

Original Research Article

Impact of pesticides application on epiedaphic invertebrate community in tomato cultivation

ABSTRACT

Our comprehension of the pesticides effects on the soil epiedaphic invertebrates, especially non-target organisms in tomato cultivation is still incipient. Our aim was to study the effects of the pesticides application on the community composition of the total epiedaphic fauna and Coleoptera order, in a commercial tomato cultivation located at Brejão municipally, Pernambuco, Brazil. The experiment was composed of two commercial crop-production, SUPERA (Treatment 1) TY10 (Treatment 2). An area Atlantic Forest native area was used as reference (Treatment 3). Epiedaphic fauna was evaluated using pitfall traps, sampled in eleven periods. Insects were identified at the level of order and, when possible, family. A total of 2571 invertebrate were collected and distributed within 7 orders. Even among those, Coleoptera were more frequently sampled. The orders that most discriminated the areas were Coleoptera and Diptera. Within the order Coleoptera, the families Lycidae, Nitidulidae, Tenebrionidae and Cantharidae had important participation in the areas discrimination. The pesticides application had a strong effect on non-target organisms, reducing the Coleoptera family's richness. Coleoptera families that discriminated the most areas of study were more sensitive to the application of insecticides.

Keywords: *Insect's diversity; Pitfall traps; Soil fauna; Neoleucinodes elegantalis.*

1. INTRODUCTION

Brazilian agribusiness has become very attractive to tomato cultivation (*Lycopersicon esculentum*). This activity plays an economic and social importance to several regions of the country (França et al., 2006; Carvalho et al., 2016). Regarding to the world's largest producers, Brazil occupies the eighth position, with approximately 63 thousand cultivated hectares and production reaching 3.5 million tons per year⁻¹ (ABCSEM 2016). However, in Brazil, tomato cultivation has been attacked by high incidence of pests. In this case, the small tomato borer (STB) - *Neoleucinodes elegantalis* (Guenée) (Lepidoptera: Crambidae) represent the most incident key-pest, increasing production costs (Franca et al., 2017; Gravena & Benvenega, 2003).

To avoid losses due to pest attack, farmers have use the control with synthetic pesticides, being carried out intensively and sometimes applied indiscriminately (Badji et al., 2007; Ortiz-Hernández et al., 2013; Gill & Garg 2014). The use of synthetic pesticides in pest control is widely recognized as the most effective way, mainly in the STB control (Reis & Souza 1996; Franca et al., 2017). On the other hand, it is known that the indiscriminate use of pesticides can lead to several environmental problems with potential to reach and contaminate the soil, water, atmosphere, non-target organisms, including humans (Badji et al. (Gill & Garg 2014, Rigotto et al, 2014).

The edaphic fauna comprises invertebrates that live permanently or spend at least one phase of their development within the soil or on its surface (Lavelle et al., 2006). These arthropods have important ecosystemic functions, sometimes ignored, since they mainly act in the predation and the processing of substrates, which facilitates the microbial attack during the process of decomposition of the organic residues (Lavelle et al. al. 2014).

Many studies have shown only the effect of soil management (i.e., conventional or no-tillage), and not pesticides, on the composition of the epiedaphic fauna (Araújo et al., 2004). In crops such as maize, the negative influence of pesticide applications was observed, mainly in the reduction of the population of insects considered natural enemies (Badji et al., 2007). However, the influence of the application of pesticides on tomato cultivation on epigeic fauna has never been studied, making this study necessary. Thus, our aim was to study the effects caused by the pesticides application on the

total epigeic and non-target coleoptera fauna present in commercial tomato cultivation in the municipality of Brejão, Pernambuco, Brazil.

2. MATERIAL AND METHODS

2.1 Experimental site and treatments

This study was carried out in Brejão (2010) (09°01'S, 36°34'W), a municipality located in the Southern Agreste of Pernambuco, Brazil. The region has a tropical rainy climate with dry summer, being As' by the of Köppen-Geiger climatic classification. The soil was classified as Quartzeneic Neosol (Brazil soil classification system), typically dystrophic, with pH = 4.8 and with low cation exchange capacity ($<10 \text{ mmol}_c \text{ dm}^{-3}$) (Raij 2001).

Briefly, we evaluated three areas, two placed in commercial tomato cultivation, as SUPERA (Treatment 1) and TY10 (Treatment 2) varieties, where pesticide applications were present. Due to the high incidence of pests and because they are commercial production areas, it was not possible to study tomato cultivation areas without pesticides application. In this case, an area adjacent to the tomato cultivation, characterized as Native Atlantic Forest (Treatment 3) was used as reference, with no pesticide application history. This dense forest fragment was dense, unchanged by anthropogenic activity and had predominantly: *Dialium guianensis*, *Parkia pendula*, *Pradosia lactescens*, *Cordia sellowiana*, *Himatanthus phagedaenicus*, *Xylopia frutescens* and other tree species. Due to the water restriction of the region, the tomato plants received water via a drip irrigation system.

