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Biological control of phytophagous arthropods in the physic nut tree *Jatropha curcas* L. in Brazil

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ABSTRACT. *Jatropha curcas* has a high biofuel oil content, which could replace polluting fuels, and has great potential for large scale monoculture cultivation in the conventional system. We explored the occurrence, spatial distribution and the functional response of the main phytophagous species of this plant and their natural enemies to explore the potential for conservative biological control. We began sampling phytophagous species and predators when *J. curcas* plants were six months old. The most common species of phytophagous insects were nymphs and adults of *Empoasca kraemeri,* followed by *Frankliniella schultzei* and *Myzus persicae*. Among the predators, *Ricoseius loxocheles, Iphiseioides zuluagai,* Araneidae, larvae and adults of *Psyllobora vigintimaculata* and *Anthicus* sp. were the most frequently encountered. The most common parasitoids were the families Encyrtidae and Braconidae. The highest densities of *E. kraemeri* and *F. schultzei* on the edges of the *J. curcas* crop follow spatial patterns similar to those of their natural enemies *I. zuluagai* and *Anthicus* sp. These arthropods can be considered efficient predators of immature stages of *E. kraemeri* and *F. schultzei* on *J. curcas*.

Keywords: predators, parasitoids, phytophagy, spatial distribution, functional response.

Controle biológico de artrópodes fitófagos em Pinhão Manso *Jatropha curcas* L. no Brasil

RESUMO. *Jatropha curcas* possui alto teor de óleo biocombustível que poderia substituir os combustíveis poluentes, possuindo grande potencial para o cultivo em larga escala de monocultivos no sistema convencional. Nós exploramos a ocorrência, a distribuição espacial e a resposta funcional das principais espécies fitófagas e seus inimigos naturais com potencial para controle biológico conservativo. Começamos a amostragem de fitófagos e predadores quando o *J. curcas* atingiu seis meses de idade. As espécies fitófagas mais frequentes foram ninfas e adultos *Empoasca kraemeri*, seguido por *Frankliniella schultzei* e *Myzus persicae*. Dentre os predadores, *Ricoseius loxochelis*, *Iphiseioides zuluagai*, Araneidae, *Psyllobora vigintimaculata* (larv), *Psyllobora vigintimaculata* (adulto) e *Anthicus* sp. foram as mais frequentes. Os parasitoides mais comuns foram das famílias Encyrtidae e Braconidae. As maiores densidades de *E. kraemeri* fitófagos e *F. schultzei* nas bordas da cultura de *J. curcas* seguem padrões espaciais semelhantes aos de inimigos naturais de *I. zuluagai* e *A.* sp. Esses artrópodes podem ser considerados eficientes predadores de estágios imaturos de *E. kraemeri* e *F. schultzei* em *J. curcas*.

Palavras-chave: predadores, parasitóides, fitofagia, distribuição espacial, resposta funcional.

Introduction

The physic nut tree (*Jatropha curcas* L.), a native species of Brazil, is considered to be a good crop option for many agricultural regions of the world (LI et al., 2010). This species, which is in the Euphorbiaceae family, has the potential for use in the prevention and control of erosion, can be grown as a hedge due to its rapid growth, has high oil content for biofuels that can replace polluting fuels (ACHTEN et al., 2008; AZAM et al., 2005), is drought tolerant, has low nutrient requirements, has high adaptability to different soil types and emits low levels of gases into the atmosphere. For these reasons, it has great potential to be cultivated in large scale monocultures in the conventional system of cultivation (FRANCIS et al., 2005; LI et al., 2010; PRUEKSAKORN; GHEEWALA, 2008).

A major concern in the conventional system of cultivation is the sustainability of production. Diseases and pests that cause damage to crops compel farmers to use pesticides, thus contaminating the humans, soil, and water and affecting beneficial organisms (DESNEUX et al., 2007). In such cases, biological control may be an alternative to chemical control, especially because there is no insecticide registered to control *J. curcas* pests in Brazil. The practice of conservative biological control (CBC), which involves the manipulation of agricultural habitats to favor the natural enemies of pests (i.e., predators, parasitoids, and pathogens), offers the promise of simultaneously conserving natural enemy biodiversity and reducing pest problems.

