



Feeding habits of Carabidae (Coleoptera) associated with herbaceous plants and the phenology of coloured cotton

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ABSTRACT. The carabids (Coleoptera: Carabidae) are recognized as polyphagous predators and important natural enemies of insect pests. However, little is known about the feeding habits of these beetles. In this work, we determine the types of food content in the digestive tracts of nine species of Carabidae associated with herbaceous plants and different growth stages of coloured cotton. The food contents were evaluated for beetles associated with the coloured cotton cv. BRS verde, *Gossypium hirsutum* L. *latifolium* Hutch., adjacent to weed plants and the flowering herbaceous plants (FHPs) *Lobularia maritima* (L.), *Tagetes erecta* L., and *Fagopyrum esculentum* Moench. The digestive tract analysis indicated various types of diets and related arthropods for *Abaris basistriata*, *Galerita brasiliensis*, *Scarites* sp., *Selenophorus alternans*, *Selenophorus discopunctatus* and *Tetracha brasiliensis*. The carabids were considered to be polyphagous predators, feeding on different types of prey.

Keywords: diet, habitat manipulation, conservative biological control, predator.

Hábito alimentar de Carabidae (Coleoptera) associado com plantas herbáceas e fenologia de algodão colorido

RESUMO. Os carabídeos (Coleoptera: Carabidae) são considerados predadores polívoros e importantes inimigos naturais de insetos pragas. No entanto, pouco se sabe sobre os hábitos alimentares destes besouros. Neste trabalho, determinamos o tipo de conteúdo alimentar no trato digestivo de nove espécies de Carabidae associados a plantas herbáceas e diferentes estágios de crescimento de algodão colorido. O conteúdo alimentar foi avaliado no cultivar de algodão colorido BRS Verde *Gossypium hirsutum* L. *latifolium* Hutch. e nas adjacências da área com algodoeiro, foi inserido canteiros com plantas daninhas e plantas herbáceas floríferas (PHF) *Lobularia maritima* (L.), *Tagetes erecta* L. e *Fagopyrum esculentum* Moench. A análise trato digestivo indicaram vários tipos de dietas e artrópodes relacionados com *Abaris basistriata*, *Galerita brasiliensis*, *Scarites* sp., *Selenophorus alternans*, *Selenophorus discopunctatus* e *Tetracha brasiliensis*. Os carabídeos estudados foram considerados predadores polívoros, alimentando-se de diferentes tipos de presas.

Palavras-chave: dieta, manipulação do habitat, controle biológico conservativo, predador.

Introduction

The coleopteran Carabidae are recognized as ground beetles, with approximately 40,000 species described. In the Neotropical region, this family includes 203 genera and 1,132 species (Costa, Vanin, & Casari-Chen, 1988; Lövei & Sunderland, 1996). These beetles have emerged as important natural enemies of insect pests of various crops including cotton (Chocorosqui & Pasini, 2000; Wyckhuys & O'Neil, 2006). The diet of carabids includes Collembola, earthworms, nematodes, slugs, snails, aphids, eggs and larvae of Diptera and Coleoptera, Lepidoptera pupae and seeds of herbaceous plants (Kromp, 1999; Holland & Luff, 2000; Holland, 2002; Tooley & Brust, 2002).

The digestive system of insects reflects a major interaction between these organisms and the environment due to their great morphological and functional digestive diversity and the assimilation of nutrients from different food types (Terra, 1988). These variations in the digestive tracts of insects facilitate the feeding habits of each species and are correlated with factors such as phenology and the type of structure produced by floriferous plants (Caetano, 1984; Ribeiro, Ferreira, & Terra, 1990). Therefore, insects can be analysed based on food availability by classifying the diets according to the nutritional composition, namely whether the food items are of animal or vegetable origin (Dow, 1986).

Conservative biological control aims to increase and conserve natural enemy populations to increase the efficiency of pest control insects (Barbosa, 1998); therefore, the techniques used in this type of control are easily integrated into pest management programmes (Collins, Boatman, Wilcox, & Holland, 2003). The manipulation of habitat using flowering herbaceous plants increases natural biological control but requires information on the natural enemies involved (Jonsson, Wratten, Landis, Tompkins, & Cullen, 2010) and the floriferous plant species used, which should only attract natural enemies (Hogg, Bugg, & Daane, 2011). Carabids use refuge areas for shelter during adverse periods of the year (Bedford & Usher, 1994). Thus, refuge areas consisting of flowering plants increase the diversity of carabids and other insect predators, which maintains the biodiversity of agroecosystems and also their stability (Frank & Reichardt, 2004; Macleod, Wratten, Sotherton, & Thomas, 2004).

