First Record of Acanthoscelides obtectus (Say) (Coleoptera: Chrysomelidae: Bruchinae) in Egypt: Development and Host Preference on Five Species of Legume Seeds

Authors: Magda H. Naroz, Sayeda S. Ahmed, Sahar Y. Abdel-Aziz, and Sobhy Abdel-Shafy

Source: The Coleopterists Bulletin, 73(3) : 727-734

Published By: The Coleopterists Society

URL: https://doi.org/10.1649/0010-065X-73.3.727

The Coleopterists Bulletin, 73(3): 727–734. 2019.

First Record of *Acanthoscelides obtectus* (Say) (Coleoptera: Chrysomelidae: Bruchinae) in Egypt: Development and Host Preference on Five Species of Legume Seeds

Magda H. Naroz, Sayeda S. Ahmed, Sahar Y. Abdel-Aziz
Department of Economic Entomology and Pesticides
Faculty of Agriculture, Cairo University, Giza, EGYPT
sayeda01@hotmail.com

and

Sobhy Abdel-Shafy
Department of Parasitology and Animal Diseases, Veterinary Research Division
National Research Centre, Dokki, Giza, EGYPT

Abstract

The bean weevil, *Acanthoscelides obtectus* (Say) (Coleoptera: Chrysomelidae: Bruchinae), which attacks seeds in various leguminous crops, is reported for the first time in Egypt. The aim of this study was to determine the duration of the developmental stages and host preference of *A. obtectus* feeding on kidney bean, broad bean, cowpea, chickpea, and lentil seeds and estimate the amino acids related to the legume seeds. *Acanthoscelides obtectus* passes through six instars. The larvae developed rapidly on cowpea followed by kidney bean, chickpea, lentils, and broad bean for 21.7, 25.4, 28.7, 34.7, and 37.1 days, respectively. Pre-pupal periods in lentil, broad bean, cowpea, kidney bean, and chickpea were 1.0, 1.4, 2.6, 2.8, and 3.4 days, respectively. The pupa lasted 5.3, 5.3, 5.2, 4.2, and 3.0 days, respectively, in chickpea, broad bean, cowpea, kidney bean, and lentils. Male longevity was slightly lower (6.6–8.2 days) than that of the female (8.2–9.4 days). Mean fecundity (number eggs per female) was significantly higher on cowpea (44.8) than in broad bean (23.1) and kidney bean (11.9). The number of emergent adults indicated that kidney bean and cowpea seeds are more significantly preferable for *A. obtectus* than the other tested seeds. The infestation rate indicated that kidney bean is significantly preferable to *A. obtectus*. Infestation also caused the highest significant weight loss in cowpea seeds. Nine amino acids (aspartic acid, theronine, serenine, glysine, valanine, methionine, leucine, tryptophane, and histadine) essential for *A. obtectus* were of better quality in kidney bean. All nine amino acids were at high quality percentages in kidney bean and positively correlated with infestation rate. In conclusion, *A. obtectus* survives and develops best on kidney bean and then on cowpea and broad bean. Chickpea and lentil seeds are unsuitable for the development of the beetle.

Key Words: biology, bean weevil, amino acids, weight loss, Fabaceae

DOI.org/10.1649/0010-065X-73.3.727

Bruchines (Coleoptera: Chrysomelidae: Bruchinae) attack beans during storage and cause losses in their qualitative and quantitative values. The bean weevil, *Acanthoscelides obtectus* (Say) is a species that attacks seeds of various leguminous crops. The primary host of this beetle is kidney bean (*Phaseolus vulgaris* L., Fabaceae) that can be infested in the field and store, thus making the commodity unfit for consumption (Thakur and Renuka 2014). The bean weevil is a destructive storage pest that has strong adaptability to the storage environment (Tucić *et al.*1996; Hagstrum and Subramanyam 2009; Mutungi *et al.* 2015). The beetle affects the physiological quality and germination capacity of seeds and increases their temperature and water content (Faroni and Sousa 2006).

