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Resistance of corn genotypes to fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae)

Lígia Alves de Paiva¹, Fernanda Corrêa², Cinthia Luzia Teixeira Silva², Tony de Lima Moura², Franciele Cristina da Silva², Marcio da Silva Araújo¹ and Flávio Gonçalves de Jesus^{2*}

¹University of Goiás State, Campus de Ipameri, Rodovia GO 330, Km 241, 75780-000, Ipameri, GO, Brazil.

²Federal Goiano Institute, Campus Urutaí, Rodovia Prof. Geraldo Silva Nascimento, 75790-000, Urutaí, GO, Brazil.

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The objective of this study was to evaluate resistance mechanisms in 12 corn genotypes (transgenic hybrids: 30A91 PW, 20A78 HX, Impacto VIP 3, 20A55 HX, NS90 PRO 2, Maximus VIP 3, BX 1293YG, RB 9004 PRO, Feroz VIP 3, LG 6036 PRO; conventional: AG 1051 and variety: AL Bandeirante). Attractiveness, aversion to feeding, and antibiosis were evaluated via free and no choice tests in the laboratory. Attractiveness was evaluated at 1, 5, 10, 15 and 30 min and 1, 2, 6, 12 and 24 h by counting the number of larvae that fed on each genotype. The preference for feeding was determined by quantifying the leaf area of each genotype consumed. Antibiosis was determined by assessing biological parameters of the fed caterpillars in relation to each genotype. The biological parameters evaluated were (a) Larval stage: the viability of the larval stage and weight of larvae at ten days; and (b) pupal stage: the viability and weight of pupae at 24 h of age. After emergence, the moths were fed and evaluated to assess the longevity of the adults and the total life cycle. The transgenic genotypes NS90 PRO2, Maximus VIP 3, Feroz VIP 3 and Maximus VIP 3 elicited an aversion and/or an antibiosis reaction from fall armyworm (FAW). The transgenic genotypes HX 20A55, 30A91 PW, LG 6036 PRO, 20A78 HX and BR 9004 PRO showed a moderate resistance to FAW. The conventional genotypes AG 1051 and AL Bandeirante were highly susceptible to FAW and the transgenic genotype BX 1293 YG was susceptible to FAW.

Key words: Integrated pest management, transgenic crop, plant resistance to insects, *Zea mays*.

INTRODUCTION

Many insects cause damage to corn and often damage the entire plant from the roots to the shoots. The fall armyworm (FAW) *Spodoptera frugiperda* (JE Smith, 1797) (Lepidoptera: Noctuidae) is a polyphagous species and is considered the primarily pest of this crop (Fernandes et

al., 2003; Lima et al., 2006; Mendes et al., 2011). The damage arises from the continual consumption of leaf tissue by the first instars through older larvae, which often cause extensive defoliation and the complete destruction of the plant. Plant cutting and feeding on the tassel

*Corresponding author. E-mail: fgjagronomia@zipmail.com.br. Tel: + 55 64 3465 1900.

and ear has also been observed. The reduction in the productivity of corn caused by FAW can reach 60%, depending on the genotype and growth stage of the plant where the damage was caused (Cruz et al., 2008).

The control of FAW has been achieved mainly using chemical insecticides that have an adverse effect on the environment and may promote the selection of resistant insects (Lima et al., 2006). The use of host plant resistance (HPR) has been studied in recent years and has the potential for use as a strategy to control FAW in corn crops. HPR is a desirable tactic because it is compatible with other control methods and often exhibits synergistic effects with insecticides and natural enemies (Azevedo et al., 2002; Janini et al., 2011; Jesus et al., 2014).

The resistance mechanism in corn plants occurs via antibiosis when the negative effects of a resistant plant affect the biology of the insect pest utilizing the plant as a host (Smith, 2005). The effects of an antibiotic plant may range from mild to lethal and are the result of either chemical or morphological plant defenses. Antixenosis is characterized by the presence of morphological or chemical plant factors that adversely alter insect behavior. As a result, the insect may search for an alternate host plant. The plant responds to pest damage by building a tolerance, producing new vegetative and reproductive structures (Smith, 2005; Seifi et al., 2013).

