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THE ENTOMOLOGICAL FAUNA VISITING CULTIVATED POPULATIONS OF *TROPAEOLUM MAJUS* L. (TROPAEOLACEAE)

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ABSTRACT
We inventoried the insects associated with a “nasturtium” *Tropaeolum majus* L. (Tropaeolaceae) plantation by sweeping the area with an entomological net once a week every two hours from 07:00 to 17:00h for 14 weeks. The parameters examined were: insect visitor dominance, abundance, diversity, frequency and constancy during the different collecting periods. The insect orders encountered were: Diptera, Coleoptera, Hemiptera, Hymenoptera, Lepidoptera, Orthoptera and Thysanoptera. Among these, the Diptera, Hemiptera and Hymenoptera were the most common in stands of “nasturtium” plants, probably because these taxa are largely represented by phytophagous insects, predators, and pollinators. The time of greatest insect abundance was from 9:00 to 13:00h for all of the insect orders observed, a situation that was most likely influenced by the high concentrations of sugars in the floral nectar during that period; the greatest insect diversity was observed at 15:00 hours during the eleventh week of cultivation. Chloropidae (Diptera) was the most frequent family; these insects use many diverse resources offered by these plants, such as nectar and pollen - and the flower itself can be used for shelter and ovipositioning. Aphididae and Cicadellidae were the most frequent families of Hemiptera, and they were represented by phytophagous insects; the families of Hymenoptera that were most frequently observed were Apidae, Megachilidae and Formicidae. The predominance of the different insect orders were strongly alternated during the different phenological phases of the plant crop (vegetative, flowering, fruiting, and senescence).

KEY WORDS: Nasturtium. associated insects. phenological phases.

INTRODUCTION
Investigations of the interactions between insects and plants are important to our understanding of biodiversity (Schoonhoven et al., 1998). The resources furnished by plants are fundamental to the adaptative irradiation of animals (Price, 2002), and flowers offer food to insects as well as sites of protection and for mating and ovipositioning (Malerbo-Souza et al*.,* 2008) - while floral visitors can act as pollinators (Kearns et al., 1998; Speight et al., 1999). Studies of interactions between plants and insects usually reveal situations that are vital to both, such as herbivory and pollination, and their mutual and sequential responses and adaptations form a gradual process known as co-evolution (Rupert et al., (2005). The *Tropaeolum majus* L. (Tropaeolaceae) plants used in the present study originated in Peru, but the ease with which this species has adapted to many different climates has aided its dissemination throughout the world. This plant in an important folk remedy in Brazil, and its leaves are widely used to treat cardiovascular diseases, urinary tract infections, and constipation (Corrêa, 1984; Ferreira et al., 2004). Recent studies have proven that the leaves and flowers of *T. majus* contain large amounts of luteina, zeaxanthin and carotenoids that can slow macular degeneration (Niizu and Rodriguez-Amaya, 2005). The *T. majus* produces various resources that attract insects, and each plant will produce a number of flowers and therefore offer considerable quantities of pollen and nectar; the corollas can be of varying colors and sizes and are often used by insects for shelter, mating, or ovipositioning. The *T. majus* belongs to the order Brassicales and, like the families Capparaceae and Brassicaceae, is important to humans as a food source providing important dietary phytochemicals (principally aromatic glycosinolates, carotenes and phenolic compounds) with anti-cancer and antioxidant proprieties (Dillard and German, 2000; Holst and Williamson, 2004). This species also produces fatty acids (erucic acid, oleic acid, linoleic acid), benzyl isothiocyanate, and flavonoids (quercetin and kaempferol) in its seeds and leaves (De Medeiros et al., 2000; Mietkiewska et al., 2004). As there have been no published inventories of the insects associated with plantings of *T. majus*, the present study surveyed the entomofauna associated with this species at different hours of the day and during different stages of its development to provide subsides for future ecological studies and cultivation efforts.

