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Effect of Diets on Biology of *Abaris basistriata* and *Selenophorus seriatoporus* (Coleoptera: Carabidae)

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ABSTRACT Ground beetles or carabids are collective terms for the beetle family Carabidae. This family contains many species considered important predators associated with agricultural crops. The current study aimed to evaluate the effect of different diet types on consumption, fecundity, and egg viability of *Abaris basistriata* Chaudoir and *Selenophorus seriatoporus* Putzeys (Coleoptera: Carabidae). The diets assessed were as follows: larvae of *Tenebrio molitor* L.; minced beef; dry cat food; the greenbug, *Schizaphis graminum* (Rondani); seeds of signal grass, *Brachiaria decumbens* Stapf; and a diet mixture. Five males and five females of each species were kept isolated in a plastic container divided by a silicon barrier, one side being filled with sifted soil that was moistened for oviposition and the other lined with filter paper to receive the diet. *A. basistriata* did not consume the *B. decumbens* seeds. The most consumed diet by *A. basistriata* and *S. seriatoporus* adults was *T. molitor* larvae. *S. graminum* and *T. molitor* larvae and diet mixture were considered the diets most favorable for the reproductive capacity of *A. basistriata* and *S. seriatoporus*, respectively. However, *T. molitor* larvae and diet mixture were the most favorable diets for rearing both carabid species in the laboratory.

KEY WORDS ground beetle, predator, consumption, reproduction

Carabids are cited as being predators of aphids, lepidopteran larvae, slugs, and herbaceous plant seeds (Kromp 1999, Holland and Luff 2000, Tooley and Brust 2002). Many species of these beetles have a role in the natural biological pest control for several crops, among which are prominent *Alabama argillacea* (Hübner) (Lepidoptera: Noctuidae) on cotton, *Gossypium hirsutum* L. (Allen 1977, Chocorosqui and Pasini 2000); *Anticarsia gemmatalis* Hübner (Lepidoptera: Noctuidae) on soybean, *Glycine max* (L.) Merr. (Fuller 1988); *Diatraea saccharalis* (F.) (Lepidoptera: Crambidae) on sugarcane (*Saccharum* spp.) and sorghum (*Sorghum* spp.) (Fuller and Reagan 1988); *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) on cabbage, *Brassica oleracea* L. (Suenaga and Hamamura 2001); and *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on corn, *Zea mays* L. (Wyckhuys and O'Neil 2006).

Adults and larvae of carabids may have diverse feeding habits, varying from carnivorous to granivorous, with the granivore species considered to have evolved from carnivorous ancestors (Hurka and Jarosik 2003, Sasakawa 2010). However, little is known of the effect of diet on the fecundity of these beetles. In general, a mixed diet stimulates egg production (Wallin et al. 1992, Bilde and Toft 1994), but fecundity also is affected by the quality of monospecific diets (Bilde and Toft 1994, Bilde et al. 2000). Wallin et al. (1992) observed insect diet adequate for the reproduction in some polyphagous predatory carabid beetles. However, the females of granivorous species generally have a higher oviposition rate when they are fed on a diet of seeds in comparison with an insect diet (Jorgensen and Toft 1997a,b; Saska 2008).

Despite the importance of this group of predatory insects, most information on carabids in the Brazilian agroecosystems pertains to population fluctuation and faunistic analysis (Pegoraro and Foerster 1988, Pinto et al. 2000, Freitas et al. 2002, Merlim et al. 2006). *Abaris basistriata* Chaudoir, *Selenophorus seriatoporus* Putzeys, *Tetracha brasiliensis* (Kirby), *Odontochila nodicornis* (Dejean), and *Calosoma granulatum* Perty are indicated as predominant species in the northeast region of the state of São Paulo (Cividanes et al. 2009).

