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Resistance of cotton varieties to *Spodoptera frugiperda* (Lepidoptera: Noctuidae)

Resistencia de variedades de algodón a *Spodoptera frugiperda* (Lepidoptera: Noctuidae)

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Abstract: The fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) is a polyphagous pest species of cultivated plants. Changes in cotton crop systems are increasing the importance of this pest in cotton in the El Cerrado region of Brazil. This work aimed to evaluate resistance types of cotton (*Gossypium hirsutum*) varieties by non-preference to oviposition and feeding along with antibiosis to *S. frugiperda* in the laboratory (27 ± 2 ºC, 70 ± 10% R.H. and photophase of 14 h). Two tests were performed to evaluate the non-preference to oviposition and feeding, one with free choice in a randomized block design and another in a completely randomized design. Leaves of the cotton varieties DeltaOpal®, NuOpal®, FMX 993®, FMT 701®, FMX 910® and FMX 996® were offered daily to *S. frugiperda* larvae. The presence of antibiosis was evaluated by the duration of each instar and of the larval and pupal stages, larval and pupal biomass, and adult longevity and fecundity. The NuOpal® variety was the most resistant to *S. frugiperda*. *Spodoptera frugiperda* fed on non-Bt cotton had heavier pupae and larvae, shorter development time for the larval stage, longer adult longevity, and a higher rate of oviposition and total viability when compared to the Bt cotton varieties.

Key words: Fall armyworm. *Gossypium hirsutum*. Plant resistance.

Resumen: El cogollero del maíz, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) es una especie polífaga de cultivos. Los cambios en los sistemas de cultivo del algodón han aumentado la importancia de esta plaga en la región de El Cerrado, Brasil. Este estudio tuvo como objetivo evaluar los tipos de resistencia de las variedades de algodón (*Gossypium hirsutum*) por la no preferencia para oviposición y antibiosis de *S. frugiperda* laboratorio (27 ± 2 ºC, 70 ± 10% HR y fotoperiodo 14 h). Dos ensayos se realizaron para evaluar la no-preferencia para oviposición y alimentación, a libre y no libre escogencia, en un diseño experimental de bloques. Las hojas de las variedades DeltaOpal®, NuOpal®, FMX 993®, FMT 701®, FMX 910® y FMX 996® se ofrecieron diariamente a las larvas de *S. frugiperda.* Se analizaron la duración de cada estadio larval y pupal, peso de larvas a los 10 días, peso de pupa a las 24 horas, la longevidad y fecundidad de los adultos. La variedad NuOpal® fue la más resistente a *S. frugiperda*, al afectar el desarrollo biológico de esta plaga, presentando resistencia de los alimentos no preferidos. Las larvas de *S. frugiperda* alimentadas sobre algodón no Bt y sus pupas tuvieron mayor peso, más corto período larval, mayor adulto longevidad y oviposición y una mayor viabilidad total.

Palabras clave: Cogollero del maíz. *Gossypium hirsutum.* Resistencia de plantas.

Introduction

Insects damage can limit cotton (*Gossypium hirsutum*) production. The defoliator *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) is present in many countries and considered an important pest of cotton (Ramalho *et al*. 2011). This insect is of economic importance to many cropping systems, but few studies are reported for this species on cotton plants (Soares *et al*. 2006).

First and second instar to *S. frugiperda* feed together near the oviposition site on parenchyma and their feeding leads to leaves becoming necrotic and translucent. As larvae develop, they disperse and natural mortality occurs as they search for food and due to natural enemies (Luthy and Wolfersberger 2000). Developed larvae prefer to feed on the reproductive structures of cotton (Ali *et al*. 1990; Luttrell and Mink 1999; Ramalho *et al*. 2011).

