Australian Journal of Crop Science

AJCS

AJCS 10(10):1404-1409 (2016) ISSN:1835-2707
DOI: 10.21475/ajcs.2016.10.10.pne61

Cultivation of resistant soybean varieties and application of silicon (Si) on biology of *Euschistus heros* (Hemiptera: Pentatomidae)

Paulo Vinicius de Souza[1], Bruna Ribeiro Machado[1], Jose Cola Zanuncio[2], Marcio Silva Araújo[3], Gleina Costa Silva Alves[1], Flávio Gonçalves de Jesus[1*]

[1]Instituto Federal Goiano – Campus Urutaí, Brazil
[2]Universidade Federal de Viçosa, Departamento de Biologia Animal, Brazil
[3]Universidade Estadual de Goiás, Brazil

***Corresponding author: flavio.jesus@ifgoiano.edu.br**

Abstract

Seed-sucking insects are economically important pests affecting soybean in Brazil. The objective of this study was to evaluate the effect of chemical inducers on insect resistance in soybean on the neotropical brown stink bug, *Euschistus heros* (F.) (Hemiptera: Pentatomidae) using varying levels of inherent resistance in soybean. Seedpods from of the soybean varieties 'IAC 100' and 'IAC 17' (antibiosis resistant and non-preference resistant varieties, respectively), 'Conquista' (moderately resistant), and 'Jataí' (susceptible) that had been treated with one of several inducers, or untreated, were evaluated in choice- and no-choice tests. In addition to analyses of feeding preference, effects of the treatments on the development of *E. heros* were also studied. The non-preference and antibiosis resistances of varieties 'IAC 17' and 'IAC 100' were observed when plants of these varieties treated with resistance inducers were fed to *E. heros*. Potassium silicate, calcium magnesium silicate, and acibenzolar-S-methyl (ASM) inducers were found to have a synergistic effect on the resistance of 'IAC 17' and 'IAC 100' to *E. heros*. These soybean varieties can be directly used by farmers or associated with silicon application to prevent damage caused by *E. heros*.

Keywords: Acibenzolar-S-methyl. *Glycine max*. Resistance induction. Silicon. Plant resistance to insects. Brown stink bug.

Introduction

Soybean, *Glycine max* (L.) Merrill (Fabaceae), is a major crop in Brazil, which has one of the largest total cultivated areas among soybean producing nations. Soybean is becoming increasingly important as a producer of biodiesel from soybean seed oil (Qiuet al., 2011). Seed-sucking insects, particularly the neotropical brown stink bug *Euschistus heros* (Hemiptera: Pentatomidae), represent a major problem affecting soybean production in Brazil (Corrêa-Ferreira, 2005). These insects are present on soybean plants beginning at the vegetative phase, and hamper pod formation from the onset of seed-filling to maturity (Nunes and Corrêa-Ferreira 2002). However, soybean plants in the later stages are the most appropriate source of food for nymphs and adults of these stink bugs, relative to earlier stages (Panizzi and Alves 1993). Feeding injury caused by these insects affects seed production, quality, and germination potential in soybean plants (Ni et al., 2010; Depieri and Panizzi 2011). Sucking insects in soybean are primarily controlled using chemical insecticides (Brown et al., 2012). Insecticide application may result in resistant insect populations in addition to environmental damage and public health (Sosa-Gómez and Silva 2010). The undesirable effects of insecticides have led to the development of alternative methods for insect control (Jackai et al., 1988; Sosa-Gómez and Moscardi 1998; Sosa-Gómez and Silva 2010), including the use of silicon for inducing plant resistance against insect pests and pathogens (Ferreira et al., 2011; Lemes et al., 2011; Cruz et al., 2012). Silicon increases plant resistance by stimulating growth and by producing phenolic defense compounds (Epstein 1999; Ferreira et al., 2011; Lemes et al., 2011; Cruz et al., 2012). Additionally, silicon accumulation and the polymerization of silicate in the epidermal cells of plants form a silicon cuticle layer that functions as a mechanical barrier (Savant et al., 1997). Epidermal silicification prevents stylet penetration and insect chewing due to the hardening of plant cell walls (Datnoff et al., 1991).Management of *E. heros* may include the cultivation of resistant soybean varieties. The resistance of soybean plants to insects is also associated with volatile substances in leaves (Li et al., 2004), variations in nutrient concentration, food stimulants or deterrents, and antibiotics (Fisher et al., 1990). Flavonoids, either constitutive or induced, such as rutin and the isoflavonoid genistin, occur in different parts of soybean plants and are the most likely candidate substances in underlying plant resistance to insects (Hoffmann-Campo et al., 2001; Piubelli et al., 2003; Piubelli et al., 2005). The use of insect-resistant cultivars along with other control methods in integrated pest management systems may reduce or even eliminate the use of insecticides and thereby improve the sustainability of soybean production.