Although studies exist on the feeding habits of carabids in temperate regions, many gaps remain in the knowledge and understanding of the feeding habits of these beetles (Toft & Bilde, 2002). The analysis of the content of the digestive tract of carabids allows the evaluation of the types of food eaten in the field. These analyses can be conducted using optical microscopy (Walrant & Loreau, 1995; Holland, 2002), ELISA assays, DNA (PCR) and radioactive isotopes (Wallace, 2004; Sheppard & Harwood, 2005; Greenstone, Rowley, Weber, Payton, & Hawthorne, 2007; Ikeda, 2010; Eitzinger & Traugott, 2011). The study of the feeding habits

of these beetles through dissection and analysis by optical microscopy is an important way to clarify the environmental aspects related to carabids, given the variety of foods that can be eaten by insects. This information may facilitate the advancement of techniques to rear these insects in the laboratory for use in biological control programmes against agricultural pests.

In this work, we determine the types of food content in the digestive tract of nine species of Carabidae associated with herbaceous plants and different growth stages of coloured cotton.

Material and methods

Experimental area

The study was conducted from August 2012 to July 2013 at Fazenda Experimental de Ensino, Pesquisa e Produção (21°15'32"S and 48°16'49"W) and in the Laboratório de Ecologia de Insetos (LECOL), Departamento de Fitossanidade, Faculdade de Ciências Agrárias e Veterinárias (FCAV), Universidade Estadual "Júlio de Mesquita Filho" (UNESP), Jaboticabal, São Paulo State, Brazil.

The coloured cotton cv. BRS verde, *Gossypium hirsutum* L. *latifolium* Hutch., was used. The seeds were sown in a 40-m-long by 40-m-wide area, for a total of 1600 m² (Figure 1), and the spacing adopted was 1 m between rows, with two plants occurring in holes spaced from 0.3 to 0.5 m.

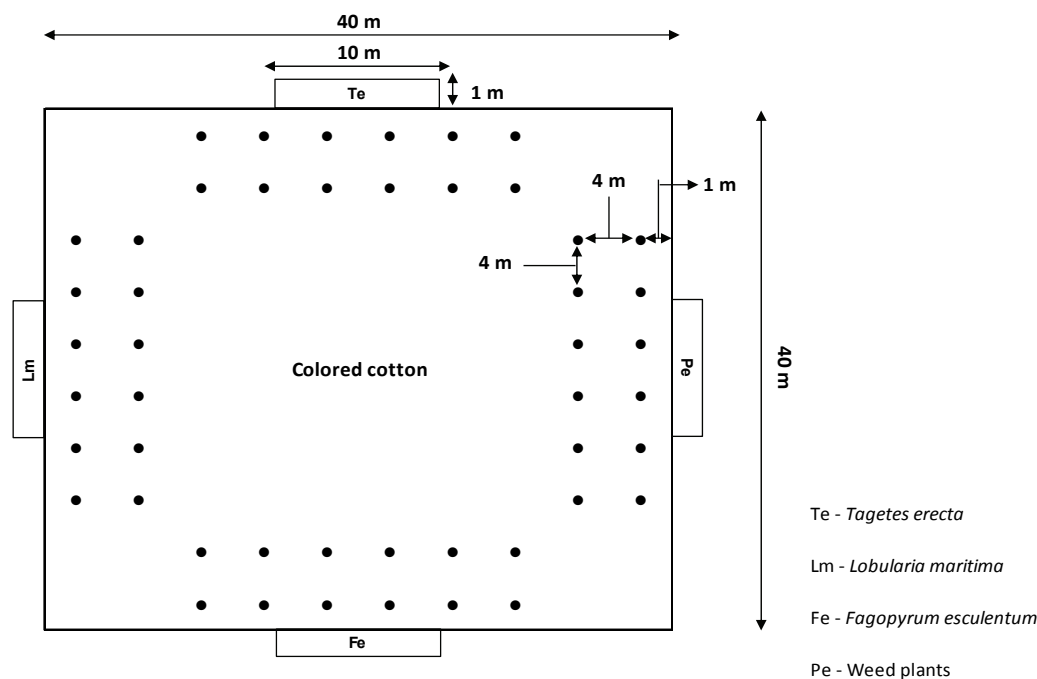


Figure 1. Schematic representation of the experimental area with colored cotton cv. BRS verde *Gossypium hirsutum* subdivided into 48 traps associated with the borders of herbaceous flowering plants (PHF) and weeds. The black dots (•) indicate the locations of the traps.