To perform CBC in an efficient and planned manner, one needs to know the species of phytophagous pests or those with the potential to become pests of a particular crop, and the main natural enemies of these pests. Additionally, one needs to know about the interactions between phytophagous pests and their natural enemies to develop strategies that conserve the habitat and encourage the maintenance and preservation of natural enemies in the area of the monoculture. Predators, in general, are generalists, feeding on a host of prey, and parasitoids are specialists, completing their life cycle in a single host. Because there is no synthetic insecticide registered to control pests of *J. curcas*, CBC could become a very popular method of control by the producers of this crop.

Understanding the spatial dynamics of insect populations can facilitate the development of CBC strategies, promoting sustainable agroecosystems through functional biodiversity conservation (DIAZ et al., 2010). Knowledge of the spatial distribution pattern of insects allows a focused management of effort in places with the highest densities. Spatial distribution patterns have been determined through the analysis of mathematical models of frequency distribution, where the adjustment of the negative binomial distribution indicates that the insect has an aggregated distribution pattern. This relationship is affected by spatial distribution, but does not represent spatial distribution. A better option for determining the spatial dependence of the density of insects is the use of geostatistics (SCIARRETTA; TREMATERRA, 2008). Geostatistics analyze whether the observed value of a variable for a given location is dependent on the variables of neighboring sites. If there is dependency, the variable exhibits spatial autocorrelation. Thus, geostatistics can be a tool used to study the spatial distribution of pests and natural enemies, which is essential for devising CBC strategies.

Despite the importance of studies of spatial distribution, studies of the functional response of a predator can be used to select key natural enemies. The functional response of a predator is one of the most important factors in the population dynamics of predator-prey systems because it improves the effectiveness of pest biological control (TIMMS et al., 2008). The functional response is based on two basic parameters: the prey handling time (Ht), which involves the gathering, death and ingestion of prey, and the attack rate (a), which represents the efficiency of prey searching. This model evaluates the behavioral aspect of the predator, which can be influenced by its age, its type, the age of the prey, the prey host plant and the climatic conditions.

Little is known about phytophagous species of *J. Curcas,* the primary natural enemies of these phytophagous species, or the interactions between these organisms and their spatial dynamics; this information would be useful for developing agents for natural biological control (SHANKER; DHYANI, 2006). We explored the occurrence, spatial distribution and the functional response of the main phytophagous species and their natural enemies to help develop potential conservative biological control methods.

Material and methods

This work was conducted at the Experimental Station Diogo Vaz de Melo in Viçosa-Minas Gerais State (latitude 20° 45' 54.3" S, longitude 42° 52' 06.07" W and an average altitude of 335 m) at the Federal University of Viçosa (FUV) in an experimental field of physic nut tree *J. curcas* that were one year of age (in the vegetative phase). This area is one hectare, and the trees were planted 2.5 x 2.5 m, with a total of 1,600 plants.

Regarding cultivation, commercial fertilizer 20-5-20 was used during planting and covering, with 0.150 kg per plant divided into three applications. Irrigation was not performed, and weeding of the area was performed when necessary. During the sampling period, no treatment was applied in any area to control pests or diseases. In September, the stems of the plant were trimmed to 0.50 m above the soil and sampling of phytophagous insects and predators stopped; in October, when the plants began sprouting leaves, sampling was resumed.

We selected a subsample of physic nut trees from the North of Minas Gerais State obtained from the Germplasm Bank of the Department of Phytotechny at the Federal University of Viçosa. The subsample studied was ‘Filomena’, which is currently the most commonly planted variety in Brazil. We started the sampling of phytophagous insects and their predators when the physic nut trees reached six months of age. The evaluation of phytophagous arthropods and their natural enemies was conducted using the technique of leaf beating onto a tray

(0.35 m length x 0.30 m width x 0.05 m of depth) (BACCI et al., 2008). The sampling units consisted of taking a leaf from either the apical, median, or basal third of the plant canopy. All sampled data points were georeferenced using a global positioning system. The samples were taken 10 m apart, and the total area sampled was 800 m^2.

During sampling, the arthropods found were counted and collected using a fine-bristled brush and stored in 70% alcohol. The mites were taken to the entomology laboratory, Entomologia da Empresa de Pesquisa Agropecuária de Minas Gerais (Epamig), where they were mounted on slides using Hoyer's Medium for later identification by Dr. Manoel GC Gondim Jr. / UFRPE, a specialist of phytoseiid mites. The other arthropods were identified in the taxonomy laboratory at FUV.