Few studies have investigated the use of silicon and resistant varieties for the control of seed-sucking insects in soybean crops. The aim of this study was to investigate the effect of treating resistant soybean varieties with silicon on the biology of *E. heros*.

Results

The preference of adult *E. heros* for soybean varieties in the multiple-choice tests differed at the different time intervals, except at 45 min, 1 h, and 2 h post-release (Table 1). The resistance inducers did not affect the preference by *E. heros* for the soybean varieties in this test. In general, 'IAC 17' was most preferred by adult *E. heros*, whereas 'BRS Jataí' was the least preferred.The no-choice tests (Table 1) revealed differences in preference by *E. heros* for the soybean at all time intervals. The adults were less attracted to 'IAC 100' and 'IAC 17', while sodium silicate reduced the preference by the insects to the soybean plants.After 1-h post-release in multiple-choice tests, adult *E. heros* exhibited decreased preference for 'IAC 17' treated with sodium silicate or calcium magnesium silicate, as well as decreased attraction to 'IAC 100' treated with ASM or calcium magnesium silicate (Table 2). After 2 h, reduced preference was observed for 'IAC 17' treated with sodium silicate and 'BRS Conquista' treated with ASM or potassium silicate (Table 2).The development time of *E. heros* differed among the examined soybean varieties (Table 3) and inducer treatments, although not significant, were observed during the second instar. The *E. heros* stadia, including the adult stage, were longer for insects on the 'IAC 17' and 'IAC 100' varieties than on the other varieties. Treatment with the inducers Ca + Mg silicate, ASM, or K silicate extended the duration of some developmental stages. Further analysis of the interactions between soybean varieties and resistance inducers (Table 4) revealed significant effects of ASM treatment or Na silicate treatment on *E. heros* development; in particular, longer development times of *E. heros* stages were observed for 'IAC 17' treated with ASM and for 'IAC 100' treated with Na silicate than for untreated 'IAC 17' and 'IAC 100', respectively. The second instar of *E. heros* was longer for the 'IAC 17' and 'IAC 100' varieties without inducers. All resistance inducers produced differences in the fourth instar (Table 4), with *E. heros* nymphs failing to complete this instar on 'IAC 100' treated with K silicate and with 'BRS Conquista' treated with Na silicate. Additionally, *Euschistus heros* development was longer in 'IAC 17' and 'IAC 100' without inducers.
Analyses of the fifth instar stage (Table 4) demonstrated that *E. heros* did not successfully complete development on ASM-treated 'IAC 100' and 'BRS Jataí' pods; K silicate-treated 'IAC 100' pods; Na silicate-treated 'BRS Conquista' and 'BRS Jataí' pods; Ca + Mg silicate-treated 'IAC 100' and 'BRS Conquista' pods; or untreated 'IAC 100' and 'BRS Conquista' pods. *Euschistus heros* completed its development on K silicate-treated 'IAC 17' and 'BRS Jataí pods; Na silicate-treated IAC 100 pods; and Ca+Mg silicate-treated IAC 17 and BRS Jataí' pods (Table 4).
The egg to adult development period of *E. heros* was longer on K silicate-treated 'IAC 17' pods and Na silicate-treated 'IAC100' pods than on K silicate-treated pods of the susceptible variety BRS Jataí (Fig. 1).

