COMPARATIVE EFFICACY OF BOLLGARD II® AND NON-BT COTTON ON THE NOCTUID COMPLEX IN THE LOWER RIO GRANDE VALLEY OF TEXAS

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Abstract

Evaluations of the comparative efficacy of Bollgard II® versus a non-Bt conventional variety of cotton against a noctuid complex were conducted in the Lower Rio Grande Valley (LRGV) of Texas during 2004-2005. Under high insect populations, Bollgard II® significantly reduced cotton leaf and fruit damage, and the presence of live larvae throughout the growing season. Under low larval populations, these two technologies were similar in damage and yield; however, under high populations, Bollgard II® had greater yield compared to non-Bt cotton.

Introduction

In the USA, arthropod pests reduced overall cotton yield about 4.2% in 2003-2004. Bollworm(s) [*Helicoverpa zea* (Boddie)] and tobacco-budworm(s) [*Heliothis virescens* (F.)] were the top cotton pests with the bollworm being the dominant species (86% in 2003 and 94% in 2004). The Heliothine complex reduced cotton yield by 1.4% in 2003 and 1.2% in 2004. Almost half the total bales lost was reported by Texas in 2004 (153,983 bales), with about 8,000 bales were lost in the LRGV (Williams 2004, 2005). Over the last 2 decades, beet armyworm(s), *Spodoptera exigua* (Hübner), has become an increasingly destructive secondary pest of cotton in the USA. In 2004, about 1.8 million acres of cotton in the United States were infested with beet armyworm and total losses from this insect were ≈3,038 bales (Williams 2005). Although this pest historically has been perceived as an occasional late-season pest of cotton, population outbreaks experienced in the 1980s and early 1990s in Alabama, Georgia, Louisiana, and Mississippi (Douce and McPherson 1991, Burris et al. 1994, Layton 1994, Smith 1994) and 1995 in Texas (Huffman 1996, Summy et al. 1996) have demonstrated the potential damage beet armyworm may cause. In outbreak years, cotton yield losses have amounted to $371 per acre, and the cost of insecticides targeted at beet armyworm was $44 per application per acre. Cabbage looper(s), *Trichoplusia ni* (Hübner), are also an occasional pest of cotton. However, the pest status of beet armyworm and cabbage looper in the LRGV of Texas cotton agroecosystem may soon change with the initiation of the Boll Weevil Eradication Program (BWEP) because of adverse effects on the natural enemies due to widespread malathion sprays. Growers are aware of the increased risk of secondary pest outbreaks during the BWEP and that Bt cotton is thought to reduce the impact by caterpillar pests.

Since it was first introduced in 1996, commercialization of transgenic cotton (Bollgard®, Monsanto Co., St. Louis, MO) that contains a gene from *Bacillus thuringiensis* var. *kurstaki* (Berliner) encoding the Cry1Ac ∂-endotoxins has proven to be highly effective against tobacco budworm, though less effective against bollworm, as well as loopers and armyworms (Mahaffey et al. 1995, Layton 1997, Jackson et al. 2003). In 2002, Bollgard II® (Monsanto Co., St. Louis, MO) was registered for commercial use. This cotton produces the Cry1Ac and Cry2Ab endotoxins. Bollgard II® cotton has shown excellent control of the bollworm (Ridge et al. 2001). Private companies continue to improve technology of Bt cotton. Dow AgroSciences, LLC (Indianapolis, IN) introduced its pyramided-gene technology onto the market in 2004 as WideStrike™. This cotton also produces two Bt endotoxins, Cry1Ac and Cry1Fa, which are both active against lepidopterans (Adamczyk et al. 2003). VipCot is a new transgenic cotton. The vegetative insecticidal protein (Vip) expressed by VipCot is structurally and functionally different than Cry proteins (∂-endotoxins). This novel mode of action will make VipCot a valuable option for delaying the potential onset of resistance. The active Bt toxin is Vip 3A, which is an exotoxin produced during vegetative stages of Bt growth

