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Entomofaunistic diversity of arthropods in cucumber farming (*Cucumis sativus* L.)

*Diversidade entomofaunística de artrópodes na cultura do pepino (*Cucumis sativus *L.)*

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ABSTRACT

Cucumber (*Cucumis sativus* Linnaeus, 1753) stands out in the Brazilian agribusiness of vegetables as it can be consumed in salads (*in natura* or pickled) or even used for the production of cosmetics and drugs. During cucumber cultivation, several insect-pests, mainly from the Orders Hemiptera, Thysanoptera, Lepidoptera, can cause significant yield losses. Therefore, this study aimed to evaluate the entomofaunistic diversity of arthropods in cucumber crop using Moericke and Pitfall traps. Cucumber seedlings were commercially obtained and grown up in the experimental area of the Federal University of Fronteira Sul – *Campus* Chapecó (SC). Three samplings were carried out between October and December, 2015. The sampled specimens were identified to the taxon of Order and placed in vials containing alcohol solution (70%). A total of 1.651 specimens were identified and classified into 11 different Orders. Pitfall traps sampled a greater number of orders (9) and specimens (1.309), with emphasis to the Order Hymenoptera (928). For the aerial traps (Moericke), 342 specimens, allocated in eight different Orders, were identified, with the Order Diptera as the most abundant one (153 individuals). Moericke and Pitfall traps showed a Shannon-Weaver diversity index of 1.53 and 1.02, respectively.

Keywords: Diptera; Hymenoptera; Moericke; Pitfall; Shannon-Weaver index.

RESUMO

O pepino (*Cucumis sativus* Linnaeus, 1753) possui grande destaque no agronegócio brasileiro de hortaliças, por ser consumido em saladas (*in natura* ou em conserva) ou até mesmo utilizado para a produção de cosméticos e medicamentos. Durante o cultivo do pepineiro, diversos insetos-pragas, principalmente das ordens Hemiptera, Thysanoptera, Lepidoptera, podem causar perdas significativas na produção. Dessa forma, objetivou-se avaliar a diversidade entomofaunística na cultura do pepino utilizando armadilhas do tipo Moericke e Pitfall. As mudas de pepino foram obtidas comercialmente e cultivadas na área experimental da Universidade Federal da Fronteira Sul – *Campus* Chapecó (SC). Realizaram-se três coletas, entre outubro e dezembro de 2015. Os indivíduos amostrados foram triados e identificados ao táxon de ordem e acondicionados em potes com solução de álcool 70%. Coletou-se um total de 1.651 indivíduos, subdivididos em 11 ordens. As armadilhas de solo (Pitfall) apresentaram a maior quantidade de ordens (9) e exemplares capturados (1.309), com destaque para a ordem Hymenoptera (928). Nas armadilhas aéreas (Moericke), 342 indivíduos, alocados em oito ordens, foram identificados, sendo a ordem Diptera a mais abundante (153 indivíduos). As armadilhas Moericke e Pitfall apresentaram um índice de diversidade de Shannon-Weaver de 1,53 e 1,02, respectivamente.

Palavras-chave: Diptera; Hymenoptera; índice de Shannon-Weaver; Moericke; Pitfall.

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INTRODUCTION

Cucumber (*Cucumis sativus* Linnaeus, 1753) belongs to the family Cucurbitaceae, and it is a very well appreciated vegetable-like fruit in all Brazilian regions, both for its high consumption as a salad, as well as for its use as raw material for the pickle, cosmetic and pharmaceutical industries (SILVA *et al*., 2015).

During its cultivation cycle, the cucumber can be affected by many phytosanitary problems, among which insect-pests are found. The control of these insects is frequently carried out by the use of insecticides which, in addition to represent 17.6% of the variable costs of production (VIEIRA NETO *et al*., 2013), can have negative impacts on the environment and the health of consumers and farmers (KIM *et al*., 2017).