Terpene and aldehydes, such as gossypol, heliocides and hemigossypolone, can help plants resistant feeding by different lepidopteran species (McAuslane *et al*. 1997) and they can be employed in management programs for *S. frugiperda*. Pilosity (Calhoun *et al*. 1994), presence or absence of extrafloral nectarines (Flint *et al*. 1992), type of bracts and leaves (Maredia *et al*. 1993) and allelochemicals content are factors that can contribute to cotton resistance (Mohan *et al*. 1996). Antixenose and/or antibiosis are the categories involved in cotton resistance to lepidopteran defoliators (Campos *et al*. 2012).

Genetically modified plants with genes of *B. thuringiensis* var. *kurstaki* (Bt) express lethal protein crystals (Cry) when ingested by lepidopteran larvae (De Polanía *et al*. 2009; Ramalho *et al*. 20011). However, cotton cultivars containing only Cry1Ac were not efficient in controlling *S. frugiperda* (Adamczyk Junior *et al*. 1998) and they increase tolerance of individuals feeding on the cultivar (Adamczyk Junior and Sumerford 2001).

Campos *et al*. (2012) evaluated different structures of the cotton plant and observed that leaves were the most attractive

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to *S. frugiperda* feeding compared to bracts, squares and carpel walls of the bolls. The Coodetec-410™ variety was more attractive and BRS Acala-90™, Fibermax-966™ and DeltaPenta™ were less attractive to *S. frugiperda*. BRS-Araça™ was most preferred for feeding and BRS-Cedro™, BRS Itamarati 90™, DeltaPenta™, Coodetec-408™ e BRS-Aroeira™ were less preferred.

Therefore, the aim of this study was to evaluate the types of resistance in non-Bt and transgenic Bt varieties of cotton grown in the Cerrado region, Brazil for *S. frugiperda*.

Material and methods

This research evaluated the resistance of the commercial cotton varieties DeltaOpal™, FMX 701™, FMX 910 ™, FMX 993™ and FMX 996™ (No Bt) and NuOpal™ (transgenic - Bt) to *S. frugiperda*. The experiments were performed at the Laboratory of Plant Resistance to Insects of the Department of Plant Protection, Faculty of Agriculture and Veterinary Sciences (FCAV) in Jaboticabal, São Paulo State, Brazil.

Cotton leaves for the bioassays were collected from cotton that was growing in the experimental plots at the Department of Plant Protection. Management practices as fertilizing, weeds control etc., were performed according to this culture needs, except insecticide application.

***Spodoptera frugiperda* rearing.** *Spodoptera frugiperda* was reared in cages of polyvinyl chloride (PVC) tubes (10 cm in diameter and 21.5 cm high) covered internally with white paper sheets as oviposition sites. The cages were covered with "voile fabric" to prevent moths from escaping (Campos *et al*. 2012; Jesus *et al*. 2014).

Cotton wads, soaked in 10% honey solution were provided as a food source for *S. frugiperda* moths. The food source was changed every two days. The white paper sheets with moth eggs were collected daily by cutting out the papers and placing them in 100 mL plastic cup with 5 g of artificial diet (Kasten Junior *et al*. 1978). These containers were covered and kept in a controlled room (25 ± 2 ºC, RH of 50 ± 10% and photophase of 14 hours).

Second instar *S. frugiperda* caterpillars were separated (around 4 mm) to avoid their cannibalistic behavior and individually placed in 50 mL plastic cups with 5 g of artificial diet. These cups were closed with acrylic lids and placed in styrofoam stands with holes on the size of the cup. The cups were kept in a controlled room until the larvae reached the pupal stage and were then separated by sex. Seven pairs of moths were placed in each cage.

Non-preference test for feeding. The attractiveness free choice test was performed in laboratory with six treatments and 2 third instar *S. frugiperda* caterpillars per variety and replication. Thirty days old leaves were collected from the plants in the field, washed and cut into 2.5 cm diameter disks and distributed in a circular manner in a Petri dish (14 cm in diameter) over a moistened filter paper. DeltaOpal™ variety was included as the susceptible control (Boiça Junior *et al*. 2012; Campos *et al*. 2012; Souza *et al*. 2012).