This study aimed to evaluate the effect of different diet types on the consumption, fecundity, and egg viability of adults of the carabids *A. basistriata* and *S. seriatoporus.*

Materials and Methods

The study was conducted from January to September 2010 in the Departamento de Fitossanidade and in an experimental area of the Fazenda de Ensino, Pesquisa e Produção at the Faculdade de Ciências Agrárias e

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Live adults of the carabids *A. basistriata* and *S. seriatoporus* were captured using trench-type traps (Clark et al. 1994) placed in soybean and corn crops. Each trap was made of galvanized guttering sheet 90 cm in length and 10 cm in width, folded in half along its length in a V shape, which was installed with the edge kept at soil level. The extremities of the sheet were kept in contact with the edges of the empty plastic cups 8 cm in diameter and 14 cm in height. The traps were checked daily for the collection of adults.

The diets assessed were as follows: 1) *Tenebrio molitor* L. larvae (Jorgensen and Toft 1997b); 2) minced beef (Sasakawa 2007); 3) Whiskas dry cat food (Wallin et al. 1992); 4) the greenbug, *Schizaphis graminum* (Rondani) (Bilde and Toft 1994, 1997); 5) seeds of signal grass, *Brachiaria decumbens* Stapf (Jorgensen and Toft 1997b); and 6) a mixture of diets 1–5 (Jorgensen and Toft 1997a).

T. molitor larvae and *S. graminum* were obtained in accordance with the method cited by Santos and Boiça (2002) and Santos et al. (2009), respectively. The seeds of *B. decumbens* were collected in an experimental area at FCAV/UNESP, according to the Jorgensen and Toft (1997a,b) method.

The assessment of the diets was carried out using gerbox-type plastic containers measuring 11 cm in length by 11 cm in width by 3.5 cm in depth. Each container was divided in two by a silicon barrier, with one part being filled with sterilized, sifted, and moistened soil and the other part lined with filter paper. The soil acted as shelter for carabid oviposition, and the filter paper enabled the food and water was provided by moistened cotton wool (Jorgensen and Toft 1997b). To maintain the humidity inside the container, the soil and cotton wool were moistened every 2 d. For the entirety of the experiments, the containers were kept in a room maintained at 26 ± 2°C, 70 ± 10% RH, and a photoperiod of 12:12 (L:D) h.

To standardize the hunger level among the studied carabids, all food was withheld four days before the experiment, with only water being offered. Subsequently, five male and five female carabids were separated in each container, the sex of species was determined by examining the shape of the protarsi, with the aid of a magnifying lens. The protarsi of male are dilated and pronounced than in the females, according to the method cited by Riddick and Mills (1994). After the start of the experiments, the diets offered were replaced with a new diet every 3 d. The diet not consumed by the insects was weighed using a Bel Engineering (0.001-g) precision scale. It should be noted that these carabids also were considered in the analysis of the effect of different diets on survival.

The quantity used of *T. molitor* larvae, mincemeat and dry cat food was 0.2 g, whereas that of *S. graminum* was of 0.01 g and of *B. decumbens* seeds, 0.09 g. Before being given to the carabids, *T. molitor* larvae were cut into small pieces by using a scalpel, and *S. graminum* were died by freezing. It should be stressed that the quantity of the diets offered to the carabids was assessed in preliminary tests ad libitum.

Consumption was assessed for each date of the diet replacement. Before being placed in the containers, the diets were weighed and the nonconsumed portions were dried in an oven at 75°C for 3 d and subsequently weighed with a precision scale. Means consumption was estimated using the following fresh (x), dry (y) weight regression model ($y = a + bx$), obtained considering the weight of 20 units of the diet without undergoing the drying process (x) and the corresponding dry weight (y), obtained from the aforementioned drying procedure (Riddick and Mills 1994). The linear regression equations obtained were *T. molitor* ($y = -0.002 + 0.4786x$; $r^2 = 0.99$), meat ($y = 0.0026 + 0.2898x$; $r^2 = 0.97$), dry cat food ($y = 0.0002 + 0.9302x$; $r^2 = 0.99$), *S. graminum* ($y = 0.0003 + 0.5203x$; $r^2 = 0.97$), and *B. decumbens* ($y = -0.0055 + 0.95x$; $r^2 = 0.99$). The consumption was evaluated during the entire time all the specimens were alive.