Therefore, the most appropriate way to reduce losses caused by crop pests is the implementation of an Integrated Pest Management (IPM) program. This management program aims to preserve and/ or increase the natural mortality factors of the pests by the use of integrated control tactics based on strategies outlined for each crop. Hence, for a good IPM program it is important to know the entomofauna present in the region of cultivation, in order to identify insect-pests and the diversity of natural enemies and pollinators (CHIDAWANYIKA *et al*., 2012; CARVALHO *et al*., 2013).

Insects belonging to the Order Hemiptera, for example, deplete plant nutrients due to the insertion of their piercing-sucking mouthparts, feeding directly in the sap of the plant, as well as being vectors for many diseases (ZACHE *et al*., 2010).

In addition, there are several species belonging to the family Pyralidae (Order Lepidoptera) that can cause significant yield losses (MICHEREFF FILHO *et al*., 2012). The Order Thysanoptera is frequently present in the whole life cycle of cucumber plants and can cause economic damage and losses due to the continuous sucking of plant cell contents, virus transmission and the release of substances on plant tissues that favors pre-digestion (PALOMO *et al*., 2015).

In light of this information and assuming that the State of Santa Catarina stands out as the main producer and consumer of pickled cucumber in Brazil (REBELO *et al*., 2016), evaluations of the arthropod populations are necessary in order to establish sustainable strategies for the management of productive agroecosystems. Hence, this study aimed to evaluate the entomofaunistic diversity of arthropods sampled with the use of Moericke (aerial) and Pitfall (soil) traps in cucumber plantations.

MATERIAL AND METHODS

STUDY AREA

Arthropods were sampled in vegetable beds cultivated with cucumber (*Cucumber sativus* L.) at the Federal University of Fronteira Sul, *Campus* Chapecó, State of Santa Catarina (SC) (latitude-27°11'89" and longitude-52°70'56"), between September 23rd and December 2nd, 2015.

SEEDLINGS AND CROP GROWTH

Cucumber seedlings (*C. sativus* L. cv. Ashley) were commercially obtained in the city of Chapecó (SC) and transplanted to four vegetable beds, having an area of 16.8 m^2 each (14 × 1.20 m). The spacing used between vegetable beds was of 0.30 meter. The seedlings were spaced 0.40 meter apart (figure 1) and by-hand irrigations were daily conducted, except when considerable precipitation (>10mm) occurred. Following the technical recommendations made by Michereff *et al*. (2012), the growing/ management of this crop was carried out in a creeping way in open air.

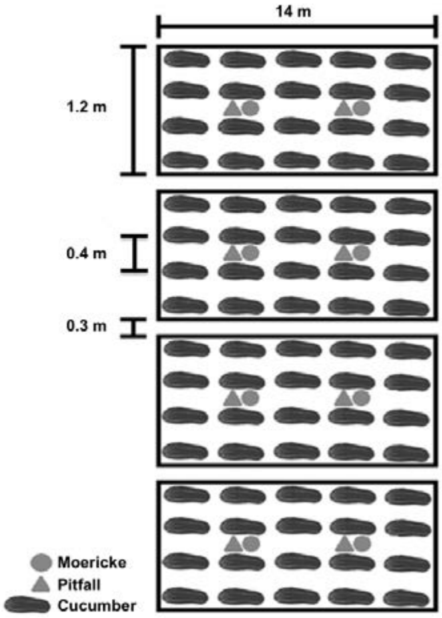

Figure 1 – Vegetable bed dimensions, spacing used and distribution of traps in cucumber beds.

TRAPS

Soil traps (pitfalls) were produced using *pet* bottles (10.5 cm in diameter and 15 cm in height) (figure 2A), positioned in the field and covered with a disposable white plastic plate (10 cm from the ground) with the help of wooden sticks (figure 2B). Aerial traps (Moericke) were produced using yellowish disposable plates (13 cm in diameter) attached to wooden sticks through the use of thermoplastic tapes (figure 2C). According to Silva *et al*. (2013), yellow plates are highly efficient for catching insects. Aerial traps were placed in the field, at a height of one meter from the ground, with the help of bamboo stakes (figure 2D). All traps contained a solution composed of water, 5% of neutral detergent and 3% of sodium hypochlorite so as to capture and preserve the specimens.