Two leaf disks (2.5 cm^2 diameters) were removed equidistant from the leaves of cotton variety. One was offered to the insects and the other known as the aliquot was oven dried at 60 °C for 48 hours. The dry matter consumed by *S. frugiperda* larvae was determined by the difference between this rate and the remaining portion of the disk consumed.

The attractiveness of caterpillars to foliar disks of each variety was evaluated by counting the number of disk fed upon at 1, 3, 5, 10, 15, 30, minutes and 1, 2, 6 and 24 hours after releasing. Leaves of the six cotton varieties were collected in the field, washed, cut into disks of 2.5 cm diameter and individually placed in Petri dishes in the attractiveness in no choice test. One disk was placed per Petri dish (6 cm diameter) over a moistened paper filter. Two third instar caterpillars were used per replication in the tests of attractiveness and free choice.

An aliquot of each variety was also dried to determine the dry matter consumed based on its dry weight and that of the disks at the end of the tests. The difference between the two foliar disk was determined to be the dry mass consumed.

Test of non-preference for oviposition. The non-preference in free choice test for oviposition was performed in a mesh (1.5 m x 0.6 m x 0.6 m) container with anti-aphid screen. Each container contained a terminal bud of each variety was put in a glass tube with water and 12 couples of *S. frugiperda* released per cage. The number of eggs per plant was evaluated at 72 hours after the release of the insects. This experiment had ten replications (cages) and six treatments (cultivars) in a randomized block design.

A couple of adults of *S. frugiperda* from the mass rearing was put per PVC cage (12 cm diameter and 20 cm of height) with a terminal bud of each variety placed in a glass tube with water for the non-preference of oviposition. Seventy-two hours after the release of the insects, the total number of eggs per plant was counted. This experiment had a complete randomized design with six treatments and ten replications (Barros *et al*. 2010; Boiça junior *et al*. 2013).

Antibiosis test. Leaves for the study were collected from cotton varieties planted in the field. The study had a completely randomized design with six treatments (cultivars) and 50 replications, each with a Petri dish (6 cm in diameter) with moistened filter paper and leaves of one variety with a newly hatched caterpillar to obtain its biological cycle. The paper filter was changed daily and leaves replaced. Length of the larva and pupa stages, mass of 10-day old larvae and 24-hour old pupae, adult longevity and fecundity were obtained (Moreno *et al.* 2008; Boiça Junior *et al*. 2012; Campos *et al*. 2012; Cataño *et al*. 2014).

Statistical analysis. Data were subjected to analysis of variance or Fisher's exact test followed by the Tukey's test at 5% probability, using the software SISVAR version 5.1 (Ferreira 2011). When necessary the means were transformed in (x + 0.5)1/2 before analysis.

Results and discussion

Mass consumed per instar of *S. frugiperda* in the free choice test differed among treatments at 3, 5 and 30 minutes and at 2, 6 and 12 hours after insect introduction (Table 1). The FMX 993 (0.0 to 0.9) and FMX 910 (0.0 to 1.0) varieties were less attractive to *S. frugiperda* while DeltaOpal™ (0.5 to 1.1) and FMX 966™ (0.3 to 2.1) varieties were more attractive. The dry mass consumed showed lower values for the NuOpal™

Table 1. Attractiveness and leaf mass consumption (LMC) (mean ± standard deviation) of third instar *Spodoptera frugiperda* (Lepidoptera: Noctuidae) larvae on leaves of different cotton varieties in a free choice test. Jaboticabal, São Paulo State, 2008