The data related to the densities of phytophagous arthropods and their natural enemies were subjected to frequency analysis and presented as the mean ± standard error. To select and study the interactions between variables (densities of phytophagous arthropods and their natural enemies) we used multivariate canonical correlation analysis by implementing the PROC CANCORR command in SAS (2008-2009). Significant variables with the highest correlation coefficient ($p \leq 0.05$) for studies of geostatistics and simple regression analysis ($p \leq 0.05$) were selected to study the causal relations between natural enemies and phytophagous arthropods. We tested the spatial dependence of the Moran Index (I) ($p \leq 0.05$) with the Z test. This method indicated whether the arthropods were distributed irregularly, uniformly or more aggregated, and values of I near 1 indicated high spatial dependence, while values near zero indicated little or no spatial dependence. If the values of I near 1 were significant ($p \leq 0.05$), linear regression analyses were used to analyze the interaction between the prey and natural enemies' densities using PROC REG.

Arthropods

The phytophagous prey *Frankliniella schultzei* (Trybom) (Thysanoptera: Thripidae) and *Empoasca kraemeri* Ross and Moore (Hemiptera: Cicadellidae) nymphs, and the predators *Iphiseioides zuluagai* (Denmark and Muma) (Acari: Phytoseiidae), *Psyllobora vigintimaculata* (Say) (Coleoptera: Coccinellidae) and *Anthicus* sp. (Coleoptera: Anthicidae) adults were selected for experiments of functional response. Adults of all predators were collected directly from the field using plastic containers and aspirators. These species were collected on random plants growing in the physic nut tree field at the FUV experimental station. Specimens of arthropods species were stored in 0.004 L vials containing 70% alcohol and sent to taxonomists for identification.

The rearing of *F. schultzei* was performed in the same manner as for *F. occidentalis*. *E. kraemeri* were reared on bean plants (cultivar IAC-Carioca) in 3-l pots filled with the substrate inside wooden cages (1.00 x 0.50 x 0.90 m) covered with white organza. These cages were placed in a greenhouse complex at the Federal University of Viçosa-Rio Paranaíba Campus, at 25 ± 5°C, 50-70% r.h., and L12:D12 photoperiod. Plants were replaced monthly, and the insects were reared for two generations.

Functional response

The experiments were conducted in Petri dishes (0.20 m diameter) lined with a thin layer of solidified agar solution to prevent desiccation of *J. curcas* leaf discs (0.10 m diameter). A single physic nut tree leaf disc was centered upside down on the agar solution. The insects used for the experiments were < 24 hours old and starved for 12 hours before the tests. Nymphs of *F. schultzei* and *E. kraemeri* were offered in densities of 1, 3, 5, 10, 15 and 20 for predators *I. zuluagai*, *P. vigintimaculata* and *Anthicus* sp. The maximum and minimum densities of each prey for all predators were determined from a preliminary study. To check survival of the nymphs of *F. schultzei* and *E. kraemeri* in the absence of the predator, the same number of replicates without predators was setup for each prey density. The predators were added to experimental arenas 1 hour after transferring the prey. The Petri dishes were sealed with Parafilm around the edge to prevent escaping. Seven replicates were conducted for each prey density. The number of consumed prey was counted 5 hours after the release of the predator into the experimental arenas. Consumed prey were not replaced during the experiments. The data from the consumption by the natural enemies were analyzed by one-way univariate ANOVA. For all analyses, the assumptions of normality and homogeneity of variance were verified using PROC UNIVARIATE and PROC GPLOT, and no transformations were necessary.

The functional response type was determined by a logistic regression of the proportion of prey consumed as a function of initial prey number ($p \leq 0.05$). Three basic types of functional response to prey density were identified: linear, convex and sigmoid (HOLLING, 1959). In a linear response (called type I), the number of consumed prey rises linearly up to a plateau. In a convex response (type II), the number of consumed prey rises with prey density but begins to decrease when reaching a maximum point (type III).

