2006 Beltwide Cotton Conferences, San Antonio, Texas - January 3 - 6, 2006

EFFICACY OF WIDESTRIKE AND BOLLGARD II COTTONS AGAINST BOLLWORM UNDER INSECTICIDE-SPRAYED AND NON-SPRAYED CONDITIONS IN NORTH CAROLINA AND VIRGINIA

R. E. Jackson
North Carolina State University
Raleigh, NC
Sean Malone
Virginia Tech
Suffolk, VA
J. R. Bradley
North Carolina State University
Raleigh, NC
John Van Duyn
North Carolina State University
Plymouth, NC
Ames Herbert
Virginia Tech
Suffolk, VA
R. M. Huckaba
Dow AgroSciences
Indianapolis, IN

Abstract

WideStrike™ (Dow AgroSciences, LLC, Indianapolis, IN) cottons were compared with regard to bollworm efficacy with Bollgard II® (Monsanto Co., St. Louis, MO) and/or non-Bt varieties under insecticide-sprayed or non-sprayed conditions in North Carolina and Virginia in 2005. The North Carolina study demonstrated that Bollgard II provided better protection against boll damage from bollworms than WideStrike when faced with moderate populations of bollworms. No differences in larval populations or boll damage levels were detected among the three untreated WideStrike genotypes. The addition of insecticides (pyrethroid + spinosad) reduced damage in all treatments except Bollgard II on two of three sample dates, although this effect was not observed in seedcotton yields. The Virginia field study verified that no differences in efficacy exist among the WideStrike genotypes under modest bollworm pressure, which was verified by seedcotton yields. Seedcotton yields between insect control technologies were not discussed because of agronomic differences between varietal backgrounds. However, differences among WideStrike near-isoline genotypes were detected in both studies; PHY440W produced more seedcotton than PHY475WRF in both trials and out-yielded PHY470WR in the Virginia study. Also, insecticide applications (spinosad only) at the Virginia site had no impact on yields of WideStrike genotypes; however, under modest heliothine larval populations, yield of PHY410R was significantly improved when oversprayed. These data demonstrate that WideStrike cottons provide excellent control of bollworm, although their efficacy is somewhat lower than that of Bollgard II when faced with moderate-to-high bollworm populations. However, because hemipteran pests will likely devalue both technologies, producers are likely to choose varieties based on agronomic performance and not insect control technology.

Introduction

Cottons expressing two *Bacillus thuringiensis* var. *kurstaki* (Berliner) endotoxins that are active against lepidopteran pests were commercialized as Bollgard II® (Monsanto Co., St. Louis, MO) in 2002. These pyramided cottons produce the Cry1Ac and Cry2Ab endotoxins and have exhibited increased efficacy against bollworm, *Helicoverpa zea* (Boddie), above the single-gene Bollgard varieties (Jackson et al. 2003). In 2004, Dow AgroSciences, LLC, (Indianapolis, IN) introduced its pyramided-gene technology onto the market as WideStrike™. These cottons also produce two Bt endotoxins, Cry1Ac and Cry1F, which are both active against caterpillar pests. Initial efficacy comparisons between these technologies indicated that Bollgard II provides better bollworm control than WideStrike under conditions of high bollworm populations (Jackson et al. 2005). However, additional comparisons must be made under diverse environmental conditions, as well as different bollworm population levels.

Thus, results from field studies conducted in North Carolina and Virginia are reported herein where WideStrike genotypes were compared with non-Bt and Bollgard II cottons with regard to efficacy against bollworm.

Materials and Methods

Field experiments were established Edgecombe County, NC, and Suffolk County, VA, in 2005 to evaluate the comparative efficacy of two Bt technologies against bollworm. Bt technologies assessed included WideStrike and Bollgard II, which were also compared to a non-Bt variety. Five cotton genotypes consisting of PHY475WRF (WideStrike), PHY470WR (WideStrike), PHY440W (WideStrike), PHY410R (non-Bt), and DP424BGII/RR (Bollgard II) were tested under insecticide-sprayed and non-sprayed conditions at the NC site, whereas only the WideStrike and non-Bt genotypes were evaluated under similar conditions at the VA test site. The NC experiment was designed as a randomized complete split plot with insecticide regime as the whole plot factor and genotype as the subplot factor, whereas the VA trial was designed as a split-block. Individual plots measured 4 rows by 40 ft on 36 in row-centers.