Varieties	Time in minutes[1]					
	1	3	5	10	22	30
DeltaOpal®	0.6 ± 0.16	0.5 ± 0.22 abc	0.7 ± 0.30 ab	0.5 ± 0.22	0.5 ± 0.22	0.7 ± 0.15 a
NuOpal®	0.6 ± 0.22	0.8 ± 0.20 a	0.8 ± 0.25 a	0.4 ± 0.22	0.4 ± 0.16	0.3 ± 0.21 abc
FMX 993®	0.2 ± 0.13	0.0 ± 0.0 c	0.2 ± 0.30 ab	0.3 ± 0.15	0.4 ± 0.16	0.2 ± 0.13 bc
FMT 701®	0.5 ± 0.17	0.5 ± 0.17 abc	0.5 ± 0.17 ab	0.1 ± 0.10	0.2 ± 0.13	0.3 ± 0.15 abc
FMX 910®	0.4 ± 0.22	0.2 ± 0.13 abc	0.1 ± 0.10 b	0.1 ± 0.10	0.0 ± 0.00	0.3 ± 0.15 c
FMX 966®	0.3 ± 0.21	0.7 ± 0.26 ab	0.7 ± 0.15 ab	0.5 ± 0.17	0.4 ± 0.16	0.6 ± 0.16 ab
C.V	31.95	29.04	30.64	30.49	30.44	28.22
F. (Tr.)	0.705^{NS}	2.42*	2.25*	1.17^{NS}	1.20^{NS}	2.34*
Varieties	**Time in hours**					
	1	**2**	**6**	**12**	**24**	**LMC (g)**
DeltaOpal®	0.9 ± 0.23 b	0.8 ± 0.29 a	0.9 ± 0.10 a	0.9 ± 0.23 a	1.1 ± 0.23	4.51 ± 0.71 a
NuOpal®	0.4 ± 0.22 b	0.4 ± 0.22 ab	0.4 ± 0.16 b	0.5 ± 0.22 ab	0.8 ± 0.20	1.58 ± 0.43 b
FMX 993®	0.1 ± 0.10 b	0.1 ± 0.10 b	0.1 ± 0.10 b	0.9 ± 0.31 a	0.6 ± 0.22	2.57 ± 0.47 ab
FMT 701®	0.3 ± 0.15 b	0.4 ± 0.22 ab	0.2 ± 0.13 b	0.1 ± 0.10 b	0.6 ± 0.27	2.61 ± 0.60 ab
FMX 910®	0.3 ± 0.21 b	0.0 ± 0.00 b	0.1 ± 0.10 b	0.3 ± 0.15 ab	1.0 ± 0.26	3.76 ± 0.90 ab
FMX 966®	2.1 ± 0.86 a	0.4 ± 0.22 ab	0.3 ± 0.15 b	0.8 ± 0.33 ab	0.9 ± 0.23	4.09 ± 0.86 ab
C.V	42.60	34.84	23.97	35.76	51.80	0.20
F. (Tr.)	3.41*	1.78*	5.46**	1.87*	0.84^{NS}	2.76*

[1] Means followed by the same letter are not different by Tukey's test at the 5% probability level. Data were transformed to (x + 0.5)1/2) for analysis purposes.
** Significant at 1% probability. * Significant at 5% probability. NS Non-significant.

variety (1.58), whereas, DeltaOpal™ (4.51) was the most preferred (Table 1).

The attractiveness and dry mass consumed by *S. frugiperda* larvae in the no-choice test showed differences among treatments at 1 minute and 1, 6 and 12 hours after the caterpillars were released (Table 2).

The FMX 966 variety (0.3 to 0.9) was less attractive and the DeltaOpal™ variety (0.5 to 1.0) was more attractive to *S. frugiperda*. The dry mass consumed by caterpillars *S. frugiperda* in the no choice test did not differed among the cotton varieties (Table 2).

Lower consumption of the NuOpal™ variety by *S. frugiperda* larvae might be explained by the presence of the Cry1Ac gene from *Bacillus thuringiensis* which induces endotoxin crystals formation in this variety (De Polania *et al*. 2009). Higher attractiveness of *S. frugiperda* to DeltaOpal™ variety may be due to kairomones (Macintosh *et al*. 1990; Adamczyk Junior *et al*. 1998; Adamczyk Junior and Gore 2004; Adamczyk Junior *et al*. 2008; Ramalho *et al*. 2011). The presence of these chemicals in these genotypes may increase its attractiveness.