(Mascarenhas et al. 2003, Shotkoski et al. 2003). Bt cotton has proven to be a useful tool in eradication boll weevil, and non-eradication zones. It minimizes risk of outbreaks of lepidopteran and other secondary pest problems, and augments activity of beneficial insects. In 2003-2004, Bt cotton was planted on about 6.5 million acres in the USA, ≈850,000 acres were planted in Texas, but only 8,000 acres in the LRGV of Texas (Williams 2004, 2005). In the LRGV of Texas, the transgenic technology is at the beginning stage of adoption in IPM of cotton and is an important tool for controlling the noctuid complex. It may be especially valuable with the initiation in 2005 of the LRDV BWEP. Assessing the efficacy of Bt cotton under this new environment and management regimes is of prime importance to the growers. The objective of this study was to evaluate the efficacy of Bt cotton to control natural populations of bollworm-tobacco budworm complex, beet armyworm, and cabbage looper at different densities in comparison with non-Bt conventional cotton.

Materials and Methods

Field activities

The field trials were conducted in 2004-2005 at the North and South Farms of the Kika de la Garza Subtropical Agricultural Research Center, ARS-USDA, in Weslaco, Texas. There were two treatments: Bollgard II® cotton (DPL 424 BGII/RR) and non-Bt conventional cotton (DPL 5415 RR). In 2004-2005, three and five plots (≈0.5 acre each) of each treatment were used, respectively. In the fall, experimental fields were disked, plowed, and bedded on 30 inch centers (North Farm) or 40 inch centers (South Farm). The plots were planted on March 2, 2004, and on March 7, 2005. Seeding rate, fertilizer, furrow irrigation and other production factors, excluding weed management, were according to the TAEX recommendations for LRGV farmers. In 2004, insecticides were used only for boll weevil control. There were three preemptive insecticide treatments; the first application was made when 80% of pinhead squares appeared, the second was made a week after the first, and the third a week after the second. The other applications were based on results of weekly examinations and were based on economic threshold harmfulness (ETH), i.e, 10% or more infested (egg punctures) squares in the terminal area of cotton plants. Vydate CLV, 17 oz/Ac (4 applications) and Baythroid, 2.6 fl.oz/Ac (2 applications) were applied six rows at a time, using two drops and one nozzle (8000 E) over the top for each row. Defoliants [Def 6 (1.5 qt/Ac), Finish 6 (32 oz/Ac), and Prep (1.0 pt/Ac)] were applied July 12, 2004. For cotton stalk destruction, the herbicide 2,4-D Amine was applied twice (July 22 and August 5, 2004) at one pound of formulated product in 10.0 gallons of water per acre on shredded cotton stalks. In 2005, the experimental plots were treated with insecticides seven times. On April 4, plots were sprayed with Orthene 90S (0. 075 lb/Ac) against thrips. Four applications of Vydate CLV, 17 oz/AC, were made against boll weevil (two preemptive insecticide treatments, and the rest when boll weevil attained ETH). On June 9, plots were sprayed with Steward, 11.5 oz/Ac, against noctuid larvae, and on June 24, with Leverage, 6 oz/AC, against whiteflies. All chemicals were applied with a John Deere 6500 sprayer. To manage plant growth height, plots were sprayed with Mepichlor 4.2% (10 oz/Ac), which was combined with Vydate (May 27 and June 3). Defoliants were applied July 15 (Dropp, 9.4 oz/Ac and Prep, 2.5 oz/Ac). On July 25, cotton was harvested by hand and cotton picker. Hand harvested seed cotton samples (two rows per treatment, 13.75 ft row) and a portion of the machine harvested samples were processed on an Eagle laboratory gin (Continental Gin Co., Birmingham AL) to determine lint yield. Then, the cotton was shredded with a Rhino Shredder, stalks were removed with a stalk puller, and the plots were plowed and disked.

