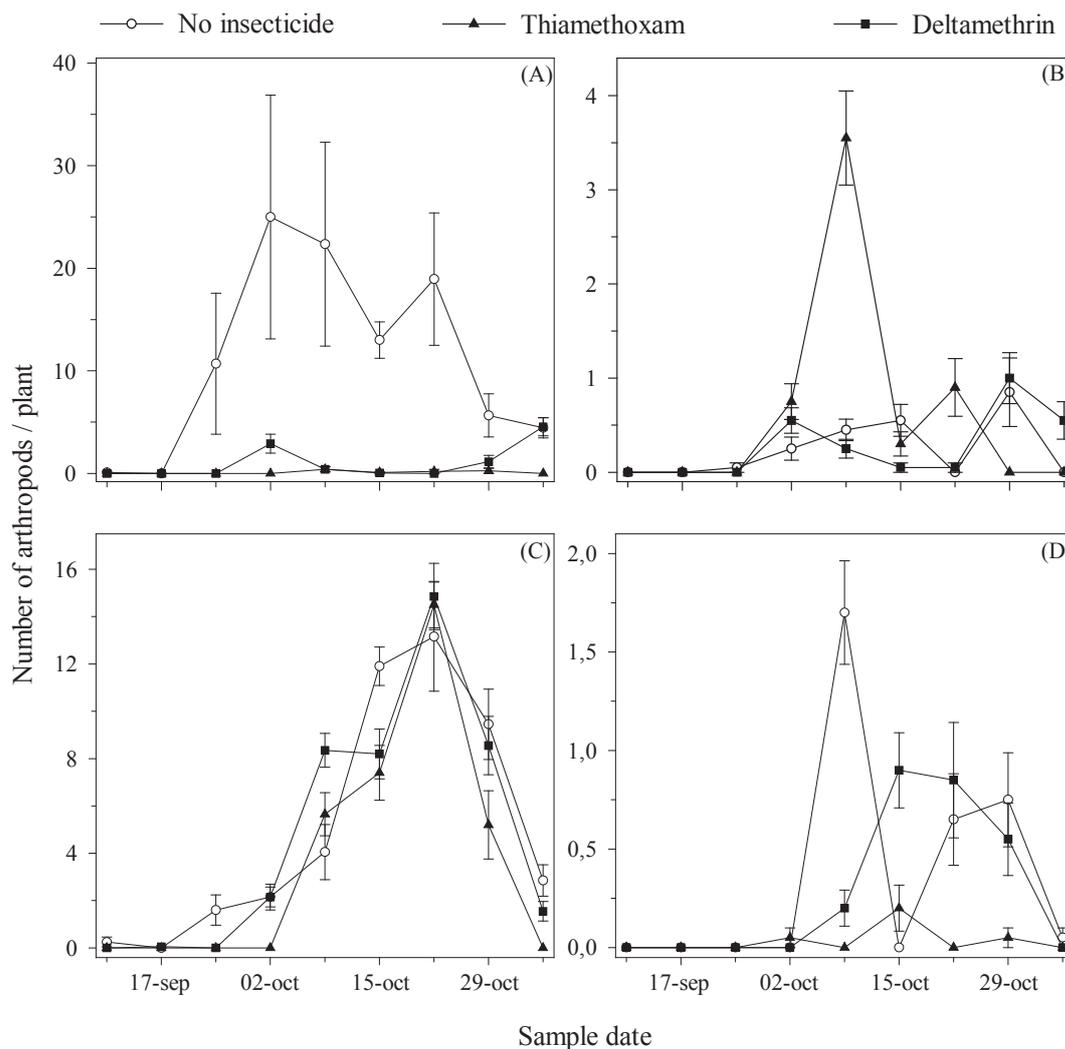
Arthropods on the soil surface

Nineteen taxa presented occurrence-frequency higher than 15% (Table 1). Among them, eight were selected as a group of arthropods that allowed to better explain the observed variation in the treatment, and were used to the subsequent analysis: Acrididae (Orthoptera), Araneae, Formicidae (Hymenoptera), Gryllidae (Orthoptera), Isotomidae (Collembola), Lagriidae (Coleoptera), Nitidulidae (Coleoptera), Reduviidae (Hemiptera) (Table 2). The ordination diagram obtained from canonical variables showed a distinction among treatments (Figure 1B). Based on Mahalanobis distance between means of classes, all treatments where insecticides were applied significantly differed by F test (p <0.05).