2.2 Pesticides application

Pest control was carried out daily from the beginning to the end tomato cultivation cycle. The pesticides applications were carried out manually, with the aid of a costal sprayer, without the previous monitoring of the pest density population, being carried out even when the level of action to control the potential pests was not reached. Table 1 describes the pesticides used during the experiment time.

Table 1. Pesticides used in pest control in tomato cultivation during the experiment.

Commercial name	Active ingredient	Chemical group	Use	Toxicological class
Actara	Thiamethoxam	Neonicotinoid	Inseticide	Moderately Toxic
Amistar	Azoxystrobin	Strobirulins	Fungicide	Low toxicity
Bravonil	Tetrachloroiso phthalonitrile	Isophthalonitriles	Fungicide	Extremely toxic
Orthene	Acefato	Organophosphorus	Inseticide	Low toxicity
Kasumin	Casugamicina	Antibiotic	Fungicide	Moderately Toxic
Lannate	Methomyl	Carbamate	Inseticide	Extremely toxic
Lorsban	Cloropirifós	Organophosphorus	Inseticide	Moderately Toxic
Polytrin	Profenós	Pyrethroid	Inseticide	Moderately Toxic
Pirate	Clorfenapir	Pirazol	Inseticide	Moderately Toxic

2.2 Epiedaphic community sampling

For the evaluation of the epigeic fauna, pitfall traps were installed in each treatment, covering all experimental areas (4 traps per treatment), which remained in the field during the interval between one collection and another. Each treatment had 4 replicates. Eleven collections were carried out at 8, 12, 19, 27, 33, 40, 48, 54, 61, 69 and 75 days after seedlings transplanting. The samples were

collected and stored in 90% ethanol solution, and then counted the total fauna number and order level classification. For the maize crop, Badji et al. (2007) identified that Coleoptera families was sensitive to pesticide application. Thus, in addition to the total community of invertebrates, the beetles were separated at the family level. The Figure 1 show the temperature, precipitation and relative humidity of the air in the period of each collection.

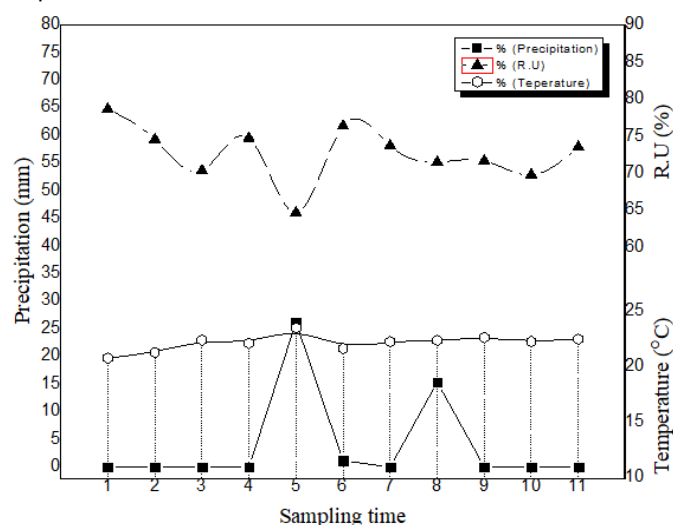


Figure 1. Climatic data on the intervals of collection of soil fauna. Values of temperature (°C) and relative humidity (%) coincide with the day of collection. Precipitation values (mm) refer to the cumulative volume of rainfall between each collection.

2.3 Statistical analyses

Previously, a Kolmogorov-Smirnov normality test was performed to test the normality of the data. The analysis of variance (ANOVA) was carried out, followed by Tukey's test ($p < 0.05$) for insect abundance according to the orders found and later for collected Coleoptera families, in order to find differences between the treatments and sampling times. The composition of epiphytic fauna was subjected to Discriminant Canonical Analysis (DCA) to identify which orders of invertebrates and/or Coleoptera families were more responsive to dissimilarities between studied areas (Baretta et al., 2008).

3. RESULTS AND DISCUSSION

2571 invertebrates were collected, distributed in 7 orders. Among these, Coleoptera was found more frequently in all treatments (Table 2).

Table 2. Average abundance and diversity of epigraphic fauna orders collected in the tomato crop (SUPERA and TY10) and in the Native Forest of reference.