Discussion

The analysis of *E. heros* preference for soybean varieties using multiple-choice and no-choice tests revealed different responses for the resistant and susceptible soybean varieties. Discrepancies between the results of multiple-choice and no-choice tests are common in studies of plant resistance to insects. For example, a host found to be less preferred in a multiple-choice test may be readily consumed in a no-choice test (Schlick-Souza et al., 2011).The resistant variety 'IAC 17' treated with sodium silicate or calcium magnesium silicate and 'IAC 100' treated with ASM or calcium magnesium silicate were less preferred by *E. heros*. The reduced preference by *E. heros* to the resistant varieties 'IAC 17' and 'IAC 100' is indicative of an indirect defense mechanism, which may have resulted from an increased production of volatile compounds in response to herbivory by *E. heros* (Li et al., 2004; Fisher et al., 1990; Piubelli et al., 2003; Piubelli et al., 2005). The induced secondary compounds present in these resistant varieties, particularly the flavonoid rutin and the isoflavonoid genistin (Hoffmann-Campo et al., 2001), reduce the attractiveness of the plants to insects and reduce feeding preference. The decreased preference of 'IAC 17' and 'IAC 100' treated with sodium silicate, calcium magnesium silicate, or ASM may have been due to an increased production of a protective layer of silica, increased trichome formation on the pods, or an increased production of phenolic compounds (Epstein 1999; Ferreira et al., 2011; Lemes et al., 2011; Cruz et al., 2012). The development period of *E. heros* varied among the different varieties and resistance inducers. The duration of the period between the second instar to the adult was longest on the resistant varieties 'IAC 17' and 'IAC 100'. The resistance inducers calcium magnesium silicate, ASM, and potassium silicate also prolonged this period.
The prolonged development time of *E. heros* may reflect a decreased host quality due to the presence of secondary compounds such as flavonoids and isoflavonoids in the resistant varieties 'IAC 17' and 'IAC 100.' These compounds are known to have antibiotic and anti-feeding effects on phytophagous insects (Hoffmann-Campo et al., 2001; Piubelli et al., 2003; Piubelli et al., 2005). Furthermore, resistance induction by the silicate sources may have increased the production of these induced compounds and/or the formation of a protective silicon layer in the epidermis of the pods, which would reduce feeding and negatively affect the biology of *E. heros* (Epstein 1999; Ferreira et al., 2011; Lemes et al., 2011; Cruz et al., 2012). The results reported here for *E. heros* differ from those for other stink bugs fed different soybean varieties and may be largely attributable to differences in the type of diets offered; the temperature, humidity and photoperiod conditions; and the location where the studies were conducted (McPherson and Paskewitz 1984; Munyaneza and McPherson 1994).

Materials and Methods

Seeds of soybean varieties 'IAC 100' and 'IAC 17' (resistant), 'BRS Conquista' (moderately resistant) and 'BRS Jataí' (susceptible) were planted in 5 kg polyethylene pots containing a 3:1 soil: organic compost mixture. After emergence, plants were thinned to one per pot. The pots were maintained in a greenhouse and covered with nylon netting to protect the plants, which had not been sprayed with insecticides, against pests. Before the critical stage of stink bug attack, the pots were transferred to a climate-controlled room with a 12-h photoperiod, 28 °C daytime temperature and 25 °C nighttime temperature, and then subjected to the following treatments: T1) plant sprayed to the point of runoff with a 1% potassium silicate solution, T2) plant sprayed to the point of runoff with a 1% sodium silicate solution, T3) application of calcium magnesium silicate in the soil, T4)

Table 1. Number of *Euschistus heros* adults feeding at several times on green soybean pods treated with resistance inducers in multiple-choice and no-choice tests.

