DOI: 10.1590/1808-1657000902018

Phytophagous insects and natural enemies in kale under organic and chemical fertilizers

Insetos fitófagos e inimigos naturais em couve sob adubação orgânica e química

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ABSTRACT: Organic agriculture is distinguished by practices that benefit the environment and support sustainable agriculture. In the present study, leafy kale, *Brassica oleracea* L. var. *acephala* DC., was submitted to chemical and organic (castor bean cake and bovine manure) fertilization treatments aiming to verify the influence of these fertilizers on the occurrence of insect pests and natural enemies. The insects were sampled by visual examination of plants and pitfall traps. *Brevicoryne brassicae* (L.) and *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) were the phytophagous insects that occurred more significantly in kale, under chemical rather than organic fertilization, whereas *Harmonia axyridis* (Pallas), *Hippodamia convergens* (Guérin-Méneville) (Coleoptera: Coccinellidae), *Diaeretiella rapae* (M'Intosh) (Hymenoptera: Braconidae) and spiders (Arachnida: Araneae) were abundant in kale under organic fertilizer. The study showed that castor bean cake and bovine manure as leafy kale fertilizers can reduce the use of insecticides and provide quality food.

KEYWORDS: family farming; *Brassica oleracea*; biological control; fertilizers; sustainability.

RESUMO: A agricultura orgânica destaca-se pelo emprego de práticas que beneficiam o meio ambiente e aumentam a sustentabilidade na agricultura. No presente estudo, a couve-de-folha, *Brassica oleracea* L. var. *acephala* DC., foi submetida a tratamentos de adubação química e orgânica à base de torta de mamona e esterco bovino para se verificar a influência dos fertilizantes na ocorrência de insetos pragas e inimigos naturais. Os insetos foram amostrados por meio de exame visual de plantas e armadilhas tipo alçapão. *Brevicoryne brassicae* (L.) e *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) foram os insetos fitófagos que ocorreram significativamente em maior número em couve sob adubação química que orgânica, enquanto *Harmonia axyridis* (Pallas), *Hippodamia convergens* (Guérin-Méneville) (Coleoptera: Coccinellidae), *Diaeretiella rapae* (M'Intosh) (Hymenoptera: Braconidae) e aranhas (Arachnida: Araneae) foram abundantes em couve sob adubo orgânico. O estudo evidenciou que o uso de torta de mamona e esterco bovino como adubo de couve-de-folha pode reduzir o uso de inseticidas e fornecer alimentos de qualidade.

PALAVRAS-CHAVE: agricultura familiar; *Brassica oleracea*; controle biológico; fertilizantes; sustentabilidade.

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Received on: 08/07/2018. Accepted on: 09/11/2019

INTRODUCTION

Vegetables of the family Brassicaceae, *Brassica oleracea* L., are considered a food eaten routinely and in quantities that constitute an important portion of people's diets in many parts of the world. The leafy kale, *Brassica oleracea* L. var. *acephala* DC., stands out for its economic importance and high nutritional value (FILGUEIRA, 2008). Among the leafy vegetables, kale is widely grown in Brazil, especially in the state of São Paulo (TRANI et al., 2015; VILELA; LUENGO, 2017).

Pest damage is widely reported as one of the major problems that concerns kale growers. For example, the aphids *Brevicoryne brassicae* (L.) and *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) cause high production losses and transmit diseases, and their presence may reduce production and crop quality (PICANÇO et al., 2000; HOLTZ et al., 2015). In fact, *Myzus persicae* can limit the commercial production of brassica vegetables, especially in organic systems (MORENO; RACELIS, 2015). Other insect pests that affect the production of kale are the whitefly, *Bemisia tabaci* (Genn.) (Hemiptera: Aleyrodidae), *Ascia monuste orseis* (Godart) (Lepidoptera: Pieridae), the diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae), and the black cutworm, *Agrotis ipsilon* (Hufnagel) (Lepidoptera: Noctuidae) (HOLTZ et al., 2015).

