FALL ARMYWORM SURVIVORSHIP AND DAMAGE IN BOLLGARD AND BOLLGARD 2 COTTON

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Abstract

Fall armyworm, *Spodoptera frugiperda* (J. E. Smith), larvae were infested on Bollgard and Bollgard 2 commercial cultivars using two methods. Larvae were confined on the white flowers of field-grown plants with cages and exposed to excised cotton tissue in plastic dishes within the laboratory. In field tests, Bollgard 2 significantly reduced the percentage of bolls penetrated by 5-d-old fall armyworm larvae compared to that on non-Bt cotton. In the laboratory test, mortality of neonate (L1) stage larvae on Bollgard 2 occurred significantly faster compared to that on Bollgard or non-Bt cultivars.

Introduction

Fall armyworm, *Spodoptera frugiperda* (J. E. Smith), has become a more common pest of cotton in recent years. This pest can cause significant economic losses, and has ranged from the 8th to 12th most important insect pest of U.S. cotton during 2003-2004 (Williams 2004, 2005). During 2005, persistent infestations of fall armyworm were reported in non-Bt, Bollgard, and Bollgard 2 cotton fields in Arkansas, Louisiana, Mississippi, and Texas. Although boll injury was observed in many of these fields, major yield losses were not reported.

Advancements in genetic engineering of plants have allowed the development of transgenic *Bacillus thuringiensis* Berliner *var. kurstaki* (Bt) cotton plants that confer resistance to a broader range of insect pests. Bollgard was the first Bt cotton and was the result of a transformation coded to express a single insecticidal crystal protein (C*ry1Ac).* Bollgard provides excellent control of tobacco budworm, *Heliothis virescens* (F.), and pink bollworm, *Pectinophora gossypiella* (Saunders). Bollgard has demonstrated limited efficacy against other Lepidopteran pests of cotton. Bollgard 2 plants produce two insecticidal proteins *(Cry1Ac* and C*ry2Ab).* This stacked gene combination provides good to excellent activity against a wider range of pests including tobacco budworm; pink bollworm; bollworm, *Helicoverpa zea* (Boddie); cabbage looper, *Trichoplusia ni* (Hübner); soybean looper, *Pseudoplusia includens* (Walker)*;* and beet armyworm, *Spodoptera exigua* (Hübner) (Allen et al. 2000, Chitkowski et al. 2003).

Many factors influence the efficacy of a Bt plant against target pests. These factors include the plant structure on which a larva is feeding (Greenplate 1999, Gore 2001, Sparks and Norman 2002), amount of photosynthetic constituents of the plant tissue (Abel and Adamczyk 2004), age of larvae feeding (Tindall et al. 2005), and fluxes in gene expression (Olsen 2005). Much of this research has been accomplished with Bollgard during its eight years of commercialization. However, the transient nature of fall armyworm has made it difficult to collect this information for Bollgard 2. Coots and Pitts (2003) demonstrated that Bollgard 2 was more efficacious against an artificial infestation of fall armyworm than Bollgard or non-Bt cotton. The objectives of these studies were to further understand larval survival and development of fall armyworm on Bollgard and Bollgard 2 cotton, as well as characterize their damage to fruiting structures.

Materials and Methods

Field Tests. Experiments were conducted during 2005 at the Macon Ridge Research Station near Winnsboro, LA, in Franklin Parish. There were four replications of three treatments, Bollgard (Stoneville 5599BR), Bollgard 2 (Stoneville 4646B2R) and non-Bt (Stoneville 4793R), arranged in a randomized block design. Fall armyworm larvae were removed from a colony that was initiated from a collection in cotton during September 2004 (C-FAW). Ten first position white flowers were infested with five to ten 2-d-old larvae (L1 stage) or one 5-d-old larva (L3 stage). Infestations with 2-d-old larvae were conducted only on 20, 26 Jul. Infestations with 5-d-old larvae were performed on 20, 26 Jul and 2 Aug. Exclusion cages (10 x 14.5 cm) were constructed of a nylon mesh fabric and were closed tightly around the stem of the white flower with a drawstring. The cages were removed at 7 days after infestation (DAI) and the infested fruiting forms (bolls) were assessed for injury and surviving larvae. Damage was categorized as abscised bolls, bracts with feeding injury, and penetrated bolls. The results for all variables were converted to percentages and were analyzed using PROC MIXED (SAS Institute 1998).