Flowering herbaceous plants and weed plants were grown along the edges (1 × 10 m) of the cotton area (Figure 1). The following flowering herbaceous plants (FHPs) were included: sweet alyssum (*Lobularia maritima* L.) (Brassicaceae), marigold (*Tagetes erecta* L.) (Asteraceae), and buckwheat (*Fagopyrum esculentum* Moench) (Polygonaceae). One of the edges was formed by weed plants: *Amaranthus retroflexus* L., *Alternanthera tenella* Colla and *Amaranthus spinosus* L. (Amaranthaceae); *Sida spinosa* L. (Malvaceae); *Digitaria insularis* (L.), *Eleusine indica* (L.) Gaer and *Cenchrus echinatus* L. (Poaceae); *Acanthospermum hispidum* DC. (Asteraceae); *Portulaca oleracea* L. (Portulacaceae); *Richardia brasiliensis* Gomes (Rubiaceae); *Euphorbia heterophylla* L. and *Chamaesyce hyssopifolia* (L.) Small (Euphorbiaceae); *Commelina benghalensis* L. (Commelinaceae); *Indigofera hirsuta* L. (Fabaceae); and *Ipomea grandifolia* (Dammer) O'Donnell (Convolvulaceae). The FHP species were planted using seedlings or seeds, and they were allowed to grow for a period of time to match the phase of flowering of these plants with the beginning of sampling of carabids on cotton.

The sampling of Carabidae

The carabid species studied were *Abaris basistriata* Chaudoir, *Calosoma granulatum* Perty, *Galerita brasiliensis* Dejean, *Odontocheila nodicornis* (Dejean), *Scarites* sp., *Selenophorus alternans* Dejean, *Selenophorus discopunctatus* Dejean, *Selenophorus seriatoporus* Putzeys and *Tetracha brasiliensis* (Kirby). These species were chosen because they are considered to be abundant in the north-eastern state of Sao Paulo (Cividanes, Barbosa, Ide, Perioto, & Lara, 2009).

In the coloured cotton area, 12 pitfall traps associated with each edge were installed, and the traps were spaced 4 m apart and 1 m from the edges of the FHPs and weeds (Figure 1). The traps were made with 8 cm plastic cups containing a water solution (48.6 mL water, 1.35 mL 36.5 to 38.0%

formaldehyde PA and 0.05 mL detergent). The samples were collected once every two weeks, and this procedure continued until no more carabids were captured in the traps, occurring between the period of 12/2012 to 05/2013. The species captured were separated and kept frozen for later dissection.

The Carabidae sampling was performed following the phenological periods of crops: (i) vegetative (V) (12/2012); (ii) reproductive (bud, blossom and boll) (R) (dates 12/2012 to 04/2013); and (iii) harvest (H) (dates 04/2013 to 05/2013).

The species were identified by Dr. George E. Ball, Department of Biological Sciences, University of Alberta, Edmonton, Canada.

Carabidae food content

For this study, individuals of each beetle species in each of the phenological periods were dissected under a stereoscopic microscope (Table 1). Using fine-point scissors, the dorsal region (tergum) and the ventral region (sternum) were separated. The digestive tract was then removed and placed in a Petri dish, sectioning the crop region and the proventriculus with a scalpel. The material was analysed in a saline solution (0.9 % sodium chloride) using an optical microscope (Barbosa, Cividanes, Andrade, & Santos-Cividanes, 2012). The classification of food content followed Holopainen and Helenius (1992), and these types were considered: (i) arthropod identifiable parts – AIP, (ii) chitinous residue of arthropods – CRA, (iii) amorphous mass – AM, (iv) vegetable material with typical cell structure – VMTCS, (v) fluid – F, and (vi) no food – NF.

