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ORIGINAL ARTICLE

Antixenosis in soybean to *Spodoptera cosmioides* (Lepidoptera: Noctuidae) mediated by leaf color and trichome density

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Abstract The importance of *Spodoptera cosmioides* (Lepidoptera: Noctuidae) in soybean crops has been growing, mainly with the cultivation of transgenic Bt plants. The objective of this study was to evaluate antixenosis to *S. cosmioides* in soybean plants with different leaf colors and trichome densities. Antioxenosis was evaluated by non-preference for feeding and oviposition assays. The study was performed in no-choice and free-choice tests using the genotypes Anta 82, BMX Desafio, BMX Potência, BRS 397, BRS GO 6970 IPRO, BRS 7270 IPRO, BRS 7470 IPRO, BRS 8170 IPRO, BRS 8482, BRS GO 7460, BRS GO Jataí, IAC 100, M 7739 IPRO, NA 5909, NS 7338 IPRO, NS 7447 IPRO, PI 227682 and PI 227687. The genotypes IAC 100, PI 227682 and PI 227687 showed antixenosis to *S. cosmioides* mediated by leaf color and trichome density. These genotypes could be appropriate for breeding programs aiming to incorporate sources of resistance to *S. cosmioides*. The cultivar M 7739 IPRO can be used by soybean producers as a control strategy for *S. cosmioides* due to moderate resistance.

Keywords Plant resistance to insects · Non preference · Black armyworm · *Glycine max*

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Introduction

The soybean is the most important crop in Brazil due to its high production and diversity of uses such as vegetable oil, animal feed, human food and, biodiesel. (Carvalho et al. 2015; Andrea et al. 2016).

Among the *Spodoptera* that attack soybeans, the black armyworm *Spodoptera cosmioides* (Lepidoptera: Noctuidae) occurs sporadically; however, infestations have become frequent in regions of the Brazilian Cerrado (Santos et al. 2010). Outbreaks are caused by several factors including the extensive area devoted to soybeans and cotton (Santos 2007; Santos et al. 2009; Boiça Júnior et al. 2015b), and the adoption of transgenic Bt plants that do not provide effective control of *Spodoptera* (e.g. those that express Cry1Ac).

S. cosmioides causes direct damage to soybean leaves and pods (Bueno et al. 2011; Panizzi et al. 2012; Boiça Júnior et al. 2015a). *S. cosmioides* is usually controlled by chemical insecticide applications (Ávila et al. 2013); however, few commercial products are registered for this species in Brazil (AGROFIT 2018). Therefore, Integrated Pest Management (IPM) programs require strategies that can reduce insecticide use (Sosa-Gomez and Silva 2010; Bernardi et al. 2014; Bortolotto et al. 2014).

Plant resistance to insects (PRI) is an important aspect of IPM that is usually simple and inexpensive for farmers to implement. The effects of plant resistance are often constant and cumulative, negatively affect the biological parameters of pests, are not harmful to the environment, and are usually compatible with other control tactics such as chemical and biological controls (Bueno et al. 2012; Boiça Júnior et al. 2015a). Antixenosis is usually associated with trichomes, leaf color changes, or volatile compounds that affect insect behavior (Smith 2005; Seifi et al. 2013). Higher trichome density in soybeans deterred stink bugs and reduced damage by *Helicoverpa zea*, *Spodoptera exigua* and *Chrysodeixis includens* (Lepidoptera: Noctuidae) (Hulburt et al. 2004; Souza et al. 2014; Silva et al. 2014).

