

Soybean genotypes on the development of soybean looper

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ABSTRACT: Constitutive mechanisms of plants are responsible for affecting herbivore/host interactions, resulting in behavioural or metabolic effects capable of reducing crop losses. The objective of this study was to evaluate the effect of soybean genotypes (*Glycine max* [L.] Merr.; Fabaceae) BRS 391, BRS 6203RR, TEC IRGA 6070RR, BMX ValenteRR, BMX Icone Ipro, and the breeding lines PELBR 10-6000RR and PELBR 10-6049RR in *Chrysodeixis includens* (Walker) (Lepidoptera: Noctuidae) through the evaluation of the following biological parameters: duration and viability of all development phases, number of larval instars, sex rate, weight and deformation of pupae, and the fertility life table. For this, 150 larvae per genotype were used, maintained at 25 ± 1 °C, $70 \pm 10\%$ RH, 14:10 h (L:D) photophase. The frequency of the width of cephalic capsules indicated the occurrence of 6 larval instars for the genotypes. The TEC IRGA 6070RR and BMX Icone Ipro genotypes caused 100% larval mortality in the first 5 d. The BRS 391 and BRS 6203RR genotypes reduced larval viability; the latter also presented the highest percentage of deformed pupae. The BMX ValenteRR genotype promoted the lowest egg viability. The PELBR 10-6049RR and PELBR 10-6000RR breeding lines are not predisposed to antibiosis and were more susceptible to *C. includens*. The BRS 6203RR, BRS 391 and TECIRGA 6070RR genotypes significantly affected the biological parameters of *C. includens*, characterizing the expression of antibiosis, thus, they can be considered for use in the southern region of Rio Grande do Sul (REC 101) to reduce the larval population.

Key words: *Chrysodeixis includens*, Noctuidae, host resistance, *Glycine max*.

Efeito de genótipos de soja no desenvolvimento da lagarta-falsa-medideira

RESUMO: Os mecanismos constitutivos das plantas são responsáveis por afetar a interação herbívoro/hospedeiro resultando em efeitos comportamentais e/ou metabólicos capazes de reduzir as perdas na cultura. O objetivo deste trabalho foi avaliar o efeito da antibiose proporcionado pelos genótipos de soja (*Glycine max* [L.] Merr.; Fabaceae), BRS 391, BRS 6203RR, TEC IRGA 6070RR, BMX ValenteRR, BMX Icone Ipro, e as linhagens PELBR 10-6000RR e PELBR 10-6049RR em *Chrysodeixis includens* (Walker) (Lepidoptera: Noctuidae), através da avaliação dos parâmetros biológicos: duração e viabilidade das fases de desenvolvimento, número de instares larvais, razão sexual, peso e deformação de pupas e elaboração da tabela de vida de fertilidade. Foram utilizadas 150 lagartas por genótipo, mantidas a 25 ± 1 °C, $70 \pm 10\%$ UR, fotofase 14:10 h (L:D). A frequência da largura das cápsulas cefálicas, indicou a ocorrência de um a seis instares larvais para os genótipos. Os genótipos TEC IRGA 6070RR e BMX Icone Ipro ocasionaram a mortalidade de 100% das lagartas nos primeiros 5 dias. Os genótipos BRS 391 e BRS 6203RR reduziram a viabilidade larval, este último, ainda apresentou a maior porcentagem de pupas deformadas. O genótipo BMX ValenteRR promoveu a menor viabilidade de ovos. As linhagens PELBR 10-6049RR e PELBR 10-6000RR, não apresentaram predisposição a antibiose. Os genótipos BRS 6203RR, BRS 391 e TEC IRGA 6070RR afetaram significativamente os parâmetros biológicos de *C. includens*, caracterizando a expressão de antibiose, dessa forma, podem ser considerados para o uso na região sul do Rio Grande do Sul (REC 101) para a redução da população da lagarta.

Palavras-chave: *Chrysodeixis includens*, Noctuidae, resistência hospedeira, *Glycine max*.

INTRODUCTION

Brazil ranks first globally in soybean production (*Glycine max* [L.] Merr.; Fabaceae). In the 2023 to 2024 harvest, the soybean crop occupied an area of 46 million ha and produced 147 million tons (CONAB, 2024). The expansion of the soybean production in the country was possible due to the use of soybean cultivars adapted to different production

systems and edaphoclimatic conditions for plants to attain their greatest productive potential (KASTER & FARIAS, 2012). However, in field conditions this potential is compromised by pest infestation (OLIVEIRA, 2017; BUENO et al., 2021; VARGAS-ALMENDRA et al., 2024).

Pest species from the Lepidoptera insect order cause considerable damage during all phenological stages of the crop; larvae feeding

on leaf tissue cause defoliation reducing the photosynthetic area which compromises pod filling during the reproductive phase, consequently resulting in productivity losses (GAZZONI & YORINIORI, 1995). In Brazil, the presence of the soybean looper, *Chrysodeixis includens* (Walker) (Lepidoptera: Noctuidae), has intensified due to the cultural practices and management of soybean crop, the behavioural aspects of the species, and the reduction in the population of entomopathogenic fungi which have been suppressed inadvertently by applications of fungicides used to control the Asian soybean rust. Therefore, the status of *C. includens* as a secondary pest has changed to a primary pest in various producing regions (PANIZZLI, 2013; SILVA et al., 2020).

The use of synthetic insecticides is the most common strategy for regulating this pest in the field. However, the call for a more sustainable cultivation system has fostered the search for alternative control methods, including varietal resistance, using plants that have some degree of pest resistance (PAINTER, 1951; CONTE et al., 2014; GOBBI et al., 2024).

The mechanisms of resistance in plants, in many cases, occur with the participation of compounds resulting from the secondary metabolism of plants, synthesized, accumulated, and stored by the plant in different plant tissues (MALVAR et al., 2008; SOUZA et al., 2021). When these compounds are ingested, they affect the development and reproduction of the insect due to the presence of toxic substances, nutritional imbalance, and absence of essential nutrients. This type of resistance is called antibiosis and is the most desirable type of resistance because it reduces the number of individuals in the next generation, keeping the pest at population levels below the critical level (PAIXÃO et al., 2013; MACHADO et al., 2017; ABDUL MALIK et al., 2020; SILVA et al., 2021).