Antibiosis has been shown in AM 013, RO 009 and MA 002 corn genotypes, where there was lower larval viability; and antixenosis was found in RR 168 and PA 110, where lower leaf consumption by FAW occurred (Lima et al., 2006). Cunha et al. (2008) observed antibiosis in BRS Missões - B and BR 111 VI Sel. Dent C, which affected the larval stage of FAW.

The advancement of biotechnology has led to the development of genetically modified (GM) plants, which can now be considered an additional strategic component of Integrated Pest Management programs, or IPMs (Betz et al., 2000). In Brazil, the use of plants modified with the *Bacillus thuringiensis* (Bt) gene, which is expressed by the Cry protein, has been the primary tactic employed to control FAW in corn crops (Waquil et al., 2002). However, the improper application of this strategy comes with certain risks; as with other strategies, failure to observe the refuge rules and the absence of pest monitoring can lead to the selection of resistant insects (Storer et al., 2010).

Given the importance of FAW and the scarcity of information about how HPR is used to control this pest, this study aimed to evaluate the resistance in conventional and transgenic corn genotypes to FAW.

MATERIALS AND METHODS

The experiment was conducted at the Agricultural Entomology Laboratory of the Goiano Federal Institute - Campus Urutaí - GO (temperature $25 \pm 2^\circ\text{C}$, relative humidity $60 \pm 10\%$; photophase 14

h light). 12 corn genotypes were evaluated (transgenic hybrids: 30A91 PW, 20A78 HX, Impacto VIP 3, 20A55 HX, NS90 PRO 2, Maximus VIP 3, BX 1293YG, RB 9004 PROVTPRO, Feroz VIP 3 and LG 6036 PRO; a conventional hybrid: AG 1051 and the variety: AL Bandeirante). Seeds of these genotypes were sown in 5 L pots in a greenhouse to obtain leaves for the maintenance and preparation of laboratory trials.

To obtain FAW larvae, pairs of moths were kept in polyvinyl chloride (PVC) cages 10 cm in diameter and 21.5 cm in height. These cages were lined with paper to provide a location for oviposition, and they were capped with "voiale". Cotton balls soaked in a 10% honey solution were kept in the cages to feed the moths. The oviposits were collected daily, separated and placed in 100 mL plastic containers containing 5 g of artificial diet. These containers were kept in the room described in the previous paragraph. The artificial diet was prepared according to Kasten Junior et al. (1978).

Larvae were separated during the second instar (approximately 4 mm) and placed into individual 50 mL plastic containers with 5 g of artificial diet. These containers were covered with acrylic (2.5 cm in diameter) and kept in a room (temperature $25 \pm 2^\circ\text{C}$, relative humidity $60 \pm 10\%$; photophase 14 hours) until pupae formation. The pupae were sexed, and males and females were transferred to cylindrical plastic tubes ($\varnothing = 10.5\text{ cm}$, $h = 15\text{ cm}$) after emergence to continue the insect colony.

Antibiosis between *S. frugiperda* and corn genotypes

Newly hatched FAW caterpillars were separated into individual Petri dishes 6 cm in diameter with humidified filter paper and corn leaves (30 days old), which was then closed using a polyethylene film. Fresh food was provided daily.

The following biological parameters were evaluated: (a) Larval stage: the viability of the larval stage and weight of larvae at ten days; and (b) pupal stage: the viability and weight of pupae at 24 h of age. After emergence, the moths were not fed, and the longevity of the adults was evaluated. For this experiment, a completely randomized design with 20 repetitions was adopted.

Aversion to feeding and attractiveness under no- and free-choice test conditions

The attractiveness of the corn to FAW larvae in the second instar was assessed for each genotype 25 days after emergence. Leaf disks were cut into 2.5 cm diameter disks and distributed in a circular manner in a Petri dish (14 cm in diameter) over moistened filter paper.