Soybean cultivars have been studied as a source of resistance to different pests. The genotypes IAC-17, IAC-18, IAC-19, IAC-24, IAC-100, PI-229358, BR-8212547, D 75–10,169, Coodetec 201 and BRS Barreiras showed antixenosis to *Bemisia tabaci* biotype B (Valle and Lourenção 2002; Lima and Lara 2004; Vieira et al. 2011; Silva et al. 2012; Valle et al. 2012; Cruz et al. 2016). PI 171451, PI 229358, PI 227687, PI 274454, PI 274453, IAC 100, IAC 19 and D 75–10,169 expressed antixenosis to *Piezodorus guildinii* (Hemiptera: Pentatomidae) (Silva et al. 2014). The genotypes PI 274454 and PI 227687 and the cultivar DM 339 showed antixenosis to *Diabrotica speciosa* (Germar) (Coleoptera: Chrysomelidae) (Costa et al. 2014). Boiça Júnior et al. (2015a) observed susceptibility in the genotypes Dowling, PI 274454, IGRA RA 626 RR, BRSGO 8360, IGRA RA 516 RR, P 98Y11 RR, PI 227682, PI 227687, IAC 100 and BR 16 to *S. cosmioides*.

A basic understanding of leaf color and trichome density is important for developing strategies to screen soybean plants for insect resistance. Dense pubescence also contributes to antixenosis. High densities of trichomes in PI 227687 and PI 274453 may serve as a source of antixenosis to *Chrysodeixis includens* (Lepidoptera: Noctuidae) (Schlink-Souza et al. 2017). Greater trichome density in IAC 100 pods was associated with antixenosis to *Euchistus heros* (Hemiptera: Pentatomidae) in soybeans (Souza et al. 2014). However, few studies have associated leaf color with antixenosis. Therefore, the current study aimed to evaluate antixenosis to *S. cosmioides* in different soybean genotypes.

Material and methods

Spodoptera cosmioides colony

An *S. cosmioides* colony was established at the Laboratory of Entomology of the Federal Goiano Institute, Campus Urutai, Goiás, Brazil, from caterpillars obtained from the Laboratory of Plant Resistance to Insects, UNESP, Jaboticabal, São Paulo, Brazil. The caterpillars were fed an artificial diet (Greene et al. 1976) and raised in plastic pots (300 mL) in groups of four caterpillars, until the pupal stage. The pupae were sexed and placed in PVC containers (20 cm high × 20 cm in diameter) for emergence and mating.

The adults were fed a 10% honey solution that was soaked in cotton, fixed to the lid and changed every two days. The eggs were removed daily and placed in plastic containers (500 mL) until caterpillar eclosion. The insects were reared in the laboratory at 25 ± 2 °C, 70 ± 10% RH, and 12:12 h (L:D).

Plant material

Table 1 shows the soybean genotypes evaluated. Seeds were sown in 5 L pots containing substrate (3: 1: 1 - soil, sand, and organic compost), corrected and fertilized according to recommendations for soybean cultivation (Sousa and Lobato 2004). The plants were kept in a greenhouse under natural light and temperature and irrigated daily at field soil levels. The experiments were performed on plants at 30 days after sowing and without pesticide applications.

Feeding attractiveness and non-preference for feeding assays

In the non-choice test, a leaf disc (2.5 cm diameter) of each genotype was given to a 3rd instar *S. cosmioides* in plastic containers (100 mL). After releasing the caterpillars, the number of insects on each genotype was evaluated at 1, 3, 5, 10, 15, 30, 60, 120, 360, 720 and 1440 min. After the last evaluation, the leaf discs were photocopied (Xerox work center 3220, São Paulo, São Paulo, Brazil) to determine the leaf area consumed (AFC) by the caterpillars. A completely randomized design with 18 treatments (genotypes) and 20 replicates was used.