Results and discussion

Vegetative stage of cotton (V)

None of the species studied showed the food content types AIP (arthropod identifiable parts) or VMTCS (vegetable material with typical cell structure) (Table 2). Barbosa et al. (2012) also

Table 1. Total number of specimens dissected of Carabidae species associated with Flowering Herbaceous Plants (FHP) during the phenological periods of cotton cv. BRS verde *Gossypium hirsutum* between 12/2012 to 05/2013, Jaboticabal, São Paulo State, Brazil.

Species	Edges											
	<i>Fagopyrum esculentum</i>			<i>Lobularia maritima</i>			<i>Tagetes erecta</i>			Weed plants		
	Stages of crop			Stages of crop			Stages of crop			Stages of crop		
	V	R	H	V	R	H	V	R	H	V	R	H
<i>Abaris basistriata</i>	-	6	2	-	6	4	-	4	4	-	8	3
<i>Calosoma granulatum</i>	1	2	-	2	13	11	1	4	-	-	7	-
<i>Galerita brasiliensis</i>	-	10	3	-	11	2	-	10	2	-	11	4
<i>Odontocheila nodicornis</i>	-	1	-	-	2	-	-	3	-	-	4	-
<i>Scarites</i> sp.	2	9	-	2	10	1	2	6	-	2	7	-
<i>Selenophorus alternans</i>	2	14	3	2	16	2	2	18	3	2	15	-
<i>Selenophorus discopunctatus</i>	2	13	4	2	14	2	2	12	4	2	113	4
<i>Selenophorus seriatoporus</i>	-	6	-	-	5	-	-	4	-	-	8	4
<i>Tetracha brasiliensis</i>	2	4	-	2	2	2	2	-	-	1	2	-
Total individuals	9	65	12	10	79	12	9	61	13	7	75	15

V = vegetative; R = reproductive; H = harvest; (-)not occurrence of Carabidae.

Table 2. Percentage of food contents present in Carabidae species associated with Flowering Herbaceous Plants (FHP) during the phenological periods of cotton cv. BRS verde *Gossypium hirsutum* between 12/2012 to 05/2013, Jaboticabal, São Paulo State, Brazil.