During the attractiveness free choice feeding test, 12 caterpillars (2nd instar) were released at the center of the Petri dish. The attractiveness of each foliar disk to the caterpillars was evaluated by counting the number of disks fed upon at 1, 3, 5, 10, 15, and 30 min and 1, 2, 6, 12 and 24 h after release. When 80% of the leaf area of one of the genotype leaf disks had been consumed, the experiment ended. The experimental design adopted was a randomized block with ten repetitions.

The attractiveness no choice test followed the same methodology described previously, except that one genotype was made available in each Petri dish (6 cm diameter). To evaluate whether there was an aversion to feeding, two leaf disks (2.5 cm in diameter) were removed equidistant from the leaves. One was offered to the insects and the other, known as the aliquot, was oven-dried at 60°C for 48 h. The amount of dry matter consumed by the FAW larvae was determined by taking the difference between the weight as measured before the experiment and the remaining portion of the disk post-experiment. A completely randomized design with 20

Table 1. Weight of larvae (10 days - g) and pupae (24 h - g), larval and pupal viability (%), adult longevity (days), cycle (days) to *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in different corn genotypes.

Genotypes ¹	Events	Larva		Pupa		Adult	Cycle
		WEI	VIA	WEI	VIA	LON	
20A55 HX	TC1507	0.03 ^b	10.0 ^c	0.12 ^{ab}	5.00 ^c	-	-
20A78 HX	TC1507	0.01 ^b	0.00 ^c	-	0.00 ^c	-	-
30A91 PW	MON89034. TC1507	0.01 ^b	5.00 ^c	-	5.00 ^c	-	-
AG 1051	Convencional	0.27 ^a	85.0 ^a	0.18 ^a	85.0 ^a	4.06	26.00 ^b
AL Bandeirante	Convencional	0.25 ^a	90.0 ^a	0.16 ^{ab}	90.0 ^a	4.12	25.12 ^b
BX 1293 YG	MON810	0.06 ^b	45.0 ^b	0.16 ^{ab}	45.0 ^b	4.00	31.85 ^a
Feroz VIP 3	BT11. MIR162	-	0.00 ^c	-	0.00 ^c	-	-
Impacto VIP 3	BT11. MIR162	-	0.00 ^c	-	0.00 ^c	-	-
LG 6036 PRO	MON89034	0.03 ^b	0.00 ^c	-	0.00 ^c	-	-
Maximus VIP 3	BT11. MIR162	-	0.00 ^c	-	0.00 ^c	-	-
NS90 PRO 2	MON89034	-	0.00 ^c	-	0.00 ^c	-	-
RB 9004 PRO	MON89034	0.02 ^b	10.0 ^c	0.12 ^b	10.0 ^c	3.0	31.50 ^a
F Test	-	18.74 ^{**}	37.63 ^{**}	4.12 ^{**}	40.49 ^{**}	0.42 ^{NS}	26.92 ^{**}
<i>P value</i>	-	<0.0001	0.0000	0.0064	0.0000	0.7375	0.0001

¹Means followed by the same letter in the column are not significantly different by the Scott-Knott test at 5% probability. NS = non significant, ** = significant at 1%. Weight of larvae and pupae (WEI), larval and pupal viability (VIA) and adult longevity (LON).

repetitions was adopted.

Statistical analysis

The data were subjected to an analysis of variance, or Fisher's exact test, followed by Tukey's test (5% probability) using the software SISVAR version 5.1 (Ferreira, 2011).

RESULTS AND DISCUSSION

Antibiosis between *S. frugiperda* and corn genotypes

The corn genotype consumed influenced the development of FAW at all life cycle stages except the adult stage (Table 1). Caterpillars that consumed AG 1051 (0.27 g) and AL Bandeirante (0.25 g) exhibited higher body weights. Caterpillars that feed on the leaves of the 30A91 PW (0.01 g), 20A78 HX (0.01 g), 20A55 HX (0.03 g), LG 6036 PRO (0.03 g), BX 1293 YG (0.06 g) and RB 9004 PRO (0.02 g) genotypes had the lowest weights. The NS90 PRO 2, Maximus VIP 3, Feroz VIP 3 and Impacto VIP 3 genotypes caused 100% larval mortality in less than 10 days after the caterpillars had hatched.

