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# Diversity of insects in conventional and organic tomato crops (*Solanum lycopersicum* L., solanaceae)

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**This study aims to compare the diversity and relative abundance of insect families collected in organic and conventional tomato production systems located in Alagoas, Northeast Brazil (09°81'76"S and 36°59'42"W). In this region, the visible spectrum is quite broad with sunlight throughout the year. Between rows of tomato plants, we set up a system of colored traps colored blue, yellow, white, green, red, and transparent. The experiment was between September 2015 and January 2017. The experimental design was completely randomized with six experiments and with five replicates. The data collected were analyzed using the Scott-Knott test at 5% probability. Analysis of the various diversity indices was made using DivEs software. A total of 56,955 insects from 25 families were collected from the organic system, and 10,660 from 22 families in the conventional system. We observed that, in the conventional system, insect diversity and relative abundance (AR) were significantly greater than those of the organic system. The averages of the indices were as follows: For the organic system: Shannon-Wiener, 2.97; Simpson, 0.79; Simpson Dominance, 0.19; Margalef, 5.13; and Pielou, 2.27, respectively. For the conventional system, the indices were 3.49; 0.86; 0.12; 6.93; and 2.56; respectively. Several families of insect orders collected in the colored traps showed significant mean values for families of pollinator insects, predators, parasitoids, and pests. This may aid in decision making for the protection of plants and other agroecosystems. The collected insects did not differ significantly in terms of diversity of families. Colored traps may be exploited for pest control and for conservation of insect.**

**Key words:** Vegetables, agricultural management, agroecology, plant protection.

## INTRODUCTION

Tomato is very important in Brazil, being the second most important vegetable crop. However, disease and pest infestation in crop have caused significant damage to tomato production. These insects' damages generate morphological and physiological derangements in the tomato, causing them to ripen irregularly (Santos et al.,

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2008b).

Environmental variation contributes diversity of species in natural ecosystems and in agroecosystems, where farm managers follow procedures aimed at causing the least impact to the environment. This applies regardless of whether the system is conventional or organic (Alencar et al., 2013). When the agroecosystem is managed with chemicals and the control of insects is done by insecticides, the diversity is damaged. Unlike the organic system, the diversity is represented by several families of insects (Letourneau and Goldstein, 2001).

Plants protect themselves through the visible portion of the electromagnetic spectrum because colors motivate insects to search for food, locate mating sites, lay eggs, and pollinate (Skorupski and Chittka, 2010; Wanga et al*.,* 2013). Paula et al. (2015) point out that colored traps may provide a potential alternative for insect control and integrated pest management. It may be possible to use such a system to monitor fluctuations in insect species and richness.

Vrdoljak and Samways (2012) argue that yellow color, compared with other colors, leads to a higher number of insects captured, with yellow traps catching insects from various groups in several growing areas and natural systems. Campos (2008) showed that various trap colors attract insects in agricultural settings and forests.

Predator insects are important in the agricultural context because they feed on other insects and control their populations. Predators are abundant in agricultural environments that have adequate management for pest control (Harterreiten- Souza et al., 2011).

Therefore, it is necessary to know which groups of insects associated with the tomato crop are attracted by what colors, in order to define a strategy for the use of colored adhesive traps for the attraction and capture of insect pests, or only attraction of beneficial insects without catching them and eliminating them from the environment.

We hypothesized that colored traps would reveal similar indices of insect diversity in conventional and organic production systems. The objective was to compare the diversity and richness indices of insect families collected in conventional and organic production systems for the tomato (*Solanum lycopersicum* L.), for the management of insects pests in crops.


**Figure 1**. Colored traps made with PET bottles placed on tomato crops.
Source: The author (2015).

## MATERIALS AND METHODS

### Research area

The study was carried out in two commercial tomato growing farms, both in Alagoas, (09°81'76"S and 36°59'42''W) in Northeast Brazil, with an altitude of 264 m. One farm was conventional and another was organic. The two agricultural areas cultivated several vegetables, in addition to tomato. The experiment was created 45 days after emergence (DAE) of the seedlings between September 2015 and January 2017. The conventional and organic systems had the same distribution of tomatoes, with single rows spaced 1.5 and 25 m long. Each plot occupied an area of 1.5 ha, with approximately 6,000 ft of tomato. Organic farming has natural product management and conventional management uses synthetic products. The planted varieties were TY-2006 and Santa Clara. In both areas, the soil was predominantly eutrophic yellow Red Latosol (Embrapa, 2009). The climate is Köppen type As', that is, tropical and warm, with minimum average temperatures of 23°C and maximum average temperature 32°C. Rainfall in autumn/winter is between 500 mm and 1,000 mm (Alagoas, 2017).