Cotton genotypes were planted on 23 May and 11 May in NC and VA, respectively. Aldicarb (Temik 15G, Bayer CropScience, Kansas City, MO) was applied in-furrow at planting at 0.75 lb ai/acre for control of early season insect pests. Acephate (Orthene 97PE, Valent USA Corp., Walnut Creek, CA) was applied at 0.75 lb ai/acre and 0.97 lb ai/acre at the NC and VA sites, respectively, as a mid-season overspray for control of plant bugs and stink bugs, as well as to eliminate arthropod natural enemies of heliothines. Insecticide-treated whole plots were treated initially based on a larval threshold in NC, and then sprayed weekly for four weeks. The first two applications were made on 2 and 8 August and consisted of gamma-cyhalothrin (Prolex 1.25 EC, Dow AgroSciences, Indianapolis, IN) at 0.02 lb ai/acre plus spinosad (Tracer 4 SC, Dow AgroSciences, Indianapolis, IN) at 0.089 lb ai/acre. The final two applications were made on 18 and 25 August and consisted of only gamma-cyhalothrin at 0.02 lb ai/acre. Insecticide-sprayed blocks were initially treated based on egg threshold in VA. Applications of spinosad at 0.089 lb ai/acre were made on 5 and 11 August. A hi-boy fitted with two 8002VS nozzles per row and calibrated to deliver 16.5 gpa at 30 psi was used to apply foliar insecticides at each site. Weed control, fertilization, plant growth regulation, and defoliation were achieved as recommended by North Carolina State University or Virginia Polytechnic Institute and State University, dependant upon test site.

Numbers of live bollworm larvae (L3-L5) and associated damage were recorded for 50 bolls per plot on 18 and 25 August, and 1 September in the NC test. Yields at each site were determined by picking the entire lengths of the two middle rows of each subplot using a mechanical cotton picker at both sites. Yields were converted to lbs seedcotton/acre prior to analysis.

Numbers of live bollworm larvae and damaged fruit were converted to percentages and subjected to arcsine square root transformation prior to analysis. Results presented herein consist of the mean percent live bollworm larvae and damage on bolls, as well as seedcotton yields, for each genotype*insecticide regime combination. These data were subjected to ANOVA using PROC MIXED (Littell et al. 1996). Treatments were compared ($P \leq 0.05$) on the basis of least-squares means (PDIFF option of the LSMEANS statement). Results for data transformed before analysis are reported as untransformed arithmetic means.

Results and Discussion

Moderate bollworm populations were encountered at each test site as demonstrated by boll damage levels and/or seedcotton yields. Bollworm larval counts differed among the genotype*insecticide regime combinations with non-sprayed non-Bt possessing the highest percentage of infested bolls on each sample date in NC (Table 1). All other treatment combinations reduced larval infestation of bolls below that of the non-treated, non-Bt variety. No differences were observed in infested bolls among the WideStrike genotypes or the Bollgard II variety, whether sprayed with insecticides or not. Similar results on larval-infested bolls have been documented in previous studies with insecticide-sprayed and non-sprayed WideStrike and/or Bollgard II (Langston et al. 2004; Huckaba et al. 2003; Jackson et al. 2003, 2005).

Differences among genotype*insecticide regime combinations were also observed with regard to the percentage of bolls sustaining damage from bollworms on all three sample dates in NC. The non-sprayed, non-Bt variety sustained significantly higher levels of boll damage compared to all other treatment combinations on all three sample dates in NC (Table 2). Boll damage levels in the control ranged from 12.5% on 18 August to 33.5% on 1 September. Non-sprayed WideStrike and Bollgard II cottons sustained similar levels of boll damage on 18 and 25 August, but Bollgard II had significantly fewer damaged bolls on 1 September when compared to WideStrike genotypes. No differences were detected between insecticide-sprayed and non-sprayed Bollgard II with respect to boll damage levels, whereas insecticide-treated WideStrike cottons had significantly fewer damaged bolls than their non-sprayed counterparts on the final two sample dates. Of the non-sprayed Bt genotypes, only Bollgard II sustained significantly less boll damage than the insecticide-sprayed non-Bt variety. These findings confirm those from previous studies (Jackson et al. 2005), which suggest that Bollgard II provides greater protection against bollworm than WideStrike. The increased bollworm efficacy of Bollgard II over WideStrike is likely due to the increased activity of Cry2A against bollworm as compared to Cry1F (Karim et al. 2000).

