Brazilian Journal of Agriculture **v.96, n.1, p. 339 – 354, 2021**
DOI: 10.37856/bja.v96i1.4269

POTENTIAL OF MAIZE, MILLET AND RATTLEBOX TO BREAK THE CYCLE OF *Spodoptera eridania* (CRAMER) (LEPIDOPTERA: NOCTUIDADE)

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ABSTRACT

This study evaluated the effect of different crops grown during soybean offseason on the development and reproduction of *Spodoptera eridania* (Cramer). The experiment was conducted in laboratory at 25°C±1°C, relative air humidity of 70% ± 10% and a 12h photophase. The plants evaluated were cotton (FMT 701), sunflower (Embrapa 122-V2000), rattlebox (*Crotalaria spectabilis* Roth), corn (Dekalb 370), and millet (DR-300). The less suitable hosts for the survival of *S. eridania* were rattlebox, corn and millet. Only in cotton and sunflower the species completed its development (egg to adult). Corn, millet and rattlebox were the crops that most affected the performance of *S. eridania*, and therefore they could potentially be used in the soybean offseason period to interrupt the life cycle of this species, and thus reduce population incidence during soybean season.

Keywords: Crop rotation, insect pest, secondary hosts

POTENCIAL DO MILHO, MILHETO E CROTALÁRIA PARA QUEBRAR O CICLO DE *Spodoptera eridania* (CRAMER) (LEPIDOPTERA: NOCTUIDAE)

RESUMO

Este estudo avaliou o efeito de diferentes culturas de entressafra da soja sobre o desenvolvimento e reprodução de *Spodoptera eridania*. O experimento foi conduzido em laboratório em 25°C±1°C, umidade de 70%±10% e fotofase de 12 horas. As plantas avaliadas foram algodão (FMT 701), girassol (Embrapa 122-V2000), crotalária (*Crotalaria spectabilis* Roth), milho (Dekalb 370) e milheto (DR-300). Os hospedeiros menos adequados para a sobrevivência de *S. eridania* foram crotalária, milho e milheto. A espécie atingiu o desenvolvimento (ovo a adulto) apenas em plantas de algodão e girassol. Milho, milheto e crotalária foram as culturas que mais afetaram o desempenho de *S. eridania*, assim, estas plantas potencialmente podem ser usadas no período de entressafra da soja para interromper o ciclo desta espécie, reduzindo os surtos populacionais na soja.

Palavras-chave: Rotação de culturas, inseto-praga, hospedeiros secundários

INTRODUCTION

The growing expansion of agricultural areas in the Brazilian Cerrado has enabled the cultivation of various species of economic importance. In this context, soybean stands out as the main crop grown in the Cerrado region, and the most representative state within this agricultural landscape is Mato Grosso, since it is the largest producer of this crop in Brazil (IBGE, 2020).

Following the soybean production cycle in the Cerrado of Mato Grosso, cotton and corn are most often grown in a system of succession and/or crop rotation. Within these systems, alternative crops are planted during the inter-harvest cultivation of soybean, such as millet and rattlebox, as well as sunflower, a promising crop for the production of oil and animal feed. The sequence of crops following soybean harvesting can influence the levels of incidence as well as the number of generations of insects attacking soybeans due to the continuous availability of food (SANTOS et al., 2005). On the other hand, non-host plant species can affect the development of insects and interrupt their life cycle. According to Altiere (1989), insects have difficulty in locating, settling and reproducing in multi cropping systems since both host and non-host plants are simultaneously grown in these areas.

The number of insect species attacking soybeans in Mato Grosso state boosted from six in 1978 to 33 in 2008, 10 of which are now considered as main pests, 11 as secondary and 12 as sporadic pests (WIEST & BARRETO, 2012). Until recently, the southern armyworm *Spodoptera eridania* (Cramer) (Lepidoptera: Noctuidae) was sporadically associated only with soybean (FUNDAÇÃO MT, 2011). Due to its recent expansion and occurrences of population outbreaks, it has become a growing problem, and is now being recorded on other crops, such as cotton (MIRANDA, 2010; SANTOS et al., 2010; FUNDAÇÃO MT, 2019).

Polyphagous defoliators such as *S. eridania* (KING & SAUNDERS, 1984; NORA & REIS-FILHO, 1988; SAVOIE, 1988; SOSA-GOMEZ et al., 1993; PICANÇO et al., 2003; DIAS et al., 2009; MIRANDA, 2010; JESUS et al., 2013) are better adapted to establish in areas with crop rotation and under succession cropping, when compared to oligophagous and monophagous insects, due to the continuous availability of food. Santos et al. (2005) reported dispersal of this species from soybean fields to weedy and cotton-growing areas using them as a refuge and feeding sites.