In the free-choice test, a leaf disc (2.5 cm diameter) of each soybean genotype ($n = 18$) was distributed

Table 1 Name and agronomic characteristics of soybean genotypes

Genotypes	Growth habitat	Maturity group	Transgenic	[e]NRC	Origin
Anta 82[a]	Semi-determinate	7.4	[c]RR	24,879	Brazil
BMX Desafio[a]	Indeterminate	7.3	RR	28,779	Brazil
BMX Potência[a]	Indeterminate	6.6	RR	22,332	Brazil
BRS 397[a]	Indeterminate	6.2	[d]CV	33,356	Brazil
BRS 6970 IPRO[a]	Indeterminate	6.9	IPRO	33,068	Brazil
BRS 7270 IPRO[a]	Indeterminate	7.2	IPRO	33,066	Brazil
BRS 7470 IPRO[a]	Indeterminate	7.4	IPRO	33,065	Brazil
BRS 8170 IPRO[a]	Indeterminate	8.1	IPRO	35,275	Brazil
BRS 8482[a]	Determinate	8.0	CV	34,078	Brazil
BRS GO 7460[a]	Determinate	7.4	RR	28,063	Brazil
BRS GO Jataí[a]	Determinate	8.9	CV	01179	Brazil
IAC 100[a]	Indeterminate	8.1	CV	01190	Brazil
M 7739 IPRO[a]	Semi-determinate	7.7	IPRO	29,692	Brazil
NA 5909[a]	Indeterminate	6.9	RR	24,590	Brazil
NS 7338 IPRO[a]	Indeterminate	7.3	IPRO	29,474	Brazil
NS 7447 IPRO[a]	Indeterminate	7.4	IPRO	33,001	Brazil
PI 227682[b]	–	–	CV	–	Japan
PI 227687[b]	–	–	CV	–	Japan

[a] Commercial cultivar

[b] Breeding line

[c] RR: Roundup ready

[d] CV: Conventional

[e] National register of cultivars

equidistantly in a circular arena (14 cm in diameter and 2 cm high) on wet filter paper. Then, one 3rd instar *S. cosmioides* caterpillar was released per genotype. Time and AFC were evaluated as in the non-choice test. The test was based on a randomized block design with 18 treatments (genotypes) and ten replicates (arenas).

Non-preference for oviposition assay

Plants of each genotype were placed in a voile cage with a pair of *S. cosmioides* (3 days old). The number of eggs in each genotype was counted seventy-two hours after release. Five replicates for each genotype were performed in a completely randomized design.

Trichome density and leaf color measurements

The total number of trichomes in 1 cm^2 was determined in three leaf regions (apical, median and basal) for each genotype (10 replicates).

Leaf color was determined in the central part of a leaflet from the middle of a plant at 30 days after emergence (Prado et al. 2016). This was accomplished using a CR 10 Plus colorimeter (Konica Minolta, Osaka, Japan) and expressed according to the International Commission and L'Eclairage (CIE). The color parameters were recorded as levels of lightness (*L), green (*a) and yellow (*b) (Minolta 1998).

Statistical analysis

Residual normality and homoscedasticity were evaluated by the Shapiro-Wilk and Bartlett tests and means compared by the Scott Knott test ($P = 0.05$). The means were transformed using the Box-Cox method. Canonical variable analysis of (CVA) was performed to determine the degree of antixenosis of each genotype. The t-test was used to evaluate the Pearson correlation between the number of eggs, trichome density and colorimetric indexes. All analyses were performed using R software (R Development Core Team 2017).

The preference index for *S. cosmioides* feeding and oviposition was determined using the formula: IP = 2A / (M + A), where: A = genotype consumption and M = standard genotype consumption (BRS GO Jataí) (Kogan and Goeden 1970). A genotype was classified as a stimulant if its index was greater than 1, neutral if equal to 1 and deterrent if less than 1.

Results

In the non-choice test, the genotypes BMX Potência, BRS 7270 IPRO, BRS 8482, BRS GO 7460, IAC 100, M 7739 IPRO, NA 5909, NS 7338 IPRO, PI 227682 and PI 227687 were the least attractive to *S. cosmioides* (Table 2). The cultivars with the highest AFC values were BRS GO Jataí and Anta 82, while M 7739 IPRO and BRS 7270 IPRO were the less consumed. The genotypes did not differ statistically regarding attractiveness in the non-choice test and the AFC index in the free-choice test.