Acanthoscelides obtectus is a native beetle in Central and South America, but it is now found on five continents (Wang *et al.* 2006). Several biological traits of the bean weevil, such as feeding behavior and preferred hosts, are important factors for the species expand its distribution long distances. Fertile females lay eggs on drying pods, and their larvae penetrate the seed and feed on the endosperm. This causes loss of thousand-kernel weight by 30–40%, even up to 60–70% when the beans are infested for many generations during storage (Oliveira *et al.* 2013; Mutungi *et al.* 2015). Bean weevil infestation reduces or eliminates the germination rate, food value, and commodity value of bean seeds (Baier and Webster 1992; Vuts *et al.* 2015). In addition, the bean weevil also infests cowpea (*Vigna unguiculata* (L.) Walp.), adzuki bean (*Vigna angularis* (Willd.) Ohwi and H. Ohashi), lentil (*Lens culinaris* Medik.), chickpea (*Cicer arietinum* L.), pigeon pea (*Cajanus cajan* (L.) Huth), broad bean (*Vicia faba* L.), and pea (*Pisum sativum* L.) (Lü *et al.* 1994; Tucić *et al.*

1995; Pemonge *et al.* 1997; Ayvaz *et al.* 2010; Duan *et al.* 2017).

Based on our 3-year field and household sampling surveys (unpublished data), bean weevils are frequently found frequently in kidney bean stores and products from many regions in Egypt. *Acanthoscelides obtectus* had not been known to occur in Egypt before our study.

The aim of our study reported herein was to determine the duration of the developmental stages and host preference of the bean weevil on kidney bean, broad bean, cowpea, chickpea, and lentil. Furthermore, the amino acid contents in undamaged legume seed hosts were estimated to detect a relation between bean weevil infestation and amino acid content in the tested legume seeds.

Material and Methods

Bean Weevil Colony. Stock material of *A. obtectus* was obtained from a sample collected from an infested field of kidney bean. Adults were reared in a dark incubator under laboratory conditions (27±1° C and 65±5% RH) on dry beans and maintained in glass bottles (18 cm high × 11 cm diameter). Beans with newly laid eggs were mixed with fresh kidney beans to allow development into subsequent stages until they reached the adult stage.

Life History. The life history of the bean weevil in kidney bean, broad bean, cowpea, chickpea, and lentil was determined under constant laboratory conditions of 27± 1° C and 65±5% RH. The seeds were certified to have not been treated with any chemicals or insecticide and conserved at 4° C before being used in experiments (Goucem *et al.* 2014). The experiments were started with newly laid eggs obtained from the bean weevil colony.

Observation of the larvae inside beans for detecting the molted integuments visually is almost impossible. Therefore, a procedure similar to that described by El-Sherif *et al.* (2008) was developed and utilized to overcome such difficulty and determine, as far as possible, the number and duration of each instar. Five glass jars of one kg capacity each were provided with sterilized host beans at a rate of 0.5 kg of seeds per jar. Each jar was inoculated with about 4,000 newly laid eggs obtained from the stock colony. After three days, a random sample of 10 seeds was taken daily from each jar and immersed in water for 20 minutes. The beans were examined under a stereoscope and carefully dissected to collect larvae, pre-pupae, and/or pupae from the infested seeds. The daily sampling of seeds continued until the transformation of all larvae to pupae. Length and width of the head capsules of larvae were measured. The number of instars was determined through statistical analysis of the length measurements. The durations of each instar and the pre-pupal and pupal periods were recorded. The experiment was repeated three times.

Adult longevity and the number of eggs produced per female on kidney bean, broad bean, and cowpea were measured; longevity and fecundity were not measured on chickpea and lentil because the beetle did not complete its development in these seeds. Ten couples of newly emerged bean weevil adults reared on kidney bean, broad bean, or cowpea were individually transferred into glass vials measuring 4 × 10 cm; the opening of the vials was then tightly closed with muslin held in place with a rubber band. Vials were examined daily to remove eggs by sieving until the female died. Adult longevity of both sexes, pre-oviposition, oviposition, and post-oviposition periods, and number of eggs laid per female were recorded for each couple.

Host Preference. About 120 g of each legume host were divided into four equal quantities of *ca.* 36, 70, 232, 58, and 775 seeds for broad bean, kidney bean, cowpea, chickpea, and lentil, respectively, each in 0.5-L, glass containers. Newly emerged adults from the stock colony were cooled in a refrigerator for 10 minutes. The four containers of each legume host were inoculated with 5, 10, 20, or 40 couples of bean weevil adults. The containers were tightly covered with muslin held in place with rubber band.