The choice of plants for cultivation may influence the insect regarding host selection, occurrence and establishment in agroecosystem. Studies on nutritional ecology contribute to understanding the dynamics of pests in crops, offering predictions about the development and reproduction of the species in agricultural areas, and this is a crucial vision for pest management and sustainable agriculture (PANIZZI & PARRA, 2009; FAVETTI et al., 2015; RODRIGUES et al., 2015; SILVA et al., 2017; SILVA et al., 2019).

Taking into account the increased frequency of outbreaks and infestations of *S. eridania* in soybean crops, it is essential to carry out studies to better understand how plants used in a system of crop rotation may interfere with the attack of *S. eridania* on soybeans. This information enables the implementation of management tactics for the control of this species in the field. Thus, this study evaluated the influence of different plant species cultivated during soybean intercropping period, on the development and reproduction of *S. eridania* under laboratory conditions.

MATERIAL AND METHODS

Colony of *Spodoptera eridania*

Spodoptera eridania was reared in the laboratory, after collecting specimens in soybean plantations. Larvae were maintained on an artificial diet (KASTEN JÚNIOR et al., 1978) in flat-bottomed glass tubes (85mm x 25mm) covered with a cotton wool ball. Pupae were placed in plastic pots lined with filter paper and the sexing was made according to Zenker et al. (2007).

The emerged adults were maintained at room temperature in PVC cages (10cm diameter and 21.5cm high), with a Petri dish at the top and bottom and internally coated with bond paper as a substrate for oviposition. A solution of 10% honey (w/v) was provided as food in a cotton ball placed within a plastic container at the bottom of the cages. The eggs were removed by cutting the paper along the margin of the egg mass, and then transferred to a Petri dish kept in a climatic chamber at 25 ± 1°C, 70 ± 10% relative air humidity and 12 hours photophase.

Host plant species studied

The commercial crops used were cotton (FMT 701), corn (Dekalb 370), rattlebox (*Crotalaria spectabilis* Roth), millet (ADR-300), and sunflower (Embrapa 122-V2000). The plants were cultivated in 8L plastic buckets with soil. The plants were kept in a greenhouse and the soil was fertilized with a 10:10:10 NPK formulation (Nitrogen, Phosphorus and Potassium). Leaves were collected 35 days after planting and immersed for 20 minutes in a solution of sodium hypochlorite (2.5% sol) at 1%, to eliminate possible entomopathogens before offering to the larvae.

Development of immature stages of *Spodoptera eridania*

Fifty newly-hatched larvae per treatment were maintained individually in 145mL plastic pots lined with filter paper, in a climatic chamber at 25 ± 1°C, 70 ± 10% relative air humidity and 12 hours photophase. Leaves from each plant species (treatments) were offered daily. The number of instars and their duration was determined by the presence of the head capsule and exuviae. Pupae were placed in Petri dishes and, after 24 hours were weighed using an analytical balance, separated by gender, and observed for the occurrence of malformations.

The biological parameters used to compare development of the immature stages were: duration (days) and viability (%) of the larval, prepupal and pupal stages, number of instars, male and female pupal weight, percentage of malformations pupae, and sex ratio (number of females/number of males + number of females).

Longevity and reproduction of *Spodoptera eridania*

To evaluate the influence of the plant species on the longevity and reproduction of *S. eridania*, 15 pairs were isolated according to the emergence date from each treatment in PVC cages (10cm diameter and 21.5cm high). The upper and bottom openings of the cages were closed with voil and a Petri dish, respectively. The inner part of the cages was lined with white paper as a substrate for oviposition. Adults were fed on a solution of 10% honey (w/v) provided in cotton balls placed at the bottom of the cages. The eggs were removed daily, placed in Petri dishes and kept in a climatic chamber at 25°C until egg hatching. The newly hatched larvae were then transferred to microtubes 1.5 mL and killed in 70% ethanol to be counted.

In order to evaluate the reproductive performance of *S. eridania*, the adult reproductive traits assessed were fecundity, egg viability, incubation period, duration of pre-oviposition, and oviposition period and male and female longevity. To record fecundity and egg viability, eggs were counted using photographic images and a stereomicroscope. The photographs of each clutch were transferred to a computer for egg counting.