### Trap set-up and monitoring

The traps were made from plastic bottles, type Polyethylene Terephthalate (PET) with capacity of 2.5 L. Eighteen bottles were painted blue, yellow, white, green, red, and unpainted (transparent), three bottles for each color. To monitor insects in each experimental area, the colored PET bottles were installed randomly, mounted with the mouth fitted onto a 1.2 m bamboo stalk, close to the height of tomato plants. We applied entomological glue over a 75.00 $cm^2$ area of the bottle body (Fig. 1A, B, C, D, and F.). The traps were initially placed in the field as pre-test and positive results were obtained regarding the use and adaptation for experimental design (Figure 1).

### Experimental design and statistical analysis

The experimental design was a randomized block with six treatments: PET0 - colorless, PET1 - yellow, PET2 - green, PET3 - red, PET4 - white, PET5 – blue. The experiment was carried out over four crop cycles. The traps were randomly arranged. For comparison purposes, insect data collected and identified at the family level were analyzed using analysis of variance - ANOVA and the Scott-Knott test at 5% probability using Assistat Software Version 7.7 (Silva and Azevedo, 2016).

### Methodological procedures

The insects caught in the traps were counted and removed in the field with the aid of a clamp and organic solvent, every five days.

**Table 1.** Average number of insects per families in the conventional system collected by the colored traps by the Skott-Nott test at 5% probability (collection period February 2015 to January / 2017) - Arapiraca-AL.

| Famílies | Average number of insects per family | | | | | |
|---|---|---|---|---|---|---|
| | PET yellow | PET blue | PET white | PET green | PET red | PET colorless |
| Agromyzidae | 85.00$^{B}$ | 300.00$^{A}$ | 308.00$^{A}$ | 68.00$^{B}$ | 62.66$^{B}$ | 64.00$^{B}$ |
| Aphididae | 30.66$^{B}$ | 1.00$^{D}$ | 20.00$^{C}$ | 1.00$^{D}$ | 45.33$^{A}$ | 1.00$^{D}$ |
| Apidae | 46.66$^{A}$ | 10.66$^{C}$ | 22.66$^{B}$ | 1.00$^{D}$ | 22.66$^{B}$ | 1.00$^{D}$ |
| Asilidae | 4.00$^{C}$ | 21.33$^{A}$ | 10.66$^{B}$ | 2.66$^{C}$ | 5.33$^{C}$ | 2.66$^{C}$ |
| Blattidae | 1.33$^{C}$ | 1.00$^{D}$ | 1.00$^{D}$ | 2.66$^{B}$ | 4.00$^{A}$ | 1.00$^{D}$ |
| Calliphoridae | 10.66$^{C}$ | 36.00$^{B}$ | 60.00$^{A}$ | 1.33$^{D}$ | 1.33$^{D}$ | 1.33$^{D}$ |
| Cicadelidae | 16.00$^{A}$ | 2.66$^{B}$ | 1.33$^{B}$ | 1.00$^{B}$ | 1.00$^{B}$ | 5.33$^{B}$ |
| Carabidae | 4.00$^{A}$ | 1.33$^{B}$ | 1.33$^{B}$ | 1.00$^{B}$ | 1.33$^{B}$ | 1.33$^{B}$ |
| Coccinellidae | 1.00$^{B}$ | 2.66$^{A}$ | 1.00$^{B}$ | 4.00$^{A}$ | 1.33$^{B}$ | 1.00$^{B}$ |
| Curculionidae | 1.33$^{A}$ | 1.66$^{A}$ | 1.33$^{B}$ | 1.00$^{B}$ | 1.33$^{A}$ | 1.33$^{A}$ |
| Elateridae | 32.00$^{B}$ | 41.33$^{A}$ | 18.66$^{C}$ | 8.00$^{C}$ | 14.00$^{C}$ | 12.00$^{C}$ |
| Formicidae | 42.66$^{B}$ | 36.00$^{B}$ | 34.66$^{B}$ | 42.66$^{B}$ | 58.66$^{A}$ | 68.00$^{A}$ |
| Muscidae | 32.00$^{C}$ | 100.0$^{A}$ | 66.66$^{B}$ | 4.00$^{D}$ | 10.66$^{D}$ | 16.00$^{D}$ |
| Nymphalidae | 1.00$^{B}$ | 6.66$^{A}$ | 1.00$^{B}$ | 1.00$^{B}$ | 2.66$^{B}$ | 4.00$^{B}$ |
| Passalidae | 5.33$^{A}$ | 1.00$^{B}$ | 1.00$^{B}$ | 10.66$^{A}$ | 2.66$^{A}$ | 5.33$^{A}$ |
| Pompilidae | 1.00$^{B}$ | 9.33$^{A}$ | 8.00$^{A}$ | 12.00$^{A}$ | 1.00$^{B}$ | 1.00$^{B}$ |
| Reduviidae | 1.00$^{B}$ | 1.00$^{B}$ | 4.00$^{B}$ | 2.66$^{B}$ | 14.66$^{A}$ | 6.66$^{B}$ |
| Scarabaeidae | 20.00$^{C}$ | 37.33$^{B}$ | 6.66$^{C}$ | 54.66$^{A}$ | 50.66$^{A}$ | 3.00$^{B}$ |
| Scoliidae | 2.66$^{C}$ | 8.00$^{A}$ | 4.00$^{B}$ | 5.33$^{B}$ | 1.00$^{D}$ | 1.00$^{D}$ |
| Tabanidae | 45.33$^{C}$ | 208.00$^{B}$ | 289.33$^{A}$ | 13.33$^{D}$ | 10.66$^{D}$ | 6.66$^{D}$ |
| Thripidae | 10.66$^{E}$ | 93.33$^{B}$ | 129.33$^{A}$ | 14.66$^{E}$ | 56.00$^{C}$ | 30.66$^{D}$ |
| Vespidae | 25.33$^{A}$ | 12.00$^{B}$ | 20.00$^{A}$ | 8.00$^{B}$ | 1.33$^{B}$ | 17.33$^{A}$ |