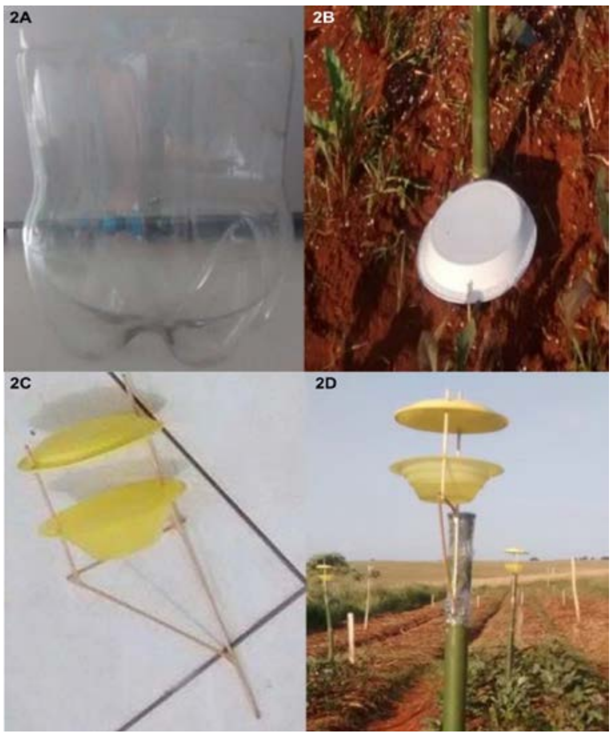

Figure 2 – Pitfall (A) and Moericke (C) traps, and their positioning in the vegetable beds (B: Pitfall and D: Moericke).

SAMPLING OF INDIVIDUALS

A total of three samplings (23rd, 51st and 70th days after transplanting – DAT) was carried out with Pitfall and Moericke traps. Each sampling was composed of eight Pitfall and eight Moericke traps. After traps were recollected, two Pitfall and two Moericke traps were randomly selected for arthropod identification, totaling 12 samplings for the whole study. Sampling dates were defined according to the growth and blooming period of the crop. Meteorological data were obtained from the Company of Agricultural Research and Rural Extension of Santa Catarina – Information Center of Hydrometeorology and Environmental Resources of Santa Catarina (EPAGRI – CIRAM), located in Chapecó (SC).

IDENTIFICATION OF INDIVIDUALS

All the collected material was initially labeled, stored in alcohol solution (70%) and kept in the Laboratory of Botany, Ecology and Entomology, located at the Federal University of Fronteira Sul – *Campus* Chapecó (SC). Subsequently, all invertebrates were classified to the taxon of Order, with the aid of tweezers, brushes and stereo microscope (LIBERA *et al*., 2017).

STATISTICAL ANALYSES

All the statistical analyses of the present work were carried out based on quantitative data that were generated from the identification of the specimens collected from the randomly selected traps. The diversity index (Shannon-Weaver) and the evenness index (Buzas-Gibson's) were calculated using the statistical program R version 3.2.3 (R Core Team, 2014). Similarity indices (dendrograms) were generated using the PAST 3.11 program (HAMMER *et al*., 2001). The computation of similarity indices, taking into account the abundance of the identified specimens, was performed for both traps through the use of the Bray-Curtis Dissimilarity index, with the Unweighted Pair Group with Arithmetic Mean (UPGMA) hierarchical clustering method.

RESULTS AND DISCUSSION

A total of 1.651 specimens was captured, and allocated in the taxa Insecta, Collembola and Arachnida. Within the Class Insecta, nine Orders were collected through the use of Pitfall and Moericke traps: Blattodea (0.06%), Coleoptera (7.99%), Dermaptera (0.12%), Diptera (10.30%), Hemiptera (4.30%), Hymenoptera (59.84%), Lepidoptera (0.42%), Orthoptera (0.96%) and Thysanoptera (2.91%). From the total number of the collected specimens, 1.309 came from the Pitfall and 342 from the Moericke traps.