The following taxa positively contributed to the divergence in the first canonical axis: Nitidulidae, Reduviidae, Formicidae and Aranea. Lagriidae, Isotomidae, Gryllidae, Acrididae and Lepidoptera (larvae) contributed negatively on

this axis divergence. In the second canonical axis Nitidulidae, Isotomidae, Aranea, Lepidoptera (larvae) and Lagriidae positively contributed. Reduviidae, Formicidae, Gryllidae and Acrididae negatively contributed to the difference between treatments in the explanation of all data (Table 3).

The insecticides negatively affected the following taxa on soil surface: Nitidulidae (F = 9.18, P = 0.01), Acrididae (F = 2.60, P = 0.093), Formicidae (F = 14.04, P = 0.01), Gryllidae (F = 2.78, P = 0.08) and Araneae (F = 6.28, P = 0.01) (Figure 3).

Figure 3. Abundance (mean ± standard error) of the arthropods associated with the soil surface in function of deltamethrin and thiamethoxam application (Gurupi – TO,2009). A= Nitidulidae; B= Noctuidae; C= Acrididae; D= Gryllidae; E= Formicidae e F= Araneae.
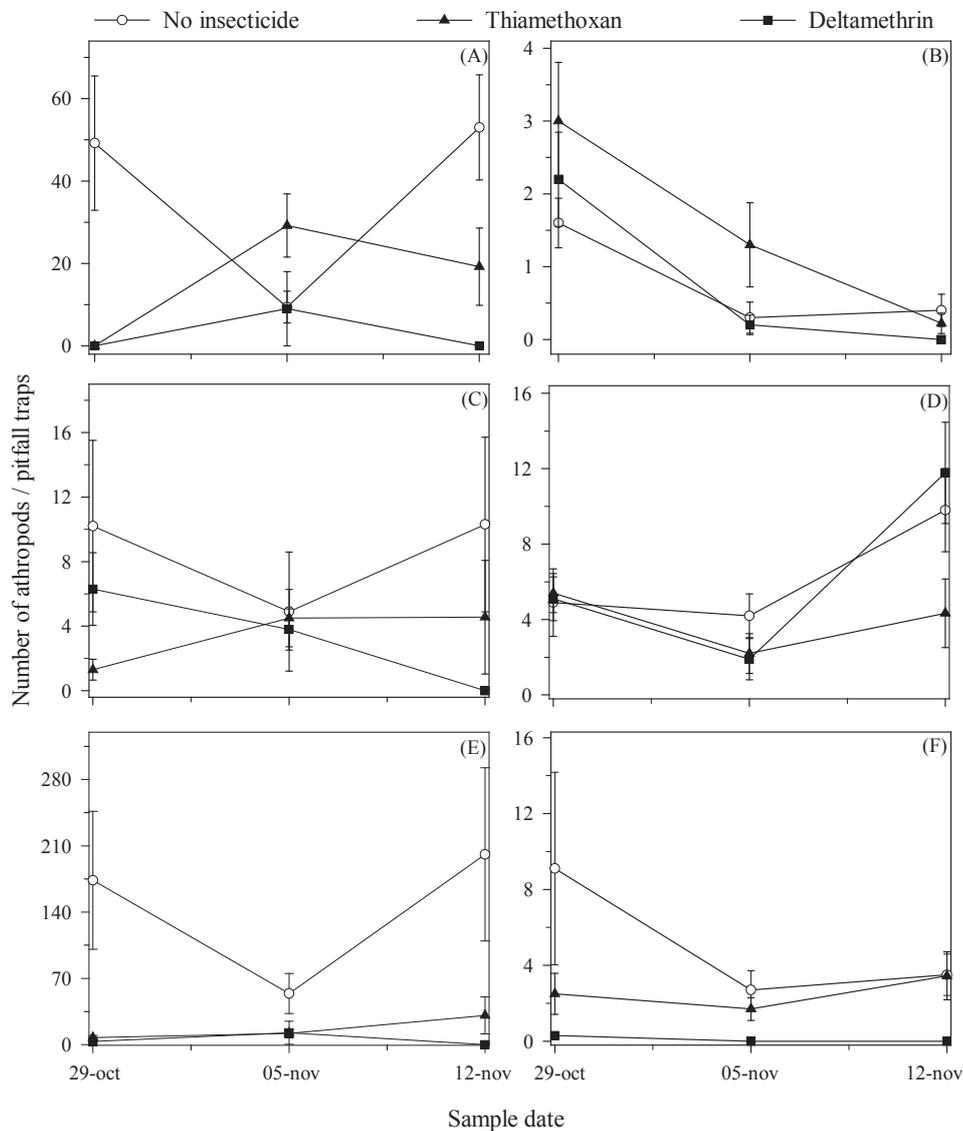
Source: Elaboration of the authors.