Crop scouting

Monitoring of the noctuid complex and their damage on cotton plants was conducted weekly beginning 40 days after the cotton was planted and until defoliation, using 3 methods. Plots were visually observed by walking diagonally from one corner to another and examining at least 25 individual plants at random. The numbers of different stages of bollworm, beet armyworm, cabbage looper, and tobacco budworm, and plant damage were recorded. Leaf damage was estimated based on the following six categories as defined by Greene et al. (1969): 0 - not apparent damage; 1 - minor feeding damage or ≤1% leaf area eaten; 2 - minor-moderate feeding damage or 1.1-5.0% leaf area eaten; 3 - moderate damage or 5.1-10.0% leaf area eaten; 4 - moderate-heavy damage or 10.1-30.0% leaf area eaten; and 5 - heavy damage or >30% leaf area eaten. Fallen fruit was collected from the soil surface at 50 randomly selected sites per 1m^2. Data were recorded for number damaged, a species making the damage, and number of live larvae in the damaged fruit. Pheromone traps were installed on sticks placed around the perimeter of the plots at 1.2 m above the ground and 50 m distance between traps. Each trap contained a dispenser (Pherocon cap), that was replaced weekly. Both traps and dispensers are available commercially (Trece, Inc. Salinas, CA, USA). Traps were checked weekly.

Statistical Analyses

Data were analyzed using analysis of variance (ANOVA), and means were separated by Tukey Studentized range honestly significant difference (HSD) test (α=0.05; Wilkinson et al. 1992). Percentage data were transformed using the arcsine-square root method (Sokal and Rohlf 1981), but were presented as non-transformed means.

Results and Discussion

In the 2004 season, we observed low densities of bollworm, beet armyworm, and cabbage looper in cotton (lesser than an economic threshold harmfulness) (Table 1).

Table 1. Seasonal noctuid composition on the KSARC South Farm, Weslaco Texas, 2004 (Mean±SE).

Date	Noctuidae	Bt-cotton	Non-Bt-cotton
05.04.04	Cabbage Looper: Eggs/100plants	5.0±0.03	3.3±0.03
	Larvae/100 plants	5.0±0.01	6.7±0.04
	Bollworm: Eggs/100 plants	6.7±0.03	6.7±0.02
	Larvae/100 plants	0	3.3±0.02
	Beet Armyworm:Egg-masses/100plants	0	0
	Larvae/100 plants	0	1.7±0.02
05.11.04	Cabbage Looper: Eggs/100plants	5.0±0.05	5.0±0.01
	Larvae/100 plants	1.7±0.02	5.0±0.03
	Bollworm: Eggs/100 plants	6.7±0.04	5.0±0.03
	Larvae/100 plants	5.0±0.03	6.7±0.02
	Beet Armyworm:Egg-masses/100plants	0	0
	Larvae/100 plants	0	0
05.18.04	Cabbage Looper: Eggs/100plants	1.7±0.02	5.0±0.03
	Larvae/100 plants	5.0±0.03	6.7±0.07
	Bollworm: Eggs/100 plants	6.7±0.03	8.3±0.04
	Larvae/100 plants	3.3±0.06	8.3±0.03
	Beet Armyworm:Egg-masses/100plants	0	0
	Larvae/100 plants	0	1.7±0.03
06. 01.04	Cabbage Looper: Eggs/100plants	1.7±0.02	3.3±0.02
	Larvae/100 plants	0	3.3±0.03
	Bollworm: Eggs/100 plants	3.3±0.06	6.7±0.03
	Larvae/100 plants	5.0±0.03	3.3±0.01
	Beet Armyworm:Egg-masses/100plants	0	0
	Larvae/100 plants	0	1.7±0.02
06.14.04	Cabbage Looper: Eggs/100plants	0	1.7±0.02
	Larvae/100 plants	3.3±0.02	1.7±0.02
	Bollworm: Eggs/100 plants	8.3±0.04	6.7±0.02
	Larvae/100 plants	1.7±0.02	6.7±0.02
	Beet Armyworm:Egg-masses/100plants	0	0
	Larvae/100 plants	0	0

The average number of bollworm eggs and larvae per 100 plants on Bollgard II® and non-Bt cotton were not significantly different (eggs: 5.0±0.07 and 6.7±0.04, respectively; larvae: 3.0±0.06 and 5.0±0.04, respectively). The same trends were seen with cabbage looper on Bt and non-Bt cotton (eggs: 2.7±0.05 and 3.7±0.04, respectively; larvae: 3.3±0.05 and 3.7±0.05) and with beet armyworm (eggs: 0 and 0; larvae: 0 and 1.0±0.03, respectively). In the 2005 season, totals for moths captured by pheromone traps were 74.4% beet armyworm, 20.1% bollworm, and 5.5% tobacco budworm (Table 2). The average numbers of cabbage looper eggs and larvae per 100 plants were relatively low; 1.6 eggs and 2.1 larvae.