Order	Abundance and Diversity (Mean $\pm$ Standard Deviation)		
	Treatment 1 (SUPERA)	Treatment 2 (TY10)	Treatment 3 (Native Forest)
Coleoptera	103.8 $\pm$ 32.4	153.5 $\pm$ 12.5 *	103.5 $\pm$ 22.9
Lepidoptera	1.5 $\pm$ 3.0	3.5 $\pm$ 2.5	1.0 $\pm$ 1.2
Heteroptera	3.3 $\pm$ 5.3	3.8 $\pm$ 4.5	2.5 $\pm$ 2.5
Hymenoptera	21.8 $\pm$ 2.2	29.8 $\pm$ 4.3	31 $\pm$ 7.9

Acarina	21.8 ± 9.9	35.8 ± 17.3	26.8 ± 19.9
Diptera	16.8 ± 5.5 *	12.0 ± 3.7	4.3 ± 2.8
Orthoptera	20.0 ± 7.1	14.8 ± 5.1	32.0 ± 16.7
Total	188.8 ± 24.4	253.0 ± 30.5 *	201.0 ± 63.4
Riqueza	5.8 ± 0.9	6.5 ± 0.6	6.0 ± 0.8
Simpson	0.65 ± 0.09	0.58 ± 0.07	0.65 ± 0.05

* Averages with an asterisk differ from one another by Tukey's test ($p < 0.05$)

There was greater abundance of Coleoptera and greater total abundance of invertebrates in TY10 than in the other treatments. In turn, the Diptera was more abundant in treatment 1 than in the other treatments (Table 2). In tomato maturation periods, there is a large increase in the concentrations of various fatty acids, carotenoids and amino acids, which are precursors of aldehydes, ketones, alcohols and volatile esters responsible for causing fruit aromas (Wang et al., 2017). which may have contributed to the greater total abundance of invertebrates in tomato crops, since these organic precursors have great palatability to the components of the epiedaphic fauna (Lavelle 1997). In addition, the greatest abundance of invertebrates in the area with tomato cultivation may be associated with the addition of chicken litter (8-10 t ha⁻¹), increasing the presence of easily degradable C source.

The occurrence of large amounts of rainfall dilutes the volatile compounds (Baldwin et al., 2000), which does not occur in the present study, in which rainfall was scarce (Figure 1). Thus, there may have been a higher concentration of these compounds, which may have attracted large numbers of invertebrates in tomato crops, even though pesticides may be highly applied in these areas.

In general, there was a greater abundance of invertebrates, as well as those belonging to the Coleoptera order in the first collections, reaching an average count of 34 and 42 individuals in the fourth collection for TY10 and SUPERA tomato varieties, respectively. From the sixth collection, there was a marked reduction in the abundance of invertebrates (Figure 2A and B). Possibly, this happened due to the intensification of the control practices of the STB, since this collection period coincided with the phase of emission of the first floral buds of the tomato, constituting a critical point for infestation of the pest.