According to the attractiveness index in the non-choice test, only the BRS 7270 IPRO cultivar was designated as a stimulant for *S. cosmioides* feeding. All other cultivars were considered deterrents, except Anta 82, BRS 397, M 7739 IPRO, which were considered neutral (Fig. 1).

Oviposition by *S. cosmioides* was lowest on ANTA 82, BMX Desafio, BRS 397, BRS 6970 IPRO, BRS 8482, IAC 100, M 7739 IPRO, NA 5909, PI 227682 and PI227687 (Table 3). The non-choice test showed that only the BRS 7338 IPRO and BRS 7270 IPRO cultivars were stimulants for *S. cosmioides* oviposition. The remaining cultivars were deterrents, except BMX Potência and NS 7447 IPRO, which were neutral (Fig. 2).

Trichome density on the abaxial leaf surface was greatest in M 7739 IPRO, PI 227682, PI 226787 and BRS 397 while NA 5909 and BMX Potência showed the lowest densities (Table 3). IAC 100 produced the highest lightness index (*L) value, whereas BRS 7470 IPRO, M 7739 IPRO and PI 227687 produced the lowest values. Green intensity (*a) was greatest in BRS GO 7460 and lowest in Anta 82, BMX Desafio, BMX Potência, BRS 397, BRS 7270 IPRO, BRS 7470 IPRO, BRS 8482, IAC 100, M 7739 IPRO, NA 5909, NS 7338 IPRO, NS 7447 IPRO and PI 227682. Yellow intensity (*b) was highest in the cultivar IAC 100 and lowest in the genotypes NS 7447 IPRO, NA 5909, NS 7338 IPRO, M 7739 IPRO, PI 227682 and PI 227687 (Table 3).

The CVA for non-preference for oviposition and attractiveness of *S. cosmioides* larvae showed that the first canonical variable explained 77.6% of all the parameters evaluated. The genotypes were categorized into four groups: I – BMX Desafio, BRS GO 7460 and BRS 7270 IPRO. II – BRS 8482, IAC 100, NA 5909, BRS 8170 IPRO and BMX Potência. III – BRS 397, PI 227682, PI 227687, BRS 7470 IPRO, NS 7338 IPRO and IV – BRS GO Jataí, Anta 82, BRS 6970 IPRO and NS 7447 IPRO (Fig. 3).

CVA separated the groups by different levels of antixenosis. According to both univariate and multivariate analyses, the cultivars in group I (BRS GO 7460 and BRS 7270 IPRO) stimulated *S. cosmioides* oviposition (Table 3 and Fig. 3). The cultivars in group IV (BRS GO Jataí, Anta 82, IAC 100, BRS 6970 IPRO and NS 7447 IPRO) were the most consumed by *S. cosmioides*. The genotypes BRS 397, PI 227682, PI 227687, BRS 7470 IPRO, and NS 7338 IPRO in group III were characterized by high leaf trichome densities. Finally, the cultivars in group II (BRS 8482 and IAC 100) were characterized by some of the lowest *S. cosmioides* oviposition rates.

Table 4 shows the correlation coefficients between the number of eggs, number of trichomes and colorimetric index. The correlations between the number of eggs, number of trichomes, index *a and index *b were not significant. However, there was a moderate negative correlation between the number of eggs and the colorimetric index (*L). Therefore, as the intensity of luminosity increased, the number of *S. cosmioides* eggs decreased.

Discussion

Antixenosis is a type of resistance in which a plant is relatively less exploited by an insect for feeding, oviposition or shelter. This resistance results from plant morphology, chemical constituents and physical characteristics (Lara 1991; Smith 2005; Seifi et al. 2013).