MATERIAL AND METHODS
The research was conducted in an experimental area of the medicinal plant garden at the Universidade Federal do Grande Dourados (UFGD) in Dourados, Mato Grosso of Sul State, Brazil. The seeds were initially sown into plastic trays containing earth, sand, plantimax® (substrate), and

discarded poultry bedding (2:2:1:1 v/v). After 22 days, the seedlings were transplanted to planting beds (30 cm spacing) and were watered twice a day for 30 days. Insect collecting was initiated 45 days after sowing. Insects were collected for 14 weeks during the period from March to June 2009 using an entomological net to sweep the area for a total of two hours once every week between 07:00 and 17:00 hours (for a total of 84 hours during the study). Sweeps were made at five different randomly chosen points in the planting field, each involving five passes with an entomological net. The captured insects were transferred to plastic bags containing cotton soaked in ethyl acetate and were subsequently examined in the entomological laboratory at FCBA/UFGD.

The constancy of insect presence (C = *p*.100/N) was calculated and classified according to Silveira Neto *et al.* (1976) into either: constant (present in more than 50% of the collections); accessory (present in between 25-50% of the collections); or accidental (present in less than 25% of the collections). Insect frequency ($P_i = n_i/N$) was calculated as the proportion of the individuals of each family in relation to the total number of individuals collected from that order (in terms of the hours of the day and the week of cultivation) (Thomazini and Thomazini, 2002). The species dominance (D% = (i/t). 100) values of the insects were calculated and classified into the following categories according to Friebe (1983): eudominant (> 10%); dominant (between 5-10%); subdominant (between 2-5%); recessive (between 1-2%); and rare (< 1%). Abundance was calculated following Garcia and Corseuil (1998), and the Shannon-Wiener diversity index (H') calculated according to Magurran (1988), as given by the formula $H' = \Sigma\, pi$ log pi.

RESULTS AND DISCUSSION

A total of 1,961 individuals were collected during the sampling period; they were distributed among five taxonomic orders, with Diptera being the most abundant (Figure 1). Dominance evaluations indicated the presence of three eudominant orders: Diptera (51%), Hymenoptera (21%), and Hemiptera (18%); a single dominant order, Thysanoptera (5%); a subdominant order, Coleoptera (4%); and two rare orders, Lepidoptera (0.25%) and Orthoptera (0.30%) (Figure 1).

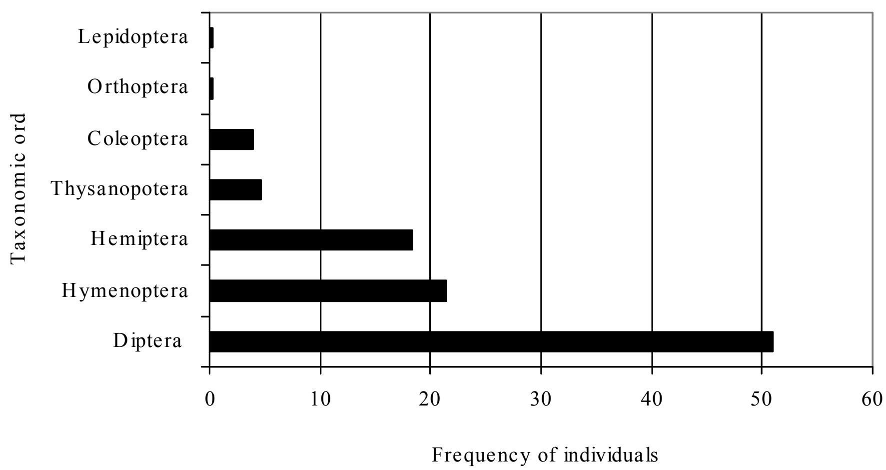

FIGURE 1. Dominance of the insect orders collected in a cultivated field of *Tropaeolum majus* L.

TABLE 1. Abundance, Constancy (C%) and Frequency (F%) of insects captured on cultures of *Tropaeolum majus* L. from 07:00 - 9:00 - 11:00 - 13:00 - 15:00 and at 17:00h.