Laboratory Experiments. Feeding assays were performed with two colonies of fall armyworm. The same colony used in the field tests (C-FAW) was included in these feeding studies. Another colony was developed by infesting samples of the C-FAW strain on Bt (YieldGard) corn and collecting the survivors that successfully completed their life cycle (YG-FAW). Both C-FAW and YG-FAW colonies were exposed to reproductive tissue of Bollgard, Bollgard 2, and non-Bt cotton plants from the plots planted in the field tests. Tissue was collected after plants began to flower. Ten neonate stage larvae (L1) were placed on a single square in 30 ml plastic cups. Mortality was rated 2 d after infestation and every 2 to 3 d after the initial rating until each larva died or pupated. At the first rating, each surviving larva was placed on a square in an individual plastic cup. Larvae were provided freshly harvested squares at each rating interval. Small bolls were used when squares were no longer available. The experiment was initiated with 100 larvae per treatment and repeated three times. Larval mortality, d to larval pupation, and pupal weights were recorded for each insect. Data were analyzed with PROC MIXED (SAS Institute 1998) to compare treatment differences in fall armyworm mortality.

Results and Discussion

Field Experiments. There were no significant differences among Bollgard, Bollgard 2, and the non-Bt cultivars for any variable measured at 7 DAI for 2-d-old fall armyworm larvae infested on white flowers (Table 1). For the 5-d-old larvae, there were no significant differences among treatments for abscised bolls and damaged bracts (Table 2). However, significant treatment effects were observed for penetrated bolls and number of larvae. Significantly fewer penetrated bolls were detected in the Bollgard 2 plots compared to that in the non-Bt plots. Bollgard and Bollgard 2 plots had significantly fewer fall armyworm larvae compared to that in the non-Bt cotton plots.

Table 1. Fall armyworm (2-d-old larvae) injury to bolls and larval survival at 7 days after infestation on white flowers of Bt and conventional cotton plants.

Treatment	% Abscission	% Damaged Bracts	% Penetrated Bolls	No. Larvae
Bollgard	19.1 ± 7.8	51.9 ± 6.0	18.8 ± 9.3	0.9 ± 0.5
Bollgard 2	15.5 ± 6.8	37.9 ± 10.5	17.5 ± 11.6	0.5 ± 0.3
Non-Bt	26.3 ± 7.3	40.9 ± 12.4	26.3 ± 13.2	0.6 ± 0.4
	F = 0.56	F = 0.67	F = 0.28	F = 0.23
	df = 2,14	Df = 2,14	df = 2,14	df = 2,14
	P = 0.5846	P = 0.5276	P = 0.7633	P = 0.7983

Table 2. Fall armyworm (5-d-old larvae) injury to bolls and larval survival at 7 days after infestation on white flowers of Bt and conventional cotton plants.

Treatment	% Abscission	% Damaged Bracts	% Penetrated Bolls	No. Larvae
Bollgard	17.1 ± 6.4	38.6 ± 7.2	35.4 ± 7.0ab	5.0 ± 1.9b
Bollgard 2	28.6 ± 8.8	26.9 ± 5.6	26.9 ± 6.5b	6.0 ± 4.4b
Non-Bt	23.5 ± 7.3	41.1 ± 8.9	50.5 ± 7.3a	17.5 ± 6.1a
	F = 0.67	F = 1.19	F = 4.63	F = 3.61
	df = 2,30	df = 2,30	df = 2,30	df = 2,30
	P = 0.5177	P = 0.3191	P = 0.0177	P = 0.0394

Laboratory Experiments. Regardless of the colony, larval mortality was higher for fall armyworm exposed to Bollgard 2 tissue compared to that on Bollgard and non-Bt tissue (Figure 1). At the initial rating after infestation, YG-FAW survival on Bollgard 2 was slightly higher than that of the C-FAW colony. By 7 DAI, mortality was nearly identical with only one YG-FAW larva surviving until pupation. There was little effect of Bollgard on larvae from either colony when compared to those larvae exposed to non-Bt cotton. These data also suggest that the YG-FAW colony was more robust than the C-FAW colony. The mean time for maximum mortality of larvae exposed to Bollgard 2 ranged from 2 to 2.4 d (Table 3). The time for larval mortality generally was faster on Bollgard 2 than for larvae exposed to Bollgard or non-Bt cotton. Although there were no differences in d to pupation or pupal weights, none of the C-FAW larvae and only one of the YG-FAW larvae survived until pupation.