In general, BMX Potência, BRS 7270 IPRO, BRS 8482, BRS GO 7460, IAC 100, M 7739 IPRO, NA 5909, NS 7338 IPRO, PI 227682 and PI 227687 were less attractive. Attractiveness may be associated with attributes of the host plant that may favor insect-plant

Table 2 Mean number (± SE) of *Spodoptera cosmioides* (Lepidoptera: Noctuidae) caterpillars and leaf area consumed (LAC - cm^2) in non-choice and free-choice tests

Genotypes	Atractiveness		AFC	
	Free-choice	Non-choice	Free-choice	Non-choice
Anta 82	0.50 ± 0.07a	1.19 ± 0.33	0.57 ± 0.06	1.24 ± 0.06 a
BMX Desafio	0.62 ± 0.08a	1.07 ± 0.15	0.45 ± 0.08	0.61 ± 0.09 c
BMX Potência	0.35 ± 0.07b	0.85 ± 0.16	0.51 ± 0.10	0.56 ± 0.10 c
BRS 397	0.60 ± 0.06a	0.12 ± 0.20	0.63 ± 0.08	1.08 ± 0.06 b
BRS 6970 IPRO	0.59 ± 0.09a	0.85 ± 0.11	0.44 ± 0.03	0.97 ± 0.07 b
BRS 7270 IPRO	0.33 ± 0.06b	1.25 ± 0.14	0.84 ± 0.06	0.37 ± 0.11 d
BRS 7470 IPRO	0.53 ± 0.07a	0.91 ± 0.15	0.75 ± 0.06	0.86 ± 0.10 bS
BRS 8170 IPRO	0.51 ± 0.07a	1.06 ± 0.09	0.28 ± 0.07	0.74 ± 0.9 b
BRS 8482	0.63 ± 0.07b	0.83 ± 0.12	0.64 ± 0.10	0.79 ± 0.3 b
BRS GO 7460	0.47 ± 0.06b	0.79 ± 0.12	0.31 ± 0.09	0.60 ± 0.11 c
BRS GO Jataí	0.52 ± 0.06a	1.19 ± 0.12	0.90 ± 0.14	1.26 ± 0.14 a
IAC 100	0.39 ± 0.08b	1.05 ± 0.11	0.51 ± 0.09	0.84 ± 0.05 b
M 7739 IPRO	0.32 ± 0.07b	1.15 ± 0.12	0.45 ± 0.05	0.12 ± 0.3 d
NA 5909	0.46 ± 0.05b	0.92 ± 0.11	0.82 ± 0.06	0.88 ± 0.09 b
NS 7338 IPRO	0.39 ± 0.08b	0.79 ± 0.13	0.60 ± 0.07	0.94 ± 0.06 b
NS 7447 IPRO	0.63 ± 0.06a	0.84 ± 0.13	0.29 ± 0.10	1.03 ± 0.10 b
PI 227682	0.33 ± 0.06b	0.84 ± 0.12	0.45 ± 0.09	1.03 ± 0.8 b
PI 227687	0.42 ± 0.03b	0.95 ± 0.15	0.32 ± 0.09	0.83 ± 0.08 b
F	2.67	1.22	1.53	10.03
P	< 0.05	0.25	0.09	< 0.05

[1] Means followed by the same letter within a column do not differ by the Scott-Knott test at 5% probability. SE = standard error

interactions such that a given substrate may sometimes behave as a stimulant and at other times may deter insect feeding and access (Lara 1991).

Genotype PI 227687 showed antibiosis resistance that is associated with isoflavone (daidzin and genistin) (Reynolds et al. 1984; Piubelli et al. 2003; Boiça Júnior et al. 2015a) and causes causes mortality and reduced growth in different insect species. This genotype has also shown antixenosis resistance associated with high trichome densities (Schlink-Souza et al. 2017).