Cultivar (C)	Preference in multiple-choice test[1,2]						
	15 min	30 min	45 min	1 h	2 h	3 h	6 h
IAC 17	0.94 a	0.94 a	0.90	1.04	0.96	0.98 a	1.12 a
IAC 100	0.76 ab	0.82 ab	0.82	0.70	0.54	0.66 ab	0.50 b
BRS Conquista	0.50 b	0.58 ab	0.56	0.64	0.72	0.76 ab	0.62 b
BRS Jataí	0.50 b	0.44 b	0.54	0.64	0.56	0.36 b	0.44 b
F (C)	3.23^{*}	3.42^{*}	2.25^{ns}	2.31^{ns}	2.29^{ns}	4.18^{**}	7.00^{**}
Inducer (I)							
ASM	0.62	0.57	0.62	0.65	0.70	0.80	0.72
K silicate	0.65	0.70	0.72	0.97	0.70	0.65	0.55
Na silicate	0.67	0.77	0.70	0.67	0.70	0.57	0.67
Ca + Mg silicate	0.65	0.65	0.67	0.67	0.70	0.65	0.87
Untreated	0.77	0.77	0.80	0.80	0.67	0.77	0.52
F (I)	0.19^{ns}	0.39^{ns}	0.23^{ns}	0.93^{ns}	0.01^{ns}	0.45^{ns}	1.18^{ns}
F (CxI)	0.92^{ns}	1.43^{ns}	1.52^{ns}	2.25^{**}	2.98^{**}	1.64^{ns}	1.13^{ns}
C.V. (%)	35.45	35.86	35.52	35.68	35.94	36.10	34.14
Cultivar (C)	Preference in no-choice test						
	15 min	30 min	45 min	1 h	2 h	3 h	6 h
IAC 17	0.31 bc	0.33 bc	0.28 b	0.35 ab	0.33 b	0.40 ab	0.43 ab
IAC 100	0.21 c	0.19 c	0.25 b	0.29 b	0.35 b	0.36 b	0.30 b
BRS Conquista	0.51 a	0.51 a	0.51 a	0.51 a	0.56 a	0.52 ab	0.46 ab
BRS Jataí	0.41 ab	0.41 ab	0.47 a	0.52 a	0.53 a	0.57 a	0.55 a
F (C)	7.54^{**}	8.27^{**}	7.85^{**}	5.67^{**}	5.88^{**}	4.09^{**}	4.50^{**}
Inducer (I)							
ASM	0.34 ab	0.34	0.45 ab	0.47	0.46	0.49	0.56 a
K silicate	0.29 ab	0.32	0.34 ab	0.34	0.39	0.36	0.40 ab
Na silicate	0.27 b	0.29	0.26 b	0.32	0.39	0.42	0.35 b
Ca + Mg silicate	0.41 ab	0.36	0.32 ab	0.42	0.47	0.49	0.36 ab
Untreated	0.49 a	0.49	0.51 a	0.52	0.50	0.55	0.50 ab
F (I)	2.89^{*}	2.11^{ns}	3.73^{**}	2.55^{*}	0.89^{ns}	1.70^{ns}	2.88^{*}
F (CxI)	0.23^{ns}	0.35^{ns}	0.71^{ns}	0.66^{ns}	0.55^{ns}	1.44^{ns}	0.72^{ns}
C.V. (%)	27.24	27.22	26.91	27.14	27.20	26.73	27.07

[1]Data transformed into (x + 0.5)1/2 for analysis. [2]Means followed by the same letter within a column do not differ according to Tukey's test at 5% probability. C.V. = coefficient of variance. ^{ns} non-significant. * Significant at 1% probability. ** Significant at 5% probability