Discussion

The application of deltamethrin and thiamethoxam negatively affect the community of pests, natural enemies and detritivore arthropods on the canopy and on soil surface of watermelon plants. Although the effectiveness of deltamethrin and thiamethoxam in controlling *A. gossypii,* as we expected, a significant negative impact was observed on non-target organisms as those predators of the family Staphylinidae and Nitidulidae.

The use of insecticides disturbs the natural balance between guilds and some phytophagous species increase rapidly resulting in pest outbreaks. These outbreaks of pest, commonly observed in the studied region, may be induced by the reduction of predators due to insecticide applications (MARC; CANARD; YSNEL, 1999; HAWKES et al., 2005). Thiamethoxam showed the highest negative effect on the Staphylinidae taxa, compared to deltamethrin. Insects from this family include important predator species associated with watermelon plantation (PFIFFNER; LUKA, 2000; CHIVERTON, 1986), and have potential to reduce populations of agricultural pests (SUENAGA; HAMAMURA, 2001). The maintenance of the steady state among these groups is important because functional biodiversity performs key ecological services and can bring sustainability to agroecosystem (ALTIERI, 1999).

Overall, the highest negative impact on soil surface arthropods was found when the insecticide deltamethrin was applied. The use of this insecticide was responsible for the exclusion of phytophagous, predators and detritivores arthropods. A negative impact on detritivore insects of the Nitidulidae family may affect structure and soil fertility (CROSSLEY; MUELLER; PERDUE, 1992). Ants, which were also negatively affected by insecticide applications, correspond to a group of insects that play an important role on the structure of arthropod communities acting as predators (TILLBERG; BREED, 2004). Besides, soil arthropods can

also impact plant performance, plant competition and plant community composition (WARDLE et al., 2004; BARDGETT; WHITTAKER; FRANKLAND, 1993). Such impacts, however, are due to a variety of mechanisms such as belowground herbivory (SCHÄDLER et al., 2004) and an acceleration of nutrient cycling via the action of arthropod detritivores (MASTERS, 2004; ENDLWEBER; SCHEU, 2007). SCHÄDLER et al. (2004) concluded that insecticide-induced changes in plant community succession in a productive old-field were partly due to the action of a phytophagous species damaging herb species.