Those caterpillars that were fed on conventional genotypes showed the highest larval weights, and the caterpillars that were fed on transgenic genotypes had the lowest larval weights. This may be an indication of the cumulative detrimental effect of the altered corn on FAW at this phase, which resulted in the death of the larvae within 10 days. This can be explained by the inclusion of Cry genes in the genome of these genotypes. A Cry protein from *B. thuringiensis* is capable of forming crystals

containing endotoxins that have an insecticidal effect on lepidoptera larvae (Schnepf et al., 1998).

These data are similar to those reported by Williams et al. (1997) and Buntin et al. (2001), who observed that FAW that fed on GM corn genotypes exhibited lower weights than those that fed on conventional genotypes. The same authors observed that larvae that fed on GM corn also showed prolongation of larval development compared with caterpillars that fed on conventional corn. Mendes et al. (2011) found that even when larvae were fed hybrid Bt corn and survived, the caterpillars' biomass was reduced compared those fed non-Bt corn.

The larval viability of FAW was also influenced by corn genotypes. When fed on AG1051 and AL Bandeirante leaves, the caterpillars showed the highest viability indices, 85 and 90%, respectively. When the caterpillars were fed the NS90 PRO 2, Maximus VIP 3, LG 6036 PRO, Feroz VIP 3 Impacto VIP 3 and 20A78 HX genotypes, they did not reach the next stage.

This impact may be the result of antibiosis, or a preference for other food types, particularly given the presence of the toxic proteins Cry1A 105 and Cry2Ab2 (PRO and PRO 2), Cry1F (HX), Cry1Ab and VIP 3Aa20 (VIP 3), which has deleterious effects on FAW. Similar results were obtained by Fernandes et al. (2003) and Michelotto et al. (2011), who concluded that Bt corn negatively impacted FAW at the larval phase.

The caterpillars fed the AG 1051 genotype showed the greatest pupal weight (0.18 g), whereas those that fed on RB 9004 PRO had the lowest weight (0.12 g). However, the 20A55 HX, BX 1293 YG and AL Bandeirante genotypes did not yield significantly different weights than AG 1051 or RB 9004 PRO.

Table 2. Average number of third-instar larvae of *S. frugiperda* (Lepidoptera: Noctuidae) attracted to corn genotypes and leaf mass consumed (mg) in free choice test.

Genotypes ¹	Events	Time in minutes					
		1	3	5	10	15	30
20 A 55 HX	TC1507	0.00 ^b	0.00 ^a	0.00 ^b	0.00 ^b	0.00 ^b	0.00 ^b
20 A 78 HX	TC1507	0.60 ^b	0.60 ^a	0.60 ^a	0.60 ^a	0.20 ^b	0.00 ^b
30 A 91 PW	MON89034. TC1507	0.20 ^b	0.20 ^a	0.10 ^b	0.00 ^b	0.00 ^b	0.00 ^b
AG 1051	Convencional	0.20 ^b	0.10 ^a	0.30 ^b	0.10 ^b	0.30 ^a	0.10 ^b
AL Bandeirante	Convencional	0.50 ^b	0.50 ^a	0.30 ^b	0.20 ^b	0.40 ^b	0.20 ^a
BX 1293 YG	MON810	0.20 ^b	0.20 ^a	0.30 ^b	0.30 ^b	0.40 ^a	0.40 ^a
Feroz VIP 3	BT11. MIR162	0.50 ^b	0.50 ^a	0.50 ^a	0.50 ^a	0.30 ^a	0.40 ^a
Impacto VIP 3	BT11. MIR162	0.50 ^b	0.40 ^a	0.60 ^a	0.80 ^a	0.70 ^a	0.30 ^a
LG 6036 PRO	MON89034	1.10 ^a	0.70 ^a	1.20 ^a	1.10 ^a	0.70 ^a	0.40 ^a
Maximus VIP 3	BT11. MIR162	0.40 ^b	0.40 ^a	0.70 ^a	0.80 ^a	0.50 ^a	0.40 ^a
NS90 PRO 2	MON89034	0.20 ^b	0.20 ^a	0.20 ^b	0.00 ^b	0.00 ^b	0.00 ^b
RB 9004 PRO	MON89034	0.30 ^b	0.30 ^a	0.40 ^b	0.10 ^b	0.00 ^b	0.00 ^b
Teste F	-	2.47 ^{**}	1.54 ^{NS}	2.42 [*]	3.82 ^{**}	3.05 ^{**}	2.38 [*]
P valor	-	0.0087	0.1281	0.0099	<0.0001	0.0013	0.0115