The practices used in organic cropping systems for vegetable production benefit both the environment and cultivated plants (DELATE et al., 2003; SILVA et al., 2012). Organic fertilizers, for instance, not only improve soil characteristics, but are also related to the production of high-quality food without causing environmental problems (SILVA et al., 2012). The use of castor bean cake and bovine manure in agriculture is directly related to sustainable practices and family farming (PINTO et al., 2016). However, published studies on these organic fertilizers usually report only the effects on vegetable production (SANTOS et al., 2012; PINTO et al., 2016), with little information about their effects on pests and natural enemies.

Management of insect pests in organic systems requires knowledge of the interactions among organisms in agroecosystems to keep pests at low population levels (VENZON et al., 2015). Nonetheless, organic systems have some information gaps, because although these farming systems increase arthropod diversity, most of the behavioral responses of pests and natural enemies to these systems are unknown (GARRAT et al., 2011). The objective of this study was to quantify the populations of phytophagous insects and natural enemies in leafy kale submitted to chemical and organic fertilization to determine the effects of the fertilizers on these organisms.

MATERIAL AND METHODS

The study was carried out at Laboratório de Ecologia de Insetos (LECOL) and an experimental area located at Universidade Estadual Paulista "Júlio de Mesquita Filho", Jaboticabal Campus, state of São Paulo, (21°15'22"S e 48°18'58"W). The soil is classified as Oxisol.

Two treatments were distributed in a completely randomized design containing 10 replications. Each sampling plot had 16 square meters (4 × 4 m), each containing four rows of leafy kale, *B. oleracea* var. *acephala*, Geórgia cultivar, manually transplanted at 0.5 m (within row) × 1.0 m (between row) spacing, in April 16th, 2010. Treatments included the following: Treatment 1 = chemical fertilizer (3.2 kg/plot or 200 g/m^2 of the 20-20-20 NPK formula); and Treatment 2 = organic fertilizer (80 kg/plot or 5 kg/m^2 of the mixture of bovine manure and castor bean cake in a 4:1 ratio).

Insects were sampled by visual examination and pitfall traps, from April to November 2010. The visual examination was carried out at weekly intervals, totaling 33 sampling dates, performed by randomly selecting 5 plants located in the center of a plot and collecting insects using plastic tubes of 8 cm high and a 2 cm diameter. Aphids were sampled considering a circular area of a 3.5 cm diameter of a leaf surface, as described by SOUSA (1990). Pitfall traps were 500 mL, 80 mm diameter plastic cups, containing 50 mL of a solution of formaldehyde in water (1%) and detergent. Traps were covered with a plastic roof (diameter 200 mm) to protect them from litter and rain. One trap was installed in the center of each plot and was emptied and serviced biweekly during the study period, totaling 15 sampling dates. At each sampling date, traps were set and remained in the field for 7 days. The coccinellids were identified to species level by Terezinha Monteiro dos Santos Cividanes, Instituto Biológico, city of Ribeirão Preto, state of São Paulo. Aphids, spiders and other insects were identified by comparison with specimens deposited in Coleção de Arthropodes do LECOL, Universidade Estadual Paulista "Júlio de Mesquita Filho", city of Jaboticabal, state of São Paulo.

All data were subjected to analysis of variance and Tukey test ($p \leq 0.05$). Here, we considered the total insect individuals captured in the 5 plants/plot and the total number of aphids (nymphs and adults) recorded on the leaf surface. For soil-dwelling insects, the total number of individuals captured in the traps was considered. Data were transformed ($\log(x + 1)$) prior to analysis.

RESULTS AND DISCUSSION

A total of three orders of insects (Coleoptera, Hemiptera and Hymenoptera) and spiders (Arachnida: Araneae) were captured. Most of them (97.2%) consisted of phytophagous insects, which were more numerous in chemically fertilized kale, whereas natural enemies prevailed in plants under castor bean cake and bovine manure fertilization (Table 1).

Table 1. Average number of arthropods captured in leafy kale cultivated with chemical (Che) and organic (Org) fertilizers. Jaboticabal city (São Paulo), 2010.