Table 2. Percentage composition of Noctuidae caught by pheromone traps during 2005.

Noctuidae	Number caught per pheromone trap	Total caught during the season in all 5 pheromone traps used	Percentage of total number Noctuidae caught
Beet armyworm	8.5±0.7a	548.0	74.4
Tobacco Budworm	0.6±0.1c	40.0	5.5
Bollworm	2.3±0.2b	148.0	20.1

Seasonal leaf damage by noctuid complex, mostly by beet armyworm and cabbage looper, was significantly different on Bt and non-Bt cotton when the insect densities were high (Fig. 1). In 2004, when the insect densities were low, the average percentage of seasonal noctuid leaf damage on Bt (2.4±0.4) and non-Bt (2.8±0.3) cotton; and categories of eaten 0.525±0.07 (Bt) and 0.608 ± 0.09 (non-Bt) were not significantly different (*t*=0.6; df=1; *P*=0.517 and *t*=0.7; df=1; *P*=0.469, respectively). In 2005, when the insect densities were high (mainly beet armyworm), the average percentage of seasonal leaf damage by noctuids on Bt (5.9±0.6) and non-Bt (17.5±1.1) cotton were significantly different (*t*=9.0; df=1; *P*=0.001). The same differences was observed on categories of eaten (0.824±0.07 on Bt cotton and 1.6±0.08 on non-Bt cotton) (*t*=7.3; df=1; *P*=0.001).

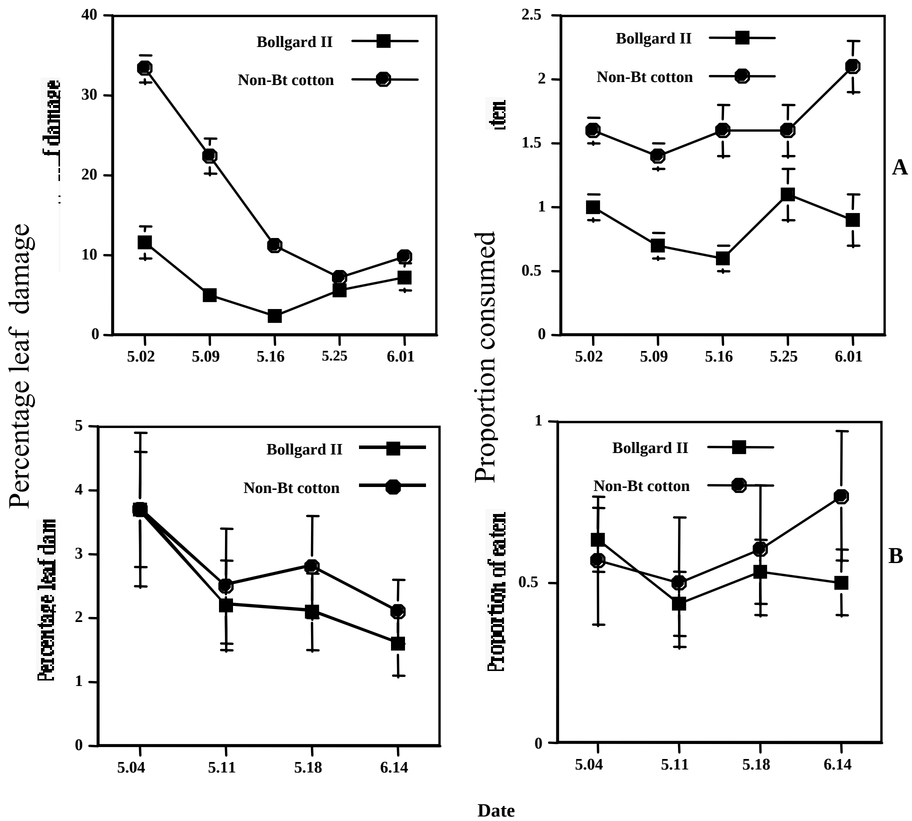
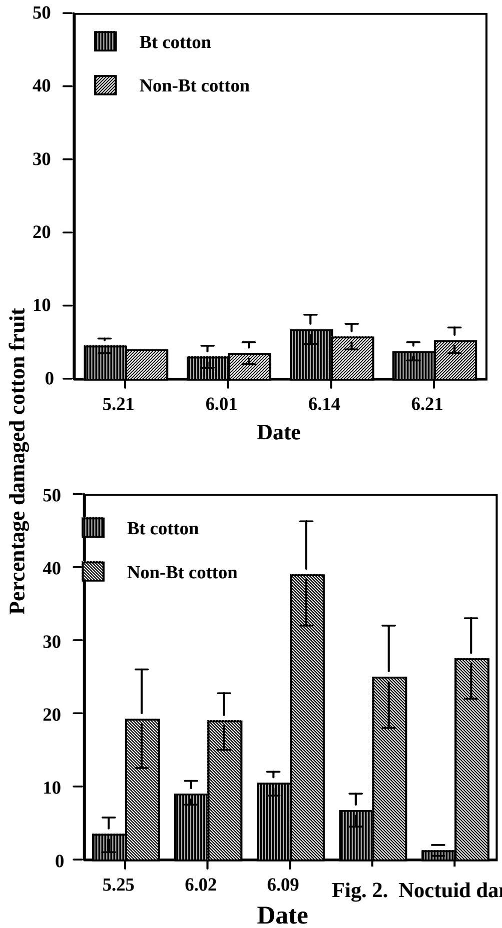