Adults used in the evaluations of diets were the same individuals used in the formation of pairs for copulation and to obtain eggs, maintained on the corresponding diets provided in the containers. These pairs were kept together for 12 h, three times a week. Subsequently, the containers with females were checked weekly, the soil was sifted to obtain eggs that were counted under a stereoscopic microscope transferred to petri dishes containing moistened soil and kept in a climatized chamber at 26 ± 2°C and a photoperiod of 12:12 (L:D) h (Jorgensen and Toft 1997b). The number of eggs observed in the containers was expressed as the mean egg production per female during a 12-wk oviposition period.

The entirely randomized statistical design was used on a factorial scheme 5×2, with factor A (five diet types), factor B (male or female), and five repetitions per treatment. To analyze fecundity, the number of hatched larvae and egg viability was measured, with each species of carabid being assessed in six treatments (six diet types), with five repetitions.

Before being analyzed statistically, the fecundity data and the number of larvae were transformed into $\ln(x + 5)$, and the egg fecundity data were transformed into arcsine $\sqrt{P}/100$. The data obtained were submitted to analysis of variance (ANOVA) using the F-test, and the means were compared with the Tukey test ($P = 0.\ 05$).

Results and Discussion

Considering separately the factors diet types and carabid sex, significant variation was found in the daily consumption of diets by *A. basistriata* and *S. seriatoporus* (Table 1). In the same way, the interaction between the factors diet type and sex of *A. basistriata* and *S. seriatoporus* was significant, indicating that the daily consumption of the diets varied as a function of the diet type and sex.

In general, the diet consumed most on a daily basis by *A. basistriata* and *S. seriatoporus* adults was that consisting of *T. molitor* larvae, followed by beef, dry

Table 1. Consumption of different diets (milligrams per day, mean ± SE) by males and females of *A. basistriata* and *S. seriatoporus*

Diet	Consumption (mg/d)			
	A. basistriata		*S. seriatoporus*	
	♂	♀	♂	♀
T. molitor larvae ($n = 5$)	9.8 ± 0.29aB	12.0 ± 0.63aA	13.2 ± 0.13aB	17.0 ± 0.09aA
Beef ($n = 5$)	7.3 ± 0.07bA	7.7 ± 0.11bA	7.0 ± 0.19bB	10.6 ± 0.13bA
Dry cat food ($n = 5$)	4.5 ± 0.11cB	5.6 ± 0.08cA	3.7 ± 0.25cA	3.6 ± 0.14cA
S. graminum ($n = 5$)	2.3 ± 0.07dB	3.3 ± 0.24dA	1.6 ± 0.03dB	2.1 ± 0.01dA
B. decumbens seeds ($n = 5$)	0.0 ± 0.00eA	0.0 ± 0.00eA	0.2 ± 0.12eB	2.0 ± 0.15dA
Diets (A) F-test	607.5**		3,440.0**	
Sex ♂ and ♀ (B) F-test	39.0**		466.8**	
(A × B) F-test	6.0**		75.6**	
CV %	10.3**		5.2**	

Values followed by same letter, lowercase in columns and uppercase in rows, are not different by Tukey test ($P > 0.05$).
**, $P < 0.01$.