Order/Family	Abundance	C (%)		F (%)
DIPTERA		Weeks	Hours	
Agromyzidae	42	50 AC	100 C	4,2
Asilidae	2	14 AD	33 AC	0,2
Bombyliidae	4	14 AD	50 AC	0,4
Calliphoridae	4	21 AD	33 AC	0,4
Cecidomyiidae	33	42 AC	100 C	3,3
Chloropidae	765	100 C	100 C	76
Culicidae	57	21 AD	66 C	5,5
Dolichopodidae	2	14 AD	33 AC	0,2
Drosophilidae	7	35 AC	50 AC	0,7
Ephydridae	19	21 AD	100 C	1,9
Muscidae	17	71 C	29 AC	1,7
Mycetophilidae	2	7 AD	33 AC	0,2
Phoridae	13	50 AC	100 C	1,3
Piophilidae	5	21 AD	50 AC	0,5
Rhagionidae	1	7 AD	16 AD	0,1

Sarcophagidae	5	21 AD	50 AC	0,5
Scatopsidae	6	14 AD	50 AC	0,6
Syrphidae	7	42 AC	66 C	0,7
Tephritidae	11	35 AC	50 AC	1,1

Order/Family	Abundance	C (%)		F (%)
COLEOPTERA				
Buprestidae	1	7 AD	16 AD	1,3
Carabidae	2	7 AD	16 AD	2,6
Coccinelidae	1	7 AD	16 AD	1,3
Crysomelidae	6	14 AD	83 C	7,9
Melyridae	64	85 C	100 C	84
Meloidae	1	7 AD	16 AD	1,3
Staphylinidae	1	7 AD	16 AD	1,3

Order/Family	Abundance	C (%)		F (%)
HEMIPTERA				
Anthocoridae	2	7 AD	33 AC	0,5
Aphididae	184	57 C	100 C	51,6
Cicadellidae	108	78 C	100 C	30,1
Membracidae	1	7 AD	16 AD	0,2
Miridae	27	42 AC	100 C	7,4
Reduviidae	31	78 C	100 C	8,5
Tingidae	8	42 AC	83 C	2,2

Order/Family	Abundance	C (%)		F (%)
HYMENOPTERA				
Andrenidae	4	21 AD	33 AC	0,1
Apidae	164	85 C	100 C	39
Bethylidae	2	14 AD	33 AC	0,4
Braconidae	2	7 AD	33 AC	0,4
Chalcididae	23	57 C	100 C	5,4
Cynipidae	9	21 AD	83 C	2,1
Diapriide	1	7 AD	16 AD	0,2
Encyrtidae	32	64 C	100 C	7,6
Eulophidae	15	35 AC	100 C	3,5
Evaniidae	2	7 AD	16 AD	0,4
Formicidae	41	93 C	100 C	9,8
Halictidae	4	21 AD	50 AC	0,1
Ichneumonidae	3	21 AD	50 AC	0,7
Megachilidae	63	85 C	100 C	15
Mymaridae	4	21AD	33AC	0,1
Platygastridae	39	57 C	100C	9,3
Scelionidae	2	7AD	33AC	0,4
Vespidae	9	42AC	83 C	2,1
Order/Family	Abundance	C (%)		F (%)
THYSANOPTERA				
Thrypidae	92	93 C	100 C	100
Order/Family	Abundance	C (%)		F (%)
LEPIDOPTERA				
Pieridae	5	28 AC	33 AC	100
Order/Family	Abundance	C (%)		F (%)
ORTHOPTERA				
Gryllidae	6	28 AC	50 AC	100

C: constancy, AC: accessory e AD: accidental.

Some of the insects observed in the flowers of *T. majus*, such as Diptera (Chloropidae) and Hymenoptera of the families Apidae and Megachilidae, have also frequently been reported in other plant cultures and corroborate reports by Mussury et al. (2003) of insects on the floral verticils of *Brassica napus* L.

