FALL ARMYWORM SURVIVORSHIP AND DAMAGE POTENTIAL ON SELECTED TRANSGENIC COTTONS

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Abstract

Field trials used a no-choice caging protocol to evaluate fall armyworm, *Spodoptera frugiperda* (J. E. Smith), mortality and damage potential on cotton lines expressing *Bacillus thuringiensis* crystal (Cry) proteins. Third instars were removed from a laboratory colony and infested on selected fruiting structures of non-Bt, Bollgard® (Cry1Ac), Bollgard II® (Cry1Ac + Cry2Ab), and WideStrike™ (Cry1Ac + Cry1F) cotton lines. Nylon mesh cages were placed over each larva and fruiting form. Mortality and damage data were recorded at 2-3 days after infestation (DAI) on squares, 5-6 DAI on white flowers, and 5-6 DAI on bolls. Significant treatment effects in larval mortality and damage to fruiting structures were observed between cotton lines. Fall armyworm was consistently more susceptible to WideStrike fruiting forms compared to those of the other cotton lines.

Introduction

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith), is a migratory pest of many U.S. cropping systems including cotton. Fall armyworm is an occasional to sporadic pest in many cotton areas each year. This pest does not overwinter in most cotton production regions, but migrates northward each year from warmer climates in South Florida, South Texas, Mexico, the Caribbean islands, and Central America (Sparks 1979, Knipling 1980, Adamczyk et al. 1997). Infestations are difficult to find in cotton with common sampling protocols and reactive insecticide sprays often yield inconsistent results. Poor insecticide deposition low in the cotton canopy, where fall armyworm larvae are predominately dispersed, can be a primary factor reducing insecticide efficacy. In addition, there are questions concerning the performance of transgenic *Bacillus thuringiensis* Berliner (Bt) cotton lines against this pest. Recently, fall armyworm has become more common even as the acreage of Bt cotton and field corn has increased.

Cotton lines expressing Bt traits were planted on 70% of U.S. cotton acreage during 2009 (Williams 2010). The first transgenic cotton, Bollgard®, was introduced in 1996 by Monsanto (Jackson et al. 2005). The crystal (Cry) protein expressed in Bollgard®, Cry1Ac, provides effective control of the tobacco budworm, *Heliothis virescens* (F.), and pink bollworm, *Pectinophora gossypiella* (Saunders) (Jackson et al. 2005, Leonard et al. 2006). The success of Bollgard® prompted rapid research and discovery of additional Bt toxins for control of lepidopteran insect pests. The first pyramided Bt protein lines included Bollgard II® (Cry1Ac + Cry2Ab) and WideStrike™ (Cry1Ac + Cry1F), which were released in 2003 by Monsanto and in 2005 by Dow AgroSciences, respectively (Siebert et al. 2008). Expression of multiple Bt toxins in cotton plants broadened the spectrum of satisfactory caterpillar control to include bollworm, *Helicoverpa zea* (Boddie), and additional secondary lepidopteran pests (Willrich et al. 2005, Tindall et al. 2006).

Several studies have evaluated Bollgard®, Bollgard II®, and WideStrike™ against heliothines (tobacco budworm and bollworm) and pink bollworm (Henneberry et al. 2001, Sims et al. 2002, Haile et al. 2004, Bommireddy and Leonard 2008). Limited efficacy data has been generated for these technologies against fall armyworm. The objective of this report is to summarize the results of preliminary field trials evaluating the effects of Bollgard®, Bollgard II®, and WideStrike™ on the mortality and damage potential of fall armyworm.

Materials and Methods

Field trials with artificial infestations were conducted at the LSU AgCenter's Macon Ridge Research Station (MRRS) near Winnsboro, LA, during 2009-2010. Bollgard® (Delta & Pine Land Co. 555 BG/RR), Bollgard II® (Stoneville 4554 B2/RF), and WideStrike (Phytogen 485 W/RF) were evaluated against fall armyworm. Phytogen 425RF, a non-Bt line, was utilized as a negative control to standardize larval survivorship and damage for a non-Bt cotton genotype and for comparison to each Bt line. Cotton lines were planted sequentially during May – June to ensure the availability of fruiting forms throughout the duration of the trial. Field plots were managed with recommended agronomic and IPM strategies to optimize plant development and production of fruiting forms.

This study used a laboratory colony of fall armyworm larvae that was generated from a cotton collection during 2005 and supplemented with larvae from field corn in 2006 and 2008. Since the initial collection, the laboratory colony has been maintained on meridic diet according to previously described methods (Adamczyk et al. 1998). The mitochondrial *Cytochrome oxidase I* (COI) gene was used to validate the colony as the corn-cotton strain (Rod Nagoshi, USDA-ARS, Gainesville, FL; personal communication).