Fig. 1. Seasonal Noctuidae leaf damage

A - Year 2005
B - Year 2004

Seasonal fallen fruit damage by noctuid complex and live larval in fallen squares or bolls, mostly by bollworm and beet armyworm, was significantly different on Bt and non-Bt cotton in 2005 when the insect densities were high (Fig. 2). In 2004 on Bt cotton the average seasonal noctuid damage on fallen cotton fruit was 4.2±0.8% and live larvae per 100 damage fruit -1.3±0.04 individuals and non-Bt cotton were 4.4±1.0% and 2.3±0.09 individuals, respectively (*t*=0.016; df=1; *P*=0.987 for damage fruit and *t*=0.983; df=1; *P*=0.328, for live larvae per 100 damage fruit). At the higher insect densities observed in 2005 (equal or higher an economic threshold harmfulness) the average seasonal fruit damage on Bt cotton was 6.1±1.0%, but on non-Bt cotton it was 25.9±4.0% (t=4.8; df=1 P=0.001). We recorded 3.4±0.8 live larvae per 100 damaged fruit on Bt cotton and 16.1±0.3 live larvae per 100 damaged fruit on non- Bt cotton (t=4.6; df=1; P=0.001).

In 2005, Bt cotton produced significantly more lint than non-Bt cotton based on hand harvest (1170.3 lb/Ac vs. 961.8 lb/Ac; t=3.0, df=1, P=0.007).