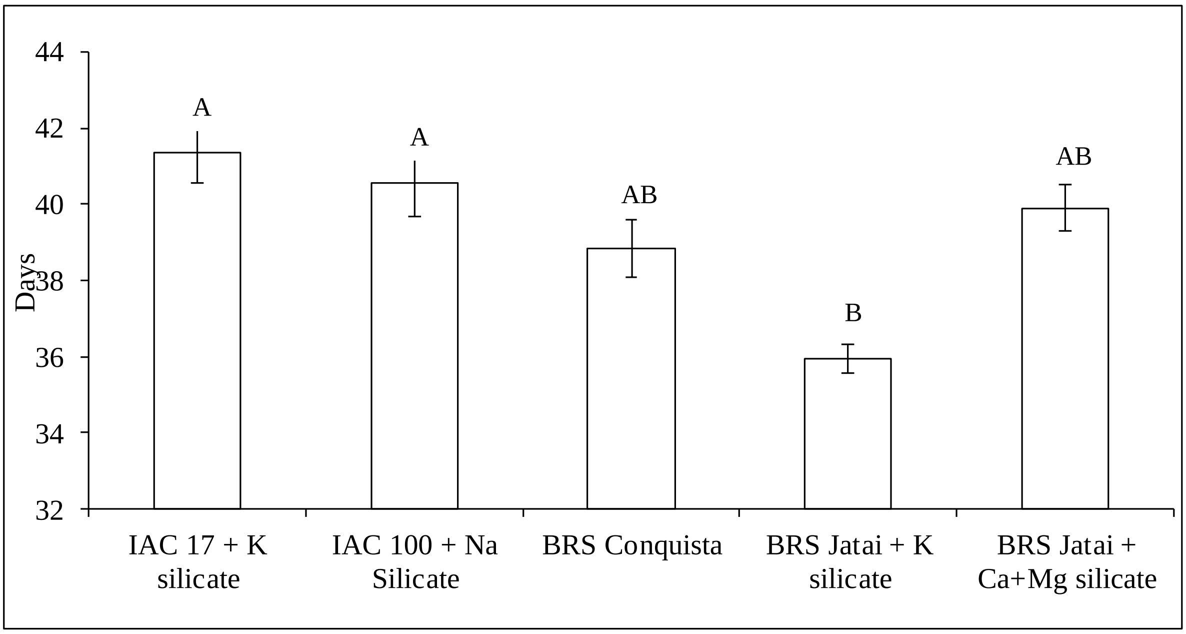

Fig 1. Egg to adult development times of *Euschistus heros* on different soybean varieties treated with resistance inducers. Means topped by the same letter do not differ according to Tukey's test ($P \leq 0.05$).

Table 2. Analysis of the interaction between soybean cultivars and resistance inducers on number of *Euschistus heros* stink bugs feeding at 1 and 2 h post-release.

Cultivar (C)	Time – One hour[1,2]					F (C)
	Inducer (I)					
	ASM	K Silicate	Na Silicate	Ca+Mg Silicate	Untreated	
IAC 17	1.40 aA	1.70 aA	0.60 bA	0.60 bA	0.90 abA	3.05*
IAC 100	0.30 bB	1.10 aAB	0.70 abA	0.30 bA	1.10 aA	3.01*
BRS Conquista	0.30 aB	0.30 aB	1.00 aA	1.20 aA	0.40 aA	2.29^{ns}
BRS Jataí	0.60 aAB	0.80 aAB	0.40 aA	0.60 aA	0.80 aA	0.35^{ns}
F (I)	3.39*	4.29**	0.78^{ns}	1.78^{ns}	1.09^{ns}	–
Cultivar (C)	Time – Two hours					F (C)
	Inducer (I)[1,2]					
	ASM	K Silicate	Na Silicate	Ca+Mg Silicate	Untreated	
IAC 17	1.80 aA	1.40 abA	0.30 bA	0.70 abAB	0.60 abA	4.66**
IAC 100	0.40 aB	0.50 aAB	1.00 aA	0.20 aB	0.60 aA	1.07^{ns}
BRS Conquista	0.30 bB	0.30 bB	1.10 aA	1.30 aA	0.60 abA	2.58*
BRS Jataí	0.30 aB	0.60 aAB	0.40 aA	0.60 aAB	0.90 aA	0.64^{ns}
F (I)	6.57**	2.94*	2.03^{ns}	2.51*	0.27^{ns}	–

[1]Data transformed into (x + 0.5)1/2 for analysis. [2]Means followed by the same letter lowercase and uppercase in the column and row, do not differ according to Tukey's test at 5% probability. ^{ns}non-significant. *Significant at 1% probability. **Significant at 5% probability.

Table 3. Mean duration of the nymphal and adult stage (days) of *Euschistus heros* fed on soybean varieties treated with resistance inducers.

Cultivar (C)	Duration[1,2]				
	2nd instar	3rd instar	4th instar	5th instar	Adult[1]
IAC 17	3.82 a	5.78 ab	5.77 a	5.05 a	2.65 a
IAC 100	3.68 a	4.82 a	4.60 ab	2.05 c	2.15 a
BRS Conquista	2.89 b	4.68 b	3.00 b	3.20 bc	1.20 b
BRS Jataí	2.46 b	4.72 ab	5.17 a	3.70 ab	1.70 b
F (C)	9.24**	2.70*	6.64**	11.13**	17.92**
Inducer (I)					
ASM	3.13	4.22 b	5.79 a	2.44 bc	-[2]
K silicate	3.50	4.90 ab	4.29 ab	6.06 a	3.75 a
Na silicate	3.04	4.62 ab	3.83 ab	1.94 c	1.50 ab
Ca+Mg silicate	2.87	5.87 a	3.62 b	3.44 bc	2.69 a
Untreated	3.52	5.37 ab	5.62 ab	3.62 b	0.81 b
F (I)	1.48^{ns}	3.26*	3.95**	14.64**	34.26**
F (CxI)	1. 83*	0.52^{ns}	6.24**	22.17**	67.24**
C.V. (%)	23.62	22.39	24.06	20.53	16.52

[1]Data transformed into (x + 0.5)1/2 for analysis. [2]Means followed by the same letter within a column do not differ according to Tukey's test at 5% probability. C.V. coefficient of variance. ^{ns}non-significant. * Significant at 1% probability. ** Significant at 5% probability.

plant sprayed to the point of runoff with a 0.3% acibenzolar-S-methyl (ASM) solution, or T5) plant sprayed to the point of runoff with distilled water. The statistical design was a randomized complete block with completely randomized treatments in a 4 x 5 factorial scheme (cultivars vs. inducers). The plants were evaluated 10 d after the application of these treatments.