Species	FHP	Phenological periods																				
		Vegetative						Reproductive						Harvest								
		Type of food content (%)						Type of food content (%)						Type of food content (%)								
AIP	CRA	AM	VMTCs	F	NF	AIP	CRA	AM	VMTCs	F	NF	AIP	CRA	AM	VMTCs	F	NF					
<i>Abaris basistriatus</i>	<i>Fagopyrum esculentum</i>	-	-	-	-	-	-	50.00	16.66	16.66	-	-	16.66	6	-	-	50.00	50.00	-	-	2	
	<i>Lobularia maritima</i>	-	-	-	-	-	-	16.66	-	33.33	-	-	50.00	6	25.00	-	25.00	50.00	-	-	4	
	<i>Tagetes erecta</i>	-	-	-	-	-	-	-	25.00	75.00	-	-	-	4	-	-	25.00	50.00	25.00	-	4	
	Weed plants	-	-	-	-	-	-	25.00	25.00	50.00	-	-	-	8	-	33.33	-	-	-	66.67	3	
<i>Calosoma granulatum</i>	<i>Fagopyrum esculentum</i>	-	-	100.00	-	-	-	1	-	-	-	-	100.00	-	2	-	-	-	-	-	0	
	<i>Lobularia maritima</i>	-	-	50.00	-	50.00	-	2	7.69	15.38	23.08	-	23.08	30.77	13	-	-	-	-	100.00	1	
	<i>Tagetes erecta</i>	-	-	100.00	-	-	-	1	-	25.00	25.00	-	25.00	25.00	4	-	-	-	-	-	0	
	Weed plants	-	-	-	-	-	-	-	-	-	-	-	57.14	42.86	7	-	-	-	-	-	0	
<i>Galerita brasiliensis</i>	<i>Fagopyrum esculentum</i>	-	-	-	-	-	-	40.00	50.00	-	-	-	10.00	10	-	-	33.33	-	-	66.67	3	
	<i>Lobularia maritima</i>	-	-	-	-	-	-	54.55	-	-	-	27.27	18.18	11	-	-	-	-	-	100.00	2	
	<i>Tagetes erecta</i>	-	-	-	-	-	-	50.00	10.00	20.00	-	10.00	10.00	10	-	50.00	-	-	-	50.00	2	
	Weed plants	-	-	-	-	-	-	27.27	9.09	27.27	9.09	9.09	18.19	11	50.00	25.00	-	-	-	25.00	4	
<i>Odontocheila nodicornis</i>	<i>Fagopyrum esculentum</i>	-	-	-	-	-	-	-	-	-	-	-	100.00	1	-	-	-	-	-	-	0	
	<i>Lobularia maritima</i>	-	-	-	-	-	-	-	-	-	-	100.00	-	2	-	-	-	-	-	-	0	
	<i>Tagetes erecta</i>	-	-	-	-	-	-	-	33.33	-	-	33.33	33.33	3	-	-	-	-	-	-	0	
	Weed plants	-	-	-	-	-	-	-	-	50.00	-	-	50.00	4	-	-	-	-	-	-	0	
<i>Scarites</i> sp.	<i>Fagopyrum esculentum</i>	-	-	-	-	100.00	2	-	11.11	11.11	-	44.45	33.33	9	-	-	-	-	-	-	0	
	<i>Lobularia maritima</i>	-	-	-	-	100.00	2	-	-	20.00	20.00	40.00	20.00	10	-	-	-	100.00	-	-	1	
	<i>Tagetes erecta</i>	-	-	-	-	50.00	50.00	2	-	-	16.67	-	16.67	66.66	6	-	-	-	-	-	0	
	Weed plants	-	50.00	-	-	-	50.00	2	-	-	28.57	-	14.29	57.14	7	-	-	-	-	-	0	
<i>Selenophorus alternans</i>	<i>Fagopyrum esculentum</i>	-	-	-	-	100.00	2	-	7.14	28.57	14.29	21.43	28.57	14	-	-	33.33	33.33	-	33.33	3	
	<i>Lobularia maritima</i>	-	-	-	-	100.00	2	-	12.5	43.75	12.5	6.25	25.00	16	-	-	-	50.00	-	50.00	2	
	<i>Tagetes erecta</i>	-	-	50.00	-	-	50.00	2	11.11	16.67	38.89	5.55	5.55	22.22	18	-	-	-	66.67	-	33.33	3
	Weed plants	-	-	100.00	-	-	100.00	2	7.69	15.39	61.54	-	7.69	7.69	13	-	25.00	75.00	-	-	4	
<i>Selenophorus discopunctatus</i>	<i>Fagopyrum esculentum</i>	-	-	100.00	-	-	2	-	7.69	61.54	7.69	-	23.08	13	25.00	-	50.00	-	-	25.00	4	
	<i>Lobularia maritima</i>	-	-	-	-	100.00	2	-	7.14	28.57	14.29	-	50.00	14	-	-	100.00	-	-	-	2	
	<i>Tagetes erecta</i>	-	-	50.00	-	-	50.00	2	25.00	-	8.33	25.00	16.67	25.00	12	-	-	25.00	-	25.00	50.00	4
	Weed plants	-	-	-	-	-	100.00	2	7.69	15.39	61.54	-	7.69	7.69	13	-	25.00	75.00	-	-	4	
<i>Selenophorus seriatoporus</i>	<i>Fagopyrum esculentum</i>	-	-	-	-	-	-	-	33.33	33.33	-	33.33	-	6	-	-	-	-	-	-	0	
	<i>Lobularia maritima</i>	-	-	-	-	-	-	-	60.00	40.00	-	-	-	5	-	-	-	-	-	-	0	
	<i>Tagetes erecta</i>	-	-	-	-	-	-	-	25.00	25.00	-	25.00	25.00	4	-	-	-	-	-	-	0	
	Weed plants	-	-	-	-	-	-	-	50.00	25.00	-	25.00	-	8	-	50.00	-	25.00	-	25.00	4	
<i>Tetracha brasiliensis</i>	<i>Fagopyrum esculentum</i>	-	-	50.00	-	-	50.00	2	-	-	25.00	-	50.00	50.00	4	-	-	-	-	-	0	
	<i>Lobularia maritima</i>	-	-	-	-	-	100.00	2	-	-	50.00	-	50.00	2	-	-	-	-	-	-	0	
	<i>Tagetes erecta</i>	-	100.00	-	-	-	2	-	-	-	-	-	-	0	-	-	-	-	-	-	0	
	Weed plants	-	100.00	-	-	-	1	-	-	-	-	-	50.00	50.00	2	-	-	-	-	-	0	