Sampling location/taxon		Che	Org
Leaves	Coleoptera		
	Coccinellidae		
	Cycloneda sanguinea (L.)	0.71	0.88
	Eriops conexa (Germar)	0.19	0.29
	Harmonia axyridis (Pallas)	1.16	2.38
	Hippodamia convergens (Guérin-Méneville)	8.96	15.93
	Chrysomelidae		
	Diabrotica speciosa (Germar)	0.23	0.31
	Elateridae		
	Heteroderes sp.	0.03	0.07
	Lagriidae		
	Lagria villosa (Fabr.)	0.07	0.19
	Hemiptera		
	Aleyrodidae		
	Bemisia tabaci (Genn.)	31.13	40.24
	Aphididae		
	Brevicoryne brassicae (L.)	372.17	299.24
	Myzus persicae (Sulzer)	726.56	512.67
	Cydinidae		
	Scaptocoris castanea (Perty)	0.12	0.41
	Hymenoptera		
	Formicidae	0.99	1.44
	Braconidae		
	Bracon lizerianus (Blanchard)	0.20	0.41
	Diaeretiella rapae (M'Intosh)	0.59	2.09
	Araneae	7.38	14.27
Soil	Coleoptera		
	Alleculidae	0.17	0.31
	Carabidae		
	Abaris basistriata Chaudoir	0.00	0.03
	Galerita brasiliensis Dejean	0.04	0.03
	Lebia sp.	0.01	0.00
	Scarites sp.	0.02	0.01
	Selenophorus alternans Dejean	0.00	0.01
	Selenophorus discopunctatus Dejean	0.00	0.10
	Tetracha brasilienis (Kirby)	0.03	0.00
Soil	Chrysomelidae		
	Diabrotica speciosa (Germar)	0.03	0.02
	Diabrotica bivitula Kirsch	0.02	0.02
	Maecolaspis pertubata (Bachyné)	0.12	0.09
	Curculionidae		
	Anthonomus grandis Boheman	0.08	0.05
	Elateridae		
	Physodactylus sp.	0.01	0.00
	Heteroderes sp.	0.26	0.65
	Melyridae		
	Astylus variegatus (Germar)	0.00	0.01
	Scarabaeidae		
	Aphodius lividus (Olivier)	0.00	0.01
	Staphylinidae		
	Lathrobium sp.	0.12	0.45
	Dermaptera		
	Forficulidae		
	Doru luteipes (Scudder)	0.17	0.45
	Labiduridae		
	Labidura riparia (Pallas)	2.36	3.43
	Labidura xanthopus (Stal)	1.17	2.77
	Hemiptera		
	Cercopidae		
	Deois flavopicta (Stal)	0.10	0.08
	Coreidae		
	Zicca nigropunctata (De Geer)	0.01	0.01
	Cydnidae		
	Scaptocoris castanea (Perty)	0.03	0.02
	Cyrtomenus mirabilis (Perty)	0.29	0.48
	Hymenoptera		
	Formicidae		
	Acromyrmex sp.1	0.28	0.98
	Atta sp.1	0.50	0.46
	Brachymyrmex sp.	0.06	0.18
	Camponotus sp.1	0.19	0.16
	Camponotus sp.2	0.00	0.02
	Dorymyrmex sp.1	3.71	6.46

Continue...

Table 1. Continuation.

Sampling location/taxon		Che	Org
Soil	*Dorymyrmex* sp.2	0.17	0.05
	Dorymyrmex sp.3	0.09	0.00
	Ectatomma sp.	0.01	0.03
	Gnamptogenys sulcata (Smith)	0.01	0.00
	Hypoponera sp.	0.05	0.17
	Neivamyrmex sp.	0.01	0.00
	Odontomachus sp.1	0.01	0.01
	Pheidole sp.1	2.42	1.72
	Pheidole sp.2	0.12	0.02
	Pheidole sp.3	0.01	0.00
	Pseudomyrmex sp.1	0.16	0.17
	Solenopsis invicta Buren	0.00	0.03
	Solenopsis sp.1	0.58	2.21
	Solenopsis sp.2	0.18	0.06
	Mutillidae		
	Hoplomutilla spinosa (Swederus)	0.01	0.00
	Vespidae		
	Polybia sericea (Oliver)	0.02	0.00
	Sphecidae		
	Ammophila sp.	0.00	0.01
	Orthoptera		
	Gryllidae		
	Acheta domesticus (L.)	0.59	0.41
	Araneae		
	Lycosidae	1.06	1.53
	Theridiidae	0.79	1.28
	Corinnidae	0.12	0.16
	Phocidae	0.02	0.02
	Therraphosidae	0.00	0.05
	Ctenidae	0.16	0.21
	Salticidae	0.19	0.39
	Nemesidae	0.03	0.01
	Oxyopidae	0.00	0.02