On a daily basis, the batches of beans in each container were placed in Petri dishes, and the number of eggs laid on each seed was counted. Eggs were harvested daily until the last female died. Mortality of females was also recorded daily. The developmental time of the bean weevils from the day of oviposition until the date of adult emergence was recorded. The experiment was conducted in four trials. At the end of the experiment, the following variables were measured: number of undamaged seeds (Nu), weight of undamaged seeds (Wu), number of damaged seeds (Nd), and weight of damaged seeds (Wd) to calculate the percentages of seed infestation and weight loss. Percentage of seed infestation for each inoculation rate and host was calculated by the following equation:

$$\%\,\text{Infestation} = \frac{\text{Nd}}{\text{Nd} + \text{Nu}} \times 100$$

For inoculation rate and host, percentage weight loss of seeds was calculated by the "count-and-weight" method described by Harris and Lindblad (1978), using the equation:

$$\%\,\text{Weight loss} = \frac{(\text{Wu} \times \text{Nd}) - (\text{Wd} \times \text{Nu})}{\text{Wu} \times (\text{Nd} + \text{Nu})} \times 100$$

Estimation of Amino Acid Contents in Seeds. Hydrolysis of total amino acids was performed as follows. The dried and defatted ground sample (*ca.* 0.2 g per solid sample or 200 μl per liquid sample) was hydrolyzed with 10 ml of 6N HCl in a sealed tube and heated in an oven at 100° C for 24 hours. The resulting solution was completed to 25 ml with de-ionized water. After filtration though filter paper, five ml of hydrolysate was evaporated to be free of HCL vapor. The residue was dissolved in citrate buffer as described by Csomos and Sarkadi (2002). Analysis of amino acid contents in seeds was conducted using an automatic amino acid analyzer (AAA 400, INGOS Ltd).

Statistical Analyses. Analysis of variance as described by Snedecor and Cochran (1956) and Fisher and Duncan tests using SPSS were used to detect significant differences in seed infestation rate, weight loss, duration of each life stage, longevity, and number of eggs produced per female among the five tested seed species. Correlation analysis (linear regression test) was used to estimate the correlation between percentage of infestation in kidney beans and their amino acid contents.

Results

Life History. Statistical analysis of the head capsule widths of *A. obtectus* larvae revealed that the larval stage passes through six instars (L1–L6). Developmental times of each instar varied significantly among bean species (Table 1). L1 lasted significantly less time in cowpea (three days) than in the other seeds (7.4–9.0 days with no significant differences among them). The duration of L2 was less than that of L1 in all seed species. Duration of L2 in broad bean, kidney bean, cowpea, and lentils ranged 3.7–5.0 days, whereas the instar took significantly longer time (7.2 days) to develop in chickpea. L3 feeding in broad bean and lentils took significantly longer time, 6.0 and 5.3 days, respectively to develop compared to L2. However, L3 feeding in kidney bean, cowpea, and chickpea took significantly less time, 3.0–3.9 days, to develop than of L2. The duration of L4 feeding in the most seed species was approximately equal to that of L3. L4 feeding in broad bean took significantly longer time (6.1 days) than L4 feeding in other seeds (3.1–4.4 days). L5 lasted less time than in L4 in most seed species except for L5 feeding in kidney bean, which took almost equal time to that recorded for L4. The duration range of L5 feeding in all seed species ranged 2.5–3.9 days. L6 feeding in broad bean and lentils took significantly longer time (8.3 and 8.1 days) to develop than L6 feeding in the other seed species. Overall, the larva developed most rapidly on cowpea followed in order by kidney bean, chickpea, lentils, and broad bean (Table 1).

Duration of the prepupa in lentil and broad bean seeds was significantly shorter (1.0 and 1.4 days, respectively) than that in the other seed species (2.6–3.4 days) (Table 1). The pupa is the exarate type and white in color. The pupal stage was shortest (3.0 days) in lentils but 4.2–5.3 days in the other seed species (Table 1).

Adults of *A. obtectus* survived several days and laid numerous eggs on broad bean, kidney bean, and cowpea seeds. Statistical analyses of the adult longevity of *A. obtectus* reared on broad bean, kidney bean and cowpea revealed insignificant differences among the three leguminous seeds (Table 2). Male longevity was slightly lower (6.6–8.2 days) than female longevity (8.2–9.4 days). The pre-oviposition periods of females on kidney bean and cowpea were significantly shorter than that on broad bean, and the oviposition periods on these two seeds were significantly longer than on broad bean (Table 2). No significant differences were detected for post-oviposition period on the three legume seeds (Table 2). Female fecundity (number of eggs per female) was significantly higher on cowpea than on kidney bean (Table 2). No adult data were obtained from

Table 1. Mean ± SE duration (days) of the life stages of *Acanthoscelides obtectus* reared on five legume seed species. Means followed by different letters within each stage are significantly different from each other (α = 0.05).