AIP = Arthropods identifiable parts; CRA = Chitinous residue of arthropod, AM = Amorphous Mass; VMTCs = Vegetable material with typical cell structure; F fluid; NF = No food. T = total individuals.

reported that *T. brasiliensis* did not have vegetable material in their digestive tract. However, when associated with *Tagetes erecta* and weed plants, *T. brasiliensis* showed fragments of arthropod exoskeleton characterized as CRA (chitinous residue of arthropods), and *Scarites* sp. also showed CRA when associated with weed plants.

A lower number of prey items was observed during the vegetative stage compared to the reproductive and harvest stages. According to Marur and Ruano (2003),

during the vegetative stage, there is a low occurrence of pests in cotton compared to the reproductive and harvest stages, especially thrips, aphids and root borers. In this study, it was observed that in the vegetative stage, *Scarites* sp. and *T. brasiliensis* were active in the search for prey because fragments of arthropod exoskeletons were lodged in the digestive tract.

The food type F (fluid) was observed only when *C. granulatum* and *Scarites* sp. were associated with *L. maritima* and *T. erecta*, respectively (Table 2).

Moreover, *C. granulatum* showed a higher frequency of AM (amorphous mass) food contents, indicating the predatory activity of this species when associated with *F. esculentum*, *L. maritima* and *T. erecta*. *Tetracha brasiliensis* showed this content in association with *F. esculentum*.

Reproductive stage of cotton (R)

Only *T. brasiliensis* did not show predatory activity during this stage (Table 2). At this developmental stage of the plant phenological stages, the occurrence of pest species is more intense, especially Lepidoptera larvae, Coleoptera (weevils), Hemiptera (bugs) and Acari (mites) (Marur & Ruano, 2003).

When associated with all FHPs, *Galerita brasiliensis* showed a higher frequency of individuals with arthropod identifiable parts (AIP), such as lepidopteran heads, legs and spiracles. This was not observed in the other studied species (Figure 2). This finding is indicative of the high level of predation shown by this carabid beetle when associated with flowering plants. In terms of *Calosoma granulatum* and *Selenophorus alternans*, AIP content was found only when these species were associated with *L. maritima* and *T. erecta*, respectively. In the predator *C. granulatum*, arrow fragments, antennae and mandibles of arthropods were found (Figure 2). These results are in accordance with those of Gidaspow (1963) and Pasini (1991), showing that *C. granulatum* is a potential predator associated with the velvetbean caterpillar, *Anticarsia gemmatalis* Hubner (Lepidoptera: Noctuidae), and other lepidopteran pests.

The presence of Collembola was observed in *Selenophorus alternans* (Figure 2). Similar results were reported by Penny (1966), who found spiders, collembolans, small flies, mites and worms in the digestive tract of *Nebria brevicollis* Fabricius. Hengeveld (1980) reported parts of Hymenoptera in the digestive tract of members of the *Pterostichus* genus.

When associated with FHPs, *S. seriatoporus* showed a high frequency of chitinous residue of arthropods (CRA), and we observed jaw and leg fragments (Figure 2), while in *O. nodicornis* and *Scarites* sp., CRA was found only when they were associated with *Tagetes erecta* and *F. esculentum*, respectively (Table 2). Sunderland (1975) analysed the gut contents of *Loricera pilicornis* Fabricius and reported the presence of residual unidentified arthropods.

Barbosa et al. (2012) noted that antennae were food contents in which antennomeres and arrows could be seen, which were not components observed in this study. In the study by Barbosa et al. (2012), this finding may possibly be related to soybean and corn, where these carabids were captured.

The presence of amorphous masses (AMs) was common in *A. basistriata*, *Scarites* sp., *S. alternans*,

S. discopunctatus and *S. seriatoporus* associated with FHPs. In contrast, *G. brasiliensis* and *O. nodicornis* presented AM less frequently when associated with weed plants. Forsythe (1982) also detected the presence of amorphous content in the digestive tract of the carabid *Abax parallelepipedus* Mitterpacker and Piller.