The occurrence of antibiosis is reported successfully in soybean production, and in the lepidopterans *Anticarsia gemmatilis* Hübner (Lepidoptera: Erebidae), *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), *C. includens* and *Spodoptera* sp. (Lepidoptera: Noctuidae), its manifestation is expressed mainly by changes in biological parameters through weight reduction of larvae and pupae, life cycle prolongation, increased mortality, and deformation of pupae and adults, reduced viability, and population reduction in subsequent generations (WILLE et al., 2017; ADIE et al., 2020; COELHO et al., 2020; GÓMEZ et al., 2020; QUEIROZ et al., 2020; ONGARATTO et al., 2021; LIMA et al., 2024; KRISNAWATI et al., 2025).

This study evaluated the effect of soybean genotypes recommended for the southern region of Rio Grande do Sul (REC 101) in *C. includens* through the study of the biological parameters and the fertility life table.

MATERIALS AND METHODS

Obtaining the soybean plants and the population of Chrysodeixis includens

The study was carried out at the Brazilian Agricultural Research Company (Embrapa), Embrapa Temperate Climate (31.481396°S, 52.244140°W), Pelotas, Rio Grande do Sul, Brazil. Five commercial genotypes: BRS 391, BRS 6203RR, BMX ValenteRR, TEC IRGA 6070RR, BMX Icone Ipro, and 2 soybean isolines from Embrapa's Plant Breeding Program, PELBR 10-6000RR and PELBR 10-6049RR were used. The genotypes were cultivated in 11 L pots containing substrate of the commercial brand Mecplant® (Composition: *Pinus* bark, vermiculite, acidity corrector pH 6.0, and macronutrients) without need for fertilization and kept in greenhouse following the technical recommendations for soybean culture, 20 to 30 °C average temperature, irrigation regimen 0.55 mm per d.

The initial population of *C. includens* was collected in the experimental area of a soybean crop of the Brazilian Agricultural Research Company using the beat cloth method and were maintained under laboratory conditions (25 ± 1 °C, 70 ± 10% RH, 14:10 h (L:D) photophase). Larvae were reared in a 500 mL plastic box containing artificial diet (GREENE et al., 1976) (Table 1) and the adults were reared in PVC cages (200 mm diameter × 200 mm height), fed with aqueous honey solution (Table 1).

Bioassays

The experiment was conducted under laboratory conditions (25 ± 1 °C; 70 ± 10% RH; 14:10 h (L:D) photoperiod), using 150 repetitions per genotype (7 genotypes). Each repetition consisted of a glass tube (25 mm diameter × 80 mm height) containing in its inside a neonate larva, fed daily with soybean leaflets (7 cm² diameter) collected from the middle portion of plants during the vegetative stage (V5) (FEHR & CAVINESS, 1977). Larvae were fed until the pupal phase, when they stopped feeding.

Evaluation of the duration and number of instars was possible through daily observations. To establish the growth rate, measurement of cephalic capsule width was done with the aid of a micrometric ocular connected to a stereomicroscope (S8AP0

Table 1 - Composition of artificial diet for feeding *Chrysodeixis includens* (Walker).

-----Larval diet*-----		-----Adult diet-----	
Composition	Quantity	Composition	Quantity
Pinto beans	112.50 g	Honey	10.00 g
Wheat germ	90.00 g	Sugar	60.00 g
Soybean protein	45.00 g	Methyl P-hydroxybenzoate	1.00 g
Casein	45.00 g	Beer	350.00 mL
Brewer's yeast	56.30 g	Distilled water	1.000 mL
Ascorbic acid	2.70 g		
Sorbic acid	5.40 g		
Methyl P-hydroxybenzoate	5.50 g		
Tetracycline	0.18 g		
Agar	35.00 g		
Vitamin	14.00 mL		
Formalin (40%)	5.40 mL		
Distilled water	1.800 mL		

*According to GREENE et al. (1976).

Leica®). The pupae obtained were classified into deformed and normal, sexed according to BUTT & CANTU (1962) and weighed when 24 h old, when the sex ratio also was determined.

After emergence, the adults from each treatment were paired up and each couple was placed into a cage receiving aqueous honey solution as food. The couples were used to evaluate adult longevity.

One sheet of sulphite paper lined the internal wall of the cage to allow oviposition; the paper was replaced daily and the eggs from each couple were counted. Viability was evaluated based on the number of hatched larvae from the second oviposition of each couple.

The biological parameters evaluated were: duration and viability of each development phase, number of instars, pupal weight, number of eggs, and sex ratio. Sex ratio was calculated according to the equation $r = N_f / (N_f + N_m)$ where N_f and N_m correspond to the number of females and males, respectively.

From the results obtained, the fertility life table was created according to SILVEIRA NETO et al. (1976) for each treatment. The life table included the total number of females (x), the cumulative female survival rate (l_x); the specific fertility (number of offspring per female) at age x , the number of females producing females (m_x), and the number of offspring reaching adult phase in next generations ($l_x \times m_x$).

Based on the life table information, the following parameters were estimated for each treatment: the net reproduction rate, $R_0 = \sum (m_x \times$

l_x), is the rate at which the species increase in each generation; the innate capacity to increase in number, $rm = \ln(R_0) / T$, is the species growth in every generation; the finite rate of increase, $\lambda = \exp(rm)$, is the daily population growth indicating the number of females generated per female per d over a generation; mean interval between generations, $T = \sum (m_x \times l_x \times x) / \sum (m_x \times l_x)$, is the mean duration of a generation; time span for the population to double in size is $TD = \ln(2) / rm$.

Data analysis

Data were analyzed for normality and homoscedasticity using the Shapiro-Wilk and Bartlett tests, respectively. It was found that in data for development period, larval viability, pupal viability and deformities, the assumptions of normality were not met and; therefore, the non-parametric Kruskal-Wallis test was used, followed by the multiple comparisons test of Dunn ($P < 0.05$), when the results were significant.

For the pupal weight data for which the assumptions were met, an ANOVA test was applied. For sex ratio and egg viability, the non-parametric chi-square test at 5% was used, whereas the egg viability results were evaluated using the Fisher test at 5% due to the large number of zeros, corresponding to the non-hatched eggs (not accepted by the chi-square test). For such analyses, the software R v.4.1.0 was used (R CORE TEAM, 2021).

The number of instars was determined using the multimodal frequency curve for capsules in

the linearized model of DYAR'S (1890) rule through the Mobae software (HADDAD et al., 1995). The parameters of the fertility life table were estimated through the jackknife technique (MEYER et al., 1986) and the means compared by the unilateral t-test at 5% probability using the SAS System 8.2 software (SAS, 2001).