The insecticides of high toxicity and broad spectrum of action, such as those evaluated in this work, are being recognized as the leading cause of imbalances in agroecosystems (SOARES et al., 1994; ZHOU et al., 2010; VASSILIOU et al., 2011). Moreover, we showed that the use of such pesticides directly kills natural enemies such as those of the family Nitidulidae. In addition to direct mortality by pesticides, their sublethal effects on arthropod physiology and behavior must be considered for a complete analysis of their impact (DESNEUX; DECOURTYE; DELPUECH, 2007). As alternative to undesirable effects of broad spectrum synthetic pesticides, selective pesticides and natural pesticides have been both recommended as they are normally less harmful to natural enemies (ISMAN, 2006; DAYAN; CANTRELL; DUKE, 2009; LEMOS et al., 2011). Besides this direct effect, the arthropod community may also have suffered an indirect effect which might have been caused by the decrease in food availability to other components of the watermelon food web. For example, a reduction in predator population may have resulted in a trophic cascade (CARPENTER; KILCHELL; HODGSON, 1985). Studies on trophic cascades have shown that the use of cultural practices, such as insecticide application to decrease pest populations over time, can cause an imbalance in the arthropod community (ROBERTSON; KETTLE; SIMPSON, 1994). We conclude that the insecticides thiamethoxam and

deltamethrin negatively affect beneficial arthropod populations in watermelon crop.

Acknowledgements

References

ABBINK, J. The biochemistry of imidacloprid. *Pflanzenschutz- Nachrichten Bayer,* Germany, v. 42, n. 2, p. 183-195, 1991.

AGROFIT Sistema de agrotóxicos fitossanitários. consulta de praga/doença. 2012. Disponível em: <http://extranet.agricultura.gov.br/agrofit_cons/principal_agrofit_cons> Acesso em: 30 jan. 2012.

ALTIERI, M. A. The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystems & Environment*, Zürich, v. 74, n. 1-3, p. 19-31, 1999.

ARMENTA, R.; MARTINEZ, A. M.; CHAPMAN, J. W.; MAGALLANES, R.; GOULSON, D. Impact of a nucleopolyhedro virus bioinsecticide and selected synthetic insecticides on the abundance of insect natural enemies on maize in southern Mexico. *Journal of Economic Entomology*. Lanham, v. 96, n. 3, p. 649-661, 2003.

BACCI, L.; PEREIRA, E. J. G.; CRESPO, A. L. B.; PICANÇO, M. C. Eficiência e seletividade de inseticidas para o manejo de mosca branca e inimigos naturais em melancia. *Revista Ceres*. Viçosa, v. 54, n. 311, p. 47-54, 2007.

BADJI, C. B.; GUEDES, R. N. C.; SILVA, A. A.; ARAÚJO, R. A. Impact of deltamethrin on arthropods in maize under conventional and no-tillage cultivation. *Crop Protection*, Pullman, v. 23, n. 11, p. 1031-1039, 2004.

BARDGETT, R. D.; WHITTAKER, J. B.; FRANKLAND, J. C. The diet and food preferences of *Onychiurus procampatus* (Collembola) from upland grassland soils. *Biology and fertility of soils*, Berlin, v. 16, n. 4, p. 296-298, 1993.

BOMMARCO, R. Scale as modifier in vegetation diversity experiments: effects on herbivores and predators. *Oikos,* Copenhagen, v. 102, n. 2, p. 440-449, 2003.

CARPENTER, S. R.; KILCHELL, J. F.; HODGSON, J. R. Cascading trophic interactions and lake productivity. *Bioscience*, Berkeley, v. 35, n. 10, p. 634-639, 1985.

CHIVERTON, P. A. Predator density manipulation and its effects on populations of *Rhopalosiphum padi* (Hom.: Aphididae) in spring barley. *Annals of Applied Biology*, Helsinki, v. 109, n. 1, p. 49-60, 1986.

CROSSLEY, J. R. B.; MUELLER, R.; PERDUE, J. C. Biodiverity of microathropods in agricultural soils: relations to processes. In: PAOLETTI, M. G.; PIMENTEL, D. (Ed.). *Biotic diversity in agroecosystems*. Amsterdam: Elservier, 1992. p. 37-46.

DANXIAO, H.; CHUNRU, H.; YALING, X.; BANWANG, H.; LIYUAN, H.; PAOLETTI, M. G. Relationship between soil arthropods and soil properties in the suburb of Qianjiang city, Hubei, China. *Critical Reviews in Plant Sciences*, Philadelphia, v. 18, n. 3, p. 467-473, 1999.