Stink bugs stock rearing

The *E. heros* stink bugs used in the study were maintained using the methods described by Depieri & Panizzi (2011). The colony originated with adults collected from soybean fields and kept under controlled conditions (25 ± 2 °C, 70 ± 10% RH and 14h photoperiod) in plastic containers (8 L) for oviposition. The insects were reared on a diet consisting of grains of peanut (*Arachis hypogaea* L.), grains of soybeans (*G. max* L.), sunflower seeds (*Helianthus annuus* L.), and green pods of bean (*Phaseolus vulgaris* L.). Eggs were collected and placed in a Petri dish (9.0 cm diam) for hatching nymphs, which remained in these plates until the second instar.

Preference of E. heros on different soybean varieties

Preference assays to identify soybeans with greater resistance to *E. heros* were performed using green pods from different soybean varieties that had been sprayed with inducers. The pods were collected from the treated plants beginning at phenological stage V5 (Fehr and Caviness 1977). Adult stink bugs were starved for 24 h prior to the tests. Preference assessments were performed as multiple-choice and no-choice tests in arenas. For multiple-choice tests, 3 pods from each treatment were randomly and equidistantly distributed per arena. An adult male-female pair of *E. heros* was released in the center of each arena (glass container with 30 cm diam), with a total of 40 insects used. A similar methodology was used for the no-choice test, except each Petri dish (6 cm diam) included only one treatment and one insect. The number of insects on each pod was recorded 15, 30, 45 min and 1, 2, 3 and 6 h after release. For both tests, 10 replicates

Table 4. Analysis of the interaction between soybean cultivars and resistance inducers on the mean duration (days) of second, fourth and fifth instars, and the adult stage, of *Euschistus heros* fed on green soybean pods treated with resistance inducers.

Cultivar (C)	ASM	K Silicate	Na Silicate	Ca+Mg Silicate	Untreated	*F* (C)
			Second instar[1,2] — Inducer (I)			
IAC 17	4.46 aA	3.62 aA	3.54 aAB	3.23 aA	4.23 aAB	1.17^{ns}
IAC 100	2.38 cB	4.46 abA	3.85 abcA	2.92 bcA	4.77 aA	4.54**
BRS Conquista	2.77 aAB	3.15 aA	2.85 aAB	3.23 aA	2.46 aC	0.43^{ns}
BRS Jataí	2.92 aAB	2.77 aA	1.92 aB	2.08 aA	2.62 aBC	0.86^{ns}
F (I)	3.71*	2.36^{ns}	3.24*	1.33^{ns}	5.94**	–
			Fourth instar — Inducer (I) [1,2]			
IAC 17	4.83 aB	4.33 aA	5.33 aA	6.33 aA	8.00 aA	1.98^{ns}
IAC 100	5.00 aB	-[3] bB	4.50 aA	0.00 bB	5.50 aAB	7.17**
BRS Conquista	9.67 aA	5.50 bA	-[3] cB	4.17 bA	3.67 bcB	11.44**
BRS Jataí	3.67 aB	7.33 aA	5.50 aA	4.00 aA	5.33 aAB	1.98^{ns}
F (I)	6.60**	9.13**	6.32**	6.55**	3.00*	–
			Fifth instar — Inducer (I) [1,2]			
IAC 17	6.00 bA	5.50 aB	3.25 abA	6.00 aA	-[3] bB	8.08**
IAC 100	-[3] bB	-[3] bC	4.50 aA	-[3] bB	5.75 aA	11.64**
BRS Conquista	3.75 bB	10.0 aA	-[3] cB	-[3] cB	-[3] cB	30.56**
BRS Jataí	-[3] bB	8.75 aA	-[3] bB	7.75 aA	8.75 aA	30.87**
F (I)	12.63**	28.73**	7.59**	23.45**	27.42**	–
			Adult — Inducer (I)[1,2]			
IAC 17	-[3] cA	10.0 aA	-[3] cB	3.25 bA	-[3] cB	86.23**
IAC 100	-[3] bA	-[3] bC	6.00 aA	-[3] bB	-[3] bB	32.91**
BRS Conquista	-[3] bA	-[3] bC	-[3] bB	-[3] bB	10.75 aA	105.66**
BRS Jataí	-[3] bA	3.50 aB	-[3] bB	-[3] bB	-[3] bB	11.20**
F (I)	0.00^{ns}	101.69**	41.14**	12.07**	132.07**	–