	Bean species						
Stage	**Broad bean**	**Kidney bean**	**Cowpea**	**Chickpea**	**Lentil**	***F***	***P***
1st instar	8.9±0.3b	7.4±0.8b	3.0 ±0.0a	8.0 ±0.7b	9.0 ±0.0b	8.850	<0.001
2nd instar	4.0±0.4a	5.0±0.0a	3.7±0.3a	7.2±0.3b	5.0±0.7a	10.550	<0.001
3rd instar	6.0±1.0c	3.0±0.4a	3.9±0.4ab	3.7±0.4ab	5.2±0.2bc	5.750	0.001
4th instar	6.1±0.9b	3.1±0.4a	4.4±0.6ab	3.8±0.2ab	4.0±0.3ab	3.510	0.013
5th instar	3.9±0.5	3.5±0.4	3.8±0.3	2.5±0.2	3.4±0.3	1.320	0.268
6th instar	8.3±0.6b	3.3±0.2a	2.9±0.4a	3.6±0.2a	8.1±0.4b	51.970	<0.001
Larva	37.1	25.4	21.7	28.7	34.7		
Pre-pupa	1.4±0.1a	2.8±0.3b	2.6±0.1b	3.4±0.2b	1.0±0.0a	12.160	<0.001
Pupa	5.3±0.7b	4.2±0.2ab	5.2±0.1b	5.3±0.5b	3.0±0.0a	8.360	<0.001

Table 2. Mean ± SE adult longevity, pre-oviposition period, oviposition period, and post-oviposition period (all in days) and female fecundity of *Acanthoscelides obtectus* reared on three legume seed species. Means followed by different letters in the same column are significantly different from each other ($\alpha = 0.05$); no letters in a column indicates no significant differences.

Legume seed	Adult longevity		Pre-oviposition period	Oviposition period	Post-oviposition period	Fecundity (eggs/female)
	Male	Female				
Broad bean	6.6±1.1	8.2±0.7	1.8±0.2b	4.1±0.3a	1.7±0.4	23.1±3.4ab
Kidney bean	7.2±0.7	8.9±1.2	1.2±0.1a	5.6±0.9b	2.1±0.4	11.9±3.3a
Cowpea	8.2±0.8	9.4±0.5	1.1±0.1a	6.6±0.4c	2.1±0.5	44.8±15.0b
F	2.24	2.16	4.87	52.43	1.88	4.19
P	0.127	0.138	0.017	0.001	0.188	0.027

chickpea and lentil seed because adults failed to emerge in sufficient numbers for experimentation.

Host Preference. Number of emergent adults, seed infestation rate, and weight loss increased gradually with the increased number of adult couples in artificial infestation (Table 3). Number of emergent adults was consistently higher from kidney bean and cowpea seeds than from the other seed species across all infestation rates. Adult emergence was consistently lowest from lentil seeds at all infestation rates. Percentage infestation of seeds was highest on kidney bean seeds but only significantly at the infestation rates of 10 and 20 adult pairs per container. Broad bean, cowpea, and chickpea seeds had significantly lower infestation rates than kidney bean, with no significant among them. Lentils seem to be unsuitable for *A. obtectus*, as very low infestation rates occurred on these seeds.

Acanthoscelides obtectus caused the more weight loss in cowpea seeds than in kidney bean, chickpea,

Table 3. Means ± SE of number of emergent *Acanthoscelides obtectus* adults, percentage of beans infested, and bean weight loss percentage for five legume seed species inoculated with 5, 10, 20, or 40 pairs of adult *A. obtectus*. Means followed by different letters in the same column within a variable are significantly different from each other ($\alpha = 0.05$).