Statistical analysis

The experimental design was completely randomized, with data being submitted to Shapiro Wilk normality test ($p>0.05$). The results were analyzed by ANOVA at 5%, and the means compared using the Student t test (5%). The data that did not follow normality were tested using the Kruskal-Wallis test (5%) for comparing different treatments. The Mann-Whitney test (5%) was used to compare data with only two treatments. To compare the sex ratio, the chi-square (5%) test was used.

RESULTS AND DISCUSSION

Development of immature stages of *Spodoptera eridania*

The incubation period was significantly longer on sunflower leaves when compared with cotton. On leaves of corn and rattlebox, *S. eridania* did not complete larval development, averaging 1.7 to 3.9 days, respectively. The mean duration of the larval stage was different among treatments ranging from 15.2 days on sunflower leaves to 24.8 days on cotton leaves. The prepupal stage was influenced by the hosts evaluated, ranging from 1.04 to 5.2 days, and on millet this stage was longer when compared to sunflower and cotton. Statistical differences were not observed in the mean duration of pupal stage of females and males reared on cotton and sunflower leaves, with values close to 10 days. Although few individuals feeding on millet leaves pupated, the duration was very similar to that found for cotton and sunflower leaves (Table 1).

In host plants that allowed *S. eridania* to complete larval development from the 4th instar, there was a progressive lengthening of the duration of instars. On cotton and sunflower, some individuals reached the 7th instar, and millet was the only food in which the 8th instar occurred (Figure 1).

All individuals fed on leaves of corn and rattlebox died in the first instar. On millet, mortality was high throughout the instars, especially in the first instar. On sunflower leaves, survival was high, and the few individuals that died were in the 4th, 6th and 7th instars, different from cotton leaves, where there was no mortality in the larval stage.

Table 1. Mean (± SD) duration (days) of immature stages of *Spodoptera eridania* on five hosts recommended as winter crop after soybean, Tangará da Serra – Mato Grosso State, July 2012.

Treatment	Duration of immatures stages (days)				
	Larvae[1]	Prepupae[1]	Pupae[ns] Female	Pupae[ns] Male	Egg[2]
Cotton	24.8 ± 1.89 a	1.5 ± 0.88 b	9.7 ± 0.52	10.5 ± 0.64	3.2 ± 0.59 b
Sunflower	15.2 ± 1.31 c	1.04 ± 0.28 b	10.1 ± 0.55	10.6 ± 0.55	3.5 ± 0.35 a
Millet	16.9 ± 13.67 b	5.2 ± 4.91 a	9.0 ± 0.00**	12.0± 0.00**	-
Rattlebox	3.9 ± 2.04*	-	-	-	-
Corn	1.7 ± 0.43*	-	-	-	-
H	46.0	38.8	-	-	-
U	-	-	165.0	852.5	38
P	<0.05	<0.05	>0.05	>0.05	<0.05

[1]Means followed by the same letter in the column do not differ statistically by the Kruskal-Wallis test at 5% probability. [2]Means followed by the same letter in the column differed by the Mann-Whitney test at 5%. [ns]Not significant according to the Mann-Whitney test at 5%. *Larvae that did not complete their development. **Due to the low number of individuals, it was not possible to apply statistical tests.