RESULTS

Larval development duration ranged from 3.42 to 23.66 d (chi-squared = 549.5267; df = 6; $P \leq 0.05$). BMX Icone Ipro and TEC IRGA 6070RR genotypes showed significantly shorter durations, 3.42 and 5.25 d, respectively, whereas for the PELBR 10-6000RR isoline, larval development lasted an average of 23.66 d. Larval viability (chi-squared = 166.7717; df = 6; $P \leq 0.05$) was less than 50% for all treatments; however, larvae were more affected by BRS 391 and BRS 6203RR where viability was less than 14%. Viability was null when larvae were fed on BMX Icone Ipro and TEC IRGA 6070RR (Table 1).

The pupal period lasted from 8.23 to 8.43 d (chi-squared = 1.1858; df = 4; $P = 0.8804$), and pupal viability ranged from 72.50% to 91.30% (chi-squared = 9.3638; df = 4; $P = 0.05$), with no significant differences between treatments (Table 2). Adult

longevity ranged from 13.50 to 17.21 d (Table 2); however, it did not differ among the genotypes tested (chi-squared = 0.6117; df = 4; $P = 0.1906$) as well as the pre-oviposition periods (chi-squared = 8.7065; df = 4; $P = 0.06887$) and egg (chi-squared = 0.4575; df = 4; $P = 0.98$) (Table 2).

Egg viability ranged from 39.26 to 69.26% and the lowest values were verified on PELBR 10-6049RR, BRS 6203RR, and BMX Valente RR genotypes, at 48.42 ($P = 0.1467$), 42.88 ($P = 0.07581$), and 39.26% ($P = 0.1238$), respectively (Table 2).

Frequency peaks, defined from the average width of the cephalic capsules, indicated the occurrence of 1 to 6 larval instars for the different genotypes. Larvae with the lowest number of instars were fed on the BMX Icone Ipro (1 instar) and TEC IRGA 6070RR (4 instars) where as for the other treatments the number of instars did not vary (Figure 1). The growth rate (K) between the larval development phases demonstrated that the width of the cephalic capsules increased in average 1.5 at each phase (Figure 1).

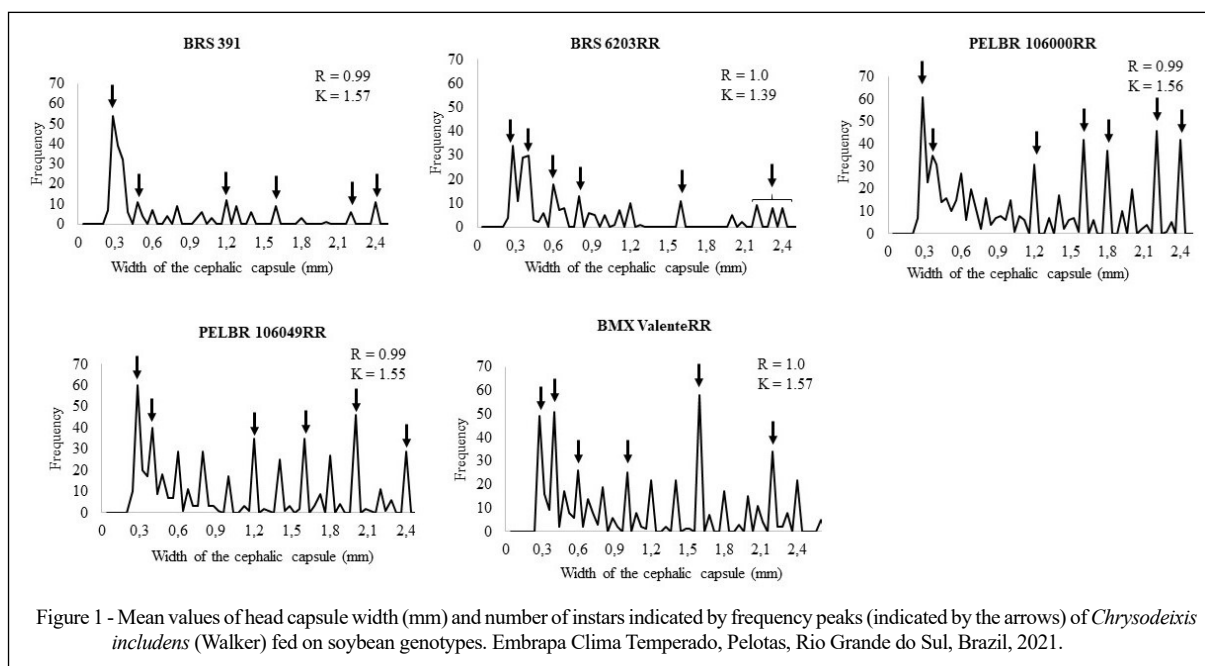
The sex ratio did not differ between treatments; however, the sex rate obtained in the BRS 391 treatment demonstrated a male bias (1.37:1, Males: Females) (Table 3). The pupal weight ranged from 0.175 to 0.193 g ($F = 0.8632$; df = 4; $P = 0.4873$)

Table 2 - Mean period ($\pm$ SE) and viability of developmental stages of *Chrysodeixis includens* (Walker) fed on different soybean genotypes. Embrapa Clima Temperado, Pelotas, Rio Grande do Sul, Brazil, 2021.

Treatment	-----Period (days)-----					-----Viability (%)-----		
	Larvae	Pupae ^a	Adults ^a	Pre-oviposition ^a	Eggs ^a	Larvae	Pupae ^a	Eggs
BMX ValenteRR	18.95 $\pm$ 0.62 b [150]	8.40 $\pm$ 0.09 [63]	15.05 $\pm$ 0.72 [54]	6.70 $\pm$ 0.64 [27]	2.90 $\pm$ 0.09 [10]	46.00 a	91.30	39.26 c
BRS 391	16.85 $\pm$ 0.90 b [150]	8.23 $\pm$ 0.13 [17]	17.21 $\pm$ 1.45 [14]	4.29 $\pm$ 0.39 [7]	3.00 $\pm$ 0.24 [6]	12.67 c	89.47	65.05 a
BRS 6203RR	13.74 $\pm$ 0.65 c [150]	8.31 $\pm$ 0.21 [16]	13.50 $\pm$ 1.74 [12]	4.50 $\pm$ 0.25 [4]	3.00 $\pm$ 0.00 [3]	13.33 c	80.00	42.88 bc
PELBR 10-6049RR	19.02 $\pm$ 0.91 b [150]	8.42 $\pm$ 0.10 [26]	16.25 $\pm$ 1.04 [16]	4.71 $\pm$ 1.00 [7]	3.00 $\pm$ 0.28 [5]	19.33 bc	89.65	48.42 b
PELBR 10-6000RR	23.66 $\pm$ 0.95 a [150]	8.43 $\pm$ 0.14 [21]	16.46 $\pm$ 0.80 [28]	4.71 $\pm$ 0.40 [14]	3.00 $\pm$ 0.00 [10]	26.67 b	72.50	69.26 a
TEC IRGA 6070RR	5.25 $\pm$ 0.18 d [150]	—	—	—	—	0.00 d	—	—
BMX Icone Ipro	3.42 $\pm$ 0.04 e [150]	—	—	—	—	0.00 d	—	—
CV (%)	76.35	7.99	31.19	50.46	13.06	—	—	—

Values in square brackets are the number of observations. Values followed by the same letter in the same column do not differ by Dunn's test ($P \geq 0.05$).