Results and discussion

The most common phytophagous species were nymphs and adults of *E. kraemeri,* followed by *F. schultzei* and *Myzus persicae* (Sulzer) (Hemiptera: Aphididae), with densities of 6.29 ± 0.12, 14.71 ± 0.22, 5.57 ± 0.19 and 2.57 ± 0.09/ beating on tray, respectively. Among the predators, *Ricoseius loxocheles* (Denmark and Muma) (Acari: Phytoseiidae), *I. zuluagai,* Araneidae, *P. vigintimaculata* larvae and adults and *Anthicus* sp. were the most common, with average densities of 461.29 ± 3.45, 257.43 ± 1.45, 35.86 ± 0.45, 11.57 ± 0.19, 9.00 ± 0.14 and 4.57 ± 0.14/ beating on tray, respectively. The most common parasitoids were *Oaencyrtus* spp., *Psyllaephagus* spp. and *Hexacladia smithii* (Encyrtidae) (3.00 ± 0.07), and *Aphidius* spp. and *Maecolaspis* sp. (Braconidae) (2.29 ± 0.07) (Table 1).

Table 1. Mean ± standard error and relative frequency of the density of phytophagous arthropods, predators and parasitoids per plant on the cultivated physic nut tree *Jatropha curcas.*

Group	Species	Arthropods per plant Mean ± standard error	Frequency (%)
Phytophagous	*Diabrotica speciosa*	0.71±0.04	0.9
	Cerotoma arcuata	0.57±0.03	0.7
	Empoasca kraemeri (nymph)	6.29±0.12	77*
	Empoasca kraemeri (adult)	14.71±0.22	79*
	Myzus persicae	2.57±0.09	31*
	Frankliniella schultzei	5.57±0.19	68*
Predators	Araneidae	35.86±0.45	43*
	Camponotus spp.	0.14±0.02	0.2
	Chrysopa sp	0.71±0.04	0.9
	Cycloneda sanguinea	0.57±0.04	0.7
	Hippodamia spp.	0.29±0.02	0.4
	Psyllobora vigintimaculata (larvae)	11.57±0.19	41*
	Psyllobora vigintimaculata (adult)	9.00±0.14	10*
	Sciminus sp	1.86±0.06	23*
	Syrphidae	0.86±0.04	10*
	Iphiseioides zuluagai	257.43±1.45	31*
	Ricoseius loxocheles	461.29±3.45	56*
	Anthicus sp.	324.57±0.14	45*
	Reduviidae	0.14±0.02	0.2
	Xylocoris sp	0.43±0.03	0.5
Parasitoids	Braconidae	2.29±0.07	28*
	Encyrtidae	3.00±0.07	37*
	Eulophidae	0.43±0.03	0.05

*Frequency > 10%.

Most phytophagous species found in this study have not yet had their pest status reported for *J. curcas*, and the damages and economic losses generated have not been quantified. However, *E. kraemeri* and *F. schultzei* have been reported to cause damage (OLIVEIRA et al., 2010; SILVA et al., 2008). The natural enemies with higher densities (*R. loxocheles* and *I. zuluagai*) have not been identified previously in the physic nut tree; however, in other crops, their presence is very common because they are generalist predators (SYMONDSON et al., 2002).

There was only one significant canonical axis in the relations between the densities of the phytophagous arthropods with the densities of the natural enemies (Wilk's Lambda = 0.005, F = 111.32, d.f. numerator/density = 5/295; $p < 0.001$). In this axis, the variation of the densities of the phytophagous nymph and adult stages of *E. kraemeri, M. persicae* and *F. schultzei* explained 85% of the variation in the densities of the natural enemies. The phytophagous insects that most influenced the density of the natural enemies were *E. persicae* nymph (r = 0.88) and *F. schultzei* (r = 0.74) (Table 2). Thus, the variables selected by the canonical correlation analysis studied in the analysis of spatial distribution and tested in the regression models were the phytophagous *E. kraemeri* nymph and *F. schultzei* and the natural enemies *P. vigintimaculata* larvae and adults*, I. zuluagai, R. loxocheles,* Anthicidae and Braconidae (Table 2).