Genotypes ¹	Events	Time in hours					CON
		1	2	6	12	24	
20 A 55 HX	TC1507	0.10 ^a	0.00 ^b	0.00 ^b	0.00 ^b	0.30 ^b	10.40 ^a
20 A 78 HX	TC1507	0.20 ^a	0.00 ^b	0.30 ^a	0.20 ^b	0.30 ^b	09.90 ^a
30 A 91 PW	MON89034. TC1507	0.00 ^a	0.00 ^b	0.00 ^b	0.10 ^b	0.20 ^b	09.70 ^a
AG 1051	Convencional	0.30 ^a	0.60 ^a	0.40 ^a	0.70 ^a	1.60 ^a	11.00 ^a
AL Bandeirante	Convencional	0.10 ^a	0.30 ^b	0.40 ^a	0.40 ^a	0.90 ^a	07.80 ^a
BX 1293 YG	MON810	0.00 ^a	0.00 ^b	0.00 ^b	0.10 ^b	0.30 ^b	09.10 ^a
Feroz VIP 3	BT11. MIR162	0.20 ^a	0.20 ^b	0.50 ^a	0.20 ^b	0.20 ^b	06.30 ^a
Impacto VIP 3	BT11. MIR162	0.20 ^a	0.70 ^a	0.20 ^b	0.30 ^b	0.30 ^b	04.10 ^a
LG 6036 PRO	MON89034	0.30 ^a	0.20 ^b	0.50 ^a	0.30 ^b	1.20 ^a	06.10 ^a
Maximus VIP 3	BT11. MIR162	0.20 ^a	0.30 ^b	0.30 ^a	0.20 ^b	0.50 ^b	03.60 ^a
NS90 PRO 2	MON89034	0.00 ^a	0.00 ^b	0.00 ^b	0.10 ^b	0.10 ^b	05.40 ^a
RB 9004 PRO	MON89034	0.00 ^a	0.10 ^b	0.10 ^b	0.00 ^b	0.40 ^b	07.00 ^a
Teste F	-	1.09 ^{NS}	3.33 ^{**}	2.29 [*]	2.29 [*]	4.98 ^{**}	1.53 ^{NS}
P valor	-	0.3717	0.0004	0.0148	0.0149	<0.0001	0.132

¹Means followed by the same letter in the column are not significantly different by the Scott-Knott test at 5% probability. NS = non significant, * = significant at 5%, ** = significant at 1%. Mass consumed (CON).

The lower weight and reduced viability of FAW pupae that were fed the transgenic genotype may be due to the presence of the Bt gene, which expresses toxic proteins. This is similar to Fernandes et al. (2003), where the weights of FAW pupae that fed on conventional corn were significantly higher than those that fed on GM corn MON810 (Cry 1 AC).

The genotypes in the present study influenced the viability of FAW pupae, and the caterpillars that fed on the conventional genotypes AL Bandeirante (90%) and AG 1051 (85%) had the highest pupal viability. The 20A55 HX (5%), 30A91 PW (5%) and RB PRO 9004 (10%) genotypes elicited the lowest viability. Of the intermediate results, the genetically modified BX 1293 YG genotype (45%) elicited the highest pupal viability.