^aNot significant by the Kruskal-Wallis test ($P \geq 0.05$). Egg viability values followed by the same letter in the same column do not differ from each other by Fisher's test ($P \geq 0.05$).



with the lowest values found in BRS 391 and BRS 6203RR treatments, with a reduction of 9 and 7.4%, respectively, when compared to the highest pupal weight reported on PELBR 10-6000RR (Table 3). The BRS 6203RR treatment also provided one of the highest numbers of pupal deformations (38.46%) (chi-squared = 20.8627; df = 4; $P \leq 0.05$) (Table 3).

The specific fertility did not show significant difference for the treatment factor (chi-squared = 7.606; df = 4; $P = 0.1071$). Most females had their maximum fertility expressed in oviposition peaks in the first 8 d after formation of couples (Figure 2).

The net reproduction rate (R_0) was significantly lower for BRS 6203RR (19.75 females per female) and BRS 391 (33.57 females per female)

($P < 0.01080$) genotypes (Table 4). The lowest intrinsic rate of growth (r_m) occurred for the treatments BRS 6203RR and BRS 391, which obtained reduced growth rates by 21 and 19% ($P < 0.00372$); respectively, when compared to BMX Valente RR genotype, which showed the highest growth rate (Table 4).

The finite rate of increase (λ) was greater than 1, indicating population growth. The finite rate of increase λ was significantly lower for BRS 6203RR and BRS 391 genotypes, at 1.082 and 1.085 females per d ($P < 0.00372$), respectively (Table 4). The mean interval between generations (T) was greater on PELBR 10-6000RR (44.30 d), PELBR 10-6049RR (44.07 d), and BRS 391 (43.43 d) (Table 4) genotypes. The time taken in d for the population to

Table 3 - Sex ratio, weight ($\pm$ SE) and pupal deformations of *Chrysodeixis includens* (Walker) in different soybean genotypes. Embrapa Clima Temperado, Pelotas, Rio Grande do Sul, Brazil, 2021.

Treatment	Sex ratio ^a (r)	Pupal weight ^b (g)	Deformation (%)
PELBR 10-6000RR	0.55	0.193 $\pm$ 0.01[40]	6.90 a
PELBR 10-6049RR	0.55	0.189 $\pm$ 0.01[29]	0.00 a
BMX ValenteRR	0.49	0.185 $\pm$ 0.00[69]	4.76 a
BRS 391	0.42	0.175 $\pm$ 0.01[19]	5.88 a
BRS 6203RR	0.56	0.178 $\pm$ 0.01[20]	38.46 b

Values in square brackets are the number of observations.

Values followed by the same letter on the column do not differ by Dunn's test ($P \geq 0.05$).

^aNot significant by chi-square test ($P \geq 0.05$).

^bNot significant by ANOVA test ($P \geq 0.05$).

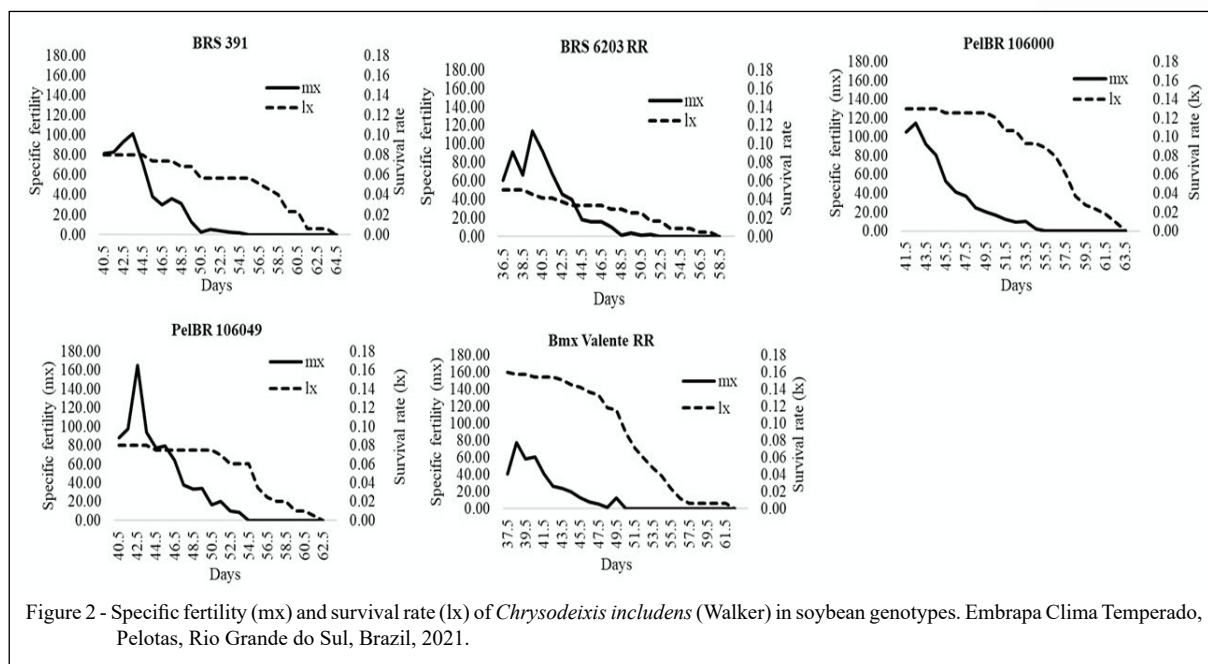


Figure 2 - Specific fertility (mx) and survival rate (lx) of *Chrysodeixis includens* (Walker) in soybean genotypes. Embrapa Clima Temperado, Pelotas, Rio Grande do Sul, Brazil, 2021.

double in size (TD) did not differ between treatments; however, it was longer on the BRS 6203RR (8.45 d) and BRS 391 genotypes (8.51 d) (Table 4).