The non-preference for oviposition in the free choice test showed that moths oviposited more frequently on FMX 966™ with 502.11 eggs and 4.0 egg masses and the NuOpal™ variety was the least preferred (321.8 and 2.9). In the no choice test, DeltaOpal™ had a higher number of eggs and egg masses (380.3 eggs and 3.3 egg masses) when compared to FMX 993™ (193.1 and 1.3) (Table 3).

The distribution of egg masses of *S. frugiperda* on Bt-cotton plants was also different from that of non-Bt plants, which suggests that moths do not show an ovipositional preference between Bt-cotton and non-Bt plants (Pitre *et al*. 1983; Ali *et al*. 1989; Hardke *et al*. 2012).

Reproductive parameters (except fecundity) of *S. frugiperda* differed among treatments (Table 4). Larval and pupal masses were higher in FMX 910 (169.9 and 225.29) and lower in the NuOpal™ (55.49 and 164.02) variety, which indicates that NuOpal™ is less suitable for development of this pest. Larval and pupal development periods were longer with NuOpal™ (30.05 days and 11.7 days) and shorter with the FMX 910™ (24.0 days) and FMX 993™ (24.9 days) varieties. The pupal period with FMT 701™ variety (10.1 days) was short among the varieties, thus demonstrating that they are more suitable for the development of this insect.

Duration of 24.0 to 30.05 days for larval period and 10.1 to 11.7 days for pupal period were close to the lower weight and larva and pupa survival of insects fed on Bt-cotton (Verissimo *et al*. 2009; Ramalho *et al*. 2011). This lower mass and longer larva period of *S. frugiperda* fed on Bt-cotton could be due to allocation of energy to regenerate the midgut epithelium damaged by endotoxin (Luthy and Wolfersberger 2000).

These results are similar to Ramalho *et al*. (2011) who observed a prolongation of 2.8 days in the lifecycle of *S. frugiperda* fed on Bt cotton compared to larvae fed on non-Bt genotypes. Cataño *et al*. (2014) observed a prolongation of 7.3 days when *S. frugiperda* fed on transgenic variety DP141 B2RF (Cry1Ac + cry2Ab2) compared to the non-Bt cotton DeltaOpal™.

The longevity of *S. frugiperda* adults with and without food showed lower values with the NuOpal™ for both parameters with 2.90 days longevity without food and 5.90 days with food while the FMX 910™ variety with food and FMT 701™ without food had insects with longer longevity, 4.8 and 9.7 days, respectively. Differences in adult longevity may be related to individual variation or ability to

Table 2. Attractiveness and leaf mass consumption (LMC) (mean ± standard deviation) of third instar *Spodoptera frugiperda* (Lepidoptera: Noctuidae) larvae on leaves of different cotton varieties in a no-free choice test. Jaboticabal, São Paulo State, 2008.

Varieties	Time in minutes[1]					
	1	3	5	10	15	30
DeltaOpal®	0.9 ± 0.09 ab	0.9 ± 0.09	0.9 ± 0.09	0.9 ± 0.09	0.8 ± 0.11	0.8 ± 0.11
NuOpal®	1.0 ± 0.00 a	0.8 ± 0.11	0.7 ± 0.12	0.9 ± 0.09	0.9 ± 0.07	1.0 ± 0.00
FMX 993®	0.9 ± 0.07 ab	0.8 ± 0.11	0.9 ± 0.09	0.8 ± 0.11	0.7 ± 0.13	0.9 ± 0.09
FMT 701®	0.6 ± 0.13 b	0.9 ± 0.09	0.7 ± 0.12	0.8 ± 0.11	0.7 ± 0.12	0.7 ± 0.12
FMX 910®	0.9 ± 0.09 ab	0.8 ± 0.11	0.9 ± 0.09	0.9 ± 0.09	0.9 ± 0.09	0.9 ± 0.09
FMX 966®	0.7 ± 0.13 ab	0.7 ± 0.12	0.7 ± 0.13	0.6 ± 0.13	0.6 ± 0.13	0.7 ± 0.12
C.V	16.78	18.48	19.21	18.57	18.57	16.99
F. (Tr.)	2.70*	0.23^{NS}	0.68^{NS}	0.98^{NS}	0.98^{NS}	1.09^{NS}