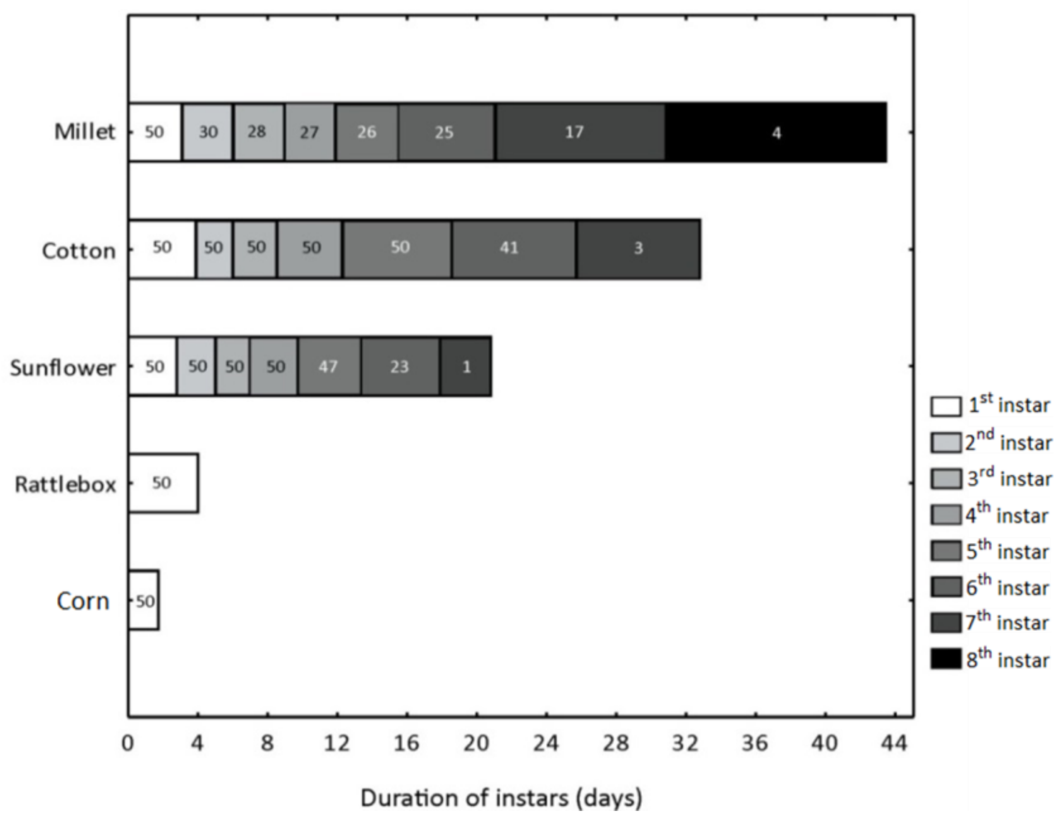

Figure 1. Duration of instars (days) and number of individuals of *Spodoptera eridania* that went through each instar, maintained on five crops planted in offseason cultures of soybean, Tangará da Serra – Mato Grosso State, July 2012.

DOI: 10.37856/bja.v96i1.4269

The mean weight of male and female pupae of *S. eridania* that fed on sunflower leaves was higher compared to those fed on cotton leaves. Malformed pupae were observed only on sunflower and millet treatments, reaching 6.3% and 25.0%, respectively (Table 2).

Larval viability of *S. eridania* was significantly affected when reared in corn, rattlebox and millet. In the prepupae and pupae no significant differences in viability were found between the treatments. The egg viability was significantly influenced by sunflower plants, where only 31.1% of the eggs hatched (Table 3).

Table 2. Mean (± SD) weight (mg) of pupae, males and females, pupal deformity (%), and sex ratio of *Spodoptera eridania* from larvae feeding on different crops planted in off-season cultures of soybean, Tangará da Serra – Mato Grosso State, July 2012.

Treatment	Weight of pupae		Pupal deformation (%)*	Sex ratio[2]
	Female[1]	Male[1]		
Cotton	222.4 ± 0.04 b	190.4 ± 0.03 b	0.0	0.4
Sunflower	341.8 ± 0.02 a	270.9 ± 0.02 a	6.3	0.4
Millet	207.9 ± 0.02 *	120.0 ± 0.00 *	25	0.7
t-test	-9.9	-10.4	-	-
χ^2	-	-	-	12.8
P	<0.05	<0.05	-	<0.05

[1]Means followed by the same letter in the column do not differ statistically according to Student's t-test at 5%. [2]Sex ratio according to the chi-square test at 5%. *Due to the low number of individuals, it was not possible to apply statistical tests.

Table 3. Mean viability (± SD) of immature stages of *Spodoptera eridania* maintained on different crops planted in off-season cultures of soybean, Tangará da Serra – Mato Grosso State, July 2012.

Treatment	Viability (%)			
	Egg[1]	Larvae[2]	Prepupae^{ns}	Pupa^{ns}
Cotton	58.7 ± 26.97 a	100.0 ± 0.00 a	100.0 ± 0.00	96.0 ± 19.79
Sunflower	31.1 ± 24.23 b	94.0 ± 23.98 a	100.0 ± 0.00	87.2 ± 33.73
Millet	-	26.0 ± 44.30 b	100.0 ± 0.00 *	50.0 ± 57.73*
Rattlebox	-	0.00 ± 0.00 b	-	-
Corn	-	0.00 ± 0.00 b	-	-
H	-	198.71	-	-
U	46	-	1175	1072.0
P	p<0.05	p<0.05	p>0.05	p>0.05

[1]Means followed by the same letter in the columns do not differ significantly using the Mann-Whitney test at 5%. [2]Means followed by the same letter in the column do not differ by Kruskal-Wallis test (5%). ^{ns}Not significant according to the Mann-Whitney test at 5%. *Due to the low number of individuals statistical tests were not applied.