Seedcotton yield comparisons will not be made between Bt technologies because of differences in varietal backgrounds. As with boll damage, yields in insecticide-sprayed and non-sprayed Bollgard II did not differ in the NC test (Table 3). Contrary to boll damage results, no yield differences were observed between insecticide-treated and non-treated WideStrike genotypes, which suggest that late-season hemipteran pests may have minimized differences in seedcotton yields. PHY475WRF appeared to possess inferior agronomic characteristics when compared to PHY440W, as yields in PHY475WRF were drastically reduced and comparable to the non-treated, non-Bt variety.
Yields at the VA site also demonstrated reduced seedcotton production by PHY475WRF (whether insecticide-sprayed or non-sprayed) as compared to PHY440W; in addition, PHY440W also out-yielded PHY470WR at this site (Table 4). Both PHY470WR and PHY475WRF produced yields similar to the non-sprayed, non-Bt variety. Because modest heliothine populations were encountered in this test, these differences must be related to inferior agronomics of these two WideStrike genotypes.

These results presented here demonstrate that the pyramided toxins in the WideStrike genotypes provided a high level of bollworm control; however, Bollgard II was more efficacious against bollworm than WideStrike under conditions of moderate bollworm populations. Results also indicated that WideStrike varieties will likely require supplemental insecticide oversprays for adequate bollworm control under certain environmental conditions when moderate-to-high bollworm populations are present. However, the difference observed in bollworm efficacy between WideStrike and Bollgard II cottons will likely be minimized in areas where bug pests are treated during the period in which heliothines are present in these cottons. Because bug pests have risen in pest status across the cotton belt, it is likely that producers will choose varieties based upon agronomic characteristics instead of insect control technology.

Acknowledgments

The authors express appreciation to Dow AgroSciences, LLC, for providing project funding. Special thanks are given to Wayne Modlin for technical assistance.

Literature Cited

Burd, A. D., J. R. Bradley, Jr., J. W. Van Duyn, and F. Gould. 2000. Resistance of bollworm, *Helicoverpa zea*, to cry1A(c) toxin. Proc. Beltwide Cotton Conf. 923-926.

Gould, F., A. Anderson, A. Reynolds, L. Bumgarner, and W. Moar. 1995. Selection and genetic analysis of a *Heliothis virescens* (Lepidoptera: Noctuidae) strain with high levels of resistance to *Bacillus thuringiensis* toxins. J. Econ. Entomol. 88: 1545-1559.

Huckaba, R. M., R. B. Lassiter, X. Huang, C. A. Blanco, V. B. Langston, L. B. Braxton, F. J. Haile, J. M. Richardson, and J. Pellow. 2003. Field efficacy of Dow AgroSciences MXB-13 transgenic cotton for control of cotton bollworm and tobacco budworm. Proc. Beltwide Cotton Conf. 1293-1298.

Jackson, R. E., J. R. Bradley, Jr., and J. W. Van Duyn. 2003. Field performance of transgenic cottons expressing one or two *Bacillus thuringiensis* endotoxins against bollworm, *Helicoverpa zea* (Boddie). J. Cotton Science. 7: 57-64.

Jackson, R. E., J. R. Bradley, Jr., and J. W. Van Duyn. 2005. Comparative efficacy of various Bt technologies against bollworm in North Carolina. Proc. Beltwide Cotton Conf. 1373-1378.

Karim, S., S. Riazuddin, F. Gould, and D. H. Dean. 2000. Determination of receptor binding properties of *Bacillus thuringiensis* delta-endotoxins to cotton bollworm (*Helicoverpa zea*) and pink bollworm (*Pectinophora gossypiella*) midgut brush border membrane vesicles. Pestic. Biochem. And Physiol. 67:198-216.