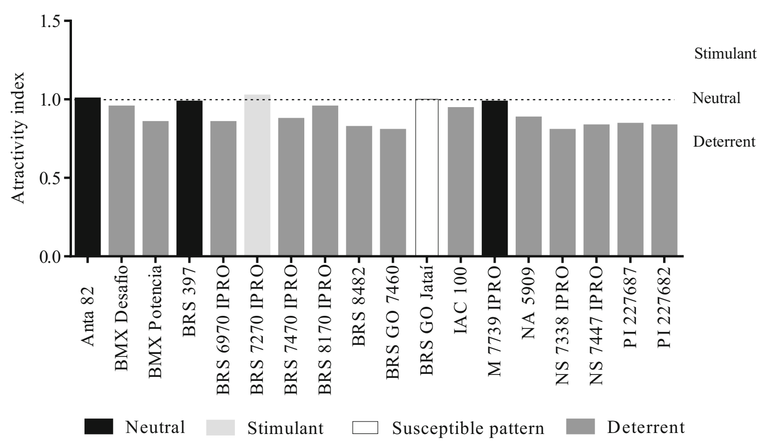

Fig. 1 Attractiveness index of 3rd instar *Spodoptera cosmioides* (Lepidoptera: Noctuidae) in soybean genotypes in a non-choice test

Table 3 Number of eggs, trichome density and colorimetric index parameters (± SE) by the CIE System in 18 soybean genotypes

Genotypes	Eggs	Trichomes	Colour		
			*L	*a	*b
Anta 82	138.80 ± 27.7b	45.00 ± 11.6d	39.94 ± 0.34b	−8.62 ± 0.11c	23.93 ± 0.40b
BMX Desafio	123.80 ± 27.7b	68.67 ± 25.6c	38.30 ± 0.27c	−8.67 ± 0.27c	21.45 ± 0.72c
BMX Potência	415.80 ± 46.7a	30.00 ± 14.3e	39.52 ± 0.31b	−8.44 ± 0.15c	22.64 ± 0.61b
BRS 397	198.42 ± 21.2b	125.67 ± 25.0a	39.89 ± 0.49b	−8.15 ± 0.26c	22.10 ± 0.81c
BRS 6970 IPRO	238.21 ± 9.4b	52.00 ± 17.3d	38.56 ± 0.33c	−8.77 ± 0.09b	22.42 ± 0.65c
BRS 7270 IPRO	455.00 ± 37.2a	49.33 ± 19.3c	38.56 ± 0.33c	−8.51 ± 0.12c	21.29 ± 0.53c
BRS 7470 IPRO	311.82 ± 34.1a	102.67 ± 30.0b	37.45 ± 0.38d	−8.57 ± 0.14c	21.82 ± 0.61c
BRS 8170 IPRO	301.82 ± 6.9a	57.33 ± 23.0c	38.54 ± 0.28c	−8.74 ± 0.10b	21.79 ± 0.59c
BRS 8482	94.60 ± 17.8b	50.67 ± 16.0d	39.52 ± 0.43b	−8.57 ± 0.14c	23.08 ± 0.67b
BRS GO 7460	311.80 ± 34.1a	65.33 ± 17.3c	38.62 ± 0.24c	−9.23 ± 0.07a	23.41 ± 0.39b
BRS GO Jataí	419.60 ± 23.4a	61.00 ± 15.3c	38.55 ± 0.26c	−8.90 ± 011b	23.76 ± 0.44b
IAC 100	94.80 ± 17.4b	65.33 ± 12.6c	41.36 ± 0.49a	−8.60 ± 0.14c	26.76 ± 0.75a
M 7739 IPRO	367.00 ± 50.1b	147.33 ± 35.3a	37.42 ± 0.28d	−8.54 ± 012c	20.60 ± 0.53d
NA 5909	248.80 ± 51.4b	76.33 ± 25.2e	38.24 ± 0.32c	−8.56 ± 0.08c	21.00 ± 0.36d
NS 7338 IPRO	635.00 ± 50.6a	85.33 ± 20.6c	39.27 ± 0.27b	−8.65 ± 0.08c	20.71 ± 0.47d
NS 7447 IPRO	403.00 ± 44.8a	21.67 ± 08.6d	39.27 ± 0.27b	−8.65 ± 0.10c	21.00 ± 0.40d
PI 227682	149.60 ± 33.0b	139.67 ± 31.0a	38.72 ± 0.29c	−8.27 ± 0.10c	19.99 ± 0.42d
PI 227687	183.40 ± 33.6b	134.33 ± 29.6a	37.46 ± 0.26d	−8.76 ± 0.09b	19.91 ± 0.61d
F	2.12	24.91	9.35	3.06	8.69
P	0.01	< 0.01	< 0.01	< 0.01	< 0.01