Mean values not followed by the same letter differ significantly in the row by the Scott-Knott test at 5% probability.
Source: Research data.

Insects were placed in jars containing 70% alcohol and that were deposited in the Laboratory of Ecology and Biodiversity of the State University of Alagoas/Campus I, for screening and identification. Insect identification was carried out by stereoscopic binocular microscopy (Opton®) at 80x. Identifications were made with the aid of arthropod pictorial identification keys and with images from entomological taxonomies (Seltmann, 2004; Carrano-Moreira, 2015; Rafael et al., 2012).

### Analysis of insect family diversity indices

For the analysis of diversity, the following indices were considered: diversity (Shannon-Wiener, Simpson), richness (Margalef), dominance (Simpson), and evenness (Pielou). These parameters were analyzed using DivEs software (Rodrigues, 2016). Relative abundance (AR) for insect families was described by the formula AR (%) = n / N x 100, where AR = abundance percentage, n = number of specimens of the order and family, and N = total number of specimens captured in each system (Soares et al., 2016).

## RESULTS AND DISCUSSION

During the period of the research (2015 to 2017), we collected 56,955 insects in the organic system and 10,660 in the conventional system. We considered for analysis only insects that are ≥ 1 were captured. The traps attracted 22 families to the conventional system and 25 in the organic system.

Amaral et al. (2010) describe densely wooded areas with well-adapted insect diversity, some attracted by colors more than the others. The control of insects in agricultural systems with agroecological management, diversity is sustainable (Letourneau and Bothwell, 2008).

Table 1 displays comparison data for the conventional system using the Scott-Knott test at 5% probability, for 22 families collected in the colored traps. The order Diptera was most prominent, with the Agromizidae and Tabanidae families being most collected in the blue and white traps. Santos et al. (2008a) reported that yellow most attracted the Agromizidae family. This order is second highest in terms of number of species, accounting for a very varied niche, including hematophagous insects, phytophagous insects, miners, predators, parasitoids, and pollinators (Azevedo et al., 2015). The Tabanidae family are dipterans of veterinary and medical interest. Those that are ectoparasites of horses, prefer dark brown and reddish brown animals (Bassi et al., 2000; Mikuška et al., 2016).

Santos et al. (2008b) points out that insects can be

**Table 2.** Average number of insects per families in the organic system collected by the colored traps by the Skott-Nott test at 5% probability (collection period February 2015 to January / 2017) - Arapiraca-AL.