Longevity and reproduction of *Spodoptera eridania*

The mean longevity of females and males from larvae fed on cotton and sunflower leaves was not influenced by the food consumed in the larval stage. The pre-oviposition and oviposition periods were not affected by sunflower and cotton, since the pre-oviposition period lasted about two days in both crops, and the oviposition period from 9.8 to 10.8 days. Among the treatments, *S. eridania* completed its life cycle (egg-adult) on cotton in 53.8 days and in sunflower in 46.5 days (Table 4).

The fecundity of *S. eridania* was similar in adults reared in the larval stage on cotton and sunflower leaves. There was no influence of the host plants on the number of eggs laid (Table 5). The number of eggs per female was higher between the 1^{st} and 4^{th} days of oviposition in both sunflower and cotton. After this period, a decrease in the number of eggs laid per female was observed (Figure 2).

The eggs of *S. eridania* fed on cotton leaves during the larval stage were viable, with values around 60% from the 1^{st} to the 10^{th} day of oviposition. Egg viability of individuals fed on sunflower leaves was close to 50% throughout the oviposition period (Figure 3).

Table 4. Mean longevity (± SD), duration of pre-oviposition, oviposition and total cycle (days) of adults of *Spodoptera eridania* maintained in cotton and sunflower in the larval stage, Tangará da Serra – Mato Grosso State, July 2012.

Treatment	Longevity^{ns1}		Pre-oviposition^{ns}	Oviposition^{ns1}	Total cycle²
	Female	Male			
Cotton	14.2 ± 3.04	21.8 ± 5.36	2.1 ± 0.40	9.8 ± 1.50	53.8 ± 3.36 a
Sunflower	15.5 ± 3.59	19.6 ± 4.37	2.3 ± 0.61	10.8 ± 2.02	46.5 ± 5.69 b
t-test	-1,11	1,29	-	-1,5	3.9
U	-	-	110.5	-	-
P	>0.05	>0.05	>0.05	>0.05	<0.05

^{ns}Not significant according to the Mann-Whitney test (5%). ^{ns1}Not significant according to the Student t-test at 5%. ¹Means followed by the same letter in the column did not differ statistically according to the Student t-test at 5%.

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Table 5. Fecundity and mean number of eggs (± SD) of *Spodoptera eridania* fed in the larval stage with cotton and sunflower, Tangará da Serra – Mato Grosso State, July 2012.

Treatment	Oviposition^{ns}		Fecundity^{ns}	
	Daily	Total	Daily	Total
Cotton	1.3 ± 0.40	13.4 ± 7.29	245.9 ± 231.93	2417.6 ± 2351.91
Sunflower	1.3 ± 0.71	12.4 ± 8.70	262.7 ± 302.10	2776.7 ± 3222.15
U	112.5	121	101.0	124.0
P	>0.05	>0.05	>0.05	>0.05

^{ns}Not significant according to the Mann-Whitney test at 5% probability.