Legume seed	Number of *A. obtectus* adult pairs: 5	10	20	40
Number of emergent adults				
Broad bean	3.0 ±2.7a	6.8 ± 6.1a	25.8 ±13.5ab	114.5 ±19.53a
Kidney bean	84.8 ±24.4b	99.0 ±14.1b	374.8 ±15.9c	293.25 ±57.53b
Cowpea	73.8 ±28.3ab	90.8 ±12.8b	123.3 ±50.8b	327.75 ±52.79b
Chickpea	16.8 ±10.0ab	10.3 ±3.8a	12.8 ±4.8a	86.25 ±21.39a
Lentil	1.3 ±1.0a	4.3 ±0.15a	1.3 ±1.0a	4.5 ±1.04a
F	5.361	28.168	40.61	13.954
P	0.007	<0.001	< 0.001	<0.001
Percentage of beans infested				
Broad bean	4.8 ±3.9a	18.1 ±8.9ab	40.2±13.9b	65.3±4.9b
Kidney bean	42.0 ±8.8b	50.9 ±2.3c	73.2 ±3.5c	73.5 ±8.3b
Cowpea	17.3 ±5.4ab	26.2 ±4.3b	37.0 ±5.6b	48.8 ±3.5b
Chickpea	21.4 ±7.6ab	13.5 ±4.8ab	17.2 ±5.3ab	57.4 ±7.5b
Lentil	1.9 ±1.2a	3.1 ±0.3a	3.3 ±1.2a	6.9 ±1.9a
F	7.022	12.819	13.252	20.529
P	0.002	<0.001	<0.001	<0.001
Percentage bean weight loss				
Broad bean	1.3 ±0.9ab	2.5 ±0.6a	3.7 ±1.2ab	10.4 ±3.0ab
Kidney bean	2.8 ±1.1ab	2.3 ±1.12a	9.6 ±4.3ab	16.5 ±5.1ab
Cowpea	5.3 ±1.7b	9.6 ±1.7b	14.5 ±4.0b	19.3 ±3.6b
Chickpea	3.1 ±1.6ab	1.1 ±0.3a	2.4 ±0.8ab	13.7 ±4.0ab
Lentil	0.7 ±1.1a	0.7 ±0.6a	0.3 ±7.9a	1.6 ±0.6a
F	2.867	13.586	3.399	3.629
P	0.060	<0.001	0.036	0.029

and broad bean seeds but only significantly more with 10 adult pairs per container (Table 3). Relatively little weight loss was recorded in lentils. Weight loss generally increased with greater number of adult pairs per container, but not significantly.

Amino Acid Content. The most abundant amino acids in nearly all seed species were aspartic acid, glysine, valanine, and lysine (Table 4). In broad beans, lysine, aspartic acid, glutamic acid, alanine, phenylalanine, leucine, and serenine were the most abundant amino acids, together representing nearly 92% of the entire amino acid content in this seed species. Glysine was absent from broad bean seeds, whereas it was relatively abundant in the other seed species. Aspartic acid, valanine, lysine, glysine, histadine, leucine, and serenine combined accounted for over 93% of the amino acid content in kidney beans. More than 90% of the amino acid content in cowpeas is from lysine, aspartic acid, valanine, glysine, and histadine. In chickpeas, the six most abundant amino acids were lysine, aspartic acid, valanine, glysine, phenylalanine, and leucine that accounted for nearly 96% of the total amino acid content. Lysine, aspartic acid, glutamic acid, phenylalanine, glysine, alanine, leucine, histadine, and serenine in lentils represented more than 95% of the total amino acid content.

Seven amino acids (aspartic acid, theronine, glysine, valanine, methionine, tryptophane, and histadine) had a significant positive correlation with infestation rate on kidney beans (Table 5). Three amino acids (glutamic acid, alanine, and phenylalanine) had a significant negative correlation with infestation rate on kidney beans. Glutamic acid is not present in kidney beans, and alanine and phenylalanine are present in low levels (Table 4).

Discussion

This is the first study on the biology of *A. obtectus* on legume seeds in Egypt, although the beetle is widespread in Africa (Msolla and Misangu 2002; Paul *et al.* 2009). The oviposition, larval, and pupal periods in our study were shorter than those recorded in previous studies (Parsons and Credland 2003; Paul *et al.* 2009; Thakur 2012). This may be due to the difference in the environment conditions used in rearing of the insects found. Larval developmental time was 26 days on black-eyed cowpeas (Howe and Currie 1964) and 66 days on lentils (Arbogast 1991) at 28° C and 75% RH. We also found that larvae developed more quickly in cowpeas compared to lentils.

Our study has shown that *A. obtectus* from Egypt develops well in broad bean, kidney bean, and cowpea and that adult females survive well and lay numerous eggs on them. *Acanthoscelides obtectus* larvae develop into pupae in chickpea and lentils but the adult emergence rates are low. This may be attributed to chickpea's chemical composition, irregular seed surface, or size (Teixeira and Zucoloto 2003). Females of *A. obtectus* lay significantly more eggs on large seeds than on seeds five times smaller in mass (Szentesi 2003).

In the USA, Godfrey and Long (2008) recorded 70 eggs laid per female kidney bean seeds at 35° C. This fecundity number contrasts significantly our results of 11.9 eggs per female on the same host. This difference can be attributed to the experimental temperature (27±1° C) or bean varieties used in the experiments. In Japan, Utida (1972) showed that fecundity differed among hosts; he recorded 23 and 110 eggs per female on lentils and broad beans,

Table 4. Relative amounts (%) of amino acids in the seeds of five legume species.