DISCUSSION

The slowest development period of *C. includens* larvae on the BMX Icone IPRO treatment is attributed to the Intacta technology, which expresses the Cry1Ac protein, a Bt toxin that promotes the rupture of the gut membrane increasing larval mortality (BEL et al., 2019). Furthermore, high mortality rates (100%) in the first 5 d on TEC IRGA 6070RR cultivar may be explained due to the presence

of allelochemicals from secondary metabolites involved in the protection of plants against herbivory, such as flavonoids rutin, quercetin, kaempferol, and genistin (PIUBELLI et al., 2005; SMITH, 2005; MALVAR et al., 2008; GÓMEZ et al., 2018).

The larval viability and the determination of the number of instars evidenced the strong influence of the genotypes, due to negative interference in feeding and insect development, indicating the occurrence of antibiosis (SMITH, 2005) which manifests itself through toxic effects of the plant, affecting the biological parameters insects (MOONGA et al., 2016; WILLE et al., 2017; VENDRAMIM et al., 2019). According to SHOUR & SPARKS (1981)

Table 4 - Mean ($\pm$ SE) fertility life table parameters (R_o , rm , λ , T , and TD) of *Chrysodeixis includens* (Walker) fed on soybean genotypes. Embrapa Temperate Climate, Pelotas, Rio Grande do Sul, Brazil, 2021.

Treatment	Parameters				
	R_o	rm	λ	T	TD
BRS 6203RR	19.75 ± 9.19 b	0.079 ± 0.013 b	1.082 ± 0.014 b	39.26 ± 0.91 b	8.45 ± 1.80 a
BRS 391	33.57 ± 5.83 b	0.081 ± 0.004 b	1.085 ± 0.004 b	43.43 ± 0.37 a	8.51 ± 0.38 a
PELBR 10-6049RR	53.02 ± 12.84 ab	0.091 ± 0.005 ab	1.095 ± 0.006 ab	44.07 ± 0.66 a	7.61 ± 0.44 a
PELBR 10-6000RR	77.55 ± 14.19 a	0.097 ± 0.004 a	1.104 ± 0.005 a	44.30 ± 0.40 a	7.01 ± 0.30 a
BMX ValenteRR	57.68 ± 10.14 a	0.100 ± 0.005 a	1.105 ± 0.005 a	40.79 ± 0.30 b	6.93 ± 0.32 a

Values represent the mean obtained from the jackknife technique. Values followed by the same letter in the same column do not differ by the unilateral t test ($P \geq 0.05$). R_o = net reproduction rate (female per female); T = interval between generations (d); rm = growth intrinsic rate; λ = finite rate of increase (females per d); TD = time required for the population to double (d).

larvae generally go through 6 instars; however, 5 to 7 instars have been reported depending on the food source and the temperature (PITRE & HOGG, 1983; SANTOS et al., 2005).

Antibiosis is the term used when a host plant exerts a negative effect on an insect due to the presence of toxic compounds or the lack of essential nutritional compounds, and thus the plant does not suffer as much damage as plants that do not have such compounds (susceptible). Effects include prolongation and mortality of the larval stage, reduction in the weight of immatures and adults, low in fecundity and fertility, inability of larvae to form pupae or adults to emerge, and occurrence of defective individuals. (VENDRAMIM et al., 2019).

The period and pupal viability in this study were similar to those observed by WILLE et al. (2017) in soybean cultivars of medium maturation ($5.5 \geq \text{RMG} \leq 6.9$) which varied from 7.5 to 7.7 d. Furthermore, the pupal weight observed in this study was similar to the ones verified in different trials using soybean genotypes, with values ranging from 0.109 to 0.217 g (MOONGA & DAVIS, 2016; WILLE et al., 2017) and higher values when insects were fed on artificial diet (0.208 to 0.261 g) (KIDD & ORR, 2001; PARRA et al., 2012; ANDRADE et al., 2016; SPECHT et al., 2019).

Food ingested during the larval phase directly affects the weight of pupae and adults, change in sex ratio, in addition to interferes the performance, longevity, dispersal capacity, copulation and oviposition rates, and egg viability (JOHANSSON, 1964). In this study adult longevity was intermediate to those reported by SOSA-GÓMEZ et al. (2014) for *C. includens* in soybeans and can vary from 12 to 19 d. However, insects fed on the BRS 391 genotype lived longer than those fed on the other genotypes.

The life cycle prolongation of pest-species is desired in plant resistance, since the insect will have a smaller number of generations and consequent reduction in population size, reducing damage to crop (SMITH, 2005). Variations in adult longevity and fecundity are regulated, principally as a function of temperature, host plant availability, and its nutritional quality (BARRIONUEVO et al., 2012; PRZYGODA et al., 2016; BENEDITO et al., 2021).

Differentiating food antixenosis from antibiosis is not always easy, as food antixenosis can also cause changes in insect biology. To identify the resistance involved in altering insect development, it is necessary to evaluate food consumption. If there are no differences in consumption between the plant that caused changes in insect biology and the plant

in which such an effect was not observed, it can be concluded that the effects are due to antibiosis (VENDRAMIM et al., 2019).

In antixenosis bioassay using the same species evaluated, GOBBI et al. (2024) did not show differences between the consumption of BRS 391 of most of the genotypes tested, confirming the presence of antibiosis for the genotype BRS 391 in our study. The bioassay also demonstrated that the genotypes BRS 6203RR and BRS 391 have a high number of glandular trichomes when compared to the genotypes Tec Irga 6070RR, BMX Icone Ipro, BMX Valente, PELBR 10-6000 and PELBR 10-6049. According to the authors, genotypes with denser trichomes are less preferred for consumption.

The presence of trichomes is one of the most important resistance factors due to the variation (shapes and types of trichomes) and ways in which they can affect the insect. The tector trichomes affect the insect's ability and access to food and are related to resistance by antixenosis, while glandular trichomes, in addition to contributing to the mechanics of resistance, compose specialized structures that store and synthesize chemical compounds that can affect the insect's development (VENDRAMIM et al., 2019).

The fertility life table demonstrated that BRS 6203RR and BRS 391 reduced the intrinsic rate of growth and the number of females generated per d, suggesting that such genotypes may reduce the population rates of *C. includens* in subsequent generations. When evaluating soybean cultivars, WILLE et al. (2017) observed a predisposition to antibiosis in genotypes of medium maturity, recommended for the southern region of Brazil by reducing the finite rate of increase and the net reproductive rate, which results in a population reduction in subsequent generations.