Varieties	Time in hours				
	1	2	6	12	LMC (g)
DeltaOpal®	1.0 ± 0.00 a	0.9 ± 0.09	1.0 ± 0.00 a	0.5 ± 0.13 b	2.47 ± 0.43
NuOpal®	1.0 ± 0.00 a	0.9 ± 0.07	0.9 ± 0.07 ab	0.2 ± 0.11 b	2.31 ± 0.21
FMX 993®	0.8 ± 0.11 ab	0.9 ± 0.09	0.9 ± 0.09 ab	0.3 ± 0.13 b	2.55 ± 0.53
FMT 701®	0.9 ± 0.07 a	0.9 ± 0.09	0.9 ± 0.09 ab	0.3 ± 0.12 b	2.55 ± 0.36
FMX 910®	0.9 ± 0.07 a	1.0 ± 0.00	1.0 ± 0.00 a	0.9 ± 0.09 a	2.49 ± 0.45
FMX 966®	0.7 ± 0.13 b	0.9 ± 0.07	0.7 ± 0.12 b	0.3 ± 0.12 b	2.91 ± 0.39
C.V	13.33	12.73	13.03	25.52	64.54
F. (Tr.)	2.84*	0.53^{NS}	1.75^{NS}	4.46**	0.46^{NS}

[1] Means followed by the same letter are not different by Tukey's test at the 5% probability level. Data were transformed to (x + 0.5)1/2) for analysis purposes. ** Significant at 1% probability. * Significant at 5% probability. ^{NS} Non-significant.

Table 3. Number of eggs and ovipositions (mean ± standard deviation) of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) on different cotton varieties with and without free choice tests. Jaboticabal, São Paulo State, 2008.

Varieties	Free choice test		No choice test	
	Number of eggs	Number of ovipositions	Number of eggs	Number of ovipositions
DeltaOpal®	348.9 ± 125.5	2.7 ± 0.8	380.3 ± 105.1	3.3 ± 0.6 a
NuOpal®	321.8 ± 170.8	2.9 ± 0.9	372.5 ± 103.1	2.7 ± 0.7 ab
FMX 993®	339.6 ± 107.5	2.8 ± 0.8	193.1 ± 81.9	1.3 ± 0.4 b
FMT 701®	353.7 ± 102.5	2.6 ± 0.7	297.2 ± 91.0	1.9 ± 0.5 ab
FMX 910®	335.0 ± 91.2	3.2 ± 0.7	346.6 ± 148.9	1.6 ± 0.4 ab
FMX 966®	502.9 ± 113.1	4.0 ± 0.8	357.6 ± 167.9	1.8 ± 0.5 ab
C.V	59.11	33.13	71.76	33.93
F. (Tr.)	0.55^{NS}	0.62^{NS}	0.37^{NS}	1.74*

[1] Means followed by the same letter in column are not different by Tukey's test at the 5% probability level. Data were transformed to (x + 0.5)1/2) for analysis purposes. * Significant at 5% probability. ^{NS} Non-significant.

convert food during the juvenile stage, therefore affecting their longevity (Luginbill 1928).

The correlation between longevity, and larva and pupa mass showed that longer-lived adults originated from heavier larvae and pupae (Table 4).