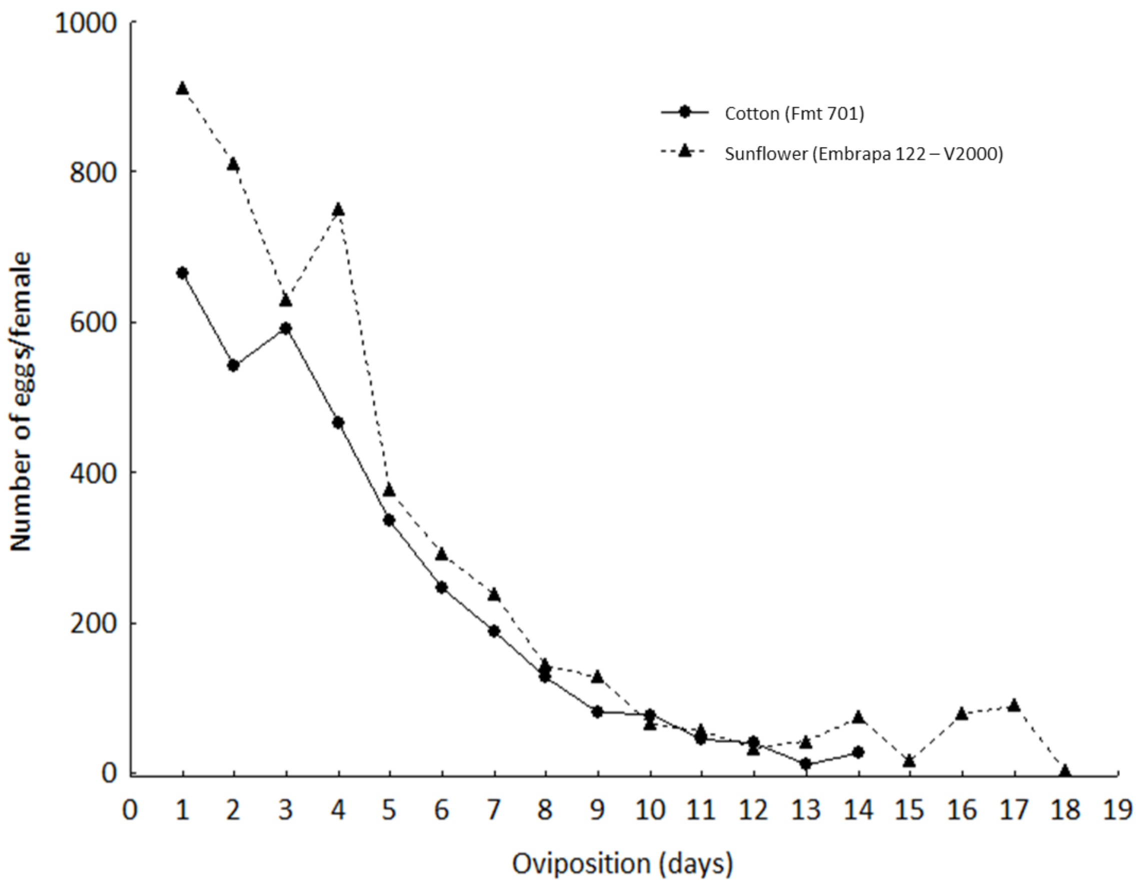

Figure 2. Number of eggs per female during the oviposition period (days) of *Spodoptera eridania*, Tangará da Serra – Mato Grosso State, July 2012.

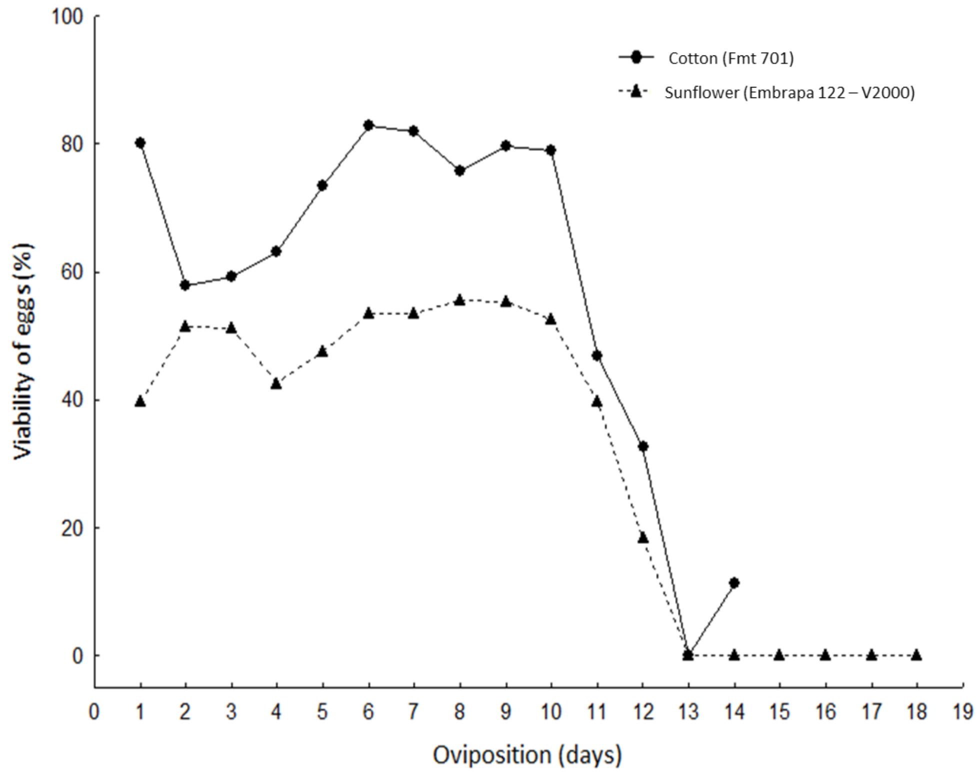

Figure 3. Viability of eggs (%) throughout the oviposition period (days) of *Spodoptera eridania*, Tangará da Serra – Mato Grosso State, July 2012.