Fruiting forms on randomly selected plants within field plots were infested with fall armyworm larvae. First position fruiting structures of the same age on a sympodial branch were infested with a single fall armyworm larva (L3 stage; 30-45 mg) using a camel's hair brush. The fruiting forms included: flower buds (squares) (≈3/8 to 1/2 inch in diameter), white flowers, and bolls (7-10 d after anthesis; ≈200 heat units). After a larva was infested, the fruiting structure was enclosed with a drawstring nylon mesh bag to prevent larval escape and to protect larvae from predators and parasitoids. A minimum of seven replicates, each with 10 – 30 larvae, produced a sample size of 100 larvae for each cotton line and fruiting form combination. Larval mortality and damage were recorded 2-3 days after infestation (DAI) on squares, 5-6 DAI on flowers, and 5-6 DAI on bolls. A larva was scored as dead if it was unable to right itself after being placed on its dorsal surface. A fruiting structure was considered damaged if the outer wall (calyx in squares and carpel in bolls) was completely penetrated or in flowers if female floral parts had evidence of feeding. Data were analyzed using a randomized complete block design (replicates = infestation events) using PROC MIXED. Cotton trait means were compared according to LSMEANS (SAS Institute 2004).

Results and Discussion

Fall armyworm larvae readily consumed squares in the non-Bt control lines. Larval mortality at 2-3 DAI ranged from 2.6% on non-Bt cotton to 5.1% on Bollgard®, 13.3% on Bollgard II®, and 42.7% on WideStrike™ cottons. Larvae successfully penetrated 77.0% of conventional non-Bt squares compared to levels of 76.3%, 54.5%, and 22.4% on Bollgard®, Bollgard II®, and WideStrike™ squares, respectively.

Table 1. Square Infestations with Fall Armyworm at 2-3 DAI

Cotton Line	% Mortality	% Damaged
Conventional non-Bt	**2.6b**	**77.0a**
Bollgard®	**5.1b**	**76.3a**
Bollgard II®	**13.3b**	**54.5b**
WideStrike™	**42.7a**	**22.4c**

Means in the same column followed by different letters are significantly different according to LSMEANS (*P=0.05*).

Results for fall armyworm larvae on flowers of selected Bt cotton were similar to that for squares. At 5-6 DAI, larval mortality ranged from 4.0% on non-Bt flowers to 7.5%, 15.4%, and 38.1% on Bollgard®, Bollgard II®, and

WideStrike™ flowers, respectively. At 5-6 DAI, larvae successfully injured 59.8% of non-Bt cotton white flowers compared with injury levels of 66.2% on Bollgard®, 59.1% on Bollgard II®, and 16.5% on WideStrike™ cotton flowers.

Table 2. White Flower Infestations with Fall Armyworm at 5-6 DAI

Cotton Line	% Mortality	% Damaged
Conventional non-Bt	**4.0b**	**59.8a**
Bollgard®	**7.5b**	**66.2a**
Bollgard II®	**15.4b**	**59.1a**
WideStrike™	**38.1a**	**16.5b**

Means in the same column followed by different letters are significantly different according to LSMEANS (*P=0.05*).

Fall armyworm larval mortality and injury to cotton bolls followed the same trends as that previously observed for other fruiting forms. Deceased larvae ranged from 13.2% on non-Bt bolls to 12.6%, 14.1%, and 45.6% on Bollgard®, Bollgard II®, and WideStrike™ bolls, respectively. Larvae were able to successfully penetrate the carpel wall of 61.9% of non-Bt bolls compared to 69.3% on Bollgard®, 56.0% on Bollgard II®, and 18.4% on WideStrike™ bolls.

Table 3. Boll Infestations with Fall Armyworm at 5-6 DAI

Cotton Line	% Mortality	% Damaged
Conventional non-Bt	**13.2b**	**61.9a**
Bollgard®	**12.6b**	**69.3a**
Bollgard II®	**14.1b**	**56.0a**
WideStrike™	**45.6a**	**18.4b**

Means in the same column followed by different letters are significantly different according to LSMEANS (*P=0.05*).

Fall armyworm larvae were able to successfully injure the non-Bt fruiting forms offered in these studies. Noticeable differences were observed in the ability of this pest to survive and damage WideStrike™ fruiting forms compared to that on the non-Bt and other Bt lines. None of the Bt traits were immune from fall armyworm injury and larval consumption of cotton tissue was required for the Bt protein to produce mortality. Further study is needed with younger larvae on vegetative tissue to determine the ability of fall armyworm to reach sufficient size on these technologies to successfully attack cotton fruiting forms. This research suggests that late instars of fall armyworm (those which primarily attack fruiting forms) are capable of causing significant levels of injury on the majority of Bt technologies currently available, including those appearing to be most effective in controlling this pest.

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