DAYAN, F. E.; CANTRELL, C. L.; DUKE, S. O. Natural products in crop protection. *Bioorganic & Medicinal Chemistry*, Elsevier, v. 17, n. 12, p. 4022-4034, 2009.

DESNEUX, N.; DECOURTYE, A.; DELPUECH, J. M. The sublethal effects of pesticides on beneficial arthropods. *Annual Review of Entomology*, Palo Alto, v. 52, p. 81-106, 2007.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA – EMBRAPA. Centro Nacional de Pesquisa de Solos (Rio de Janeiro, RJ). Sistema brasileiro de classificação de solos. Brasília: Embrapa-SPI, Embrapa-CNPS, 1999. 412 p.

ENDLWEBER, K.; SCHEU, S. Interactions between mycorrhizal fungi and Collembola: effects on root structure of competing plant species. *Biology and Fertility of Soils*, Berlin, v. 43, n. 6, p. 741-749, 2007.

FERNANDES, F. F. *In vitro* activitty of permethrin, cipermethrin and deltamethrin on larvae of *Rhipicephalus sanguineus* (Latreille, 1806) (Acari, Ixodidae). *Arquivo Brasileiro de Medicina Veterinária e Zootecnia,* Belo Horizonte, v. 52, n. 6, p. 621-626, 2000.

FILGUEIRA, F. A. R. *Novo manual de olericultura:* agrotecnologia moderna na produção e comercialização de hortaliças. Viçosa, MG: UFV, 2000.

GREEN, R. H. Application of repeated measures designs in environmental impact and monitoring studies. *Australian Journal of Ecology*, Melbourne, v. 18, n. 1, p. 81-98, 1993.

HAWKES, N. J.; JANES, R. W.; HEMINGWAY, J.; VONTAS, J. Detection of resistance-associated point mutations of organophosphate-insensitive acetylcholinesterase in the olive fruit fly, *Bactrocera oleae* (Gmelin). *Pesticide Biochemistry and Physiology*, Amherst, v. 81, n. 3, p. 154-163, 2005.

ISMAN, M. B. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annual Review of Entomology*, Palo Alto, v. 51, p. 45-66, 2006.

JAMES, D. G. Pesticide susceptibility of two coccinellids (*Stethorus punctum picipes* and *Harmonia axyridis*) important in biological control of mites and aphids in Washington hops. *Biocontrol Science and Technology*, Abingdon, v. 13, n. 2, p. 253-259, 2003.

KOSS, A. M.; JENSEN, A. S.; SCHREIBER, A.; PIKE, K. S.; SNYDER, W. E. comparison of predator and pest communities in washington potato fields treated with broad-spectrum, selective, or organic insecticides. *Environmental Entomology*, Lanham, v. 34, n. 1, p. 87-95, 2005.

KRZANOWSKI, W. J.; RADLEY, D. Nonparametric confidence and tolerance regions in canonical variate analysis. *Biometrics*, Arlington, v. 45, n. 4, p. 1163-1173, 1989.

LEITE, G. L. D.; PICANÇO, M. C.; JHAM, G. N.; GUSMÃO, M. R. Fatores naturais que influenciam o ataque da mosca-branca em pimentão. *Pesquisa Agropecuária Brasileira*, Brasília, v. 37, n. 8, p. 1195-1200, 2002.

LEMOS, F.; SARMENTO, R. A.; TEODORO, A. V.; SANTOS, G. R.; NASCIMENTO, I. R. Agroecological strategies for arthropod pest management in Brazil. *Recent Patents on Food, Nutrition & Agriculture*, Sharjah, v. 3, n. 2, p. 142-154, 2011.

LUFF, M. L. Some features influencing the efficiency of pitfall traps. *Oecologia*, Berlin, v. 19, n. 4, p. 345-357, 1975.

MARC, P.; CANARD, A.; YSNEL, F. Spiders (Araneae) useful for pest limitation and bioindication. *Agriculture, Ecosystems & Environment*, Zürich, v. 74, n. 1-3, p. 229-273, 1999.