The peak of fecundity of *S. eridania* occurred between the 2nd and 4th days on sunflower leaves, and between the 3rd and 5th days on cotton, followed by a decrease in the number of eggs and larvae in both treatments at the end of the oviposition period (Figure 4).

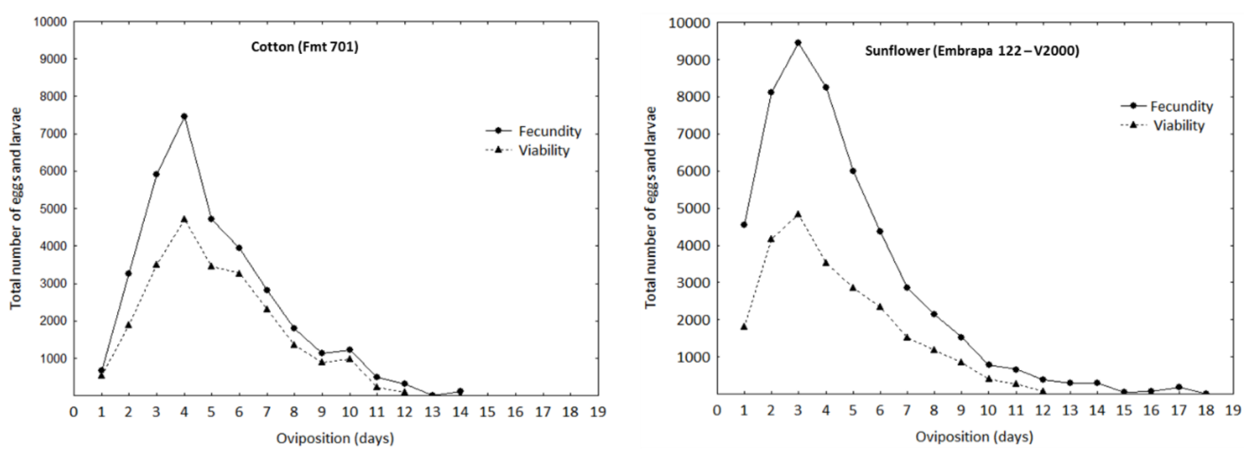

Figure 4. Total number of eggs and larvae of *Spodoptera eridania* throughout the oviposition period, fed in the larval stage with cotton (a) and sunflower (b), Tangará da Serra – Mato Grosso State, July 2012.

Development, survival and reproduction of *S. eridania* were affected by the plant species tested. *S. eridania* did not fulfill development on rattlebox and corn and all larvae died in the first instar. On millet, pupal weight was reduced and only two individuals reached the adult stage. Larvae fed on cotton exhibited longer development and on sunflower, egg viability was low. Possible causes for the influence of different host plants on the life-history traits of *S. eridania* are the presence of structures in the plants which inhibit feeding, the low nutritional quality of the host, and/or the presence of toxins in the plants.

Plant resistance to insects, among pest control methods, is responsible for damage reduction and lower insect populations (SOUZA et al., 2012). Among the types of resistance, antibiosis causes negative effects on insect biology, ranging from mild to lethal, and is triggered by morphological and chemical factors, acting alone or in conjunction. The presence of trichomes, toxins, digestibility reducers, rigidity of the leaf epidermis, and nutritional inadequacies, among others, can provide different degrees of resistance to insects (SMITH, 2005). Among the resistance factors cited above, morphological characteristics of corn and rattlebox may have influenced their consumption by *S. eridania*, justifying the high mortality in the first instar.

These factors may be due to the presence of trichomes (LARA, 1991), waxes, and rigidity of leaves that alone or in combination prevent larval feeding by neonates and their subsequent establishment on the host. They must overcome this mechanical barrier in order to survive (ZALUCKI et al., 2002). Although some studies have reported the occurrence of *S. eridania* in corn (PICANÇO et al. 2003) and rattlebox (DIAS et al., 2009), this study showed that it did not develop normally on these hosts. In a study recently developed by Silva et al. (2017), oat, wheat and maize negatively affected the development and survival of the larvae of *S. eridania* and *S. cosmioides*, thus corroborating our results for *S. eridania* in maize.