	Relative amount (%)				
Amino acid	**Broad bean**	**Kidney bean**	**Cowpea**	**Chickpea**	**Lentil**
Aspartic acid	16.31	28.24	17.66	13.58	16.52
Theronine	0.78	1.12	0.69	0.58	0.99
Serenine	3.31	3.14	2.45	2.19	3.07
Glutamic acid	14.54	0.00	0.00	0.00	12.40
Proline	0.05	0.00	0.00	0.00	0.06
Glysine	0.00	11.21	8.68	7.29	8.14
Alanine	8.97	1.16	0.93	0.16	5.00
Valanine	2.19	18.82	13.35	10.66	1.62
Methionine	0.65	1.28	0.84	0.85	0.56
Isoleucine	1.00	0.59	0.00	0.00	0.92
Leucine	4.45	5.18	0.33	3.35	4.14
Tryptophane	0.90	1.25	0.53	0.35	0.90
Phenylalanine	7.82	1.26	0.33	5.14	8.46
Histadine	2.60	8.75	6.07	0.00	3.42
Lysine	36.45	17.99	45.17	55.85	33.79

Table 5. Simple correlation coefficients (r) for the relationship between infestation of kidney beans by *Acanthoscelides obtectus* and amino acid content. * = significant; ** = highly significant.

Amino acid	r
Aspartic acid	0.760**
Theronine	0.856**
Serenine	0.112
Glutamic acid	-0.800**
Proline	0.000
Glysine	0.656*
Alanine	-0.683*
Valanine	0.945**
Methionine	0.856**
Isoleucine	-0.458
Leucine	0.188
Tryptophane	0.851**
Phenylalanine	-0.763**
Histadine	0.609*
Lysine	-0.389

respectively. These data are dissimilar with ours for females on the same hosts. These results suggest that the beetle adapts itself to the environmental conditions in Egypt, but its fecundity may be lower than that recorded in studies from other regions.

Host type is one significant factor affecting *A. obtectus* development. Tucić *et al.* (1995) observed that females lay significantly fewer eggs on chickpeas than on kidney beans. Based on the number of emergent adults and infestation rate, we found that kidney bean and cowpea seeds were more preferred than other seeds. However, seed weight loss differed among seed species; higher weight loss occurred in cowpea seeds than in kidney beans. This could be attributed to the size of the cowpea seed being smaller than that of kidney bean. Furthermore, lentils seem to be unsuitable for *A. obtectus* because very low infestation percentage occurred on this host. Host size probably plays an important role in oviposition (Simmonds *et al.* 1989). Other factors that influence ovipositions are seed texture (Johnson and Kistler 1987), chemical characteristics of the seed coat (Lale and Makoshi 2000), and nutritional quality (Janz and Nylin 1997). The texture of all five host seeds in our study is smooth. It is likely that only the relative quantity and/or quality of the seeds affected oviposition rates on the seeds (Cope and Fox 2003).

The chemical composition of seeds may be the most important factor determining the development of bruchids in their hosts (Tuda *et al.* 2006). Secondary metabolites, such as non-protein amino acids, can serve as chemical defense against herbivores including granivores (Gatehouse *et al.* 1990; Tuda *et al.*2006). Primary metabolites (*e.g.* lectins and proteinase and amylase inhibitors present in leguminous seeds) are also involved in crop plant resistance (Omitogun *et al.* 1999). Our analysis of amino acid contents in kidney beans may explain why this seed is the preferred host for *A. obtectus*. Nine amino acids were recorded with the highest correlative value in kidney bean. The second most preferred hosts were cowpea and broad bean, which share with kidney beans high correlative values for some amino acid. Although lentil seeds contain many amino acids excessively found in kidney beans, they are less suitable for *A. obtectus.* This may be attributed to the lentil seeds small size that leads to lower nutrition value and thus incomplete development occurs.

References Cited

Arbogast, R. T. 1991. Beetles: Coleoptera [pp. 131–176]. *In*: Ecology and Management of Food-Industry Pests. (J. R. Gorham, editor). FDA Technical Bulletin 4. Association of Analytical Chemists, VA.

Ayvaz, A., O. Sagdic, S. Karaborklu, and I. Ozturk. 2010. Insecticidal activity of the essential oils from different plants against three stored-product insects. Journal of Insect Science 10: 1–13.

Baier, A. H., and B. D. Webster. 1992. Control of *Acanthoscelides obtectus* Say (Coleoptera: Bruchidae) in *Phaseolus vulgaris* L. seed stored on small farms – I. Evaluation of damage. Journal of Stored Products Research 28: 289–293.