[1] Means followed by the same letter within a column do not differ by the Scott-Knott test at 5% probability. SE = standard error

The IAC 100 cultivar has been studied as a source of resistance to soybean insect pests. IAC 100 presented antixenosis to *Anticarsia gemmatalis* (Lepidoptera: Erebidae), evidenced by lower percentages of leaf area consumed (Hoffmann-Campo et al. 1994). IAC 100 showed antixenosis to *Spodoptera eridania* (Lepidoptera: Noctuidae) in free-choice and non-choice tests (Souza et al. 2012). IAC 100, IAC 78–2318 and PI 227687 were the least attractive soybean genotypes for *P. guildinii* adults (Silva et al. 2014). IAC 100 and M

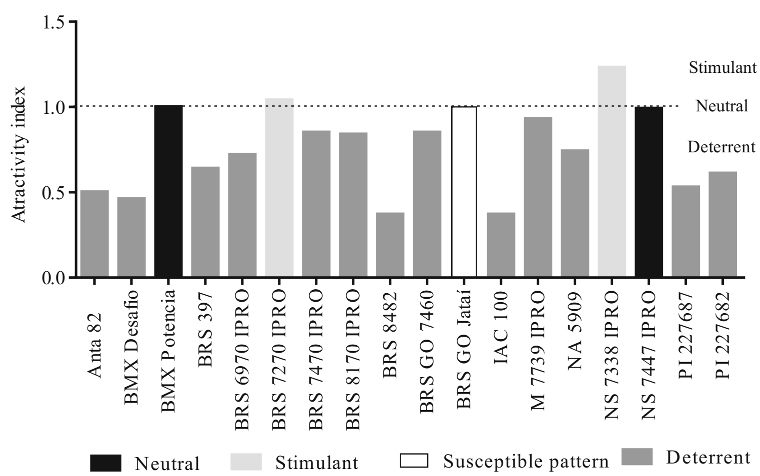

Fig. 2 Oviposition attractiveness index for adult *Spodoptera cosmioides* (Lepidoptera: Noctuidae) in soybean genotypes in a non-choice test

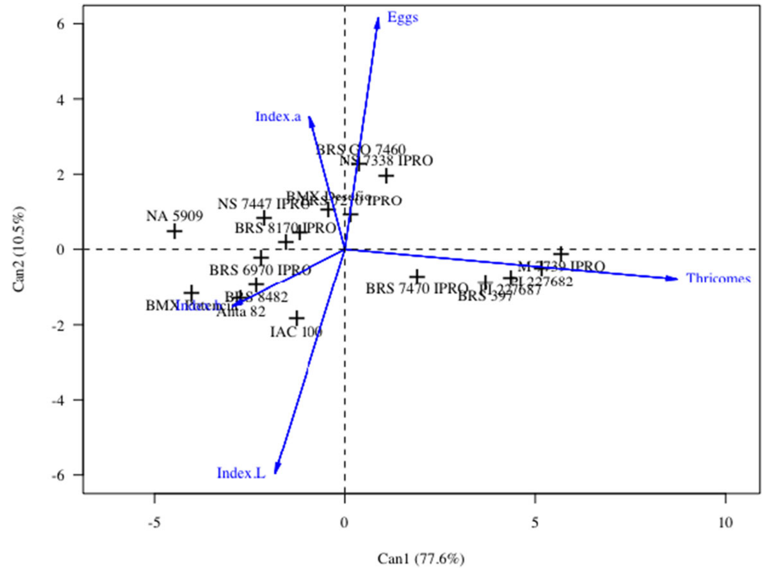

Fig. 3 Biplot container as average of 18 soybean genotypes for two canonical variables. Characteristics evaluated: mean number of eggs, number of trichomes and colorimetric index

7110 IPRO (Bt) cultivars presented antixenosis and antibiosis to *Chloridea* (*Heliothis*) *virescens* (Lepidoptera: Noctuidae) (Almeida et al. 2017a; Almeida et al. 2017b).