Caterpillars that fed on NS90 PRO 2, Maximus VIP 3, LG6036 PRO, Feroz VIP 3, Impacto VIP 3, and 20A78 HX did not yield values for larval viability because they failed to complete this stage. Of the adults that did emerge, no significant differences were observed for this parameter.

Aversion to feeding and attractiveness in the free and no choice tests

The results obtained from the attractiveness free and no choice tests are presented in Table 2. The attractiveness of FAW (2nd instar) to the various genotypes varied significantly except for at the 3 min and 1 h sample points.

Table 3. Average number of third-instar larvae of *S. frugiperda* (Lepidoptera: Noctuidae) attracted to corn genotypes and leaf mass consumed (mg) in no choice test.

Genotypes ¹	Events	Time in minutes					
		1	3	5	10	15	30
20 A 55 HX	TC1507	0.25 ^b	0.15 ^c	0.15 ^b	0.30 ^b	0.25 ^b	0.15 ^b
20 A 78 HX	TC1507	0.60 ^a	0.20 ^c	0.25 ^b	0.20 ^c	0.20 ^b	0.20 ^b
30 A 91 PW	MON89034. TC1507	0.30 ^b	0.00 ^c	0.25 ^b	0.35 ^b	0.45 ^a	0.50 ^a
AG 1051	Convencional	0.80 ^a	0.80 ^a	0.45 ^a	0.80 ^a	0.75 ^a	0.75 ^a
AL Bandeirante	Convencional	0.45 ^a	0.50 ^b	0.55 ^b	0.65 ^a	0.60 ^a	0.60 ^a
BX 1293 YG	MON810	0.40 ^b	0.30 ^c	0.30 ^b	0.40 ^b	0.40 ^a	0.30 ^b
Feroz VIP 3	BT11. MIR162	0.50 ^a	0.30 ^c	0.75 ^a	0.80 ^a	0.55 ^a	0.45 ^a
Impacto VIP 3	BT11. MIR162	0.60 ^a	0.30 ^c	0.50 ^a	0.55 ^a	0.45 ^a	0.45 ^a
LG 6036 PRO	MON89034	0.20 ^b	0.15 ^c	0.05 ^b	0.00 ^c	0.10 ^b	0.10 ^b
Maximus VIP 3	BT11. MIR162	0.35 ^b	0.25 ^c	0.45 ^a	0.40 ^b	0.40 ^a	0.35 ^b
NS90 PRO 2	MON89034	0.15 ^b	0.20 ^c	0.10 ^b	0.05 ^c	0.20 ^b	0.25 ^b
RB 9004 PRO	MON89034	0.55 ^a	0.40 ^c	0.60 ^a	0.50 ^a	0.35 ^b	0.30 ^b
Teste F	-	3.28 ^{**}	4.64 ^{**}	4.71 ^{**}	7.13 ^{**}	3.21 ^{**}	3.49 ^{**}
P valor	-	0.0003	0.0000	0.0000	0.0000	0.0004	0.0002

Genotypes ¹	Events	Time in hours					CON
		1	2	6	12	24	
20 A 55 HX	TC1507	0.10	0.10	0.25	0.25	0.20 ^b	10.45
20 A 78 HX	TC1507	0.15	0.20	0.30	0.15	0.35 ^b	09.60
30 A 91 PW	MON89034. TC1507	0.20	0.20	0.25	0.25	0.35 ^b	11.64
AG 1051	Convencional	0.35	0.45	0.25	0.40	0.70 ^a	14.10
AL Bandeirante	Convencional	0.20	0.20	0.10	0.25	0.70 ^a	10.80
BX 1293 YG	MON810	0.10	0.10	0.35	0.10	0.40 ^b	07.70
Feroz VIP 3	BT11. MIR162	0.20	0.30	0.20	0.05	0.40 ^b	07.50
Impacto VIP 3	BT11. MIR162	0.30	0.15	0.30	0.10	0.20 ^b	08.90
LG 6036 PRO	MON89034	0.15	0.15	0.40	0.15	0.45 ^b	06.40
Maximus VIP 3	BT11. MIR162	0.15	0.25	0.25	0.10	0.35 ^b	07.90
NS90 PRO 2	MON89034	0.05	0.20	0.10	0.05	0.05 ^b	09.00
RB 9004 PRO	MON89034	0.20	0.15	0.35	0.35	0.40 ^b	13.40
Teste F	-	0.94 ^{NS}	1.14 ^{NS}	0.88 ^{NS}	1.73 ^{NS}	3.29 ^{**}	0.9377 ^{NS}
P valor	-	0.4939	0.3254	0.5556	0.0665	0.0003	0.5049