cat food, and *S. graminum* (Table 1). The mean daily quantity of *T. molitor* larvae consumed by *S. seriatoporus* was higher than the quantity consumed by *A. basistriata.* However, despite the adults of *S. seriatoporus* being larger (10.4 mm) than those of *A. basistriata* (6.2 mm), the consumption of dry cat food and of *S. graminum* by that species was less than the consumption observed for *A. basistriata.* It should be stressed that there was no consumption of *B. decumbens* seeds by *A. basistriata,* whereas for *S. seriatoporus,* this was the least consumed diet. Some studies also assessed the feeding preferences of carabid species. Johnson and Cameron (1969) observed that *Pterostichus melanarius* Illiger and *Amara apricaria* Paykull preferred to feed on larvae and pupae of a curculionid (*Hyperodes* sp.) instead of seeds, whereas Jorgensen and Toft (1997a) observed that seeds of the weed *Taraxacum* sp. were the most preferred by adults of *Harpalus rufipes* Degeer, followed by diets aphid *Metopolophium dirhodum* Walker and *Drosophila melanogaster* Meigen. Fawki and Toft (2005) studied the food preference of *Amara similata* Gyllenhal and observed higher consumption mixed seed–insect diet.

There was a significant difference by sex in the consumption of diets by *A. basistriata* and *S. seriatoporus* (Table 1). Mean daily consumption by the females was higher than that of males. Males and females of *A. basistriata* consumed similar daily quantities of beef, whereas for the diets of *T. molitor* larvae, dry cat food, and *S. graminum,* the females consumed significantly more than the males (Table 1). For *S. seriatoporus,* there was no significant difference for the mean daily consumption of dry cat food by males and females, but for the other diets, the females consumed significantly more than the males. The higher consumption by the females was probably due to the need to produce eggs, which uses considerable energy (O'Neil and Wiedenmann 1990).

The females of *A. basistriata* showed higher fecundity when were fed on *T. molitor* larvae and lower when fed on beef and dry cat food (Table 2). The fecundity of this carabid fed on *S. graminum* and diet mixtures did not differ significantly from the other diets. Females of this species did not feed, nor oviposit when kept on seeds of *B. decumbens.* The diets of beef and dry cat food enabled *A. basistriata* to produce an intermediate quantity of eggs in relation to the other diets; however, they did not differ significantly from the diets of *S. graminum* and diet mixtures. The females of *S. seriatoporus* fed on beef, *S. graminum* and seeds of *B. decumbens* did not produce eggs (Table 3), whereas the diet mixtures, dry cat food, and *T. molitor* larvae enabled *S. seriatoporus* to produce a higher quantity of eggs. Saska (2008) also found that a diet of

Table 2. Mean fecundity, number of hatched larvae, and egg viability of *A. basistriata* females fed on different diets

Diet	Fecundity (mean ± SE)[a,b]	No. hatched larvae (mean ± SE)[a,c]	Egg viability (%, mean ± SE)[a,d]
T. molitor larvae ($n = 5$)	9.0 ± 0.09a	5.0 ± 0.07a	47.2 ± 4.73a
Beef ($n = 5$)	3.8 ± 0.09b	1.2 ± 0.07c	34.0 ± 4.73a
Dry cat food ($n = 5$)	3.9 ± 0.09b	1.8 ± 0.07bc	51.5 ± 4.73a
S. graminum ($n = 5$)	7.1 ± 0.09ab	4.5 ± 0.07a	51.8 ± 4.73a
B. decumbens seeds ($n = 5$)	0.0 ± 0.00c	0.0 ± 0.00c	0.0 ± 0.00b
Mixture with all five diets ($n = 5$)	7.9 ± 0.09ab	4.1 ± 0.07ab	46.0 ± 4.73a
F-test	18.0**	14.8**	17.7**
CV (%)	8.8**	8.0**	27.6**

Values followed by the same letter in the column do not differ significantly with the Tukey test ($P > 0.05$).
**, $P < 0.01$.

[a] Original fecundity data and number of hatched larvae were transformed into $\ln(x + 5)$. Egg viability data were transformed into arcsine $[\sqrt{P/100}]$.

[b] Mean number of eggs per female during a 12-wk oviposition period.

[c] Mean number of hatched larvae during a 12-wk period.

[d] Mean number of egg viability in percentage during a 12-wk period.