Analyses of the frequencies of insect families observed during the development of *T. majus* indicated that insects in the order Diptera of the family Chloropidae were the most frequent visitors (76% - eudominant), while Culicidae (6%) was dominant, and Agromyzidae (4%), Cecidomyiidae (3%), Ephydridae (2%), and Muscidae (2%) were subdominant (Table 1). The high frequency of Diptera on *T. majus* can be explained (according to Borror 1992) by the fact that it is one of the largest insect orders and is represented by many diverse species that are found almost everywhere; most of them subsist on nectar, although others are predators of other insects. Diptera is the second largest order of flower-visiting insects, and they are considered important plant pollinators (Larson et al., 2001).

Among the Hymenoptera, the most frequent families were Apidae (39%) and Megachilidae (15%), classified as eudominants; while Formicidae (9.8%), Encyrtidae (7.6%) and Chalcididae (5.4%) were classified as dominant; and Eulophidae (3.5%) as subdominant (Table 1). The data obtained in the present study corroborated with the observations of Santana et al., (2002) who reported that the families Apidae and Megachilidae were the most frequent visitors to flowers of *Phaseolus vulgaris* L.

According to Souza et al. (2007), the frequency of the bees mentioned above can be explained by the fact that they are the principal pollinators of flowering plants, receiving in turn resources necessary for their survival (including pollen, which is the principal protein source for bees). The families of Hymenoptera (Bethylidae, Chalcididae, Diapriidae, Encyrtidae, Eulophidae, Evaniidae and Ichneumonidae) have special value as agents of biological control. The Bethylidae are gregarious ectoparasites that attack the larva (and occasionally the pupa) of coleopterans and are used in the biological control of coffee borers; the Chalcididae are a very abundant and widely distributed group of parasitoids and hyper-parasitoids of Lepidopterons and other hymenoptera; the Diapriidae are the largest group of Proctotrupoidea and are commonly encountered in humid habitats parasitizing dipterans, and many species have been reported attacking fruit flies, and there are reports of yet other species parasitizing army ants; the Encyrtidae are warm-climate insects and have been successfully used to control mealybugs; the Eulophidae are one of the largest families of Chalcidoidea, being largely cenobionts and idiobionts, and can be endoparasites or ectoparasites on a wide variety of hosts, although a few species are leaf-miners; the Evaniidae are predators of eggs and parasites of cockroach oothecas, and the adult females will search in leaf-litter and fallen tree trunks for their prey to deposit their eggs; the Ichneumonidae are very abundant and generally attack spiders and other holometabolous insects, being carnivorous in their larval stages (Fernandez and Sharkeym, 2006). The Cynipidae classified here as accidental finds are known to lay their eggs in plant tissues, forming galls in many plant organs (Liu and Ronquist, 2006). Ants function at many trophic levels and can be predators of large numbers of insect species as well as important agents of biomass recycling; harvester ants are of great agricultural importance as they can cause significant crop damage. The ant genera most commonly found in agricultural environments (excluding leaf-cutters) are *Pheidole* and *Solenopsis* - which predate the larva of various agricultural pests (Höldobler and Wilson, 1990; Risch and Carroll, 1982).

The most frequent families encountered within the order Hemiptera were Aphididae (51.6%) and Cicadellidae (30.1%), both classified as eudominant, while Miridae (7.4%) and Reduviidae (8.5%) were considered dominant (Table 1). The high frequency with which this order appears can be explained by the fact that it comprises many phytophagous insects, some of which are considered pests of global importance (Gallo et al., 2002); other members of this group are voracious insect predators (Gil-Santana and Zeraik, 2003). Analyses of insect abundance at different times of day (Figure 2) indicated their predominance during the period between 09:00 and 13:00h (the period with the greatest floral nectar abundance). While Diptera was the most abundant order between 09:00 and 17:00h, Hymenoptera and Coleoptera were most abundant at 11:00h and Thysanoptera at 09:00h. Hemiptera demonstrated relatively constant presence during the entire collection period, while the orders Lepidoptera and Orthoptera were less abundant at these times. In general, there was low insect diversity at 15:00h (H'= 1.4), followed by decreasing diversity at 09:00 (H'=1.32), 11:00 (H'=1.3), 13:00 (H'=1.28), 07:00 (H'= 1.14) and 17:00h (H'=1.08) (Fig. 3). According to Magurran (1988), the Shannon-Wiener index expresses the uniformity of all of the sampling values and rarely passes 4.5 (as could be seen in the present work). Insect abundance was variable during the course of cultivation of *T. majus.* The order Diptera appeared in abundance during the 3rd and 4th collection weeks, while the order Coleoptera predominated in the 3rd and 7th weeks. The order Hemiptera demonstrated greatest abundance during the 1st and 2nd weeks, while Hymenoptera predominated in the 7th and 14th weeks and Thysanoptera in the 7th and 9th weeks. Lepidoptera and Orthoptera were encountered in low numbers during the entire sampling period (Figure 4).