Cope, J. M., and C. W. Fox. 2003. Oviposition decisions in the seed beetle, *Callosobruchus maculatus* (Coleoptera: Bruchidae): Effects of seed size on superparasitism. Journal of Stored Products Research 39: 355–365.

Csomos, E. S., and L. Sarkadi. 2002. Characterization of tokaj wines based on free amino acid and bioganic amine using ion-exchange chromatography. Chromatographia Supplement 56: 185–188.

Duan, C., Z. Zhu, W. Li, S. Bao, and X. Wang. 2017. Genetic diversity and differentiation of *Acanthoscelides obtectus* Say (Coleoptera: Bruchidae) populations in China. Agricultural and Forest Entomology 19: 113–121.

El-Sherif, S. I., M. Y. Hashem, and S. S. Ahmed. 2008. The life history of the Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) on maize (*Zea mays* L.) grains. Bulletin Faculty of Agriculture Cairo University 59(4): 333–338.

Faroni L. R. D., and A. H. de Sousa. 2006. Aspectos biológicos e taxonômicos dos principais insetos-praga de produtos armazenados [pp. 371–402]. *In*: Tecnología de Armazenagem em Sementes (F. A. C. Almeida, M. E. M. Duarte, and M. E. R. M. C. Mata, editors). Universidade Federal de Campina Grande, Brazil.

Gatehouse, A. M. R., B. H. Minney, P. Dobie, and V. Hilder. 1990. Biochemical resistance to bruchid attack in legume seed; investigation and exploitation [pp. 241–256]. *In*: Bruchids and Legumes:

Economics, Ecology and Co-evolution (K. Fujii, A. M. R. Gatehouse, C. D. Johnson, R. Mitchel, and T. Yoshida, editors). Kluwer, Dordrecht, Netherlands.

Godfrey, L. D., and R. F. Long. 2008. Dry Bean Weevils. UC IPM Pest Management Guidelines: Dry Beans. UC ANR Publication 3446.

Goucem, K., K. F. Medjdoub, B. Ensaad, E. Leppik, and B. Frérot. 2014. Dry bean volatile organic compounds mediating host choice in *Acanthoscelides obtectus* Say (Coleoptera: Chrysomelidae: Bruchinae). Annales de la Société entomologique de France (N.S.) 50: 167–176.

Hagstrum, D. W., and B. Subramanyam. 2009. A review of stored-product entomology information sources. American Entomologist 55: 174–183.

Hamraoui, A., and C. Regnault-Roger. 1995. Oviposition and larval growth of *Acanthoscelides obtectus* Say (Col., Bruchidae) in regard to host and non-host plants from leguminosae family. Journal of Applied Entomology 119: 195–l99.

Harris, K. L., and C. J. Lindblad. 1978. Postharvest Grain Loss Assessment Methods. A Manual of Methods for the Evaluation of Postharvest Losses. American Association of Cereal Chemists, Bethesda, MD.

Howe, R. W., and J. E. Currie. 1964. Some laboratory observations on the rates of development, mortality and oviposition of several species of Bruchinae breeding in stored pulses. Bulletin of Entomological Research 55: 437–477.

Janz, N., and S. Nylin. 1997. The role of female search behaviour in determining host plant range in plant feeding insects: A test of information processing hypothesis. Proceedings of the Royal Society of London 264: 701–707.

Johnson, C., and R. A. Kistler. 1987. Nutritional ecology of bruchid beetles [pp. 259–276]. *In*: Nutritional Ecology of Insects, Mites, Spiders and Related Invertebrates (F. Slansky Jr. and J. G. Rodrigues, editors). John Wiley, New York, NY.

Lale, N. E. S., and M. S. Makoshi. 2000. Role of chemical characteristics of the seed coat in the resistance of selected cowpea varieties to *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) in Nigeria. International Journal of Pest Management 46: 97–102.

Lü, J., B. S. Song, N. Z. Li, and R. L. Xu. 1994. A tentative observation of damage loss caused by bean weevil, *Acanthoscelides obtectus* Say. Plant Quarantine 8: 263–267.

Msolla, S. N., and R. N. Misangu. 2002. Seasonal distribution of common bean (*Phaseolus vulgaris* L.) bruchid species in selected areas in Tanzania [pp. 1–5]. *In*: Proceeding Bean Seed Workshop, Arusha, Tanzania.

Mutungi, C., H. D. Affognon, A.W. Njoroge, J. Manono, D. Baributsa, and L. L. Murdock. 2015. Triple-layer plastic bags protect dry common beans (*Phaseolus vulgaris*) against damage by *Acanthoscelides obtectus* (Coleoptera: Chrysomelidae) during storage. Journal of Economic Entomology 108: 2479–2488.