Table 3. Mean fecundity, number of hatched larvae, and egg viability of *S. seriatoporus* females fed on the different diets

Diet	Fecundity (mean ± SE)[a,b]	No. hatched larvae (mean ± SE)[a,c]	Egg viability (%, mean ± SE)[a,d]
T. molitor larvae (n = 5)	7.6 ± 0.07a	4.1 ± 0.05b	45.2 ± 1.61a
Beef (n = 5)	0.0 ± 0.00b	0.0 ± 0.00c	0.0 ± 0.00c
Dry cat food (n = 5)	8.3 ± 0.07a	2.5 ± 0.05b	32.3 ± 1.61b
S. graminum (n = 5)	0.0 ± 0.00b	0.0 ± 0.00c	0.0 ± 0.00c
B. decumbens seeds (n = 5)	0.0 ± 0.00b	0.0 ± 0.00c	0.0 ± 0.00c
Mixture of all five diets (n = 5)	11.6 ± 0.07a	7.0 ± 0.05a	51.3 ± 1.61a
F-test	61.2**	57.0**	227.5**
CV (%)	7.7**	5.8**	16.8**

Values followed by the same letter in the column do not differ significantly with the Tukey test ($P > 0.05$).

**, $P < 0.01$.

[a] Original fecundity data and number of hatched larvae were transformed into $\ln(x + 5)$. Egg viability data were transformed into arcsine $[\sqrt{P/100}]$.

[b] Mean number of eggs per female during a 12-wk oviposition period.

[c] Mean number of hatched larvae during a 12-wk period.

[d] Mean number of egg viability in percentage during a 12-wk period.

T. molitor was adequate for the reproduction of *Amara aenea* Degeer. Similar results observed for *Amara* (*Curtonotus*) *macronota* (Solsky) and *Anisodactylus punctatipennis* Morawitz fed on *T. molitor* larvae favoring the production of eggs (Sasakawa 2009a,b). Wallin et al. (1992) also found that the diet with cat food was adequate for the reproduction of *Bembidion lampros* Herbst, *Pterostichus cupreus* Linnaeus and *P. melanarius.* There are little information is available on nonproduction of eggs by carabids fed on different diets. However, it should be noted that nonproduction of eggs by *S. seriatoporus* fed on seeds of *B. decumbens* is consistent with studies of Hurka and Jarosik (2003) and Saska (2008). Hurka and Jarosik (2003) observed that *A. aenea* not produce eggs when fed on seeds of *Potentilla argentela,* whereas Saska (2008) reported nonproduction of eggs by *Amara familiaris* (Duftschmid) and *A. similata* when fed on seeds of *Capsella bursa-pastoris* (L.) Medik. and *Stellaria media* (L.) Vill., respectively.

In the current study, larval emergence rate hatched was greater when the species fed on diets that enabled higher egg production. Thus, *T. molitor* larvae and *S. graminum* allowed *A. basistriata* to produce more larvae, which occurred with *S. seriatoporus* when it fed of diet mixtures and *T. molitor* larvae (Tables 2 and 3).

The egg viability of *A. basistriata* ranged from 34.0 to 51.8%, without a significant difference between the number of eggs and the diet types (Table 2). The greatest egg viability 52% was obtained for females fed *S. graminum.* With the exception of *B. decumbens* seeds, the test diets enabled *A. basistriata* to produce eggs in similar quantities. *S. seriatoporus,* the diets of dry cat food, *T. molitor* larvae and diet mixtures enabled the carabid to produce eggs at viability of 32.3, 45.2, and 51.3%, respectively (Table 3). Mols (1988) reported that the quantity and quality of the diet directly influences carabid oviposition and egg viability, with reabsorption of formed eggs by the insect also being possible, should food be inadequate or scarce.