The 1st and 2nd weeks of collecting corresponded to the vegetative phase (phenological stage A) of "nasturtium" - when phytophagous and predator insects would be expected - thus justifying the abundance of insects of the order Hemiptera. Flowering was observed from the 3rd to the 10th week (phenological stage B), which justified the abundance of insects of the orders Diptera, Coleoptera, Hymenoptera and Thysanoptera that feed on pollen and nectar (with many of them being considered pollinators) (Figure 4).

During the 9th and 12th weeks (phenological stage C, which correspond to the fruiting phase of *T. majus*) some individual plants still had flowers, which justified the presence of coleopterans in the collections as some of these insects use flowers as shelters and as mating sites.

During the 13th and 14th weeks (phenological stage D - the stage of senescence) some individuals of *T. majus* still had flowers and bees of the genus *Trigona* were collected; these bees apparently sought supplemental food resources and thus increased the numbers of Hymenoptera recorded (Figure 4).

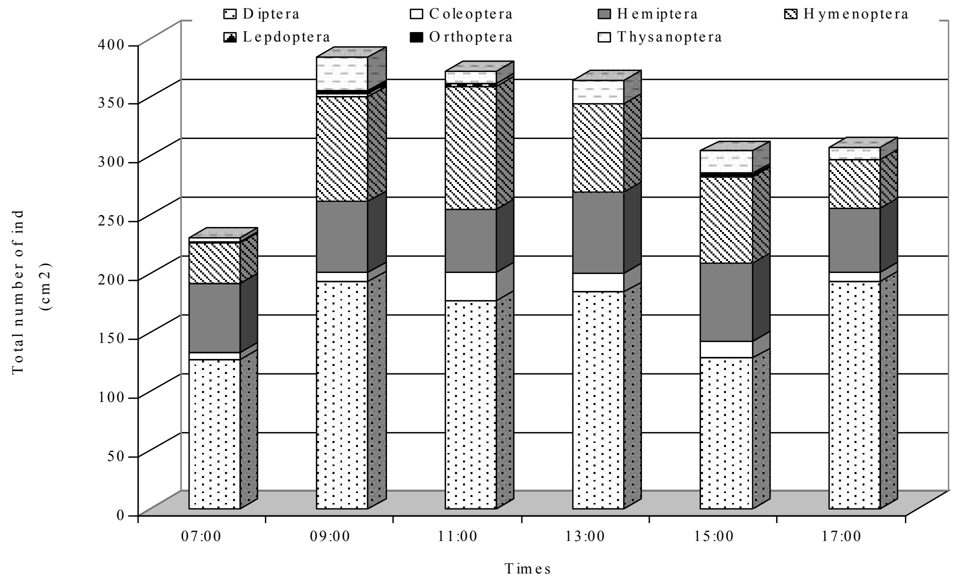

FIGURE 2. Abundance of the different insect orders at different times of day in a cultivated field of *Tropaeolum majus* L.