The results show that, for Pitfall traps, specimens belonging to the Order Hymenoptera (928) were the most dominant ones, followed by Collembola (194), Coleoptera (83) and Hemiptera (44). The least abundant Orders of arthropods caught in these traps were Orthoptera (16 specimens), Thysanoptera (5) and Dermaptera (2), as it can be seen in table 1. Araújo *et al*. (2010) uncovered similar results when using interval estimation to compare the abundance of soil invertebrates in different environments in the city of Ituiutaba (MG), as they found, among the most abundant Orders of the rural area of that city, the Orders Hymenoptera, Coleoptera and the Class Collembola.

In a research carried out on the diversity of arthropods in zucchini plantations, the taxa Hymenoptera (56.33%) and Collembola (26.66%) were the most dominant ones in Pitfall traps whereas, for Moericke traps, Diptera (40.18%) and Coleoptera (26%) were the most abundant ones (LIBERA *et al*., 2017). These results corroborate the data of the present study.

Table 1 – Number of arthropods collected at the 23rd, 51st and 70th DAT (days after transplanting) with Pitfall traps, in cucumber plantations.

Group	Day of Sampling			
	23rd	51st	70th	Total
Araneae	4	10	6	20
Collembola	90	80	24	194
Coleoptera	25	40	18	83
Dermaptera	1	0	1	2
Diptera	2	12	3	17
Hemiptera	18	19	7	44
Hymenoptera	452	147	329	928
Orthoptera	7	7	2	16
Thysanoptera	3	2	0	5
Total	**602**	**317**	**390**	**1309**
Shannon-Weaver (H') Index	0.87	1.48	0.67	
Buzas-Gibson's Evenness Index	0.24	0.55	0.24	
General H' Index	1.02			
General Evenness Index	0.30			

Soil dwellers are affected by several factors such as the soil type, vegetation, climatic conditions, among others, which make their populations vary as a function of time (AMARAL & SANTOS, 2015).

Hymenoptera has more than one hundred thousand described species, including, among them, insects commonly known as ants, bees, wasps and microhymenopterans, justifying the high number of these specimens caught in the Pitfall traps (table 1). The parasitoid hymenopterans represent the most abundant group in the Order and play an important role in pest control (MARTINS *et al*., 2010).

The greatest number of Hymenoptera individuals was obtained in the first sampling, performed at 23 DAT (table 1), coinciding with the driest month in the experiment (242 mm) (figure 3). This finding diverges from that presented by Oliveira & Frizzas (2008) when reporting the results from a study carried out with insects of *cerrado* biome, in which the Hymenoptera presented a population peak at the beginning of the rainy season in November, a fact justified by these authors as due to the increase in the supply of hosts and preys and, besides, to the fact that the rainy season coincides with the blooming period of most plant species. However, one should consider that the seasonality in soil fauna populations is very common (RODRIGUES *et al*., 2011).