Langston, V. B., R. B. Lassiter, L. B. Braxton, E. A. Flora, F. J. Haile, B. Haygood, R. M. Huckaba, J. W. Pellow, J. M. Richardson, and J. S. Richburg. 2004. Efficacy of WideStrike Cotton against heliothine insects. Proc. Beltwide Cotton Conf. 1348-1352.

Littell, R. C., G. A. Milliken, W. W. Stroup, and R. D. Wolfinger. 1996. SAS system for mixed models. SAS Institute, Cary, NC.

Table 1. Mean percent live bollworm larvae[a] on bolls in insecticide-sprayed and non-sprayed WideStrike, Bollgard II, and non-Bt cotton genotypes on three sample dates in Edgecombe Co., NC. 2005.

Genotype	**Insecticide**	**18-August**	**25-August**	**1-September**
PHY410R	No	3.5 a	1.5 a	1.0 a
PHY440W	No	0.0 b	0.0 b	0.0 b
PHY470WR	No	0.5 b	0.0 b	0.0 b
PHY475WRF	No	0.0 b	0.5 b	0.0 b
DP424BGII/RR	No	0.0 b	0.5 b	0.0 b
PHY410R	Yes	0.5 b	0.0 b	0.0 b
PHY440W	Yes	0.0 b	0.0 b	0.0 b
PHY470WR	Yes	0.0 b	0.0 b	0.0 b
PHY475WRF	Yes	0.0 b	0.0 b	0.0 b
DP424BGII/RR	Yes	0.0 b	0.0 b	0.0 b

[a]Means within the same column and followed by the same letter are not significantly different, Fisher's Protected LSD ($P\leq0.05$).

Table 2. Mean percent bollworm damaged bolls[a] in insecticide-sprayed and non-sprayed WideStrike, Bollgard II, and non-Bt cotton genotypes on three sample dates in Edgecombe Co., NC. 2005.

Genotype	**Insecticide**	**18-August**	**25-August**	**1-September**
PHY410R	No	12.5 a	24.0 a	33.5 a
PHY440W	No	1.0 b	2.5 b	4.5 b
PHY470WR	No	0.5 b	3.0 b	3.0 b
PHY475WRF	No	0.5 b	2.5 b	2.5 b
DP424BGII/RR	No	0.0 b	1.5 bc	0.0 c
PHY410R	Yes	0.5 b	0.5 b	2.5 b
PHY440W	Yes	0.0 b	0.0 c	0.0 c
PHY470WR	Yes	0.0 b	0.0 c	0.0 c
PHY475WRF	Yes	0.0 b	0.0 c	0.0 c
DP424BGII/RR	Yes	0.0 b	0.0 c	0.0 c

[a]Means within the same column and followed by the same letter are not significantly different, Fisher's Protected LSD ($P\leq0.05$).

Table 3. Seedcotton yields from insecticide-sprayed and non-sprayed WideStrike, Bollgard II, and non-Bt cotton genotypes in Edgecombe Co., NC. 2005.

Cotton Genotype	**Insecticide**	**Lbs. Seedcotton / Acre[a]**
PHY410R	Yes	2995 a
DP424BGII/RR	Yes	2950 a
DP424BGII/RR	No	2777 ab
PHY440W	Yes	2763 ab
PHY440W	No	2727 ab
PHY470WR	Yes	2677 ab
PHY470WR	No	2546 bc
PHY410R	No	2242 cd
PHY475WRF	Yes	2223 cd
PHY475WRF	No	2101 d

[a]Means within the same column and followed by the same letter are not significantly different, Fisher's Protected LSD ($P \leq 0.05$).

Table 4. Seedcotton yields from insecticide-sprayed and non-sprayed WideStrike and non-Bt cotton genotypes in Suffolk Co., VA. 2005.

Cotton Genotype	**Insecticide**	**Lbs. Seedcotton / Acre[a]**
PHY440W	No	4013 a
PHY440W	Yes	3977 a
PHY410R	Yes	3832 ab
PHY470WR	Yes	3630 bc
PHY475WRF	Yes	3557 bc
PHY475WRF	No	3533 bc
PHY470WR	No	3519 bc
PHY410R	No	3424 c

[a]Means within the same column and followed by the same letter are not significantly different, Fisher's Protected LSD ($P \leq 0.05$).