| Famílies | Average number of insects per family | | | | | |
|---|---|---|---|---|---|---|
| | PET yellow | PET blue | PET white | PET green | PET red | PET colorless |
| Agromyzidae | 128.00$^{B}$ | 173.33$^{A}$ | 93.33$^{B}$ | 76.00$^{B}$ | 232.00$^{A}$ | 40.00$^{B}$ |
| Apidae | 20.00$^{A}$ | 13.33$^{A}$ | 8.00$^{B}$ | 6.66$^{B}$ | 4.00$^{B}$ | 1.33$^{B}$ |
| Asilidae | 85.33$^{B}$ | 49.33$^{C}$ | 140.00$^{A}$ | 8.00$^{C}$ | 12.00$^{C}$ | 46.66$^{C}$ |
| Blattidae | 1.00$^{C}$ | 1.00$^{C}$ | 1.00$^{C}$ | 1.33$^{B}$ | 2.66$^{A}$ | 1.33$^{B}$ |
| Calliphoridae | 73.33$^{A}$ | 166.66$^{A}$ | 80.00$^{A}$ | 20.00$^{B}$ | 100.00$^{A}$ | 46.66$^{B}$ |
| Carabidae | 66.66$^{C}$ | 82.66$^{B}$ | 200.00$^{B}$ | 93.33$^{B}$ | 966.66$^{A}$ | 213.33$^{B}$ |
| Cicadelidae | 786.0$^{A}$ | 498.0$^{A}$ | 151.0$^{B}$ | 126.0$^{B}$ | 66.6 $^{C}$ | 248.0$^{B}$ |
| Coccinelidae | 20.00$^{A}$ | 1.00$^{B}$ | 2.66$^{B}$ | 0.00$^{B}$ | 24.00$^{A}$ | 6.66$^{B}$ |
| Chrysomelidae | 1573.33$^{A}$ | 800.00$^{B}$ | 300.00$^{D}$ | 253.33$^{D}$ | 133.33$^{D}$ | 500.00$^{C}$ |
| Curculionidae | 1.33$^{B}$ | 28.00$^{A}$ | 1.33$^{B}$ | 5.33$^{B}$ | 1.33$^{B}$ | 1.00$^{B}$ |
| Formicidae | 6.66$^{B}$ | 48.00$^{A}$ | 38.66$^{A}$ | 10.66$^{B}$ | 13.33$^{B}$ | 4.00$^{B}$ |
| Miridae | 20.00$^{B}$ | 1.00$^{D}$ | 4.00$^{C}$ | 6.66$^{C}$ | 40.00$^{A}$ | 1.00$^{D}$ |
| Muscidae | 27.00$^{C}$ | 267.66$^{B}$ | 120.33$^{C}$ | 187.00$^{B}$ | 469.33$^{A}$ | 173.33$^{B}$ |
| Nitidulidae | 46.66$^{C}$ | 200.33$^{B}$ | 1.00$^{C}$ | 1.00$^{C}$ | 286.6$^{A}$ | 1.00$^{C}$ |
| Notodontidae | 28.66$^{B}$ | 16.00$^{C}$ | 6.66$^{C}$ | 9.33$^{C}$ | 66.66$^{A}$ | 13.33$^{C}$ |
| Pompilidae | 5.33$^{C}$ | 13.33$^{B}$ | 1.00$^{B}$ | 1.00$^{B}$ | 80.00$^{A}$ | 1.00$^{B}$ |
| Reduviidae | 4.00$^{B}$ | 24.33$^{A}$ | 1.00$^{B}$ | 1.00$^{B}$ | 1.33$^{B}$ | 1.00$^{B}$ |
| Scarabaeidae | 767.00$^{C}$ | 1634.33$^{B}$ | 267.00$^{D}$ | 273.33$^{D}$ | 3003.33$^{A}$ | 142.66$^{D}$ |
| Sphecidae | 12.00$^{A}$ | 1.00$^{B}$ | 1.00$^{B}$ | 1.00$^{B}$ | 14.66$^{A}$ | 5.33$^{B}$ |
| Sthaphylinidae | 52.00$^{B}$ | 97.33$^{B}$ | 120.00$^{B}$ | 21.33$^{B}$ | 6.66$^{B}$ | 346.66$^{A}$ |
| Stratiomyidae | 53.33$^{C}$ | 560.00$^{A}$ | 270.66$^{B}$ | 126.66$^{C}$ | 453.33$^{A}$ | 212.66$^{C}$ |
| Syrphidae | 1.33$^{B}$ | 1.00$^{B}$ | 1.33$^{B}$ | 1.00$^{B}$ | 6.66$^{A}$ | 1.00$^{B}$ |
| Tabanidae | 29.33$^{B}$ | 40.00$^{B}$ | 1.00$^{C}$ | 1.00$^{C}$ | 262.66$^{A}$ | 6.66$^{C}$ |
| Thripidae | 24.00$^{D}$ | 500.00$^{A}$ | 82.66$^{B}$ | 44.00$^{C}$ | 34.66$^{C}$ | 40.00$^{C}$ |
| Vespidae | 4.00$^{B}$ | 2.66$^{B}$ | 16.00$^{A}$ | 1.00$^{B}$ | 1.00$^{B}$ | 1.00$^{B}$ |

Mean values not followed by the same letter differ significantly in the row by the Scott-Knott test at 5% probability.
Source: Research data.

attracted by different colors. For example, *Lyriomiza trifolii* (Burgess, 1880) (Diptera: Agromyzidae) is attracted by yellow, and *Thrips tabaci* (Lindeman, 1889) *(*Thysanoptera: Thripidae) by blue. However, Vrdoljak and Samways (2012) highlight that yellow and black may be repellent to some families and attractive to others.