The aphids *B. brassicae* and *M. persicae* were the most numerous phytophagous insects when plants were fertilized with chemical fertilizer, followed by the whitefly *Bemisia tabaci* biotype B (Genn.) (Hemiptera: Aleyrodidae); but, in this case, there was no statistically significant difference between treatments (Table 2). On the other hand, *Hippodamia convergens* (Guérin-Méneville), *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae), *Diaeretiella rapae* (M'Intosh) (Hymenoptera: Braconidae) and spiders were natural enemies that occurred significantly more often in kale under the organic fertilizer (Table 2). Ladybugs accounted for 51.7% of these natural enemies, and *H. convergens* was the most numerous species followed by H. axyridis, *Cycloneda sanguinea* (L.) and *Eriopis connexa* (Gemar). Coccinellids have potential as biological control agents of agricultural insect pests (GONZÁLEZ, 2014). For example, *H. axyridis* and *H. convergens* are effective aphid predators (RICE; WILDE, 1988; FLINT; DREISTADT, 2005; RAMOS et al., 2017), whereas the greenbug, *Schizaphis graminum* (Rondani), has been effectively controlled by *H. convergens*, *C. sanguinea* and *E. connexa* in vegetables and other crops (FIORENTIN et al., 2013). Araneae and *D. rapae* are considered important natural enemies associated with kale. Araneae was considered a significant mortality factor of *B. brassicae* in relation to several predatory ant species, including *Solenopsis* spp. (CIVIDANES, 2002), whereas *D. rapae* was indicated as the dominant natural enemy in kale, and have the potential to control aphids (BUENO; SOUZA, 1993; CIVIDANES, 2002).

In the present study, the significantly low number of *B. brassicae* and *M. persicae* found in leaves of kale plants under organic fertilization can probably be related to the action of natural enemies, such as *D. rapae*, spiders and especially ladybugs (Table 2). The high number of aphids and, especially, the low number of natural enemies observed in kale under chemical fertilization in comparison to the abundance of these insects found in organically fertilized plants provide further evidence that castor bean cake and bovine manure favored the occurrence of natural enemies. These results are consistent with STALEY et al. (2010), who reported that the diamondback moth, *P. xylostella*, and the green peach aphid, *M. persicae*, were more numerous in Brassicaceae plants cultivated in soil under chemical fertilization than in those cultivated in soil fertilized with animal manure.

Arthropods captured with pitfall traps represented six orders of insects and spiders (Table 1). Phytophagous insects and natural enemies occurred in high density in plants cultivated with chemical and organic fertilizers, respectively, which is a similar result for insects found in kale leaves. However, natural enemies represented 85.6% of the soil-inhabiting individuals, the opposite of the composition of insects observed in kale leaves.

Heteroderes sp. (Coleoptera: Elateridae) was significantly more numerous in kale under organic fertilization (Table 2). Generally, adult elaterids are phytophagous insects. Although there are no records of *Heteroderes* damaging kale plants, some species of *Heteroderes* are considered pests of peanut, sugarcane and oilseed crops (MORRIS; WATERHOUSE, 2001; SAMSON; CALDER, 2003).

Ants (Formicidae), earwigs (Dermaptera) and spiders (Araneae) were predatory arthropod groups that prevailed

Table 2. Number (mean ± standard error) of phytophagous insects and natural enemies captured in kale under chemical (Che) and organic (Org) fertilizers. Jaboticabal city (São Paulo), 2010.