Table 2. Canonical correlation between the densities of the phytophagous arthropods with the densities of the natural enemies in the physic nut tree *Jatropha curcas.*

Density of phytophagous insects	Canonical axis	
	Coefficient	r
Empoasca kraemeri (nymph)	-0.87	0.88
Empoasca kraemeri (adult)	-0.14	0.12
Myzus persicae	1.65	0.45
Frankliniella schultzei	-0.95	0.74
Density of natural enemies		
Araneidae	0.11	0.21
Psyllobora vigintimaculata (larvae)	1.25	0.75
Psyllobora vigintimaculata (adult)	1.74	0.78
Sciminus sp	0.10	0.20
Syrphidae	0.05	0.12
Iphiseioides zuluagai	2.14	0.89
Ricoseius loxocheles	2.74	0.71
Anthicus sp.	2.01	0.87
Braconidae	1.01	0.61
Encyrtidae	0.12	0.21
Characteristics of the axis	$R^2 = 0.85$, F = 9.85, $p < 0.01$	

The pattern of positive spatial dependence of the density of the phytophagous species *E. kraemeri* and *F. schultzei* and the natural enemies *P. vigintimaculata* larvae and adults, *I. zuluagai, R. loxocheles,* Anthicidae and Braconidae showed that some areas favor the permanence of phytophagous species and their natural enemies. Phytophagous species most likely contain enough food for the natural enemies' diets without competition for resources with other organisms. The natural enemies *P. vigintimaculata* larvae and adults and Anthicidae may have a density dependent relationship with the phytophagous *E. kraemeri* and *F. schultzei.* Density dependent relationships between natural enemies and pests are often cited in the literature (BYRNES et al., 2006; CARDINALE et al., 2003; HOUGARDY; MILLS, 2008; SNYDER et al., 2006; SNYDER et al., 2008), especially when these relationships involve interactions between prey and natural enemies in a spatial scale.

There was a positive spatial dependence of the density of phytophagous *M. persicae* and *F. schultzei* and their natural enemies *P. vigintimaculata* larvae and adults, *I. zuluagai*, *R. loxocheles*, Anthicidae and Braconidae (I = 0.71, Z = 3.37, $p \leq 0.05$; I = 0.88, Z = 5.52, $p \leq 0.05$; I = 0.65, Z = 4.23, $p \leq 0.05$; I = 0.55, Z = 3.11; $p \leq 0.05$, I = 0.68; Z = 3.08, $p \leq 0.05$, I = 0.61, Z = 3.43, $p \leq 0.05$; I = 0.64, Z = 3.34, $p \leq 0.05$ and I = 0.84, Z = 4.98, $p \leq 0.05$, respectively). This spatial dependence is consistent with the patchy distribution of these arthropods. In addition, there was a trend of early attack and action of natural enemies on the sides of the region evaluated at the *J. curcas* farm, where the adult density is markedly higher (Figure 1).

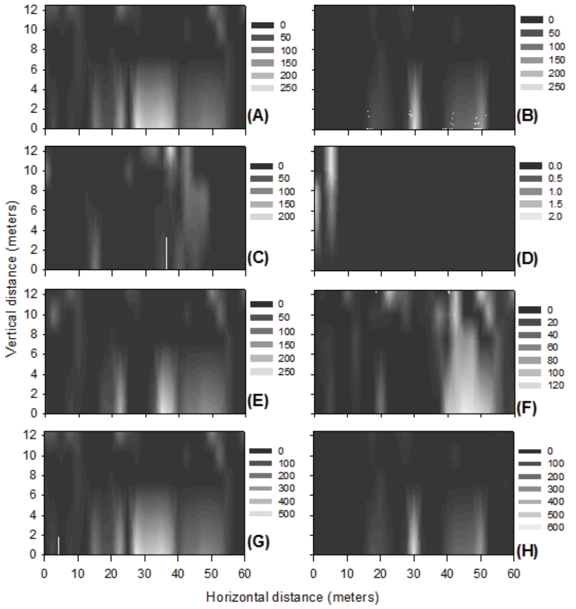

Figure 1. Maps of spatial distributions of natural enemies (A) *Iphiseioides zuluagai,* (B) *Ricoseius loxocheles*, (C) *Psyllobora vigintimaculata* larva, (D) *Psyllobora vigintimaculata* adult, (E) *Anthicus* sp., (F) Braconidae, (G) *Frankliniella schultzei* and (H) *Empoasca kraemeri* nymph. The colors on the maps show the different densities of arthropods per 100 plants.