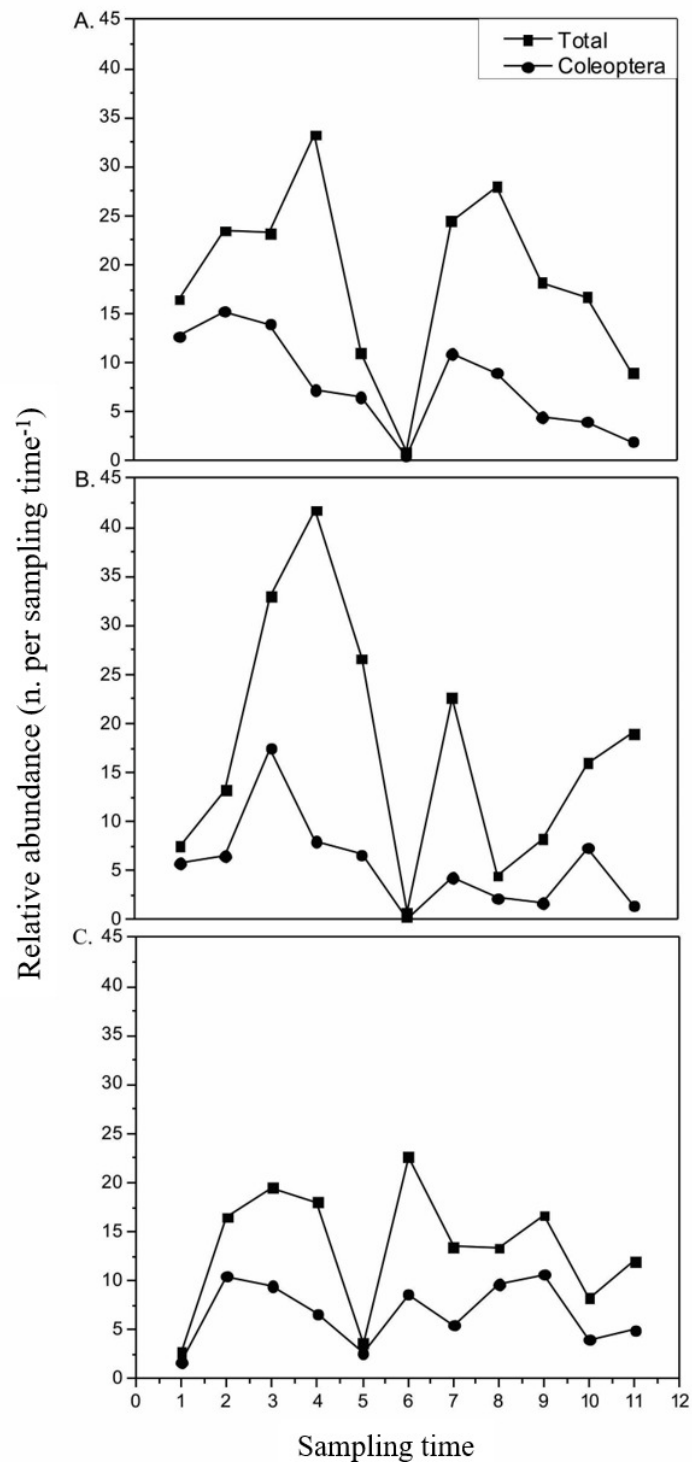


Figure 2. Influence of pesticides on the non-target epigeal fauna of the applications. Figure A indicates the variety TY10; Figure B, indicates the variety SUPERA, while figure C, refers to the Native Forest area.

The Coleoptera order had an increase in the count of individuals, with average values varying from 7 to 11 individuals in the TY10 variety between the fourth and seventh collection, while the number of beetles in the SUPERA variety was reduced from 7 to 5 individuals in the same collection interval (Figures 2A and B). In later collections, there was a gradual decrease in the abundance of this

order. In the native forest area adjacent to the crops, there was lower abundance for both total invertebrates and members of the order Coleoptera (Figure 2C). In the total invertebrate count, the native forest area presented a smaller number of individuals than the tomato cultivation sites (Treatments 1 and 2) (Table 2, Figure 2C).

The impact of the use of pesticides on non-target epigeal fauna, especially from repeated applications, has been of great concern (Badji et al., 2007), considering the valuable role that these organisms play in the soil, acting in the structuring, soil aggregation and aeration, nutrient cycling, organic matter mineralization and pest control and disease suppression (Lavelle et al., 2006; Gill & Garg, 2014). Effects on these organisms may result from the direct toxicity of the pesticide or the effect caused by the removal and / or increase in the abundance of certain species (Howell et al., 2014).

In a recent study, Nare et al. (2017) observed a strong effect of the lambda-cyhalothrin and chlorpyrifos insecticides used to control tomato pests on soil fauna. In this study, the authors reported a greater effect of pesticides on soil macrofauna members (worms, termites, beetles, ants, bedbugs, spiders, and spiders). In the latter study, in the treatments of organic fertilization, such as (bovine manure, swine manure and compound of vegetal residues + bovine manure) there was an increase in the abundance of earthworms and termites, even in the presence of pesticides.

The lowest total abundance of invertebrates, as well as of Coleoptera observed in the native forest, was possibly due to the low volume of precipitation between collection intervals (Figure 1), with occurrence of precipitation in the fifth, sixth and eighth collections, with volumes of 26.20, 1.20 and 15.60 mm accumulated in the respective intervals. Associated with this, crop irrigation management may have favored higher counts of invertebrates in tomato crops. In spite of the effect exerted by the insecticides used in the chemical control of BPT, the greater abundance of invertebrates, especially the order Coleoptera in the crops, can indicate the avoidance of invertebrate fauna from the forest to the crops, especially in dry periods, as well characterized throughout the experiment.

Discriminant canonical analysis (ACD) indicated a separation between treatments, mainly in the native forest (Figure 3).

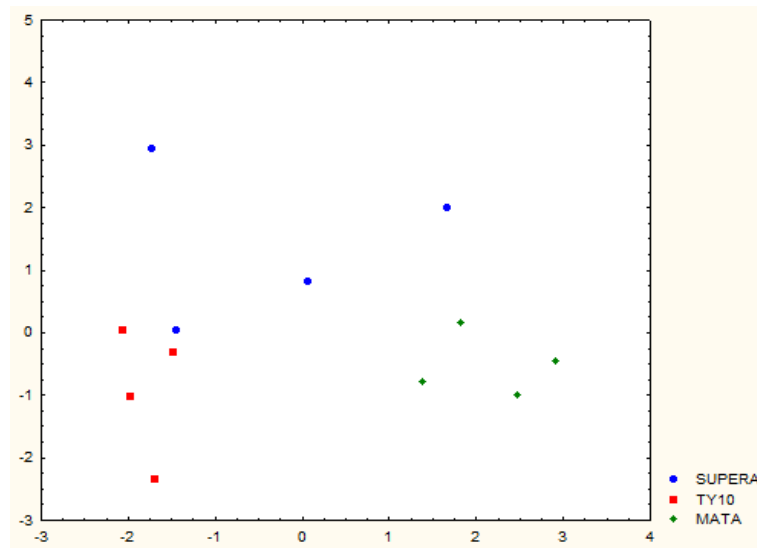


Figure 3. Discriminant Canonical Analysis (ACD) for the orders of invertebrates associated to the separation of the areas of tomato cultivation with intensive application of pesticides (SUPERA and TY10) and the reference Native Forest, without application of pesticides.