Our results showed that the pre-oviposition period exhibited intermediate values from those found for *C. includes* in plant resistance studies (1.40 to 5.5 d) (MORANDO et al., 2017; PASTÓRIO, 2023). The egg incubation period of approximately 3 d was similar to those described by MOSCARDI et al. (2012) in all treatments at 25 °C. According to GOBBI et al. (2024), the oviposition peak occurs around 7 d after couples were assembled, supporting the results found in this study. Although, egg viability showed differences between treatments, it was within the range of 40 to 100%, except for the BMX ValenteRR genotype, which showed lower viability.

The TEC IRGA 6070RR genotype negatively affected the biological parameters of *C. includens*. Furthermore, in an antixenosis study,

the Tec Irga 6070RR genotype was less consumed by *C. includens*, when compared to other soybean genotypes, indicating antixenosis to feeding (GOBBI et al., 2024).

CONCLUSION

The results showed that soybean cultivars influenced the biological parameters and presented different degrees of resistance to *C. includens*; however, only the BRS 6203RR and BRS 391 genotypes significantly affected the biological parameters of *C. includens*, characterizing the expression of antibiosis.

The BMX Icone IPRO and TEC IRGA 6070RR genotypes caused larval mortality in the first 5 days and may be an alternative for plant improvement programs, which requires a greater amount of information for the introduction into pest management programs in soybean crops.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

DATA AVAILABILITY STATEMENT

The raw data are available in a permanent repository. Available at <<https://doi.org/10.5281/zenodo.5655788>>.

DECLARATION OF USE OF ARTIFICIAL INTELLIGENCE

We declare that this study is original authorship and that no artificial intelligence resources were used in its production.

REFERENCES

ABDUL MALIK, N. A. et al. Elicitor and receptor molecules: orchestrators of plant defense and immunity. **International Journal of Molecular Sciences**, v.21, n.3, p.963, 2020. Available

from: <<https://pmc.ncbi.nlm.nih.gov/articles/PMC7037962/pdf/ijms-21-00963.pdf>>. Accessed: Jul. 11, 2023. doi: 10.3390/ijms21030963.

ADIE, M. M. et al. Evaluation for soybean resistance to armyworm *Spodoptera litura* (Lepidoptera: Noctuidae). **IOP Conference Series: Earth and Environmental Science**, v.484, n.012020, 2020. Available from: <<https://iopscience.iop.org/article/10.1088/1755-1315/484/1/012020/pdf>>. Accessed: Jul. 03, 2023. doi: 10.1088/1755-1315/484/1/012020.

ANDRADE, K. et al. Bioecological characteristics of *Chrysodeixis includens* (Lepidoptera: Noctuidae) fed on different hosts. **Austral Entomology**, v.55, n.4, p.449-454, 2016. Available from: <<https://doi.org/10.1111/aen.12208>>. Accessed: Jun. 28, 2023. doi: 10.1111/aen.1220.

BARRIONUEVO, M. J. et al. Life table studies of *Rachiplusia nu* (Guenée) and *Chrysodeixis* (= *Pseudoplusia*) *includens* (Walker) (Lepidoptera: Noctuidae) on artificial diet. **Florida Entomologist**, v.95, n.4, p.944-951, 2012. Available from: <<https://doi.org/10.1653/024.095.0419>>. Accessed: Aug. 07, 2023. doi: 10.1653/024.095.0419.

BEL, Y. et al. Specific binding of *Bacillus thuringiensis* Cry1Ea toxin, and Cry1Ac and Cry1Fa competition analyses in *Anticarsia gemmatilis* and *Chrysodeixis includens*. **Scientific Reports**, v.9, n.18201, 2019. Available from: <<https://www.nature.com/articles/s41598-019-54850-3>>. Accessed: Jun 03, 2023. doi: 10.1038/s41598-019-54850-3.

BENEDITO, A. D. S. et al. Thermal requirements and population viability of *Chrysodeixis includens* (Lepidoptera: Noctuidae). **Neotropical Entomology**, v.50, n.2, p.186-196, 2021. Available from: <<https://www.nature.com/articles/s41598-019-54850-3>>. Accessed: Jul. 12, 2023. doi: 10.1007/s13744-020-00825-3.

BUENO, A. F. et al. Challenges for adaption of integrated pest management (IMP): the soybean example. **Neotropical Entomology**, v.50, p.5-20, 2021. Available from: <<https://link.springer.com/article/10.1007/s13744-020-00792-9>>. Accessed: May, 22, 2025. doi:10.1007/s13744-020-00792-9.

BUTT, B. A.; CANTU, E. **Sex determination of lepidopterous pupae**. Agriculture Research Service, U.S.: Department of Agriculture, Washington, 1962. 7p. Available from: <<https://www.biodiversitylibrary.org/bibliography/67261>>. Accessed: Jul. 12, 2023. doi: 10.5962/bhl.title.67261.

COELHO, M. et al. Assessing soybean genotypes for resistance to *Helicoverpa armigera* (Lepidoptera: Noctuidae). **Journal of Economic Entomology**, v.113, p.471-481, 2020. Available from: <<https://academic.oup.com/jee/article-abstract/113/1/471/5588651?redirectedFrom=fulltext>>. Accessed: Jul. 15, 2023. doi: 10.1093/jee/toz269.

CONAB - National Supply Company. Monitoring of the Brazilian grain harvest - Sixth harvest survey, 2023/2024. **CONAB**, v.11, n.12, p.1-116, 2024. Available from: <<https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safrade-graos?limitstart=0>>. Accessed: Sept. 27, 2024.

CONTE, O. et al. Results of integrated management of soybean pests in the 2013/2014 crop in Paraná - **Documents Embrapa Soybean**, 2014. Available from: <<https://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/996841>>. Accessed: May, 13, 2023.