In this study, the distributions of *E. kraemeri* and *F. schultzei* follow spatial patterns similar to those of the natural enemy *P. vigintimaculata*, both larvae and adults. The causal relationship between the phytophagous *E. kraemeri* and *F. schultzei* with the larvae and adults of *P. vigintimaculata* and adult Anthicidae explains the clustered distribution of these arthropods. These predators have been reported to feed on *E. kraemeri* and *F. schultzei*. Coccinellids have been observed feeding on aphids, thrips, mites and eggs of lepidoptera (ONKAR, 2014; SARMENTO et al., 2007). Because *Anthicus* are coleopterous, according to (MAES; CHANDLER, 1994), they feed on Lepidoptera eggs and first stage larvae and the pupae of other insects. Given the small sizes of the leafhopper *E. kraemeri* and the thrips *F. schultzei* associated with one place of occurrence of predators (vicinity of niches), they could serve as a suitable food source for these predators. Bastos et al. (2003), studying the diversity of phytophagous arthropods and predators, found high densities of *E. kraemeri* (Ross and Moore) and the predator *Anthicus* sp. in beans (*Phaseolus vulgaris*).

The highest densities of phytophagous *E. kraemeri* and *F. schultzei* on the edges of the *J. curcas* crop follow spatial patterns similar to those of the natural enemies *I. zuluagai* and *Anthicus* sp. (Figure 1A and E). This trend may be because of a causal relationship between phytophagous densities and these natural enemy densities (Figure 2A and E).

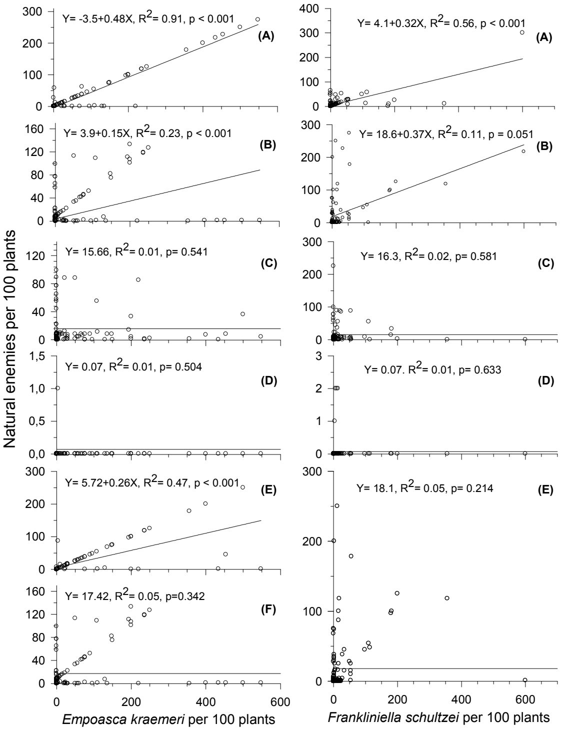

Figure 2. Causal relationship between phytophagous (independent variable) *Empoasca kraemeri* nymph and *Frankliniella schultzei* with (dependent variable) natural enemies (A) *Iphiseioides zuluagai*, (B) *Psyllobora vigintimaculata* adults, (C) *Psyllobora vigintimaculata* larvae, (D) *Ricoseius loxocheles,* (E) *Anthicus* sp. and (F) Braconidae.

The non-causal relationship between the other natural enemies with phytophagous insects may be due to a greater dispersal to other locations in the area. This behavior may have reduced the chances of an encounter between natural enemies and phytophagous insects. Relations between phytophagous insects, predators and parasitoids on a spatial scale are important in establishing the rates of dispersal of species. These rates may be higher or lower depending on the available resources.

Functional response

The mean numbers of *F. schultzei* and *E. kraemeri* nymphs consumed were significantly different among the predators *P. vigintimaculata* (F = 60.48; d.f. = 1,39; $p < 0.0001$), *I. zuluagai* (F = 32.44; d.f. = 1,39; $p < 0.0001$) and *Anthicus* sp. (F = 28.57; d.f. = 1,39; $p < 0.0001$), respectively. The predators *P. vigintimaculata*, *I. zuluagai* and *Anthicus* sp. consumed 1.00 ± 0.41, 5.55 ± 1.06 e 4.98 ± 1.30 *F. schultzei* nymphs, and 0.28 ± 0.15, 5.39 ± 1.05 and 3.14 ± 0.90 nymphs of *E. kraemeri*, respectively.