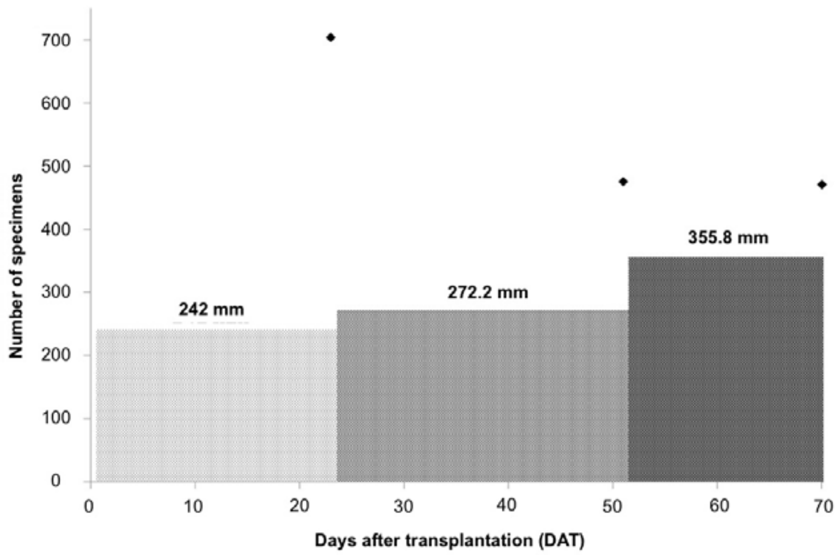

Figure 3 – Distribution of arthropods (dots) at the 23rd, 51st and 70th DAT (days after transplanting) using Moericke and Pitfall traps as a function of mean precipitation (mm) (columns) between samplings, in cucumber plantations.

According to Fernandes *et al*. (2004), in a study in which the efficiency of Pitfall traps as a function of their diameter was evaluated for the sampling of Formicidae specimens, the treatment that contained traps with the largest diameter (8.5 cm) presented as the most efficient one, showing that the sampling of a larger number of ants is proportional to the diameter of the traps, which corroborates the results of the present study, in which the diameter of the Pitfall traps was larger (10.5cm) than the one used by the mentioned authors.

The greater representativeness of the Order Hymenoptera, in all the samplings performed with Pitfall traps in the present study, is similar to that reported by França *et al*. (2014) when studying the entomofauna of insects as bio-indicators of environmental quality in Boa Esperança (MG).

Pitfall traps sampled a total of 194 specimens of Collembola (table 1). These arthropods are abundant in soil fauna and play an important role in nutrient cycling as they decompose plant and animal remains. Collembolans are considered the base of the trophic chain, serving as food for several insects and arachnids (BELLINI & ZEPPELINI, 2009).

The Order Coleoptera was the third more abundant in this study, with 83 sampled specimens. This abundance is justified by the fact that these organisms spend at least one phase of their life cycle in the soil (POVALUK & MENDES, 2017).

For Pitfall traps, the sampling performed at the 51st DAT was the one that presented the highest Shannon-Weaver diversity index (table 1), in comparison to the other samplings. What may explain this greater diversity is the fact that, in this sampling, specimens were more equally spread among the Orders identified in the study (table 1). This fact may be linked to the blooming phase of the crop, which supplies a more vast quantity of resources, i.e. food, for arthropods as reported by Solera *et al*. (2007) and Oliveira & Frizzas (2008).

The lowest Shannon-Weaver diversity index found in the third sampling (table 1) is linked to the high abundance of the Order Hymenoptera which, in this case, made the diversity index drop, considerably.

Among the insects collected with the Moericke traps, the Orders with the highest abundance were Diptera (153 individuals), Hymenoptera (60 individuals) and Coleoptera (49 individuals) (table 2). The predominance of these Orders is related to their large number of species and the wide geographical distribution of these groups (COSTA, 2012). According to Krug & Alves-dos-Santos (2008), the use of this type of trap is satisfactory as the easiness and/ or difficulty for the sampling of some species does not influence the final sampling result, and because the sampling noises generated by the collector are decreased.

Table 2 – Number of arthropods collected at the 23rd, 51st and 70th DAT with Moericke traps, in cucumber plantations.

Group	Day of Sampling			
	23rd	51st	70th	Total
Araneae	2	0	0	2
Blattodea	0	1	0	1
Coleoptera	12	13	24	49
Diptera	29	90	34	153
Hemiptera	9	12	6	27
Hymenoptera	22	26	12	60
Lepidoptera	1	3	3	7
Thysanoptera	27	14	2	43
Total	**102**	**159**	**81**	**342**
Shannon-Weaver (H') Index	1.62	1.33	1.41	
Buzas-Gibson's Evenness Index	0.72	0.54	0.68	
General H' Index		1,53		
General Evenness Index		0.57		

Even in smaller proportions, the presence of Orders such as Hemiptera and Thysanoptera is crucial for the balance of the ecosystem, mainly for the energy flow of food chains (COSTA, 2012).