The orders of invertebrates that contributed the most to the separation of the areas were: Coleoptera ($p < 0.02$) and Diptera ($p < 0.04$). Among the insects that inhabit the soil and the litter, the

order Coleoptera is the most diverse, with 350,000 to 370,000 species described (Brown et al., 2015). These invertebrates present the most diverse feeding habits, such as rhizophagia, detritivorous, fungivory and predation, which allows them to develop in the most varied environments (Brown et al., 2015), so much that in the present study, (Table 2), possibly attracted by volatile compounds exhaled by tomato plants (Wang et al., 2017).

It is likely that the great dispersal power contributed greatly to the Diptera order discriminating areas of study (Figure 3), since hardly any winged Diptera collected in pitfall traps, especially those of the Phoridae family, present their larvae in the soil, due to the fact that they are parasites, such larvae require very specific conditions to develop and then pupate in the soil (Frouz 1999).

The analysis of variance with Tukey's test ($p < 0.05$) for the families of the order Coleoptera found only significant difference for the variable Wealth. The native forest area obtained a larger number of families than the other treatments (Table 3), considering that the order Coleoptera performs several functions in the ecosystem and the forest presents a great diversity of niches that allows colonization by more families than more simplified systems, especially to detritus and predators (Yekwayo et al., 2017).

Table 3. Average abundance of individuals and diversity of Coleoptera families collected in tomato culture.

Famílias	Abundance and Diversity (Mean $\pm$ Standard variation)		
	Treatment 1 (SUPERA)	Treatment 2 (TY10)	Treatment 3 (Native Forest)
Coccinellidae	46.3 $\pm$ 22.2	59.3 $\pm$ 15.9	60.0 $\pm$ 23.8
Staphylinidae	6.5 $\pm$ 2.5	3.3 $\pm$ 3.3	4.5 $\pm$ 3.7
Crysomelidae	1.5 $\pm$ 1.9	1.0 $\pm$ 1.41	1.0 $\pm$ 1.41
Elateridae	2.8 $\pm$ 1.5	3.3 $\pm$ 1.9	3.3 $\pm$ 3.4
Lagriidae	2.3 $\pm$ 2.6	2.8 $\pm$ 3.2	1.3 $\pm$ 2.9
Curculionidae	4.0 $\pm$ 2.9	9.3 $\pm$ 7.3	6.8 $\pm$ 7.5
Carabidae	1.0 $\pm$ 1.41	0.5 $\pm$ 0.5 A	1.8 $\pm$ 0.9
Lycidae	0.0 $\pm$ 0.0	1.0 $\pm$ 1.5	1.5 $\pm$ 1.58
Lamparydae	0.3 $\pm$ 0.50	0.0 $\pm$ 0.0	0.3 $\pm$ 0.50
Nitidulidae	0.0 $\pm$ 0.0	0.2 $\pm$ 0.5	2.0 $\pm$ 1.4
Cantharidae	0.0 $\pm$ 0.0	1.0 $\pm$ 1.4	2.0 $\pm$ 1.4
Tenebrionidae	0.0 $\pm$ 0.0	4.3 $\pm$ 8.5	3.0 $\pm$ 3.2
Riqueza	5.8 $\pm$ 0.9	6.8 $\pm$ 0.9	9.0 $\pm$ 0.2 *
Simpson	0.48 $\pm$ 0.07	0.48 $\pm$ 0.12	0.47 $\pm$ 0.21

* Means followed by asterisks differ from one another by the Tukey test ($p < 0.05$)

The ACD revealed that the families of Coleoptera that separated most of the study areas were Lycidae ($p < 0.001$), Nitidulidae ($p < 0.008$), Tenebrionidae ($p < 0.01$) and Cantharidae ($p < 0.03$) (Figure 4).