MARQUINI, F.; GUEDES, R. N. C.; PICANÇO, M. C.; REGAZZI, A. J. Response of arthropods associated with the canopy of common beans subjected to imidacloprid spraying. *Journal of Applied Entomology,* v. 126, n. 10, p. 550-556, 2002.

MASTERS, G. J. Belowground herbivores and ecosystem processes. In: WEISSER, W. W.; SIEMANN, E. (Ed.). *Insects and ecosystem function (ecological studies)*. Berlin: Springer-Verlag, 2004. v. 173, p. 93-114.

MATSUDA, K.; BUCKINGHAM, S. D.; KLEIER, D.; RAUH, J.J.; GRAUSO, M.; SATTELLE, D. B. Neonicotinoids: insecticides acting on insect nicotinic acetylcholine receptors. *Trends in Pharmacological Sciences*, Stanford, v. 22, n. 11, p. 573-580, 2001.

MOREIRA, M. A. B. *Pragas na cultura da melancia e recomendações de controle*. Aracaju: Embrapa Tabuleiros Costeiros, 2002. (Circular técnica, 29).

PAINE, M. D. Repeated measures designs. *Environmental Toxicology & Chemistry*, Malden, v. 15, n. 9, p. 1439-1441, 1996.

PECK, D. C. Comparative impacts of white grub (Coleoptera: Scarabaeidae) control products on the abundance of non-target soil-active arthropods in turfgrass. *Pedobiologia*, Berlin, v. 52, n. 5, p. 287-299, 2009.

PFIFFNER, L.; LUKA, H. Overwintering of arthropods in soils of arable fields and adjacent semi-natural habitats. *Agriculture, Ecosystem & Environment,* Zürich, v. 78, n. 3, p. 215-222, 2000.

ROBERTSON, L. N.; KETTLE, B. A.; SIMPSON, G. B. The influence of tillage practices on soil macrofauna in a semi-arid agroecosystem in northeastern Australia. *Agricultura, Ecosystems and Environment*, Zürich, v. 48, n. 2, p. 149-156, 1994.

ROCHA, L. C. D.; CARVALHO, G. A.; MOURA, A. P.; COSME, L. V.; VILELA, F. Z. Toxicidade de produtos fitossanitários utilizados na cultura do crisântemo para ovos e ninfas de *Orius insidiosus* (Say) Hemiptera: Anthocoridae). *Neotropical Entomology*, Londrina, v. 35, n. 1, p. 83-92, 2006.

RUSSO, V. M.; RUSSO, B. M.; PETERS, M.; PERKINS-VEAZIE, P. Interaction of *Colletotrichum orbiculare* with thrips and aphid feeding on watermelon seedlings, *Crop Protection*, Pullman, v. 16, n. 6, p. 581-584, 1997.

SANTOS, G. R.; SARMENTO, R. A.; CASTRO NETO, M. D.; NASCIMENTO, I. R.; IGNÁCIO, M. Influência da adubação da melancia e doenças. In: SANTOS, G. R.; ZAMBOLIM, L. (Ed.). *Tecnologias para produção sustentável de melancia no Brasil*. Viçosa: UFV, 2011a. p. 34-46.

SANTOS, V. C.; SIQUEIRA, H. A. A.; SILVA, J. E.; FARIAS, M. J. D. C. Insecticide resistance in populations of the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), from the State of Pernambuco, Brazil. *Neotropical Entomology*, Londrina, v. 40, n. 2, p. 264-270, 2011b.

SAS Institute. *SAS user's guide*: statistics. Version 8.2. 6th ed. SAS Institute, Cary, NC. 2001.

SCHÄDLER, M.; JUNG, G.; BRANDL, R.; AUGE, H. Secondary succession is influenced by belowground insect herbivory on a productive site. *Oecologia*, Berlin, v. 138, n. 2, p. 242-252, 2004.