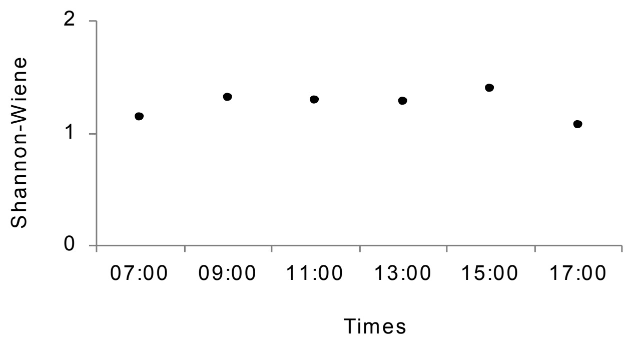

FIGURE 3. The Shannon-Wiener Diversity Indexes of the insects collected at different times on *Tropaeolum majus* L.

The greatest insect diversity seen during the entire collection period in the *T. majus* planting area occurred in the 11th week (stage B) (H'= 1.53), followed by weeks 10 (H'= 1.39), 12 (H'= 1.36), 7 (H'= 1.34), 9 (H'= 1.26), 1 (H'= 1.20), 8 (H'= 1.17), 13 (H'= 1.15), 14 (H'= 1.10), 6 (H'= 1.07), 2 (H'= 1.06), 3 (H'= 1.01), 5 (H'= 0.93), and 4 (H'= 0.79) (Figure 5).

There was a predominance of Diptera during the first weeks of development of the *T. majus* plantings (Figure 4), which could be explained by the fact that this order comprises many predators and insects that seek out varied plants as food resources and as sites for ovipositioning and mating. These findings corroborated the data presented by Marinoni and Dutra, (1991), who listed the order Diptera as the most abundant in the majority of the localities sampled in Paraná State, Brazil. The high diversity of insects seen in *T. majus* plantations probably also reflects the diversity of plant species growing around the agricultural plot itself - thus increasing the numbers of ecological niches available for insects (as was noted by Poggiani and Oliveira, (1998) in their analyses of forest fragments).

The families Chloropidae, Culicidae, Agromyzidae, Cedidomyiidae, Ephydridae, Phoridae and Syrphidae stood out within the order Diptera during the collection periods and were classified as constant, with frequency levels of 76; 5.5; 4.2; 3.3; 1.9; 1.3 and 0.7% respectively. Chloropidae was also observed to be constantly present during the collection periods together with Muscidae (which had a frequency level of 1.7%) (Table 1).

Within the order Coleoptera, the family Melyridae was observed to be constant in terms of both daytime hours and collection weeks (resulting in a Frequency level of 84%). Crysomelidae was only constant in terms of the collection hours, and had a frequency level of 7.9% (Table 1).

Among the Hemiptera, the families Aphididae, Cicadellidae, and Reduviidae were observed to be constant in terms of the collection hours and weeks, with frequency levels of 51.6, 30.1 and 8.5% respectively. The family

Miridae was constant only in terms of the collection hours, with a frequency level of 7.4% (Table 1).