The AM food contents may be related to the predation of arthropods because *A. basistriata*, *C. granulatum*, *O. nodicornis*, *S. seriatoporus* and *T. brasiliensis* contained identifiable parts of arthropods and chitinous residue of arthropods (Figure 2). This result coincides with the reports of Barbosa et al. (2012), who found the absence of plant material in the food content of *A. basistriata*, *S. seriatoporus*, *T. brasiliensis*, *Scarites* sp. 2 and *Scarites* sp. 3. In contrast, in *S. alternans* and *S. discopunctatus*, identifiable parts of arthropods (AIP), chitinous residue of arthropods (CRA) and vegetable material with typical cellular structure (VMTCS) were observed. In this case, the origin of the AM content is unclear due to the presence of both food contents related to the activity of other predatory arthropods, such as plant material (Figure 2).

The crops of all *Scarites* sp. individuals had the presence of rock fragments identified as AM content (Figure 2). The presence of these fragments in *Scarites* sp. suggests that members of this genus live in galleries on the ground and that when ingesting food, they also ingest this type of substrate. These fragments may also function as grinding aids for food that is indigestible or has a nutritional need for carabids, such as minerals, which are essential for development and reproduction (Nation, 2001).

When associated with FHPs, *S. alternans* and *S. discopunctatus* showed a higher frequency of VMTCS content, which was found less frequently in *G. brasiliensis* and *Scarites* sp. associated with weeds and in *L. maritima*, respectively. These results are in accordance with those of Honek, Martinkova, Saska, and Pekar (2007) and Hurka and Jarošík (2003), which showed that insects of the genus *Selenophorus* are known to feed on the seeds of herbaceous plants and small invertebrates. Insect seed predators can be studied in research on the biological control of weeds in agroecosystems (Tooley & Brust, 2002).

The species *C. granulatum* and *Scarites* sp. had type F contents when associated with FHP (Table 2). According to Valencia-Jiménez, Bustillo, Ossa, and Chrispeels. (2000), the presence of this type of food content is characterized by the rapid digestion of food by enzymatic action or lack of prey. We observed a low frequency of the food content type F in the other species.