In the second sampling, using Moericke traps (table 2), a greater number of dipterans was captured, probably because this sampling coincided with the blooming period of the crop. According to Carvalho *et al*. (2013) and Glaeser *et al*. (2014), many adults belonging to this Order feed on pollen and floral nectar.

The highest Shannon-Weaver diversity index, for Moericke traps, was found in the first sampling (table 2), which may be explained considering the even distribution of specimens within the Orders identified for this trap.

In relation to the general Shannon-Weaver diversity (general H' index), the Pitfall and the Moericke traps had a General H' of 1.02 and 1.53, respectively (tables 1 and 2). Although the Pitfall traps presented 1.309 specimens distributed in nine different orders and the Moericke traps presented 342 individuals divided into eight orders, Pitfall traps presented a lower Shannon-Weaver diversity index. This is justified by the fact that even containing almost ¼ of the number of individuals sampled by the Pitfall traps, samplings performed with Moericke traps presented a much more homogeneous distribution of the sampled specimens within the identified Orders.

In Pitfall trap samplings (table 3), the Order Hymenoptera represented 70.89% of the captured insects due to the great abundance of this order in the soil. Some representatives of this Order, especially ants, dominate ecosystems both by the species richness and the number of individuals (ALBUQUERQUE & DIEHL, 2009).

Table 3 – Quantity (No.) and relative frequency (RF%) of arthropods collected with Moericke and Pitfall traps, in cucumber plantation.

Group	Pitfall traps		Moericke traps		Total	
	No.	RF(%)	No.	RF(%)	No.	RF(%)
Araneae	20	1,53	2	0,58	22	1,33
Blattodea	0	0,00	1	0,29	1	0,06
Collembola	194	14,82	0	0,00	194	11,75
Coleoptera	83	6,34	49	14,33	132	8,00
Dermaptera	2	0,15	0	0,00	2	0,12
Diptera	17	1,30	153	44,74	170	10,30
Hemiptera	44	3,36	27	7,89	71	4,30
Hymenoptera	928	70,89	60	17,54	988	59,84
Lepidoptera	0	0,00	7	2,05	7	0,42
Orthoptera	16	1,22	0	0,00	16	0,97
Thysanoptera	5	0,38	43	12,57	48	2,91
Total	**1309**		**342**		**1651**	

As it can be observed in table 3, Moericke traps were also efficient for the sampling of the Order Hymenoptera (17.54%). According to Haro (2011), Moericke traps are excellent for sampling Hymenoptera when compared to light traps, not only quantitatively but also qualitatively.

When correlating the total amount of collected insects by both traps and the rainy season (figure 3), it can be seen that the largest number of sampled specimens corresponded to the driest month of the experiment. In a study for population assessment conducted by Dorval & Peres Filho (2001), similar results were obtained, showing that species of higher frequencies are more populous in drier periods.

Azevedo *et al*. (2011), using McPhail soil traps and yellow plates, found similar results to those obtained with the Pitfall traps in this study, also reporting a greater abundance of Orders such as Hymenoptera and Coleoptera for the dry season.

The use of Pitfall traps may limit the sampling of individuals of all sizes and body classes, as the space between the surface of the soil and the edge of the trap may vary. As samplings are subject to human and/ or climatic interferences, this influences the sampling of very small specimens (ARAÚJO *et al*., 2010).

According to figure 4, individuals classified to the Order Hymenoptera, during the three samplings (Pitfall trap), were concentrated within the family Formicidae, representing more than 95% of the number of specimens placed in this Order, which agrees with the reports of Costa (2013) who, in his study on the entomofauna associated to the implantation phase of agroforestry systems, verified that the family Formicidae was the most representative, independently of the sampling period.