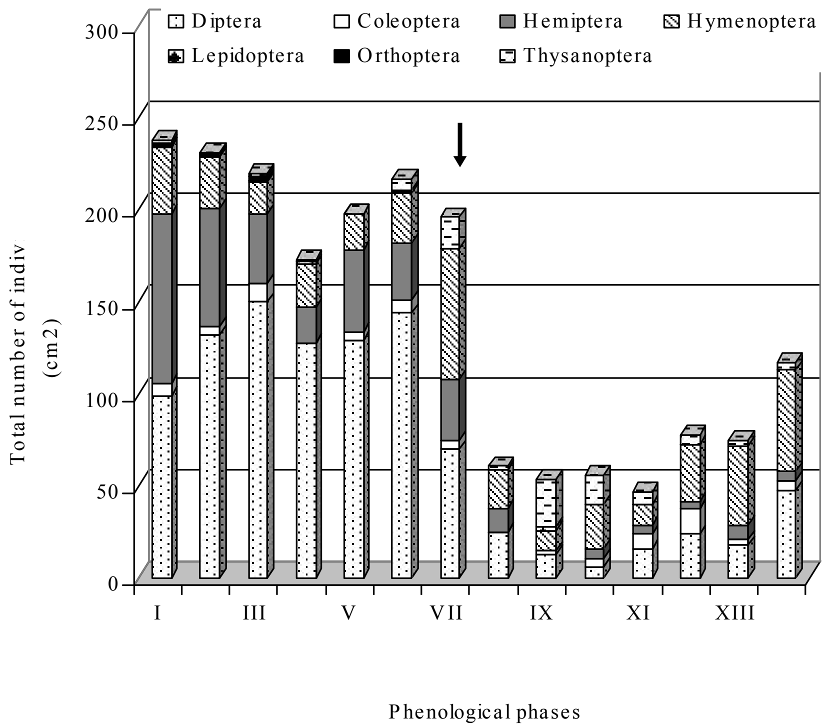

FIGURE 4. Abundance of insect orders collected during the different phenological stages on *Tropaeolum majus* L. A: vegetative phase; B: flowering phase (flowering peak - arrow); C: fruiting phase; D: senescent phase

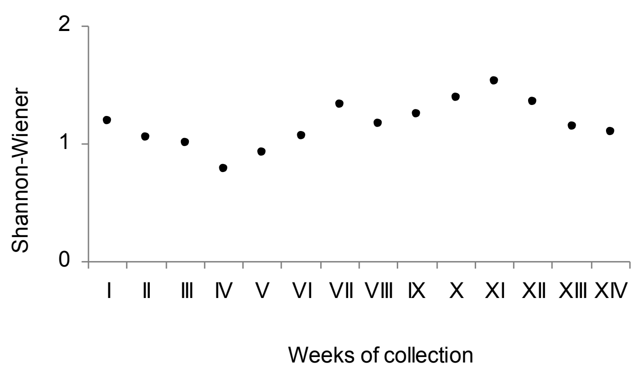

FIGURE 5. The Shannon-Wiener Diversity Indexes of insects encountered on *Tropaeolum majus* L.

The Hymenoptera were constant in terms of both the collection hours and weeks, and the families Apidae, Megachilidae, Formicidae, Platygastridae, Encyrtidae and Chalcididae had frequency levels of 39, 15, 9.8, 9.3, 7.6, and 5.4% respectively. Eulophidae, Cynipidae and Vespidae were constant only in terms of the collection hours. Eulophidae had a frequency level of 3.5%, while Cynipidae and Vespidae both had frequency levels of 2.1% (Table 1). Thysanoptera was constant throughout the weekly collections, with a frequency level of 100%. Orthoptera and Lepidoptera were not constant (Table 1). Pascarella et al. (2001) observed that some species of floral visitors might not be effective pollinators, while others might consume floral structures or seeds (Diptera and coleopterans), or utilize the flowers as sites for capturing other insects (coleopterans and wasps) or simply as resting sites (Diptera). Among the 235 bees collected in the present study (mostly acting as pollinators), there was a great abundance of the families Apidae (69.8%), Megachilidae (26.9%) and Halictidae (1.7%) (Table 1). Individuals of the family Andrenidae (1.7%) were observed making holes in the calcar. This information corroborates data published by Lopes et al. (2007) who observed a predominance of the families Apidae (44%), Halictidae (29%), Andrenidae (23%), and Megachilidae (4%) among the 218 bees encountered in their studies in eucalyptus plantations.

The most abundant orders found in the present work were Diptera, Coleoptera, Hemiptera and Hymenoptera, represented especially by the families Chloropidae, Melyridae, Aphididae and Cicadellidae, and Apidae and Megachilidae respectively.

The greatest abundance of insects was seen from 09:00 to 13:00h, with large numbers of Diptera. The greatest diversity of insects occurred at 15:00h (H'= 1.4) and during the 11th week (H'= 1.53).

In terms of the development phases of the *T. majus* crop, the predominant orders occurred in the following sequence: vegetative phase (A) - the order Hemiptera; flowering phase (B) - the orders Diptera, Coleoptera, Hymenoptera, and Thysanoptera; fruiting phase (C) - the order Coleoptera; and during the senescence phase (D) - the order Hymenoptera.

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