[1]Data transformed into (x + 0.5)1/2 for analysis. [2]Means followed by the same letter lowercase and uppercase in the column and row, do not differ according to Tukey's test at 5% probability. ^{ns}non-significant. *Significant at 1% probability. **Significant at 5% probability. [3]All larvae fed on this treatment died (null variance).

were performed per treatment. A randomized complete block design was used for the multiple-choice test and a completely randomized experimental design was used for the no-choice test.

Biology of E. heros on soybean varieties

Green pods from the different soybean varieties treated with inducers or a control solution were offered individually to *E. heros* nymphs in Petri dishes (6 cm in diam) to monitor the development time for *E. heros*. Second-instar nymphs were used because they remained aggregated until the end of the second instar and began feeding at the third instar. Additionally, the high natural mortality rate during the first instar may hamper evaluations (Panizzi and Smith 1977). Each Petri dish containing one insect represented one replicate with 20 total replicates performed for each treatment using a completely randomized design. The daily evaluations of the varieties with or without inducer application were performed in the morning. The variables assessed were instar duration (N2, N3, N4 and N5) and the nymph-to-adult period.

Statistical analysis

The data on preference and biology to *E. heros* were subjected to analysis of variance, and the means were compared using Tukey's test at 5% probability using the statistical software SISVAR version 5.1 (Ferreira 2011).

Conclusions

Overall, it appears that the soybean varieties 'IAC 17' and 'IAC 100' are relatively non-preferred or exhibit antibiosis-type resistance, respectively, to the neotropical brown stink bug *E. heros*, as evidenced by the negative effect of these varieties treated with resistance inducers on *E. heros*. Application of potassium silicate, calcium magnesium silicate and ASM resistance inducers had a synergistic effect with these resistant varieties.

Acknowledgements

We thank TJ Prochaska from North Dakota University – North Central Research Extension Center for the helpful suggestions in reviewing the manuscript. We also thank to Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Instituto Federal Goiano – Campus Urutaí for financial support. F.G Jesus received a research productivity fellowship from CNPq [Proc. 311280/2015-3].

References

Brown SA, Davis JA, Richter AR (2012) Efficacy of foliar insecticides on eggs of *Nezara viridula* (Hemiptera: Pentatomidae). Fla Entomol. 95:1182-1186.

Corrêa-Ferreira BS (2005) Suscetibilidade da soja a percevejos na fase anterior ao desenvolvimento das vagens. Pesqu Agropecu Bras. 40:1067-1072.

Cruz MFA, Silva LF, Rodrigues FA, Araújo JM, Barros EG (2012) Silício no processo infeccioso de *Phakopsorapa chyrhizi*em folíolos de plantas de soja. Pesqu Agropecu Bras. 47:142-145.

Datnoff LE, Raid RN, Snyder GH, Jones DB (1991) Effect of calcium silicate on blast and brown spot intensities and yields of rice. Plant Dis. 75:729-732.

Depieri NA, Panizzi AR (2011) Duration of feeding and superficial and in-depth damage to soybean seedby selected species of stink bugs (Heteroptera: Pentatomidae). Neotrop Entomol. 40:197-203.

Epstein E (1999). Silicon. Annu Rev Plant Physiol Plant Mol Biol. 50:641-664.

Fehr WR, Caviness CE (1977) Stages of soybean development. Special Report 80. Iowa State Univ. Ames, Iowa.12 pp.

Ferreira RS, Moraes JC, Antunes CS (2011) Silicon influence on resistance induction against *Bemisia tabaci* Biotype B (Genn.) (Hemiptera: Aleyrodidae) and on vegetative development in two soybean cultivars. Neotrop Entomol. 40:495-500.

Ferreira DF (2011) Sisvar: a computer statistical analysis system. Cienc Agrotecnol. 35:1039-1042.