The Apidae family, who is important for tomato pollination in the conventional system, comprised 46.66% of insects collected in the yellow traps. Barbosa et al. (2016) reported the presence of *Apis mellifera* (Linnaeus, 1758) and *Trigona spinipes* (Fabricius, 1793), of the Apidae family. Freitas et al. (2006) commented that bees of the genus *Exomalopsis*, *Epicharis* and *Centris* were good tomato pollinators. *Nanotrigona pirilampoides* (Cresson, 1878) (Hymenoptera: Apidae), use a mechanism involving wing vibration that results in cross-pollination of heavier fruits with more seeds (Cauich et al., 2004; Castro et al., 2006) (Table 1).

Table 2 displays 25 insect families in the organic system by the Scott-Nott average comparison test, at 5% probability. The number of insects was higher in the organic system than in the conventional system. As for the diversity of insect families, the organic system was slightly larger than the conventional system. Santos et al. (2008a) suggested that yellow attracted adults of *Diabrotica speciosa* (Germar, 1824), (Coleoptera: Chrysomelidae), *Bemisia tabaci* (Gennadius, 1889) (Hemiptera: Aleyrodidae), *Liriomyza trifolii* (Burgess, 1880) (Diptera: Agromyzidae), *Myzus persicae* (Sulzer, 1776)*,* and *Macrosiphum euphobiae* (Thomas, 1878) (Hemiptera: Aphididae).

The diversity of families and the number of insects can serve as bioindicators of diversified management, indicating polyculture areas where shrub and tree plants such as the neem (*Azadirachta indica* A. Juss.; Meliaceae) function as wind barriers. In addition, the growing area includes cashew (*Anacardium occidentale* L.; Anacardiaceae), guava (*Psidium guajava* L.*;* Myrtaceae), mango (*Mangifera indica* L.; Anacardiaceae), coconut (*Cocos nucifera* L.; Arecaceae), jocote (*Spondias purpúrea* L.; Anacardiaceae), mulberry (*Morus nigra* L.; Moraceae), acerola (*Malpighia emarginata* DC;

**Table 3**. Diversity indexes of insect families collected under the influence of color of the colored traps.

| Index of diversity | Index of diversity of insect families in PET traps | | | | | | |
|---|---|---|---|---|---|---|---|
| | Crops | Yellow | Blue | White | Green | Red | Colorless |
| Shannon-Wiener | Organic | 2.38 | 3.08 | 3.51 | 3.14 | 2.63 | 3.10 |
| | Convencional | 3.93 | 3.17 | 3.08 | 3.43 | 3.64 | 3.71 |
| Simpson | Organic | 0.66 | 0.82 | 0.89 | 0.85 | 0.71 | 0.84 |
| | Conventional | 0.91 | 0.82 | 0.82 | 0.86 | 0.90 | 0.88 |
| Margalef | Organic | 5.55 | 5.05 | 4.54 | 4.78 | 6.34 | 4.53 |
| | Conventional | 7.95 | 6.64 | 5.41 | 7.21 | 6.37 | 8.03 |
| Simpson's Dominance | Orgânic | 0.33 | 0.17 | 0.10 | 0.14 | 0.28 | 0.15 |
| | Conventional | 0.08 | 0.17 | 0.17 | 0.13 | 0.09 | 0.11 |
| Equity of Pielou | Organic | 1.75 | 2.29 | 2.80 | 2.50 | 1.82 | 2.47 |
| | Conventional | 2.77 | 2.29 | 2.36 | 2.56 | 2.75 | 2.65 |

Source: Research data.

Malpighiaceae), orange (*Citrus sinensis* L.; Rutaceae), lime (*Citrus limon* L.; Rutaceae), and various weeds. Cardozo (2007) reports that these trees, when maintained in the agroecosystem, serve to protect plants, both from pesticide drift from neighboring areas, and from the spores and/or invasive propagules.

The presence of pollinators, predators, and parasitoids in the area guarantees stability of the families of insects collected in the various colored traps. Campos (2008), in an open field study, listed 22 species of tomato pollinators distributed among the families Apidae, Halictidae and Andrenidae. Insects can be attracted to colors, by means of their long photoreceptor fibers (Skorupski and Chittka, 2010; Wanga et al., 2013).