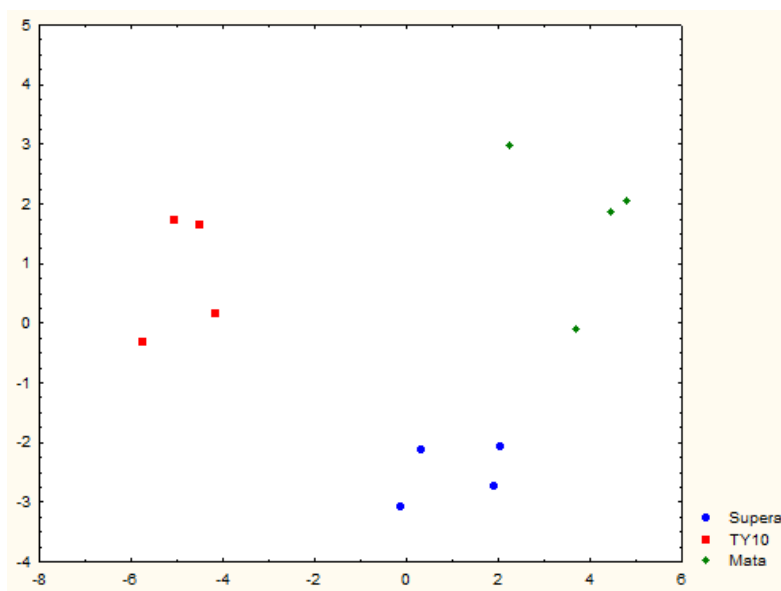


Figure 4. Discriminant Canonical Analysis (ACD) for the families of Coleoptera associated with the separation of tomato cultivation areas with intensive application of pesticides (SUPERA and TY10) and Native Forest as reference, without application of pesticides..

These invertebrates presented low abundance (Table 3) but were sampled more frequently in the forest area. The Tenebrionidae family is widely distributed in places with arid climate, but as a result of management, significant changes can be found in the community, especially at the species level, affecting the ecosystem services provided, since these beetles are found predominantly inside the soil, where they dig galleries and deeply alter the soil structure (Lescano et al., 2017).

Lamparydae, Cantharidae and Lycidae belong to the superfamily Elateroidea. Most beetles of the Lycidae and Cantharidae families are day-old and have a short life cycle, while the Cantharidae live about 3 weeks, the Lycidae, remain alive in the environment for a few hours. These beetles are predominant in forests, inhabiting mainly flowers and logs. Due to the hostile environment found in such habitats, they have developed a slightly sclerotized body, which allows the development of glands and differentiated staining patterns that protect the invertebrate from adversities, especially predators (Zaragoza-Cabalero & Perez-Hernandez 2014).

Another family of beetles that helped discriminate treatments was Nitidulidae (Figure 4). The main function of these insects is the pollination and the detritivoria, being able to be vector of yeasts and pathogenic bacteria in industrial fruits. Studies have shown that pyrethroids are effective in combating this vector (Eickermann et al., 2011), so much so that there was practically no presence of these insects in the areas cultivated with tomatoes (Table 3). However, the indiscriminate use of this compound alone can cause resistance to the insect (Heimbach & Muller 2013), which does not occur in the present study, since several insecticides are applied in tomato crops (Table 1).

The other coleopteran families sampled, cosmopolitan and less sensitive to applied insecticides, showed similar abundances and were not significant to discriminate the areas (Table 3) in both tomato and native forest. However, the impact of such pesticides on the identification of species-level beetles is not known. Possibly, the sensitivity to pesticides would be much higher and the impact of these on the edaphic invertebrate community would be more marked than that presented in the present study.

4. CONCLUSION

The application of pesticides had an effect on the total community of invertebrates and the Coleoptera order, reducing Coleoptera family wealth, but this effect did not necessarily affect the abundance of the epigenetic invertebrates. The low precipitation favored greater abundance of invertebrates in tomato areas when compared to the native forest. As the taxonomic resolution was

increased, it was possible to observe more significant differences, so much so that only two orders discriminated the study areas, whereas four families of Coleoptera were significant to discriminate such areas. Coleoptera families that discriminated the most areas of study (Lycidae, Nitidulidae, Tenebrionidae and Cantharidae) were more sensitive to the application of insecticides and showed higher affinity for the forest area.

REFERENCES

ABCSEM (Associação Brasileira do Comércio de Sementes e Mudas), Tomate lidera crescimento e lucratividade no setor de hortaliças. Disponível em: Acesso em <http://www.abcsem.com.br/noticia.php?cod=284>. 26 abr. 2016

Araújo, R.A.; Badji, C.A.; Corrêia, A.S.; Ladeira, J.A.; Guedes, R.N.C. Impacto causado por deltametrina em coleópteros de superfície do solo associados a cultura do milho em sistemas de plantio direto e convencional. *Neotropical Entomology*, v.33, p.379–385, 2004. <http://dx.doi.org/10.1590/S1519-566X2004000300017>.

Badji, C.A.; Guedes, R.N.C.; Silva, A.A.; Corrêa, A.S.; Queiroz, M.E.L.R.; Michereff-Filho, M. Non-target impact of deltamethrin on soil arthropods of maize fields under conventional and no-tillage cultivation. *Journal of Applied Entomology*, v.131, p. 50–58, 2007. doi:10.1111/j.1439-0418.2006.01118.x.