Fischer DC, Kogan M, Paxton JD (1990) Effect of glyceollin, a soybean phytoalexin, on feeding by three phytophagous beetles (Coleoptera: Coccinelidae): Dose x response. Environ Entomol. 19:78-82.

Hoffmann-Campo CB, Harborne JB, MCCaffery AR (2001) Pre-ingestive and postingestive effects of soybean extracts and rutin on *Trichoplusia ni* growth. Entomol Exp Appl. 98:181-194.

Jackai LEN, Dashiell KE, Bello LL (1988) Evaluation of soybean genotypes for field resistance to stink bugs in Nigeria. Crop Prot. 7:48-54.

Lemes EM, Mackowiak CL, Blount A, Marois JJ, Wright DL, Coelho L, Datnoff LE (2011) Effects of silicon applications on soybean rust development under greenhouse and field condition. Plant Dis. 95:317-324.

Li Y, Hill CB, Hartman GL (2004) Effect of three resistant soybean genotypes on the fecundity, mortality and maturation of soybean aphid (Homoptera: Aphididae). J Econ Entomol. 97:1106-1111.

McPherson JE, Paskewitz SM (1984) Life history and laboratory rearing of *Euschistus ictericus* (Hemiptera: Pentatomidae), with descriptions of immature stages. J N Y Entomol Soc. 92:53-60.

Munyaneza J, McPherson JE (1994) Comparative study of life histories, laboratory rearing, and immature stages of *Euschistus servus* and *Euschistus variolarius* (Hemiptera: Pentatomidae). Gt Lakes Entomol. 26:263-274.

Ni X, Da K, Buntin GD, Cottrell TE, Tillman PG, Olson DM, Powell Junior R, Lee RD, Wilson JP, Scully BT (2010) Impact of brown stink bug (Heteroptera: Pentatomidae) feeding on corn grain yield components and quality. J Econ Entomol. 103:2072-2079.

Nunes MC, Corrêa-Ferreira BS (2002) Desempenho alimentar e sobrevivência de *Euschistusheros* parasitado por *Hexacladia smithii* em sementes de soja. Pesqu Agropecu Bras. 37:1219-1223.

Panizzi AR, Smith JG (1977) Biology of *Piezodorus guildinii*: oviposition, development time, adult sex ratio and longevity. Ann Entomol Soc Am. 70:35-39.

Piubelli GC, Hoffmann-Campo CB, Arruda IC, Franchini JC, Lara FM (2003) Flavonoid increase in soybean as a response to *Nezara viridula* injury and its effect on insect feeding preference. J Chem Ecol. 29: 1223-1233.

Piubelli GC, Hoffmann-Campo CB, Moscardi F, Miyakubo SH, Oliveira MCN. 2005. Are chemical compounds important for soybean resistance to *Anticarsia gemmatalis*? J Chem Ecol. 31:1509-1525.

Qiu F, Li Y, Yang D, Li X, Sun P (2011) Biodiesel production from mixed soybean oil and rapeseed oil. Appl Energy. 88:2050-2055.

Savant NK, Datnoff LE, Snyder GH (1997) Depletion of plant available silicon in soils: a possible cause of declining rice yields. Commun Soil Sci Plant Anal. 28:1245-1252.

Schlick-Souza EC, Baldin ELL, Lourenção AL (2011) Variation in the host preferences and responses of *Ascia monuste orseis* Godart (Lepidoptera: Pieridae) to cultivars of collard greens *Brassica oleracea* (L.) var. *acephala*. J Pest Sci. 84:429-436.

Sosa-Gomez DR, Moscardi F (1998) Laboratory and field studies on the infection of stink bugs, *Nezara viridula*, *Piezodorus guildinii*, and *Euschistus heros* (Hemiptera: Pentatomidae) with *Metarhizium anisopliae* and *Beauveria* bassiana in Brazil. J Invertebr Pathol. 71:115-120.

Sosa-Gomez DR, Silva JJ (2010) Neotropical brownstink bug (*Euschistus heros*) resistance to methamidophos in Paraná, Brazil. Pesqu Agropecu Bras. 45:767-769.

Panizzi AR, Alves RML (1993) Performance of nymphs and adults of the southern green stink bug (Heteroptera: Pentatomidae) exposed to soybean pods at different phenological stages of development. J Econ Entomol. 86:1088-1093.