Differences in instar duration showed different levels of resistance among the cotton varieties to *S. frugiperda*. The NuOpal™ variety exhibited the highest level of antibiosis. This variation of biological parameters of *S. frugiperda* fed on the cotton varieties may be due to the presence of chemicals of these plants interfering with the development of the insect (Bavaresco *et al*. 2004; Meagher *et al*. 2004). The chemical defenses of plants repel and reduce digestibility of herbivores. Tannins stored in plant leaves combined with proteins from leaves and digestive enzymes in the gut of insects can hinder digestion and thus negatively affecting their current and future generations (Mauricio and Rausher 1997). In the NuOpal variety the lower performance of *S. frugiperda* can be due the damage in the midgut epithelium caused by endotoxin (Luthy and Wolfersberger 2000).

Conclusions

The NuOpal™ variety was the most resistant with the development of the larvae and pupae being severely impacted. *S. frugiperda* fed on non-Bt cotton resulted in heavier larvae

Table 4. Caterpillar mass, pupae mass, larval period, pupal period and adult longevity with and without food and fecundity (mean ± standard deviation) of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) on different cotton varieties. Jaboticabal, São Paulo State, 2008.

Varieties	Parameters evaluated			
	Caterpillar mass (mg)	Pupae mass (mg)	Larval period (days)	Pupae period (days)
DeltaOpal®	108.95 ± 10.12 c	200.25 ± 6.96 bc	27.2 ± 0.77 b	10.4 ± 0.27 bc
NuOpal®	55.49 ± 6.47 d	164.02 ± 6.86 d	30.05 ± 0.96 a	11.7 ± 0.33 a
FMX 993®	139.33 ± 21.04 abc	212.65 ± 8.12 ab	24.9 ± 0.38 c	11.1 ± 0.23 ab
FMT 701®	128.85 ± 13.22 bc	185.77 ± 8.67 cd	25.9 ± 0.81 bc	10.1 ± 0.28 c
FMX 910®	169.94 ± 12.98 a	225.29 ± 8.54 a	24.0 ± 0.51 c	10.4 ± 0.27 bc
FMX 966®	150.39 ± 11.34 ab	207.09 ± 9.06 abc	25.1 ± 0.72 bc	11.0 ± 0.37 abc
C.V	9.03**	7.17**	9.08**	9.04**
F. (Tr.)	6.53	18.14	12.24	8.62
Varieties	**Parameters evaluated**			
	Adult longevity without food (days)	**Adult longevity with food (days)**	**Fecundity (number of ovipositions)**	**Fecundity (number of eggs)**
DeltaOpal®	4.2 ± 0.36 ab	7.8 ± 0.71 ab	1.36 ± 1.12 ab	288.9 ± 173.20
NuOpal®	2.9 ± 0.18 c	5.9 ± 0.90 b	1.03 ± 0.79 b	124.2 ± 98.87
FMX 993®	3.9 ± 0.18 ab	8.1 ± 0.43 ab	1.41 ± 0.79 ab	166.3 ± 69.52
FMT 701®	3.5 ± 0.22 bc	9.7 ± 1.16 a	1.46 ± 2.26 ab	108.5 ± 87.02
FMX 910®	4.8 ± 0.61 a	8.9 ± 0.57 ab	2.13 ± 1.43 a	243.9 ± 7242
FMX 966®	3.9 ± 0.23 ab	7.6 ± 0.88 ab	1.86 ± 1.91 ab	246.4 ± 87.33
C.V	3.67**	2.53*	1.54*	0.76NS
F. (Tr.)	27.35	32.04	64.49	71.56

[1] Means followed by the same letter in column are not different by Tukey's test at the 5% probability level. Data were transformed to (x + 0.5)1/2) for analysis purposes. ** Significant at 1% probability. * Significant at 5% probability. [NS] Non-significant.

and pupae, shortened larval development times, increased longevity and fecundity rates of adults. *S. frugiperda* had a longer pupal development and shorter adult longevity and viability when fed on Bt-cotton.

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