- DYAR, H. G. The number of molts of lepidopterous larvae. **Psyche**, v.5, p.420-422, 1980. Available from: <<https://onlinelibrary.wiley.com/doi/10.1155/1890/23871>>. Accessed: May, 27, 2023. doi: 10.1155/1890/23871.
- FEHR, W. R.; CAVINESS, C. E. **Stages of soybean development**. Special Report 80. Iowa Agricultural and Home Economics Experiment Station: Iowa State University, Ames, Iowa, USA, CODEN: IWSRBC (80), 1977, 12p.
- GAZZONI, D. L.; YORINIORI, J. T. **Soybean Pest and Disease Identification Manual**. Brasília: Embrapa-SPI, 1995. 128p.
- GOBBI, P. C. et al. Oviposition behavior and foliar consumption of *Chrysodeixis includens* (Lepidoptera: Noctuidae) in soybean genotypes. **Ciência Rural**, v.54, n.2, e20220474, 2024. Available from: <<https://doi.org/10.1590/0103-8478cr20220474>>. Accessed: Jun. 25, 2025. doi: 10.1590/0103-8478cr20220474.
- GÓMEZ, J. D. et al. Leaf metabolic profiles of two soybean genotypes differentially affect the survival and the digestibility of *Anticarsia gemmatilis* caterpillars. **Plant Physiology and Biochemistry**, v.155, p.196-212, 2020. Available from: <<https://pubmed.ncbi.nlm.nih.gov/32771931/>>. Accessed: May, 27, 2023. doi: 10.1016/j.plaphy.2020.07.010.
- GÓMEZ, J. D. et al. Broad range flavonoid profiling by LC/MS of soybean genotypes contrasting for resistance to *Anticarsia gemmatilis* (Lepidoptera: Noctuidae). **PLoS One**, v.13, n.10, e0205010, 2018. Available from: <<https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205010>>. Accessed: Jun. 01, 2023. doi: 10.1371/journal.pone.0205010.
- GREENE, G. L. et al. Velvetbean caterpillar: arearing procedure and artificial medium. **Journal of Economic Entomology**, v.69, n.4, p.487-488, 1976. Available from: <<https://academic.oup.com/jee/article-abstract/69/4/487/2212175>>. Accessed: May, 13, 2023. doi: 10.1093/jee/69.4.487.
- HADDAD, M. L. et al. Computerized system for statistical models applied to entomology. In: 15th Brazilian Congress of Entomology. Caxambu, Minas Gerais, Brazil, 1995. **Annals...** p.244, 1995. Available from: <<https://www.seb.org.br/cbe/>>. Accessed: May, 13, 2023.
- JOHANSSON, A. S. **Feeding and nutrition in reproductive processes in insects**. London: Symposia of the Royal Entomological Society, United Kingdom, n. 2, 1964.
- KASTER, M.; FARIAS, J. R. B. Regionalization of cultivation value tests and use and indication of soybean crops - third approach - **Documents Embrapa Soybean**, 2012. Available from: <<https://infoteca.cnptia.embrapa.br/infoteca/handle/doc/917252>>. Accessed: Jul. 08, 2023.
- KIDD, K. A.; ORR, D. B. Comparative feeding and development of *Pseudoplusia includens* (Lepidoptera: Noctuidae) on kudzu and soybean foliage. **Annals of the Entomological Society of America**, v.94, n.2, p.219-225, 2001. Available from: <<https://academic.oup.com/aesa/article/94/2/219/187150>>. Accessed: May, 11, 2023. doi: 10.1603/0013-8746(2001)094[0219:CFADO PJ2..0.CO;2].
- KRISNAWATI, A. et al. Resistance reaction of soybean genotypes to *Spodoptera litura* under free-choice and no-choice tests and selection based on multiple traits. **Chilean Journal of Agricultural Research**, v.85, n.2, p.194-205, 2025. Available from: <<http://dx.doi.org/10.4067/S0718-58392025000200193>>. Accessed: Jun. 25, 2025. doi: 10.4067/S0718-58392025000200193.
- LIMA, F. de et al. Antixenosis and antibiosis characterization on soybean cultivars of *Anticarsia gemmatilis* (Lepidoptera: Erebiidae). **Ciência Rural**, v.54, n.4, e20220534, 2024. Available from: <<http://doi.org/10.1590/0103-8478cr20220534>>. Accessed: Jun. 25, 2025. doi: 10.1590/0103-8478cr20220534.
- MACHADO, S. W. et al. Inga laurina trypsin inhibitor (ILTI) obstructs *Spodoptera frugiperda* trypsins expressed during adaptive mechanisms against plant protease inhibitors. **Archives of Insect Biochemistry and Physiology**, v.95, e21393, 2017. Available from: <<https://onlinelibrary.wiley.com/doi/abs/10.1002/arch.21393>>. Accessed: May, 03, 2023. doi: 10.1002/arch.21393.
- MALVAR, R. A. et al. Causes of natural resistance to stem borers in maize. In: BURTON, E. N.; WILLIAMS, P. V. (Eds.) **Crop Protection Research Advances**. Nova Science Publishers, New York, 2008. Ch. 2, p.51-96.
- MEYER, J. S. et al. Estimating uncertainty in population growth rates: jackknife vs. bootstrap techniques. **Ecology**, v.67, n.5, p.1156-1166, 1986. Available from: <<https://esajournals.onlinelibrary.wiley.com/doi/10.2307/1938671>>. Accessed: Jul. 02, 2023. doi: 10.2307/1938671.
- MOONGA, M. N.; DAVIS, J. A. Partial life history of *Chrysodeixis includens* (Lepidoptera: Noctuidae) on summer hosts. **Journal of Economic Entomology**, v.109, n.4, p.1713-1719, 2016. Available from: <<https://academic.oup.com/jee/article-abstract/109/4/1713/2202996?redirectedFrom=PDF>>. Accessed: Jun. 16, 2023. doi: 10.1093/jee/tow156.
- MORANDO, R. et al. Assessing common bean cultivars for resistance to the soybean looper *Chrysodeixis includens* (Lepidoptera: Noctuidae). **Neotropical Entomology**, v.46, n.5, p.561-570, 2017. Available from: <<https://link.springer.com/article/10.1007/s13744-017-0486-2>>. Accessed: Jun. 23, 2023. doi: 10.1007/s13744-017-0486-2.
- MOSCARDI, F. et al. Arthropods that attack soybean leaves. In: HOFFMANN-CAMPO, C. B. et al. (Eds.), **Soybean: Integrated Management of Insects and Other Arthropod Pests**. Brasília: Embrapa, Ch. 4, p.213-334, 2012.
- OLIVEIRA, A. C. B. Soybean cultivars. In: EMYGDIO, B. M. et al. (Eds.) **Soybean and corn cultivation in lowlands of Rio Grande do Sul**. Brasília: Embrapa, 2017. Ch. 6, p.127-140.
- ONGARATTO, S. et al. Resistance of soybean genotypes to *Anticarsia gemmatilis* (Lepidoptera: Erebiidae): antixenosis and antibiosis characterization. **Journal Economic Entomology**, v.114, p.2571-2580, 2021. Available from: <<https://academic.oup.com/jee/article/114/6/2571/6414065>>. Accessed: May, 11, 2023. doi: 10.1093/jee/toab197.
- PAINTER, R. H. **Insect Resistance in Crop Plants**. New York: Macmillan, 1951.
- PAIXÃO, G. P. et al. Biochemical responses of *Anticarsia gemmatilis* (Lepidoptera: Noctuidae) in soybean cultivars sprayed with the protease inhibitor Berenil. **Journal of Agricultural and Food Chemistry**, v.61, p.8034-8038, 2013. Available from: <<https://academic.oup.com/jee/article/114/6/2571/6414065>>. Accessed: May, 15, 2023. doi: 10.1093/jee/toab197.