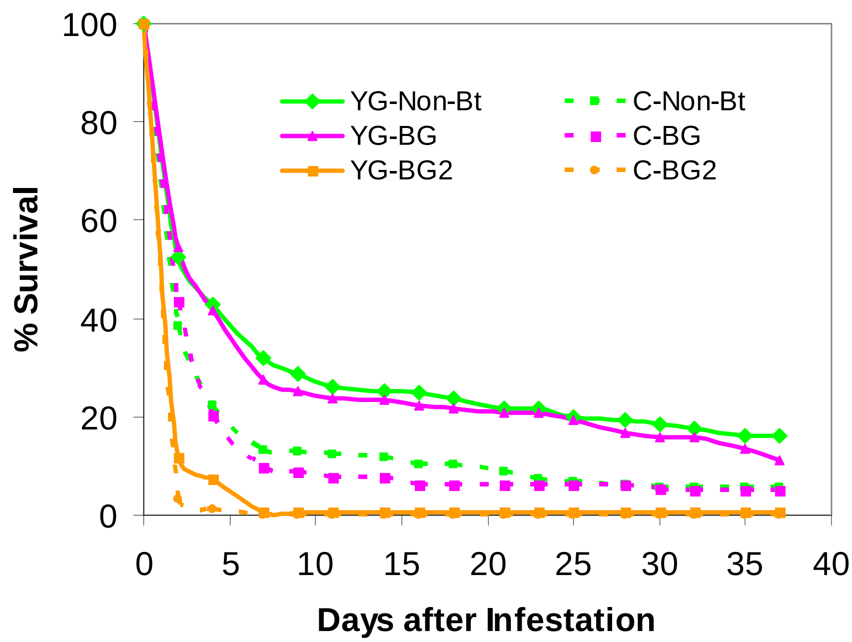

Figure 1. Larval survival of two colonies (C-FAW and YG-FAW) of fall armyworm larvae offered Bt and non-Bt cotton tissue.

Table 3. Larval mortality/development times and pupal weights of two colonies (C-FAW and YG-FAW) of fall armyworm larvae exposed to Bt and non-Bt cotton tissue.

Treatment	FAW-colony	DTD[1]	DTP[2]	Pupal Wt.[3]
Bollgard	C-FAW	3.6 ± 0.3bc	27.8 ± 0.6	116.9 ± 5.5
	YG-FAW	6.5 ± 0.7a	27.2 ± 0.6	110.2 ± 5.0
Bollgard 2	C-FAW	2.0 ± 0.1d	n/a[4]	n/a[4]
	YG-FAW	2.4 ± 0.1cd	36.0 ± 0.0	181.0 ± 0.0
Non-Bt	C-FAW	4.0 ± 0.4b	29.1 ± 1.2	109.5 ± 9.1
	YG-FAW	5.9 ± 0.6a	27.3 ± 0.5	103.5 ± 4.2

[1]Days to Death – Treatment: F = 43.59, df = 2, 1254; P <.0001; FAW-colony: F = 33.19, df = 1, 1254; P <.0001; Treatment*FAW-colony: F = 6.312, df = 2, 1254; P = 0.0019.
[2]Days to Pupation – Treatment: F = 4.92, df = 2, 78; P = 0.097; FAW-colony: F = 2.81, df = 1, 78; P = 0.0976; Treatment*FAW-colony: F = 0.61, df = 1, 78; P = 0.4376.
[3]Pupal Weight – Treatment: F = 5.07, df = 2, 75; P = 0.0086; FAW-colony: F = 1.01, df = 1.75, P = 0.3187; Treatment*FAW-colony: F = 0.00, df = 1, 75; P = 0.9517.
[4]100% larval mortality occurred before pupation.

Bollgard 2 generally performed better than Bollgard against fall armyworm in these tests. Bollgard 2 demonstrated significant levels of control, but was not immune to fall armyworm feeding, especially from L3 stage larvae. However, when L1 stage larvae were started on Bollgard 2 tissue, few larvae completed development to pupation. In most situations, Bollgard 2 should provide effective control of this species. But in instances of persistent fall armyworm infestations, supplemental foliar insecticides should be considered an option.

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