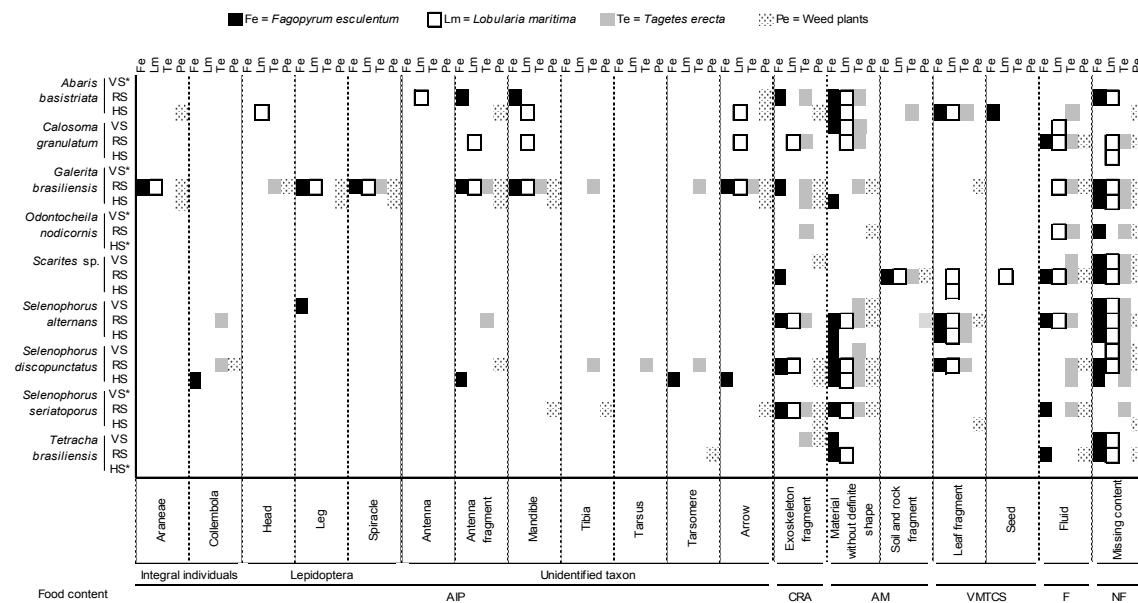


Figure 2. Types of food content in Carabidae species associated with flowering herbaceous plants in phenological period of colored cotton cv. BRS verde *Gossypium hirsutum*. 12/2012 to 05/2013, Jaboticabal, São Paulo State Brazil. *Phenological period of cotton without the presence of Carabidae species. VS = vegetative stage, RS = reproductive stage, HS = harvest stage; AIP = Arthropods identifiable parts; CRA = Chitinous residue of arthropod, AM = Amorphous Mass; VMTCS = Vegetable material with typical cell structure; F = Fluid; NF = No food.

Harvest stage of cotton (H)

Abaris basistriata, *G. brasiliensis* and *S. discopunctatus* when associated with *L. maritima*, weed plants and *F. esculentum*, respectively, showed identifying parts of arthropods (AIP), such as those of spiders and collembolans as well as antennae, tarsi and arrow fragments (Figure 2). These results show that these species feed on a wide variety of prey, from Lepidoptera to Araneae (Figure 2).

Abaris basistriata, *G. brasiliensis*, *S. discopunctatus* and *S. seriatoporus* showed chitinous residue of arthropods (CRA), such as fragments of exoskeleton, when associated with weed plants. The food type MA was observed in *A. basistriata* and *S. discopunctatus* when associated with FHPs and in *G. brasiliensis* and *S. alternans* when associated with *F. esculentum* (Table 2).

Typical vegetable material with cellular structure (VMTCS), such as seeds and other plant structures, was observed in *A. basistriata* and *S. alternans* associated with *F. esculentum*, *L. maritima* and *Tagetes erecta* (Figure 2). The same result was found for *Scarites* sp. associated with *L. maritima* and in *S. seriatoporus* associated with weed plants. Johnson and Cameron (1969) observed vegetable material in the digestive tract of the carabid *Amara cupreolata* Putzeys, while Lindroth (1974) found plant material in the gut contents of *Amara aulica* Panzer.

Only *A. basistriata* and *S. discopunctatus* had type F food content when associated with *Tagetes erecta*

(Table 2). A similar result was observed by Sunderland (1975), who reported the presence of only fluid substances in the digestive tract of *A. dorsales*.

When associated with FHPs, digestive tracts without food (NF) were more frequent in *G. brasiliensis* and *S. alternans* compared to *A. basistriata*, *C. granulatum*, *S. discopunctatus* and *S. seriatoporus*. Several authors (Davies, 1953; Hengeveld, 1980) also found no traces of food in the digestive tract of *Pterostichus madidus* (Fabricius) and *Pterostichus oblongopunctatus* (Fabricius).

The edge *L. maritima* presented the highest number of Carabidae in the vegetative and reproductive stages, and weed plants presented the greatest number in the harvest stage. During the vegetative stage, *T. brasiliensis* associated with *Tagetes erecta* and weed plants can be considered the most efficient predator. On the other hand, during the reproductive and harvest stages, *G. brasiliensis* can be considered the most efficient predator in association with all edges in the reproductive stage and associated with *Tagetes erecta* and weed plants in the harvest stage.

The analysis of ingested material can show the preferences and feeding habits of Carabidae. These predators are polyphagous, but we observed that they prefer prey that occurs during specific phenological periods of cotton crops. Therefore, studies about feeding habits using tests such as ELISA and DNA (PCR) that can identify genera or species are important in the development of rearing

techniques for these predators and their future use in the biological control of pests.

Conclusion

In conclusion at flowering herbaceous plants *F. esculentum*, *L. maritima*, *T. erecta* and weeds plants promote the occurrence and abundance of species carabids, with emphasis *Selenophorus discopunctatus*. *Galerita brasiliensis* has behaved as the most efficient predator in different phenological periods, being observed in feeding habit, spiders, head, leg and spiracle of Lepidoptera and others unidentified taxon. *Abaris basistriata*, *Scarites* sp. and *S. alternans* it was more associated with vegetable material with typical cell structure. Finally, *Scarites* sp. only species to all individuals consumed soil and rock fragment.

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