One possibility for the occurrence of *S. eridania* on corn and rattlebox, as mentioned above, is its mass-dispersion of adults in the absence of their preferred hosts; however, this fact does not indicate that the species will establishe and survive on these plants (BELLANDA & ZUCOLOTO, 2009). The presence of toxic substances to insects in cotton can also be acting negatively on the biological characteristics such as the delay of the larval stage, the total development time and the incubation period, through the ingestion of toxic metabolites and enzyme inhibitors, among others by *S. eridania* (VENDRAMIM & GUZZO, 2009).

According to Stipanovic et al. (2006), compounds such as gossypol, predominant in the green structures of cotton plants, can affect the nutritional gain by the plant herbivore and some terpenoids also present in this plant can have antigrowth effects (SMITH, 2005). The impact on the metabolism of *S. eridania* after feeding on different host plants, such as cotton and millet, may also have been due to the low nutritional property of the plant (qualitative or quantitative deficiency of nutrients) (VENDRAMIM & GUZZO, 2009). This fact may have contributed to the lengthening of the larval stage in cotton and of the pre-pupal stage in millet, where the larvae continued to feed for a longer period thus delaying pupation.

Additional instars were recorded on cotton and sunflower (seven) and millet (eight) and similar results were obtained by Parra et al. (1977) for *S. eridania*, where the number of instars was six when fed on cotton leaves and up to seven when fed on soybean leaves. According to Bavaresco et al. (2003), this may have been due to the quality of the food ingested since in lepidopterans an extra instar may occur when the food has low nutritional attributes.

Greater pupal mass may be due to the high level of nutritional reserves present in this stage which are fundamental for the reproductive success of the species (GAZZONI & TUTIDA, 1996). Thus, the pupal mass of *S. eridania* found in this study was greater in sunflower than in the other hosts. These values were higher than those obtained by Santos et al. (2005) for cotton (female 0.2853g, male 0.2367g), morning-glory, *Ipomoea* sp. (Convolvulaceae) (female 0.2721g, male 0.2367g), and soybean (female 0.1900g, male 0.1705g). Our results were similar to those observed by Parra et al. (1977) for cotton (male 0.3g, female 0.4g) and soybean (male 0.2g, female 0.23g), and Mattana & Foerster (1988) for sweet potato (male 0.2g, female 0.3g), and *Mimosa scabrella* (0.2g for both sexes) for *S. eridania*.

The mean duration of the egg to adult cycle varied according to the leaf species in which individuals completed larval development, being greater in cotton than in sunflower. These values were higher than those reported by Parra et al. (1977) for *S. eridania*, being 28.5 days in cotton and 34.3 days in soybean cultures. The viability of the development stages of *S. eridania* maintained on different crops grown after soybean harvest was affected. The larval stage was affected when the insect fed on rattlebox, corn, and millet, as was the egg stage, when *S. eridania* fed on sunflower.

Although this species exhibits a high degree of polyphagy, low initial survival in the larval stage when fed on rattlebox, corn, and millet indicates that in the field this can be a major impediment to the successful colonization of *S. eridania* in these crops and can interrupt its life cycle, thus decreasing its population throughout the year. Interference in egg viability observed when larvae fed on sunflower leaves may have occurred due to poor quality of existing nutrient content in the egg for the development of the embryo of *S. eridania*.

Among the different control practices, crop rotation has been poorly studied as a means of reducing insect infestations. However, it can be useful in pest management as reported by Silva (1996), who observed in the field that the system of crop rotation with corn and soybeans significantly reduced infestation by adults and larvae of the soybean stalk weevil *Sternechus subsignatus* (Boheman) (Coleoptera, Curculionidae) when compared to continuous soybean monoculture, due to the fact that inclusion of corn in the rotation breaks the reproductive cycle of this insect.

CONCLUSION

In this context, the present study brings promising data for a potential disruption in the cycle of *S. eridania*, given the unsuitability of corn, rattlebox and millet as food sources for the larvae of this species. It is expected that in the field these host plants will prevent the multiplication of the insect between soybean harvests.

ACKNOWLEDGEMENTS

This study was financed in part by the Coordination for the Improvement of Higher Education Personnel – Finance Code 001. The authors thank the team of the Entomology Laboratory of the University of Mato Grosso - Professor Eugênio Carlos Stieler Campus, in Tangará da Serra and of Integrated Insect Control Laboratory of the Universidade Federal do Paraná for the support in the accomplishment of this research.

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Received in: February, 3, 2021
Accepted in: April, 9, 2021