Albuquerque et al. (2006) highlight melitophilia as a common pollination among the various solanaceous species, it is particularly attracted by floral structure, as is the case of the tomato in this study (Del Sarto, 2005). To pollinate the tomato, the bee's anthers need to vibrate in order to the release pollen. This fact reduces the number of effective pollinators, since such species as *Trigona spinipes* (Fabricius, 1793) (Hymenoptera: Apidae) cannot vibrate (Vianna et al., 2007). Santos and Nascimento (2011), in a study of diversity indices in organic crops, reported that the most abundant family was Apidae, representing 48.76% of the total sample (Table 2).

Table 3 displays various ecological indices (Shannon-Wiener and Simpson for diversity, Simpson for dominance, Margalef for richness, and Pielou for evenness) with respect to the colors of the PET traps. The data show differences in terms of diversity and richness of the insect families, highlighting the indices for the conventional system. The collected insects were attracted by the colors in each visited habitat, and foraging occurred on the basis of this attraction. We found that yellow, blue, and white attracted more insects than did green, red, and colorless.

The diversity indices of the insects collected in the colored traps revealed a tendency of attraction for the colors. This study highlighted the α (alpha) diversity that is constituted in the number of species (richness) in homogeneous fragments of a particular habitat type (Whittaker et al., 2001; Tuomisto, 2010; Chi et al., 2014). For both systems, the Jaccard similarity index was 0.88. The Jaccard index varies between 0 for different communities regarding the composition of species and 1 in similar communities regarding species composition (Zanzini, 2005).

In both systems, the Margalef indices were greater than 5.0, suggesting considerable families richness. Higher values of the Margalef index suggest proportional value for rare species. The Shannon-Wiener and Simpson indices were significantly different in each system. The Pielou index revealed a balance between the number of families in the two systems. According to Pielou (1966, 1975), values of the index vary between 0 for minimum uniformity, and 1 for maximum uniformity. In this study, the values were higher than 1.5.

Virginio et al. (2016) argue that the greater the knowledge regarding the fauna of an area, the more effective are the strategies for its conservation. This is especially true for northeastern ecosystems, where there is a shortage of studies.

Wilsey et al. (2005) suggest that species richness is dependent on sample size. In the conventional system, there was greater dominance index compared with the organic system. However, the samples collected during the study showed a balance in terms of evenness index.

**Table 4.** Relative abundance - AR (%) of orders and families of insects of agricultural importance for protection of plants in conventional and organic tomato crops.

| Order | Famíly | Presence in crop AR (%) | | Agricultural importance | References |
|---|---|---|---|---|---|
| | | Conv. | Org. | | |
| Coleoptera | Chrysomelidae | 0.22 | 1.17 | Pollinators | Santos (2009), Triplehorn and Johnson (2005) and Silva and Carvalho (2015) |
| | Carabidae | 0.41 | 8.53 | Predators | Parra et al. (2002) and Cárcamo et al. (2009) |
| | Coccinellidae | 0.22 | 0.28 | Predators pollinators | Parra et al. (2002) |
| | Elateridae | 3.54 | 0.03 | Predators pollinators | Susek and Ivancic (2006) |
| | Nitidulidae | 2.81 | 0.00 | Predators pollinators | Fernandes et al. (2012) and Lima (2002) |
| | Scarabaidae | 5.66 | 3.05 | Pollinators | Triplehorn and Johnson (2005) |
| | Curculionidae | 0.89 | 0.18 | Predators | Bustillo et al. (2002) |
| | Staphylinidae | 0.20 | 3.39 | Predators | Cunha et al. (2014) |
| Diptera | Agromyzidae | 24.92 | 3.91 | Predators pollinators | Cunha et al. (2014) |
| | Asilidae | 1.79 | 1.39 | Predators | Parra et al. (2002) |
| | Calliphoridae | 3.11 | 2.56 | Pollinators | Gullan and Cranston (2008) and Azevedo et al. (2015) |
| | Muscidae | 6.45 | 6.55 | Pollinators | Triplehorn and Johnson (2005, 2011) |
| | Stratiomyidae | 0.17 | 8.82 | Pollinators | Malerbo-Souza and Halak (2009) |
| | Syrphidae | 0.23 | 0.83 | Pollinators predators | Malerbo-Souza and Halak (2009) and Parra et al. (2002). |
| | Tabanidae | 1.78 | 16.13 | Parasites or predators | Cunha et al. (2014) |
| Hemiptera | Cicadelidae | 18.74 | 0.71 | Phytophagous | Cunha et al. (2014) and Silva and Carvalho (2015) |
| | Miridae | 0.26 | 0.37 | Predators | Cunha et al. (2014) |
| | Reduviidae | 0.78 | 0.15 | Predators | Parra et al. (2002) |
| Lepidoptera | Nymphalidae | 0.33 | 0.00 | Pollinators | Noubissié et al. (2012) |
| | Notodontidae | 0.00 | 0.73 | Pollinators | Gullan and Cranston (2008). |
| Hymenoptera | Apidae | 3.29 | 0.28 | Pollinators | Santos (2009), Silva and Carvalho (2015) and Ramalho (2004) |
| | Formicidae | 7.95 | 0.63 | Predators Decomposers | Parra et al. (2002), Bustillo et al. (2002) and Silva and Carvalho (2015) |
| | Pompilidae | 0.82 | 0.07 | Predators | Cunha et al. (2014) |
| | Scoliidae | 0.56 | 0.00 | Predators or Parasites | Cunha et al. (2014) |
| | Vespidae | 2.36 | 0.11 | Predators Pollinators | Parra et al. (2002). |

