MANAGING FALL ARMYWORM WITH BT COTTON

Ryan Jackson
USDA-ARS, SIMRU
Stoneville, MS
Jeff Gore
Stoneville, MS

Abstract

Two-day old and 5-day old fall armyworm, *Spodoptera frugiperda* (J. E. Smith), were tested for survival and damage potential on non-Bt, Bollgard, Bollgard II, WideStrike, and VipCot cotton lines. In the first test, four 2-day old and one 5-day old larva(e) were confined to white flowers of a non-Bt cotton variety, as well as Bollgard, Bollgard II, and WideStrike varieties. When averaged across larval ages, percent survival after 5 d did not differ between the non-Bt and Bollgard varieties. Bollgard II and WideStrike reduced survival below that of the control. When averaged across varieties, 5-d old larvae had higher survival than 2-d old larvae. In general where differences were observed in feeding, Bollgard performed more similarly to the non-Bt than Bollgard II or WideStrike. No differences in feeding were observed between Bollgard II and WideStrike regardless of larval age or when averaged across larval ages. In the second test, larvae were confined to white flowers of a non-Bt line (Coker312) and an experimental VipCot line (COT102/67B). VipCot reduced percent survival, bract feeding, boll grazing, and boll penetration below that of the non-Bt cotton line when averaged across larval ages. No differences were observed between larval ages for any measurement when averaged across cotton lines. These data demonstrate the increased efficacy of dual-gene Bt cotton lines against fall armyworm infestations.

Introduction

Fall armyworm, *Spodoptera frugiperda* (J. E. Smith), has been a periodically destructive pest of cotton (Bass 1978; King et al. 1986). Only recently has fall armyworm become a common pest of cotton. Even Bt cotton, which is planted to greater than 80% of the cotton acreage in the mid-South and southeastern US, is not immune to economic damage by fall armyworm (Adamczyk et al. 1997).

Cottons expressing the Cry1Ac and Cry2Ab Bt endotoxins were commercialized as Bollgard II® (Monsanto Co., St. Louis, MO) in 2002, and have exhibited increased efficacy against fall armyworm above the single-gene Bollgard® (Monsanto Co., St. Louis, MO) varieties (Coots and Pitts 2003; Leonard et al. 2006). In 2004, Dow AgroSciences, LLC, (Indianapolis, IN) introduced WideStrike™, which produces the Cry1Ac and Cry1F Bt endotoxins. These varieties have also shown an increased efficacy against fall armyworm (Tindall et al. 2006). Similarly, Syngenta Crop Protection (Greensboro, NC) has an experimental cotton line, COT102/67B, which produces the Cry1Ab and Vip3A proteins. This cotton line has also demonstrated efficacy against fall armyworm (Adamczyk and Mahaffey 2007).

To date, no studies have made comparisons between the Bollgard II and WideStrike technologies relative to fall armyworm efficacy. Also, little data are available for fall armyworm performance on VipCot cotton lines. Thus, reported here are cage studies comparing Bollgard II and WideStrike technologies relative to the survival and damage potential of fall armyworm, as well as a cage study evaluating VipCot cotton on fall armyworm efficacy.

Materials and Methods

Fall Armyworm Strain

Late instar fall armyworms were collected from non-Bt (Pioneer 34B23) sweet corn in June 2006 near Stoneville, MS. F_0 larvae completed development on corn tissue. All generations since this time have been reared on artificial diet as described by Burton (1970). This colony was used in a cage experiment with non-Bt (ST4664RF), Bollgard (ST4575BR), Bollgard II (ST4554B2RF), and WideStrike (PHY485WRF). This fall armyworm strain was also used in additional cage experiment with another non-Bt (Coker312) cotton line and an experimental VipCot (COT102/67B) cotton line.

Cage Studies

Cotton varieties used in the first study with Bollgard, Bollgard II, and WideStrike were planted on 1 May 2007, whereas lines used in the second study with VipCot were planted on 6 June 2007 near Stoneville, MS. Cage experiments were initiated 6 August for all cotton lines tested. One 5-d old larva or four 2-d old larvae were infested onto 10 first position white flowers of each variety per replicate. Treatment combinations were replicated four times for a total of 40 infested white flowers per treatment combination in test one. In test two, treatment combinations were replicated three times for a total of 30 white flowers infested per treatment combination. Immediately after infestation, a cloth cage (10 x 16 cm) was used to enclose each flower and was tightly closed around the stem with its drawstring. After 5 d, cages were removed and small bolls were examined for feeding injury.

Analyses

Survival and damage estimates were converted to percentages, which were subjected to the arcsine-square root transformation prior to analyses. These data were subjected to ANOVA using a mixed model. In the model, larval age (main plot), cotton line (sub-plot), and the larval age by cotton line interaction were designated as the fixed components. Replicate and replicate by larval age were designated as the random components, and replicate by larval age served as the error term for larval age. Residual error served as the error term for cotton line and the larval age by cotton line interaction. Means were separated ($P \leq 0.05$) using LSMEANS, and were reported as untransformed means.