No relation was observed between the number of *F. schultzei* and *E. kraemeri* consumed by *P. vigintimaculata* (Figure 3A). However, the number of *F. schultzei* and *E. kraemeri* consumed by *I. zuluagai* and *Anthicus* sp. increased as a function of the density, with a positive and highly significant correlation (Figure 3B and C). Thus, the functional response to prey density of *I. zuluagai* and *Anthicus* sp. were type II, where the number of killed prey rises linearly up to a plateau (Figure 3). It was also established that the three predators found and captured prey even at the lowest densities, killing them even after satiation.

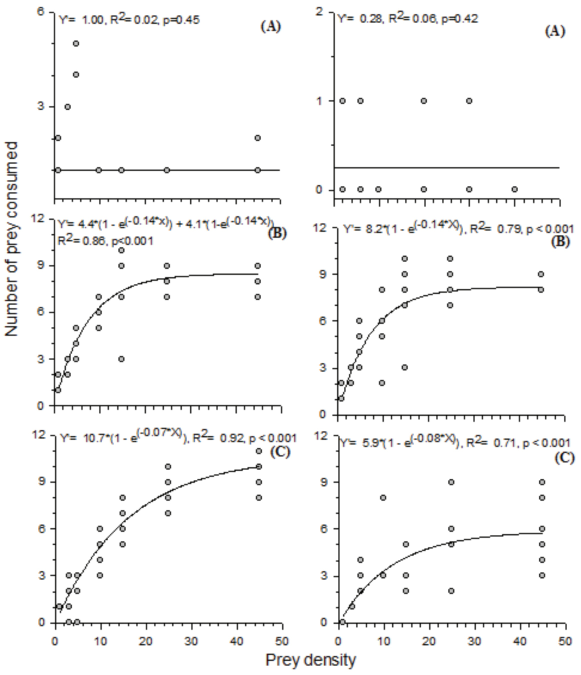

Figure 3. The functional response of *Psyllobora vigintimaculata* adult (A), *Iphiseioides zuluagai* (B) and *Anthicus* sp. (C) to *Frankliniella schultzei* and *Empoasca kraemeri* nymphs at temperature: 25.21±1.05°C, relative humidity: 65.32±2.12%, photoperiod: 12 hours.

The stabilization of type II functional response is derived from a limitation of the predators; they cannot increase their rate of predation due to the limitation of time for searching, handling prey, and their satiation (see Figure 3). It was established that the three predators found and captured prey even at the lowest densities, killing prey even after satiated. The nature of the functional response of *I. zuluagai* and *Anthicus* sp. to *F. schultzei* and *E. kraemeri* is expected because the type II response is common in many predatory mites and Anthicidae: *Phytoseiulus persimilis* Athias-Henriot, *Neoseiulus californicus* (McGregor), *Phytoseiulus macropilis* (Banks) and *Orius insidiosus* (Say) (GOTOH et al., 2004; POLETTI et al., 2007; RUTLEDGE; O'NEIL, 2005; XIAO; FADAMIRO, 2010).

Considering the obtained results, it is possible that *I. zuluagai* and *Anthicus* sp. can reduce the population of *E. kraemeri* and *F. schultzei* nymphs in field conditions of *J. curcas*, even if they reach high densities. The fact that *P. vigintimaculata* needs less prey than *I. zuluagai* and *Anthicus* sp. suggests that its survivorship will be better than predators with a low prey density in the field. The high aggressiveness of *I. zuluagai* was also recorded by Reis et al. (2000).

Knowledge of spatial distribution is important because dispersal behavior, such as immigration and inter- and intra-field crop movement, must be precisely monitored to understand the population dynamics of insect predators and prey. Thus, creating ideal conditions for natural enemies in physic nut tree crops can be very important in reducing dispersion and increasing the encounter rates between predators and prey.

Conclusion

In conclusion, the phytoseiid *I. zuluagai* and the anthicid *Anthicus* sp. can be considered efficient predators of immature stages of *E. kraemeri* and *F. schultzei* at different densities, and they contribute to the reduction of the prey population on *J. curcas*, where they are most commonly present. These data are extremely important for developing CBC measures for this crop of great economic value because there are still no insecticides registered for the control of its pests.

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