SILVA, R. A.; CARVALHO, G. A.; CARVALHO, C. F.; REIS, P. R.; SOUZA, B.; PEREIRA, A. M. A. R. Ação de produtos fitossanitários utilizados em cafeeiros sobre pupas e adultos de *Chrysoperla externa* (Hagen, 1861) (Neuroptera: Chrysopidae). *Ciência Rural*, Santa Maria, v. 36, n. 1, p. 8-14, 2006.

SOARES, J. J.; YAMAMOTO, P. T.; GRAVENA, S.; BUSOLI, A. C. Efeito de inseticidas sobre *Anthonomus grandis* e inimigos naturais em soqueira-isca de algodoeiro. *Pesquisa Agropecuária Brasileira*, Brasília, v. 29, n. 3, p. 375-379, 1994.

SOUZA, C. R.; SARMENTO, R. A.; VENZON, M.; IGNÁCIO, M.; SANTOS, G. R.; CHAVES, C. C. Pragas associadas ao cultivo da melancia e estratégias de manejo alternativo:In: SANTOS, G. R.; ZAMBOLIM, L. (Ed.). *Tecnologia para produção sustentável de melancia no Brasil*. Viçosa: UFV, 2011. p. 158-219.

SUENAGA, H.; HAMAMURA, T. Occurrence of carabid beetles (Coleoptera: Carabidae) in cabbage fields and their possible impact on lepidopteran pests. *Applied Entomology and Zoology*, Ibaraki, v. 36, n. 1, p. 151-160, 2001.

TILLBERG, C. V.; BREED, M. D. Placing an omnivore in a complex food web: dietary contributions to adult biomass of an ant. *Biotropica*, Malden, v. 36, n. 2, p. 266-271, 2004.

TOMIZAWA, M.; CASIDA, J. E. Neonicotinoid insecticide toxicology: mechanisms of selective action. *Annual Review of Pharmacology and Toxicology*, Palo Alto, v. 45, p. 247-268, 2005.

TOMIZAWA, M.; OTSUKA, H.; MIYAMOTO, T.; ELDEFRAWI, M. E.; YAMAMOTO, I. Pharmacological characteristics of insect nicotinic acetylcholine receptor with its ion channel and the comparison of the effect of nicotinoids and neonicotinoids. *Journal Pesticide Science*, Innsbruck, v. 20, n. 1, p. 57-64, 1995a.

TOMIZAWA, M.; OTSUKA, H.; MIYAMOTO, T.; YAMAMOTO, I. Pharmacological effects of imidacloprid and its related compounds on the nicotinic acetylcholine receptor with it ion channel from Torpedo electric organ. *Journal Pesticide Science*, Innsbruck, v. 20, n. 1, p. 49-56, 1995b.

TORRES, J. B.; RUBERSON, J. R. Toxicity of thiamethoxam and imidacloprid to *Podisus nigrispinus* (Dallas) (Heteroptera: Pentatomidae) nymphs associated to aphid and whitefly control in cotton. *Neotropical Entomology*, Londrina, v. 33, n. 1, p. 99-106, 2004.

VASSILIOU, V.; EMMANOUILIDOU, M.; PERRAKIS, A.; MOROU, E.; VONTAS, J.; SAGKARAKOU, A.; RODITAKIS, E. Insecticide resistance in *Bemisia tabaci* from Cyprus. *Insect Science*, Malden, v. 18, n. 1, p. 30-39, 2011.

WARDLE, D. A.; BARDGETT, R. D.; KLIRONOMOS, J. N.; SETÄLÄ, H.; VAN DER PUTTEN, W. H.; WALL, D. H. Ecological linkages between aboveground and belowground biota. *Science*, Washington, DC, v. 304, n. 5677, p. 1629-1633, 2004.

ZHOU, X-M.; WU, Q-J.; ZHANG, Y-J.; BAI, L-Y.; HUANG, X-Y. Effects of abamectin selection on the genetic differentiation within *Plutella xylostella* (Lepidoptera: Plutellidae) based on amplified fragment length polymorphism. *Insect Science*, Malden, v. 17, n. 4, p. 353-360, 2010.