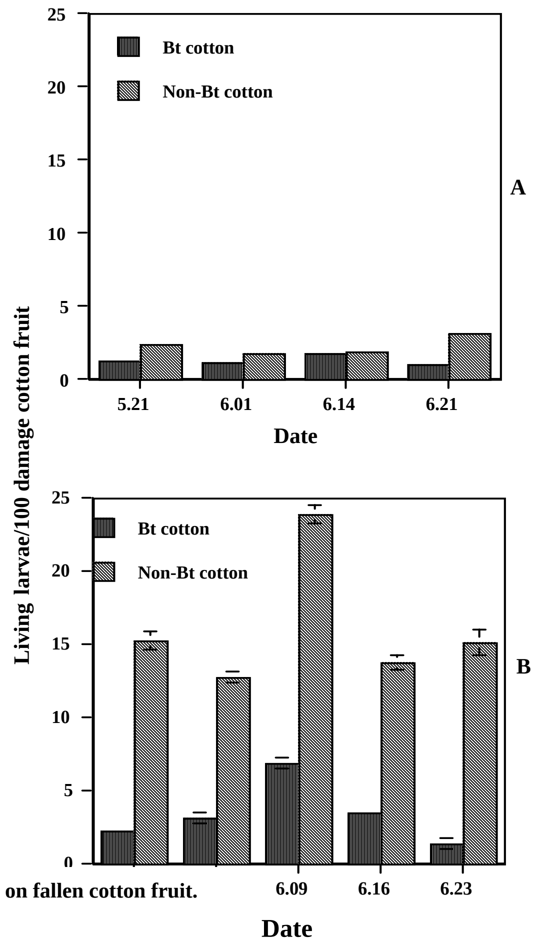


Fig. 2. Noctuid damage on fallen cotton fruit.

Fig. 3. Noctuidae damage on fallen cotton

A - Year 2004
B - Year 2005

Our data showed that in the LRGV cotton mostly distributed boll worm and beet armyworm (sporadic), and relatively fewer cabbage looper and tobacco budworm. The beet armyworm and cabbage looper mostly damaged cotton leaves in comparison with bollworm/tobacco budworm complex, while the latter mostly damaged fruit. When the insect densities were low, their injury on Bt and non-Bt cotton was not significantly different. In the years with heavy worm infestations, the leaf and fruit damage were significantly higher on non-Bt cotton, than on Bt. In this study we used a dual-gene construct of the Bollgard II variety as Bt cotton. The single-gene Bollgard varieties have demonstrated a very high efficacy against tobacco budworm and pink bollworm [*Pectinophora gossypiella* (Saunders)] across the cotton belt where these insects dominated. However, Bollgard is less effective against bollworms, as well as armyworms and loopers (Mahaffey et al. 1995, Layton 1997, Perlak et al. 2001, Jackson et al. 2005). Bollgard II provided better efficacy against most lepidopteran pests of cotton than Bollgard (Steward and Knighten 2000, Adamczyk et al. 2001, Norman and Sparks 2001). In 2000 and 2002, 2.5-4.0 fold fewer fruiting structures were infested in Bollgard II versus Bollgard plots. In 2000, during a moderate bollworm infestation, cotton yields were 7.1% and 28.6% higher in Bollgard II plots versus those observed in Bollgard and conventional cotton plots, respectively (Boyd and Phipps 2005). Bollgard II held cotton boll damage to almost non-detectable levels (Bacheler and Mott 2003). Bollgard II provided excellent protection against beet armyworm and soybean looper [*Pseudoplusia includens* (Walker)] as compared to Bollgard and non-Bt cotton (Sherrick et al. 2003). Brickle and Catchot (2002) found 0.4, 9.6, and 10.2 beet armyworm larvae per meter of row and 0.4, 8.0, and 10.7 soybean looper larvae per meter of row in unsprayed Bollgard II, Bollgard, and conventional genotypes, respectively. The seasonal mean percentage of damaged squares was 0.6, 1.9, and 7.2, and damaged bolls was 0.3, 2.0, and 6.7 for Bollgard II, Bollgard, and conventional cotton respectively. Bollgard II also provided $17.46 profit compared to the Bollgard plots, and a $73.27 advantage over the conventional cotton (Howell and Pitts 2002).

Growers are aware that the risks of secondary pest outbreaks can increase during the Boll Weevil Eradication Program and Bt cotton is known to reduce the risks from certain caterpillar pests. Our data suggests that Bollgard II can be a vital tool in the LRGV, especially under the Boll Weevil Eradication Program, providing management options that have positive environmental, social, and economic outcomes. Bt cotton large field performance can be assessed from both an environmental standpoint in terms of the reduction in chemical pesticides usage and from a commercial standpoint in terms of the benefit to the growers in producing high yield and quality with acceptable costs.

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