When *A. basistriata* fed on diet mixtures, *T. molitor* larvae, beef and dry cat food ≈50% of the carabids survived up to 150, 135, 120, and 90 d, respectively (Fig. 1). The diet mixtures and *T. molitor* larvae also allowed individuals to survive until 225 d. Approximately 50% of *S. seriatoporus* fed on *T. molitor* larvae and diet mixtures survive up to 240 and 210 d, respectively, whereas 50% of *S. seriatoporus* fed on beef and dry cat food only survive up to 90 and 45 d, respectively (Fig. 2). Therefore, the effects of *T. molitor* larvae and diet mixtures on survival are different from those of beef and dry cat food, although the last individual of four groups all died at 255 d. Besides providing the longest period of adult survival of *A. basistriata* and *S. seriatoporus* (Figs. 1 and 2), the diet of *T. molitor* larvae and diet mixtures also allowed these carabid species reach the highest fecundity and egg viability (Tables 2 and 3). Therefore, *T. molitor* larvae and diet mixtures were the most favorable diets for rearing both carabid species in the laboratory.

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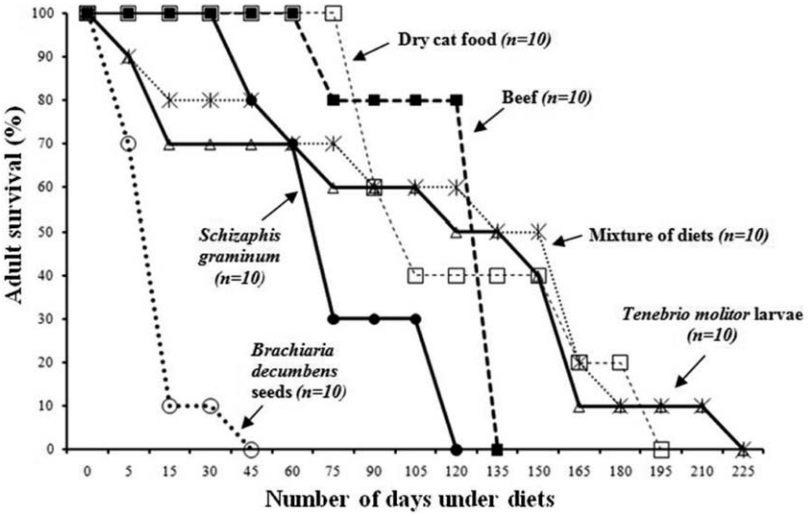

Fig. 1. Survival for adults of *A. basistriata* fed on different diets.

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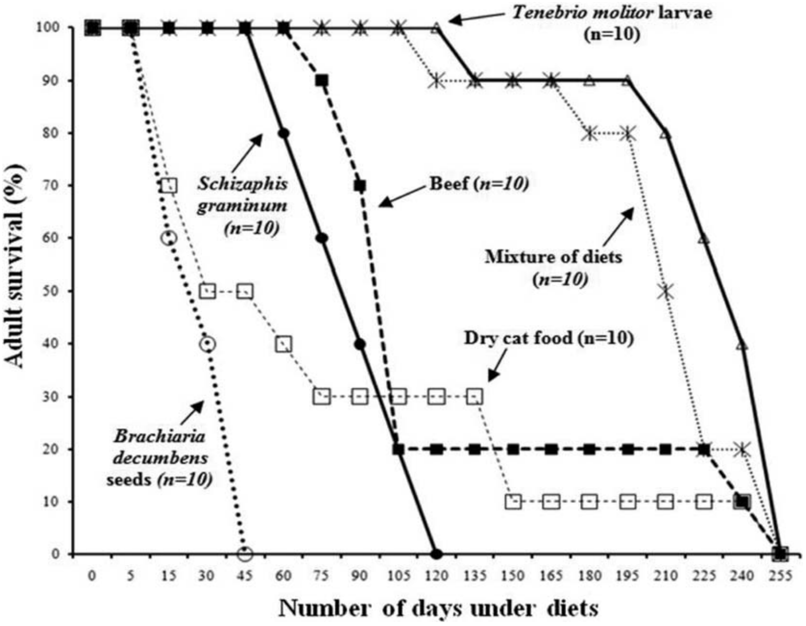

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