An insect's feeding preferences for a specific cultivar are related to plant stimuli that can be positive or negative, chemical (Hoffmann-Campo et al. 2001), physical (Coelho et al. 2009) and/or morphological (Silva et al. 2012; Silva et al. 2014; Souza et al. 2014). Therefore, cultivars may possess characteristics or combinations of charcteristics that either stimulate or deter *S. cosmioides* feeding.

The influence of insect versus host interactions on oviposition seems to be mediated by chemical, morphological, physical and other characteristics of the plant. Color is the most important factor for host selection at a distance (Lenteren and Noldus 1990). Color perception mechanisms even allow insects to distinguish between color shades that are similar to plant foliage (Lenteren and Noldus 1990). Leaf trichomes can provide a microclimate with favorable temperature and humidity levels for eggs and nymphs and protection against natural enemies (Inbar and Gerling 2008).

The classification of genotypes with the lowest number of eggs (e.g. PI 227682 and PI 227687) as deterrent to *S. cosmioides* oviposition may result from high trichome densities. The cultivars with the lowest trichome densities, BMX Potência and NS 7447 IPRO, were classified as susceptible. Schlink-Souza et al. (2017) observed that genotype PI 274453 repelled *C. includens* oviposition because of high leaf trichome densities. Plants with high trichome densities tend to be more resistant (low oviposition) than those with low densities (Handley et al. 2005). However, in the current study, the correlation between *S. cosmioides* oviposition and the leaf trichome density of soybean genotypes showed no statistical difference, indicating that this morphological characteristic did not influence the oviposition behavior of *S. cosmioides* for the genotypes evaluated. This suggests that other stimuli, such as plant volatiles (Hilker and Meiners 2011) and light environment (Connor 2006) affect host selection for oviposition.

IAC 100 was classified as a deterrent and showed the highest luminosity (*L) and yellow (*b) intensities. BRS 7470 IPRO stimulated *S. cosmioides* oviposition and showed the lowest luminosity intensity (*L). These relationships demonstrate the negative correlation

Table 4 Pearson correlation between number of eggs, number of trichomes and colorimetric index in 18 soybean genotypes

Variable	Correlation coefficient[1]	*P value*
Number of eggs x Trichomes	0.08^{ns}	0.7088
Number of eggs x Index L	-0.50^{*}	0.0316
Number of eggs x Index a	0.19^{ns}	0.3925
Number of eggs x Index b	-0.16^{ns}	0.4670

[1] Significant at 5% probability by t Test. L = brightness index; a = index of variation from green to red; b = index of variation from blue to yellow

between oviposition and luminosity intensity (*L) and suggest that these characteristics may be associated with a non-preference for oviposition by adult *S. cosmioides* in soybean cultivars.

Although trichome density and leaf color are associated with antioxenosis resistance, these are not the only characteristics that generate such resistance to *S. cosmioides*. Therefore, these physical and morphological characteristics (leaf color and trichome density) of soybean leaves appear to directly influence *S. cosmioides* oviposition.

Genotypes IAC 100, PI 227682 and PI 227687 showed antixenosis resistance to *S. cosmioides* that was related to trichome density and leaf color. These genotypes could be used in soybean breeding programs as a source of resistance to *S. cosmioides*. Soybean growers could also use M 7739 IPRO in IPM strategies since this cultivar showed moderate resistance to *S. cosmioides*. Finally, trichome density and plant leaf color could be used to screen genotypes for antixenosis resistance to insects.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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