Source: Research data.

We observed that the more homogeneous the number of individuals per species, the greater the evenness and uniformity.

Following this reasoning, a given diversity index may indicate that community A is more diverse than B, while another index indicates the opposite (Mendes et al., 2008). Diversity is defined as a set of multivariate statistical procedures that inform various characteristics of the structure of biological communities (Ricotta, 2005).

According to Medeiros et al. (2011), it is essential to understand the interactions between insects and plants in order to understand biodiversity, since the resources provided by the plants are fundamental for the adaptive spread of the animals (Gaertner and Borba, 2014). Similarly, Ribeiro (2005) and Ferraz et al. (2009) emphasize that higher values of these indices suggest greater dominance and the lower diversity (Table 3).

Table 4 displays relative abundance - AR (%) of insect families and orders in both systems. The highest relative abundance of individuals collected in the traps were from the order diptera, 40.19% for the organic system and 37.45% for the conventional system. The Agromizydae family (AR = 24.92% organic) featured prominently, obtaining greater significance for yellow, blue, white, and

**Table 5**. Mean orders of insects in the two cropping systems collected in the colored PET traps by the Skott-Nott test at 5% probability.

| Order | Crops | Yellow | Blue | White | Green | Red | Colorless |
|---|---|---|---|---|---|---|---|
| Blattodea | Orgnic | $1.00^{C}$ | $1.00^{C}$ | $1.00^{C}$ | $1.33^{B}$ | $2.67^{A}$ | $1.33^{B}$ |
| | Conventional | $1.33^{B}$ | $1.00^{C}$ | $1.00^{C}$ | $2.66^{B}$ | $4.00^{A}$ | $1.00^{C}$ |
| Coleoptera | Organic | $963.00^{C}$ | $2085.3^{B}$ | $689.66^{C}$ | $430.66^{D}$ | $4346.00^{A}$ | $762.66^{C}$ |
| | Conventional | $68.00^{B}$ | $96.00^{A}$ | $48.00^{C}$ | $85.33^{A}$ | $72.66^{B}$ | $64.00^{B}$ |
| Diptera | Organic | $396.33^{D}$ | $1265.00^{B}$ | $704.33^{C}$ | $41.66^{D}$ | $1536.00^{A}$ | $525.33^{D}$ |
| | Conventional | $186.66^{C}$ | $668.00^{B}$ | $780.66^{A}$ | $96.66^{D}$ | $90.66^{D}$ | $97.33^{D}$ |
| Hemiptera | Organic | $159.33^{A}$ | $824.00^{B}$ | $304.00^{D}$ | $260.00^{D}$ | $174.66^{D}$ | $500.00^{C}$ |
| | Conventional | $57.33^{B}$ | $12.00^{D}$ | $29.33^{C}$ | $4.00^{D}$ | $98.66^{A}$ | $22.66^{C}$ |
| Hymenoptera | Organic | $42.66^{C}$ | $77.33^{A}$ | $62.66^{B}$ | $17.33^{D}$ | $33.33^{C}$ | $10.66^{D}$ |
| | Conventional | $129.33^{A}$ | $78.66^{B}$ | $89.33^{B}$ | $68.00^{B}$ | $88.00^{B}$ | $89.33^{B}$ |
| Lepidoptera | Organic | $30.66^{B}$ | $16.00^{C}$ | $6.66^{C}$ | $9.33^{C}$ | $66.66^{A}$ | $13.33^{C}$ |
| | Conventional | $9.33^{B}$ | $6.66^{B}$ | $1.00^{C}$ | $1.00^{C}$ | $46.66^{A}$ | $1.00^{C}$ |
| Thysanoptera | Organic | $1.00^{B}$ | $1.33^{B}$ | $1.00^{B}$ | $1.00^{B}$ | $80.00^{A}$ | $1.00^{B}$ |
| | Conventional | $10.66^{D}$ | $93.33^{B}$ | $129.33^{A}$ | $14.66^{D}$ | $56.00^{C}$ | $14.66^{D}$ |

Mean values not followed by the same letter differ significantly in the row by the Scott-Knott test at 5% probability.
Source: Research data.

red. Lima and Serra (2008) affirm that this order has a wide range of niches and diversity of families.