BALDWIN, E.A.; SCOTT, J.W.; SCHEWMAKER, C.K.; SCHUCH, W. Flavor trivial and tomato aroma: biochemistry and possible mechanisms for control of important aroma components. *HortScience*, v.35 p.1013-1022, 2000. <http://hortsci.ashspublications.org/content/35/6/1013.full.pdf+html>. 8 mai. 2017.

Baretta, D.; Maluche-Baretta, C.R.D.; Cardoso, E.J.B.N. Análise multivariada de atributos microbiológicos e químicos do solo em floresta com *Araucaria angustifolia*. *Revista Brasileira de Ciência do Solo*, v. 32, p. 2683-2691, 2008. <http://dx.doi.org/10.1590/S0100-06832008000700011>.

Brown, G.G.; Niva, C.N.; Zagatto, M.R.G.; Ferreira, S.; Nadolny, H.; Cardoso, G.; Santos, A.; Martinez, G.; Pasini, A.; Bartz, M.L.C.; Sautter, K.D.; Thomazini, M.J.; Baretta, D.; Silva, E.; Antonioli, Z.I.; Decaens, T.; Lavelle, P.; Sousa, J.P.; Carvalho, F.C. Biodiversidade da fauna do solo e sua contribuição para os serviços ambientais. In: Parron, L.; Garcia, J.R.; Oliveira, E.B.; Brown, G.G.; Prado, R.B. Serviços ambientais em sistemas agrícolas e florestais do bioma mata atlântica. Brasília, DF: Ministério da Agricultura, Pecuária e Abastecimento, 2015, 370 p.

Carvalho, C.R.F.; Ponciano, N.J.; De Souza, C.L.Melo. Levantamento dos agrotóxicos e manejo na cultura do tomateiro no município de Cambuci-RJ. *Revista Ciência Agrícola*, v.14, n.1, p. 15-28, 2016. <http://www.seer.ufal.br/index.php/revistacienciaagricola/article/view/2327/2374>.

Eickermann, M.; Delfosse, P.; Hoffmann, L.; Beyer, M. A note on the insecticide sensitivity status of the *Meligethes* species (Coleoptera: Nitidulidae) in Luxembourg. *Journal of plant disease and protection*, v.18, p.134-140, 2011. <http://doi.org/10.1007/BF03356393>

- 290 Frouz, J. Use of soil dwelling Diptera (insecta: Diptera) as bioindicators: a review of
291 ecological requirements and response to disturbance. *Agriculture, Ecosystem and*
292 *Environment*, v. 74, p. 167-186, 1999. [https://doi.org/10.1016/S0167-8809\(99\)00036-5](https://doi.org/10.1016/S0167-8809(99)00036-5).
- 293 Gill, H.K.; Garg, H. Pesticides: Environmental Impacts and Management Strategies,
294 Pesticides - Toxic Aspects, Dr. Sonia Soloneski (Ed.), *InTech*, 2014. DOI: 10.5772/57399.
295 Available from: [https://www.intechopen.com/books/pesticides-toxic-aspects/pesticides-](https://www.intechopen.com/books/pesticides-toxic-aspects/pesticides-environmental-impacts-and-management-strategies)
296 [environmental-impacts-and-management-strategies](https://www.intechopen.com/books/pesticides-toxic-aspects/pesticides-environmental-impacts-and-management-strategies). 12 mai, 2017.
- 297 Gravena S, Benvenha SR (2003). Manual prático para manejo ecológico de pragas do tomate.
298 *Gravena-Man Ecol.* LTDA: Jaboticabal.
- 299
- 300 Heimbach, C.H.; Muller, A. Incidence of pyrethroid-resistant oilseed rape pests in Germany.
301 *Pest Management Science*, v.69, p.2019-216, 2013. <http://doi.org/10.1002/ps.3351>.
- 302 Howell, C.C.; Hilton, S.; Semple, K.T.; Bending, G.D. Resistance and resilience responses of
303 a range of soil eukaryote and bacterial taxa to fungicide application. *Chemosphere*, Oxford,
304 v.112, p.194-202, 2014. <https://doi.org/10.1016/j.chemosphere.2014.03.031>.
- 305 Lavelle, P. Faunal activities and soil processes: adaptive strategies that determine ecosystem
306 function. *Advances in Ecological Research*, v. 27, p. 93-132, 1997.
307 [http://doi.org/10.1016/S0065-2504\(08\)60007-0](http://doi.org/10.1016/S0065-2504(08)60007-0)
- 308 Lavelle, P.; Decaens, T.; Aubert, M.; Blouin, M.; Bureau, F.; Margerie, P.; Mora, P.; Rossi,
309 J.P. Soil invertebrates and ecosystems services. *European Journal of Soil Biology*, v. 42, p.
310 S3-S15, 2006. <https://doi.org/10.1016/j.ejsobi.2006.10.002>.
- 311 Lescano, M.N.; Elizalde, L.; Werenkraut, V.; Pirk, G.I.; Flores, G.E. Ant and tenebrionidae
312 beetle assemblages in arid lands: Their associations with vegetation types in the Patagonian
313 steppe. *Journal of arid environments*, v. 138. p. 51-57, 2017.
314 <http://dx.doi.org/10.1016/j.jaridenv.2016.12.002>.
- 315 Marichal, R.; Grimaldi, M.; Feijoo, A.M.; Oszwald, J.; Praxedes, C.; Cobo, D.H.R.; Hurtado,
316 M.P.; Desjardins, T.; Silva Junior, M.L.; Costa, L.G.S.; Miranda, I.S.; Oliveira, M.N.D.;
317 Brown, G.G.; Tselouiko, S.; Martins, M.B.; Decaens, T.; Velasquez, E.; Lavelle, P. Soil
318 macroinvertebrates communities and ecosystems services in deforested landscapes of
319 Amazonia. *Applied Soil Ecology*, v.83, p.177-185, 2014.
320 <https://doi.org/10.1016/j.apsoil.2014.05.006>.
- 321 Nare, R.W.A.; Savadogo, P.W.; Traore, M.; Gountan, A.; Nacro, H.B.; Sedogo, M.P. Soil
322 macrofauna behaviour in the presence of pesticides and organic amendments. *Journal of*
323 *Geoscience and Environment Protection*, v.5, p.202-212, 2017. DOI:
324 <https://doi.org/10.4236/gep.2017.53014>.
- 325
- 326 Ortiz-Hernández, M.L.; Sánchez-Salinas, E.; Dantán-González, E.; Castrejón-Godínez, M.L.
327 Pesticide Biodegradation: Mechanisms, Genetics and Strategies to Enhance the Process. In:
328 Chamy, R. e Rosenkranz, F. (Ed.). Biodegradation – Life of Science. Rijeka: *Intech*, 2013.
329 p.251-287.
- 330
- 331 Raij, B. Van.; Andrade, J.C.; Cantarella, H.; Quaggio, J.A. Análise química para avaliação da
332 fertilidade de solos tropicais. Campinas, *Instituto Agrônomo*, 2001. 284p.