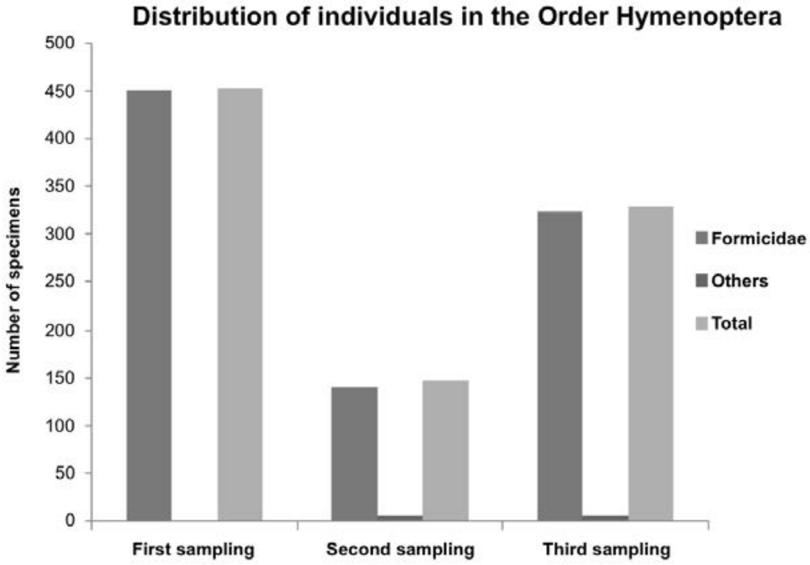

Figure 4 – Distribution of specimens belonging to the Order Hymenoptera in Pitfall traps, in cucumber plantations.

In the dendogram plotted for the similarity as a function of the abundance of individuals for Pitfall traps (figure 5), we can notice the difference of similarity in relation to the abundance of the Orders sampled. Hymenoptera and Dermaptera, for example, are very distant in their similarity of abundance (0.43%) because they had a large difference of sampled individuals, 928 and 2, respectively. High similarity of abundance is observed between the Orders Coleoptera and Hemiptera (70%) and between Diptera and Araneae (75%). Thysanoptera showed a similarity of abundance of 47% in relation to Orthoptera, 28% to Dermaptera, 4.7% to Coleoptera and 1% to Hymenoptera. Collembolans were the ones that, in similarity of abundance, approached the Order Hymenoptera the most (34%).

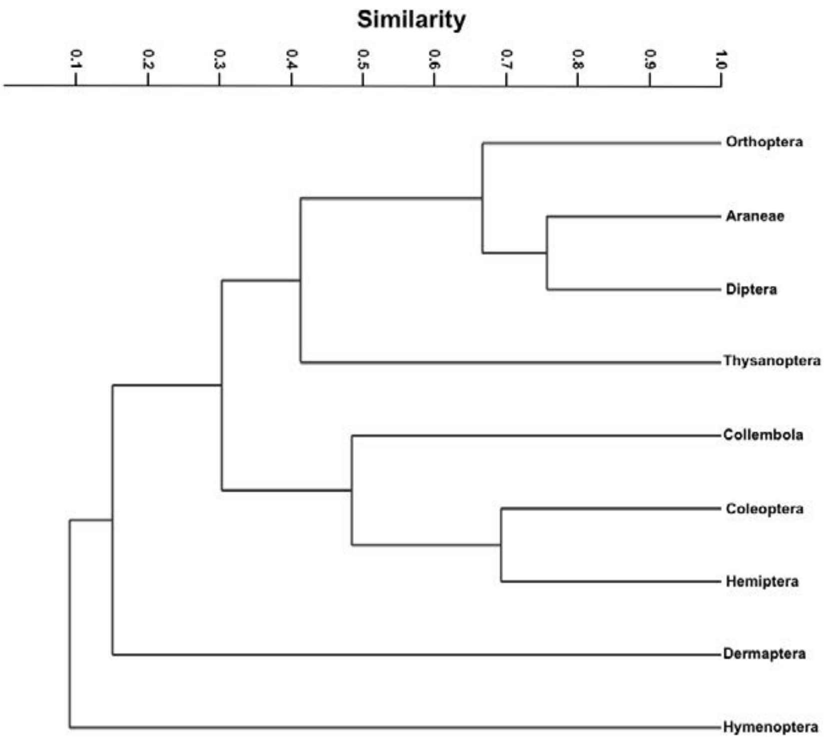

Figure 5 – Similarity as a function of the abundance of specimens collected with the Pitfall trap, in cucumber plantations.