Oliveira, M. R. C., A. S. Corrêa, G. A. D. Souza, R. N. Guedes, and L.O. D. Oliveira. 2013. Mesoamerican origin and pre- and post-Columbian expansions of the ranges of *Acanthoscelides obtectus* Say, a cosmopolitan insect pest of the common bean. PLoS One 8: 70039. DOI: 10.1371/journal.pone.0070039.

Omitogun, O. G., L. E. N. Jackai, and G. Thottappilly. 1999. Isolation of insecticidal lectin-enriched extracts from African yam bean (*Sphenostylis stenocarpa*) and other legume species. Entomologia Experimentalis et Applicata 90: 301–311.

Parsons, D. M. J., and P. F. Credland, 2003. Determinants of oviposition in *Acanthoscelides obtectus*: A nonconformist bruchid. Physiological Entomology 28: 221–231.

Paul, U. V., J. S. Lossini, P. J. Edwards, and A. Hilbeck. 2009. Effectiveness of products from four locally grown plants for the management of *Acanthoscelides obtectus* (Say) and *Zabrotes subfasciatus* (Boheman) (both Coleoptera: Bruchidae) in stored beans under laboratory and farm conditions in northern Tanzania. Journal of Stored Products Research 45: 97–107.

Pemonge, J., M. J. Pascual-Villalobos, and C. Regnault-Roger. 1997. Effects of material and extracts of *Trigonella foenum-graecum* L. against the stored product pests *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) and *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae). Journal of Stored Products Research 33: 209–217.

Simmonds, M. S. J., W. M. Blaney, and A. N. E. Birch. 1989. Legume seeds: The defenses of wild and cultivated species of Phaseolus against attack by bruchid beetles. Annals of Botany 63: 177–184.

Snedecor, G. W., and W. G. Cochran. 1956. Statistical Methods Applied to Experiments in Agriculture and Biology. 5th edition. Iowa State University Press, Ames, IA.

Szentesi, Á. 2003. Resource assessment and clutch size in the bean weevil, *Acanthoscelides obtectus.* Pest Management Science 59: 431–436.

Teixeira, I. R. V., and F. S. Zucoloto. 2003. Seed suitability and oviposition behaviour of wild and selected populations of *Zabrotes subfasciatus* (Boheman) (Coleoptera, Bruchidae) on different hosts. Journal of Stored Products Research 39: 131–140.

Thakur, D. R. 2012. Taxonomy, distribution and pest status of Indian biotypes of *Acanthoscelides obtectus* (Coleoptera: Chrysomelidae: Bruchinae) – a new record. Pakistan Journal of Zoology 44: 189–195.

Thakur, D. R., and R. Renuka. 2014. Biology and Biointensive Management of *Acanthoscelides obtectus* (Say) (Coleoptera: Chrysomelidae) – A Pest of Kidney Beans Wordwide. 11th International Working Conference on Stored Product Protection. Himachal Pradesh University, Summer Hill, Shimla, India.

Tucić, N., I. Gliksman, D. Šešlija, D. Milanović, S. Mikuljanac, and 0. Stojković. 1996. Laboratory evolution of longevity in the bean weevil (*Acanthoscelides obtectus*). Journal of Evolutionary Biology 9: 485–503.

Tucić, N., D. Milanović, and S. Mikuljanac. 1995. Laboratory evolution of host plant utilization in the bean weevil (*Acanthoscelides obtectus*). Genetics Selection Evolution 27(6): 491–502.

Tuda, M., J. Rönn, S. Buranapanichpan, N. Wasano, and G. Arnqvist. 2006. Evolutionary diversification of the bean beetle genus *Callosobruchus* (Coleoptera: Bruchidae): Traits associated with stored-product pest status. Molecular Ecology 15: 3541–3551.

Utida, S. 1972. Density dependent polymorphism in the adult of *Callosobruchus maculatus* (Coleoptera, Bruchidae). Journal of Stored Products Research 8: 111–126.

Vuts, J., S. J. Powers, J. C. Caulield, J. A. Pickett, and M. A. Birkett. 2015. Multiple roles of a male-specific compound in the sexual behavior of the dried bean beetle, *Acanthoscelides obtectus.* Journal of Chemical Ecology 41: 287–293.

Wang, J. P., X. Q. Wang, F. Lü, and P. Gao. 2006. Risk analysis of *Acanthoscelides obtectus* in China. China Plant Protection 26: 8–11.

(Received 27 August 2018; accepted 27 June 2019. Publication date 22 September 2019.)