- 333 Reis, P.R.; Souza, J.C. Controle da Broca-pequena, *Neoleucinodes elegantalis* (Guenée)
334 (Lepidoptera: Pyralidae), com Inseticidas Fisiológicos, em Tomateiro Estaqueado. **An. Soc.**
335 **Entomol. Brasil**, v.25: p.65- 69, 1996.
- 336 Rigotto, R.M.; Vasconcelos, D.P.E.; Rocha, M.M. Pesticide use in Brazil and problems for
337 public health. *Cadernos de Saúde Pública*, Rio de Janeiro, v. 30, p. 1360-1362, 2014.
338 <http://dx.doi.org/10.1590/0102-311XPE020714>.
- 339 Franca, S.M.; Oliveira, J.V.; Badji, C.A.; Guedes, C.A.; Duarte, B.L.R.; Oliveira, C.M.;
340 Breda, M.O. Management of *Neoleucinodes elegantalis* (Lepidoptera: Crambidae) in
341 tomatoes using mating disruption and attract and kill. *Journal of Agricultural Science and*
342 *Technology*, v.19, p.133-144, 2017. http://jast.modares.ac.ir/article_15931.html.
- 343
344 França, S.M.; Oliveira, J.V.; Badji, C.A.; Guedes, C.A.; Barbara. L.R.; Breda, M.O.
345 Integrated management of tomato fruit borer (*Neoleucinodes elegantalis*). *African Journal of*
346 *Agricultural Research*, v. 10, p. 4561-4569, 2015 DOI: 10.5897/AJAR2015.10171 Article
347 Number: A46C06A56332.
- 348
349 Wang, L.; Baldwin, E.A.; Bai, J. Recent advance in aromatic volatile research in tomato fruit:
350 The metabolism and regulations. *Food and Bioprocess Technology*, v.9, p.203-216, 2017.
351 <http://doi.org/10.1007/s11947-015-1638-1>.
- 352 Yekwayo, I.; Pryke, J.S.; Roets, S.; Samways, M.J. Response of ground living arthropods to
353 landscape contrast and context in a forest grassland mosaic. *Biodiversity and Conservation*,
354 v.3, p. 631-651, 2017. <https://doi.org/10.1007/s10531-016-1262-z>.
- 355 Zaragoza-Cabalero, S.; Perez-Hernandez, C.X. Biodiversidad de cantaroides: Coleoptera:
356 Elateroidea [Cantharidae, Lampyridae, Lycidae, Phengodidae, Telegeusidae] em México.
357 *Revista Mexicana de Biodiversidad*, v.85, p.S279-S289, 2014.
358 <http://doi.org/10.7550/rmb.31748>.