From the dendogram for the Moericke trap (figure 6), it can be observed that spiders (Araneae) obtained the lowest similarity of abundance when compared to the Order Diptera (2.58%), because of their great difference in abundance, 2 and 153 respectively.

The Orders Hymenoptera and Thysanoptera, which had an amount of 60 and 43 specimens sampled, respectively, obtained a high similarity of abundance (67.96%). A similar clustering pattern was observed between the Orders Coleoptera and Hemiptera (68.42%), which had a total of 49 and 27 specimens, respectively. Through figure 6, it is possible to notice the occurrence of a grouping among these Orders, due to the proximity of the their amount of specimens.

The lowest similarity of abundance observed for the Moericke trap was between the Orders Diptera and Blattodea (1.30%), a fact that can be justified due to the disparity in abundance of these two Orders 153 and 1, respectively, and to the fact that the degree of confidence is very small, when comparing the similarity of abundance with an Order that has only one representative.

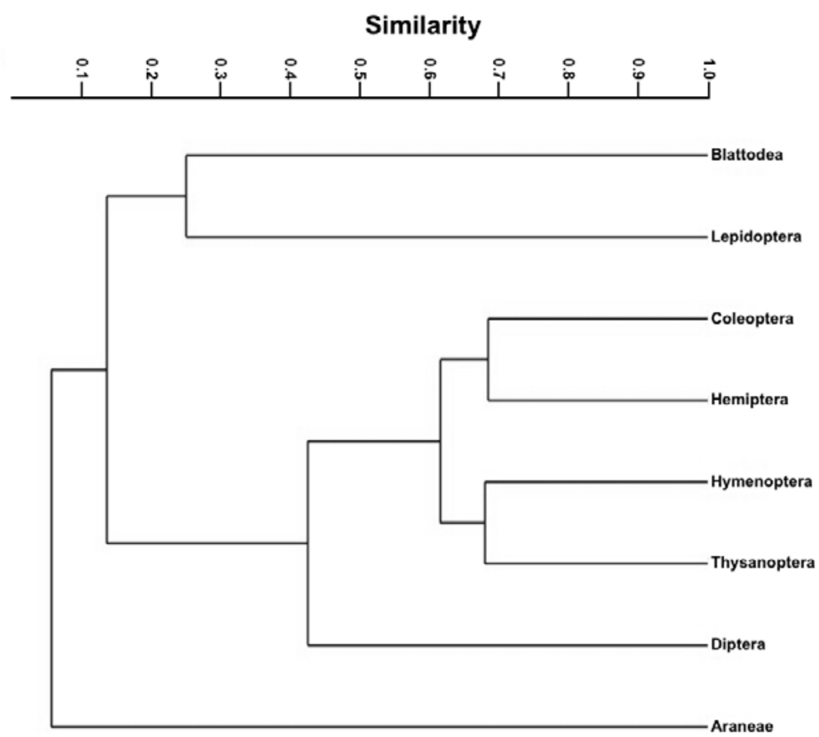

Figure 6 – Similarity as a function of the abundance of specimens collected with the Moericke trap, in cucumber plantations.

CONCLUSION

The evaluation of the entomofaunistic diversity of arthropods in a cucumber plantation, through the use of Pitfall and Moericke traps, proved to be efficient in the sampling of arthropods, as a total of 1.651 specimens were sampled in 12 traps. The main sampled Orders were Hymenoptera (59.84%), Collembola (11.75%) and Diptera (10.30%). The diversity of arthropods in aerial traps was superior to that found in soil traps due to the large presence of Hymenoptera, with predominance of those belonging to the family Formicidae. The taxa Hymenoptera in Pitfall and Araneae in Moericke traps were the ones that presented the lowest similarity of abundance in comparison to the other sampled Orders.

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