Some families in Table 4 represent predatory insects, phytophagous, natural enemies, and pollinators in the agroecosystem. Even with the systematic application of insecticides three times a week, these insects acquire resistance and remain active. Moura et al. (2014) point out that the most common predators found are wasps, ants, the neuropteran *Chrysoperla externa* (Hagen, 1861) (Neuroptera: Chrysopidae), spiders and bedbugs of the Reduviidae, Pentatomidae and Nabidae families. According to Togni et al. (2010), this abundance and diversity of families is mainly due to the greater availability of spaces protected from intra-species predation and access to alternative food resources.

The presence of the leafminer *Liriomyza trifolii* (Burgess, 1880) (Diptera: Agromizydae) in tomato crops suggests that integrated pest management requires greater attention, since this insect causes direct damage to the tomato leaf, reducing its productivity. Gusmão (2004) found abundant leafminer larvae in tomato leaves. In this study, we performed a random survey of ten plants and found two leafminer nests larvae on leaves of each tomato plant examined.

The order Coleoptera had an AR of 45.63% in the organic system and 13.95% in the conventional system. The Scarabaidae family had an AR of 32.05% in the organic system and 5.66% in the conventional system. Lima et al. (2013) studied diversified environments and found a significant number of this family. Matta et al. (2017) report predatory activity of the Carabidae family on weeds in cotton fields.

The Carabidae family had and AR of 8.53% in the organic system and 0.41% in the conventional system. Al-Attal et al. (2003) found 36% of the total number of insects identified as specimens of this family, with diversified functions in the agroecosystem. According to Cividanes et al. (2003), specimens of the Carabidae family spread by walking or flying. In this niche, they contribute to the pollination and decomposition of particulate matter.

The order Hymenoptera, generally abundant in vegetable environments, in the collections had an AR of 14.98% in the conventional system and 1.09% in the organic system. Alencar et al. (2007) and Kaminski et al. (2009) observed that this order has a diverse behavior in the agroecosystem. They are associated with specific ecological interactions as detritivores, predators, granivores, and herbivores. The Apidae family achieved an AR of 3.29% in the conventional system and 0.28% in the organic system. This is notable because these insects are important pollinators (Vianna et al., 2007).

The order Hemiptera had an AR of 19.78% in the organic system and 1.23% in the conventional system. The Cicadelidae family had a higher presence with an AR of 18.74% in the conventional system and 0.71% in the organic system. These are phytophagous insects, vectors of *Xylella fastidiosa* (Wells et al., 1987) (Table 4).

Table 5 shows the significant results of the orders of insects collected in the colored traps. Seven orders of insects were attracted, including many of agricultural interest. The red traps attracted the orders Coleoptera and Lepidoptera, which are useful for plant pollination in both tomato growing systems.

Paz and Pigozzo (2012) investigated mangrove, Atlantic Forest and Restinga, using traps with colored water. They report the most attractive colors to the insects were green, white, and blue. They show that Atlantic Forest was the environment with the greatest abundance of individuals and orders of insects, being a biome with a greater diversity of plants than other areas. The colors of the flowers and or plants serve as an attraction to insects, who visit in order to feed and lay eggs. In so doing, they pollinate as well. In this niche, there are also predators and parasitoids (Skorupski and Chittka, 2010; Wanga et al., 2013).

According to Vasconcellos et al. (2010), the seasonality in the Caatinga region favors the presence of the insect orders found. They found 20 orders belonging to the Insecta class, of which seven are found in the table collected in this study: Blattodea, Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, and Thysanoptera. The order Hymenoptera, with a mean of between 10.0 and 129.0 individuals in both systems, represents a good part of the collections as social insects, a result corroborated in Dutra and Machado (2001), Santos and Nascimento (2011), Souza (2011), and Rocha et al., 2010).

In this study, the red trap was significantly superior to the others, attracting a greater number of insects of the order Coleoptera. We hypothesize that these insects are attracted to red, since electromagnetic waves have wavelength ≥ 700 nm (Table 5).

## Conclusions

The use of colored traps is an efficient strategy to know the diversity of insects of the agricultural environments, allowing an integrated pest management planning. The insect family diversity indexes collected were different in the colored traps for the two cropping systems.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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