¹Means followed by the same letter in the column are not significantly different by the Scott-Knott test at 5% probability. NS = non significant, * = significant at 5%, ** = significant at 1%. Mass consumed (CON).

The Feroz VIP 3, Impacto VIP 3, LG 6036 PRO and Maximus VIP 3 genotypes were more attractive to FAW from 5 to 30 min after release. Over time, the caterpillars became stimulated by conventional genotypes AG 1051 and AL Bandeirantes, as shown from 6 to 24 h after the release of the caterpillars.

This lower preference of the FAW larvae for the transgenic genotypes may be associated with insect perception of the Bt protein in food or damage to the microvilli in the caterpillars' gut, which is caused by the endotoxin present in the protein crystals of Bt (Schnepf et al., 1998). Boiça Junior et al. (2012) also observed an initially greater attractiveness of *Alabama argilacea* (Lepidoptera: Noctuidae) on the cotton cultivar NuOpal (GM), and the cultivar FMX 966 (conventional) was more attractive to this caterpillar over time. Berdegué et al.

(1996) and Stapel et al. (1998) studied the feeding of diets with or without the added protein Cry 1A (b) to *Spodoptera exigua* (Lepidoptera: Noctuidae) and observed a greater preference for the diet without the toxin. This is evidence that the aversion to specific genotypes is related to the presence or absence of a toxin in the diet of the caterpillar.

The attractiveness of specific genotypes to FAW in the no choice test was significantly different at 1, 3, 5, 10, 15 and 30 min and 24 h after the release of the insects (Table 3).

In the free choice test, the Feroz VIP 3 and Impacto VIP 3 genotypes were more attractive to FAW from 5 to 30 min. Although the conventional genotypes AG 1051 and AL Bandeirante were attractive to the caterpillars at all sample points, especially during the early periods, the

results show that they were most attractive 6 to 24 h after the release of the caterpillars. This proves that corn genotypes with inserted Bt genes can be used as an IPM strategy to control FAW, particularly in conjunction with other control tactics.

Williams et al. (1997) found that the leaf area of corn consumed by FAW was significantly lower in transgenic hybrids. Waquil et al. (2002) reported that the 2722 IMI hybrid expressing the Cry 1F toxin is resistant to FAW and has a degree of resistance immunity, and a hybrid expressing the Cry 1A (b) toxin and natural resistance was moderately resistant to FAW larvae.

Others mechanisms that may reveal the cause of this resistance may be involved, as Williams et al. (1998) data show. These researchers conducted tests to determine which mechanisms supported corn's resistance to FAW and observed that morphological characteristics such as hardness of the grains and leaves are factors involved in the expression of resistance. May be these genotypes also have this characteristic, which contributed to the manifestation of resistance to FAW in this study.

Conclusions

The transgenic NS90 PRO2, Maximus VIP 3, Feroz VIP 3 and Impacto VIP 3 genotypes elicited an aversion and antibiosis reaction from FAW. The transgenic HX 20A55, 30A91 PW, LG 6036 PRO, 20A78 HX and BR 9004 PRO genotypes were moderately resistant to the insect, whereas the conventional AG 1051 and AL Bandeirante genotypes were highly susceptible and the transgenic BX 1293 YG genotype was susceptible to FAW.

Conflict of Interests

The authors have not declared any conflict of interests.

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