Sampling location/taxon		Che	Org	F	CV (%)
Leaves	Coleoptera				
	Coccinellidae				
	Harmonia axyridis (Pallas)	1.16 ± 1.1b[1]	2.38 ± 1.6a	8.41**	12.5
	Hippodamia convergens (Guérin-Méneville)	8.96 ± 3.2b	15.93 ± 4.2a	32.25**	4.4
	Hemiptera				
	Aphididae				
	Brevicoryne brassicae (L.)	372.17 ± 20.3a	299.24 ± 18.2b	5.11*	2.6
	Myzus persicae (Sulzer)	726.56 ± 28.4a	512.67 ± 23.9b	9.94**	2.9
	Hymenoptera				
	Braconidae				
	Diaeretiella rapae (M'Intosh)	0.59 ± 0.8b	2.09 ± 1.5a	52.08**	9.8
	Araneae	7.38 ± 2.9b	14.27 ± 4.0a	150.25**	2.4
Soil	Coleoptera				
	Carabidae				
	Selenophorus discopunctatus Dejean	0.0 ± 0.0b	0.10 ± 0.3a	6.88*	8.3
	Elateridae				
	Heteroderes sp.	0.26 ± 0.5b	0.65 ± 0.9a	7.00*	15.2
	Hymenoptera				
	Formicidae				
	Solenopsis sp.1	0.58 ± 0.8b	2.21 ± 1.6a	9.73**	21.2
	Araneae				
	Lycosidae	1.06 ± 1.1b	1.53 ± 1.3a	7.67*	7.4
	Theridiidae	0.79 ± 0.9b	1.28 ± 1.2a	5.89*	11.0

[1]Numbers followed by different letters in same line are different by Tukey test ($p < 0.05$); *, ** significant at $p < 0.05$ and $p < 0.01$, respectively; numbers are not transformed to (log x + 5).

among those captured in the soil (Table 1). Overall, Araneae (Lycosidae and Theridiidae), *Solenopsis* sp. 1 (Hymenoptera: Formicidae), and *Selenophorus discopunctatus* (Dejean) (Coleoptera: Carabidae) were significantly more numerous in organically fertilized plants than the chemically fertilized ones (Table 2). Although ants of the genus *Solenopsis* are considered agricultural pests (WOJCIK et al., 2001), some *Solenopsis* species are predators of small arthropods. For example, ROSSI; FOWLER (2002) reported that *Solenopsis invicta* (Buren) played a major role in suppressing a population of *Diatraea saccharalis* Fabr. (Lepidoptera: Crambidae). A marked reduction in *D. saccharalis* larvae in areas where ants of the genus *Solenopsis* have always been more numerous than other ant species was also observed (ROSSI; FOWLER, 2000). Carabids are recognized as predatory beetles inhabiting soils. *Selenophorus* species can feed on plant seeds (TOOLEY; BRUST, 2002) and larvae of *Anticarsia gemmatalis* Hübner (Lepidoptera: Erebidae) (CIVIDANES et al., 2014). In this study, the presence of *S. discopunctatus*, and even other carabid species in kale under organic fertilization (Tables 1 and 2), suggest that carabids may have acted as control agents of insect pests. Spiders (Araneae), as discussed above, acted as an important mortality factor of *B. brassicae* (CIVIDANES, 2002).

CONCLUSIONS

This study revealed that natural enemies occurred in higher numbers than insect pests, such as *B. brassicae*, *M. persicae* and *B. tabaci* in leafy kale organically fertilized with castor

bean cake and bovine manure in comparison with kale under chemical fertilization. Thus, the use of these organic fertilizers should be encouraged among kale growers due to their potential to reduce the amount of insecticides, which have been used in the control of insect pests. In addition, the use of castor bean cake and bovine manure agrees with sustainable agriculture practices, and they also contribute to encouraging family farming and to obtain better quality food.

ACKNOWLEDGMENTS: We thank José Carlos Barbosa for his assistance with statistical analysis, and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) (Process 304930/2009-1) for providing a scholarship to the first author.

FUNDING: This work was supported by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) (Process 304930/2009-1)

CONFLICTS OF INTEREST: All authors declare that they have no conflict of interest.

ETHICAL APPROVAL: Not applicable.

AVAILABILITY OF DATA AND MATERIAL: The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

AUTHORS' CONTRIBUTIONS: Conceptualization: Cividanes, F.J.; Santos-Cividanes, T.M.S. Data curation: Silva, K.P.; Martins, I.C.F. Formal analysis: Silva, K.P.; Martins, I.C.F. Methodology: Cividanes, F.J.; Santos-Cividanes, T.M.S.; Martins, I.C.F. Writing – review & editing: Cividanes, F.J.; Santos-Cividanes, T.M.S.

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