- PANIZZI, A. R. History and contemporary perspectives of the integrated pest management of soybean in Brazil. **Entomologia Neotropical**, v.42, p.119-127, 2013. Available from: <<https://doi.org/10.1007/s13744-013-0111-y>> Accessed: Jun. 20, 2025. doi: 10.1007/s13744-013-0111-y.
- PARRA, J. R. P. et al. Nutritional indices for measuring food intake and utilization. In: PANIZZI, A. R.; PARRA, J. R. P. (Eds.) **Insect Bioecology and Nutrition for Integrated Pest Management**. CRC Press: Boca Raton, 2012. Ch. 2 p.3-49.
- PASTÓRIO, M. A. et al. Resistance of common bean genotypes to *Chrysodeixis includens* (Walker, 1858) (Lepidoptera: Noctuidae). **Insects**, v.14, n.12, 2023. Available from: <<https://www.mdpi.com/2075-4450/14/12/905>>. Accessed: Jan. 24, 2024. doi: 10.3390/insects14120905.
- PIUBELLI, G. C. Are chemical compounds important for soybean resistance to *Anticarsia gemmatilis*? **Journal of Chemical Ecology**, v.31, n.7, p.1509-1525, 2005. Available from: <<https://pubmed.ncbi.nlm.nih.gov/16222789/>>. Accessed: Jun. 17, 2023. doi: 10.1007/s10886-005-5794-z.
- PITRE, H. N.; HOGG, D. B. Development of the fall armyworm on cotton, soybean and corn. **Journal of Georgia Entomological Society**, v.18, n.2, p.182-187, 1983. Available from: <<https://www.cabdigitalibrary.org/doi/full/10.5555/19830504210>>. Accessed: May, 18, 2023.
- PRZYGODA, A. et al. Effect of diet on mortality and larval duration in *Chrysodeixis includens* (Lepidoptera: Noctuidae). **Journal of Georgia Entomological Society**, v.74, n.2, art.19, 2016. Available from: <<https://digitalcommons.gaacademy.org/gjs/vol74/iss2/19>>. Accessed: Jul. 06, 2023.
- QUEIROZ, E. B. et al. Antibiosis in soybean genotypes to *Spodoptera cosmioides* (Lepidoptera: Noctuidae). **Revista Brasileira de Entomologia**, v.64, n.2, e20200010, 2020. Available from: <<https://www.scielo.br/j/rbent/a/VPgHddPQSty7f57HPsj8qhw/>>. Accessed: Jul. 13, 2023. doi: 10.1590/1806-9665-RBENT-2020-0010.
- R CORE TEAM. **R: a language and environment for statistical computing**. R Foundation for Statistical Computing. Vienna: Austria, 2021.
- SANTOS, K. B. Biology of *Spodoptera eridania* (Cramer) (Lepidoptera: Noctuidae) in different hosts. **Neotropical Entomology**, v.34, n.6, p.903-910, 2005. Available from: <<https://www.scielo.br/j/ne/a/kwTZGXNZrzm3B54vjM9pQBP/>>. Accessed: May, 06, 2023. doi: 10.1590/S1519-566X2005000600005.
- SAS INSTITUTE. **Statistical Analysis System: getting started with the SAS learning**. SAS Institute: Cary, North Carolina, 2001.
- SHOUR, M. H.; SPARKS, T. C. Biology of the soybean looper, *Pseudoplusia includens*: characterization of last-stage larvae. **Annals of the Entomological Society of America**, v.74, n.6, p.531-535, 1981. Available from: <<https://academic.oup.com/aesa/article-abstract/74/6/531/69301>>. Accessed: May, 19, 2023. doi: 10.1093/aesa/74.6.531.
- SILVA, C. S. et al. Population expansion and genomic adaptation to agricultural environments of the soybean looper, *Chrysodeixis includens*. **Evolutionary Applications**, v.13, p.2071-2085, 2020. Available from: <<https://doi.org/10.1111/eva.12966>>. Accessed: Jun. 20, 2020. doi: 0.1111/eva.12966.
- SILVEIRA NETO S. **Handbook of Insect Ecology**. CERES: Piracicaba. 1976.
- SMITH, C. M. **Plant resistance to arthropods: molecular and conventional approaches**. Springer: Dordrecht, 2005.
- SPECHT, A. Biotic potential and life tables of *Chrysodeixis includens* (Lepidoptera: Noctuidae), *Rachiplusia nu*, and *Trichoplusia ni* on soybean and forage turnip. **Journal of Insect Science**, v.19, n.4, 8, 2019. Available from: <<https://academic.oup.com/jinsectscience/article/19/4/8/5531794>>. Accessed: Jun. 13, 2023. doi: 10.1093/jisesa/iez072.
- SOSA-GÓMEZ, D. R. et al. **Identification manual of insects and other invertebrates of soybean crop**. Londrina: Embrapa Soja, 2014.
- SOUZA, B. H. S. et al. Soybean leaf age and plant stage influence expression of resistance to velvetbean caterpillar and fall armyworm. **Chemoecology**, v.31, p.377-390, 2021. Available from: <<https://doi.org/10.1007/s00049-021-00360-6>>. Accessed: Jun. 25, 2025. doi: 10.1007/s00049-021-00360-6.
- VARGAS-ALMENDRA, A. et al. Advances in Soybean Genetic Improvement. **Plants**, v.13, n.21, 3073, 2024. Available from: <<https://www.mdpi.com/2223-7747/13/21/3073#B27-plants-13-03073>>. Accessed: May, 22, 2024. doi: 10.3390/plants13213073.
- VENDRAMIM, J. D. et al. Antibiosis. In: BALDIN, E. L. L. et al. (Eds.) **Resistance of plants to insects: Fundamentals and Applications**. FEALQ: Piracicaba. 2019. Ch.5, p.185-224.
- WILLE, P. E. et al. Natural resistance of soybean cultivars to the soybean looper larva *Chrysodeixis includens* (Lepidoptera: Noctuidae). **Pesquisa Agropecuária Brasileira**, v.52, p.18-25, 2017. Available from: <<https://www.scielo.br/j/pab/a/LzyGFKr8pDjR9GvX5ZbvkKf/?lang=en>>. Accessed: Jun. 12, 2023. doi: 10.1590/S0100-204X2017000100003.