Results and Discussion

In the first cage study, there was a significant difference in larval survival among cotton varieties (F=6.83; df=3, 18; P=0.0029) and larval ages (F=22.08; df=1, 3; P=0.0182) (Table 1). When averaged across larval ages, percent survival after 5 d did not differ between non-Bt and Bollgard varieties. Bollgard II and WideStrike reduced survival below that of the non-Bt, although only Bollgard II reduced survival below that of Bollgard. These data agree somewhat with reports from Leonard et al. (2006) and Tindall et al. (2006) where 5-d old larval survival was reduced by Bt varieties as compared to non-Bt varieties. When averaged across cotton varieties, 5-d old larvae had higher survival than 2-d old larvae. With regard to percent bract feeding, there was a significant larval age by cotton variety interaction (F=5.25; df=3, 18; P=0.0089) (Table 2). For 2-d old larvae, only Bollgard and WideStrike reduced bract feeding below that of the non-Bt (F=5.51; df=3, 9; P=0.0200). However, no differences in bract feeding existed among the Bt varieties. No differences were observed in bract feeding for 5-d old larvae (F=1.22; df=3, 9; P=0.3572). This is also supportive of reports from Leonard et al. (2006) and Tindall et al. (2006), which showed no differences among cotton varieties with regard to bract feeding for 5-d old fall armyworm larvae. A significant larval age by cotton variety interaction was also evident for boll grazing (F=4.20; df=3, 18; P=0.0203) (Table 3). No differences in boll grazing by 2-d old larvae were observed among cotton varieties (F=1.16; df=3, 9; P=0.3785). However, for 5-d old larvae, significantly less boll grazing was sustained by Bollgard II and WideStrike than by Bollgard (F=5.21; df=3, 9; P=0.0233). Bollgard did not differ from the non-Bt variety with regard to boll grazing by 5-d old fall armyworm larvae. Averaged across larval ages, Bollgard II and WideStrike sustained significantly less boll penetration than the Bollgard and non-Bt variety (F=10.71; df=3, 18; P=0.0003) (Table 4). No differences in boll penetration were observed between larval ages when averaged across cotton varieties (F=0.06; df=1, 3; P=0.8256).

In test two, when averaged across larval ages, the VipCot cotton line had significantly less larval survival (F=65.15; df=1, 4; P=0.0013), bract feeding (F=30.09; df=1, 4; P=0.0054), boll grazing (F=32.21; df=1, 4; P=0.0048), and boll penetration (F=225.02; df=1, 4; P<0.0001) than the non-Bt cotton line (Tables 5-8). These data agree with those from Adamczyk and Mahaffey (2007) where high mortality of fall armyworm larvae was observed when fed upon VipCot leaf tissue. No differences were observed between larval ages when averaged across cotton lines with regard to larval survival (F=4.88; df=1, 2; P=0.1578), bract feeding (F=0.62; df=1, 2; P=0.5133), boll grazing (F=0.31; df=1, 2; P=0.6341), and boll penetration (F=0.85; df=1, 2; P=0.4539) (Tables 5-8).

Results presented here suggest that Bt crops with various toxins and levels of expression impact fall armyworms differently. Bt cotton lines with two toxins provide more protection than single-gene varieties. However, the dual-gene Bt varieties are not immune to fall armyworm damage, and supplemental control may be required in some situations.

Acknowledgments

The authors would like to thank Michelle Mullen, Jessica King, John Kirk Manning, and Andrew Adams for technical assistance with this project.

Literature Cited

Adamczyk, J. J., and J. S. Mahaffey. 2007. Efficacy of Vip3A and Cry1Ab genotypes against various lepidopteran pests, 1106-1113. *In* Proc. Beltwide Cotton Conf. National Cotton Counc., Memphis, TN.

Adamczyk, J. J., Jr., J. W. Holloway, B. R. Leonard, and J. B. Graves. 1997. Susceptibility of fall armyworm collected from different plant hosts to selected insecticides and transgenic Bt cotton. J. Cotton Sci. 1: 21-28.

Bass, M. H. 1978. Fall armyworm: evaluation of insecticides for control. Auburn Univ. Leafl. 93: 7.

Burton, R. L. 1970. A low cost artificial diet for the corn earworm. J. Econ. Entomol. 63: 1969-1970.

Coots, B, and D. Pitts. 2003. Bollgard II efficacy on fall armyworm in a screened enclosure bioassay, pp. 1029-1030. In Proc. Beltwide Cotton Conf. National Cotton Counc., Memphis, TN.

King, E. G., J. R. Phillips, and R. B. Head. 1986. 39th annual conference report on cotton insect research and control, pp. 126-135. *In* Proc. Beltwide Cotton Conf. National Cotton Counc., Memphis, TN.

Leonard, B. R., K. V. Tindall, and K. D. Emfinger. 2006. Fall armyworm survivorship and damage in Bollgard and Bollgard 2 cotton, pp. 1080-1084. *In* Proc. Beltwide Cotton Conf. National Cotton Counc., Memphis, TN.

Tindall, K. V., B. R. Leonard, and K. D. Emfinger. 2006. Fall armyworm survivorship and damage in WideStrike cotton, pp. 1541-1544. *In* Proc. Beltwide Cotton Conf. National Cotton Counc., Memphis, TN.

Table 1. Mean percent survival of 2-d and 5-d old *Spodoptera frugiperda* larvae after 5d on non-Bt, Bollgard, Bollgard II, or WideStrike cotton flowers.

Genotype	2-d old	5-d old	Mean
Non-Bt	42.5	75.0	58.8 a
Bollgard	35.0	70.0	52.5 ab
Bollgard II	26.3	40.0	33.1 c
WideStrike	60.0	50.0	40.0 bc
Mean	33.4 b	58.8 a	

Means within the same column or row followed by the same letter are not significantly different, LSMEANS, ($P \leq 0.05$).

Table 2. Mean percent bract feeding by 2-d and 5-d old *Spodoptera frugiperda* larvae after 5d on non-Bt, Bollgard, Bollgard II, or WideStrike cotton flowers.

Genotype	2-d old	5-d old	Mean
Non-Bt	100.0 a	70.0 a	85.0
Bollgard	75.0 b	75.0 a	75.0
Bollgard II	90.0 ab	65.0 a	77.5
WideStrike	85.0 b	80.0 a	82.5
Mean	87.5	72.5	

Means within the same column or row followed by the same letter are not significantly different, LSMEANS, (*P*≤0.05).

Table 3. Mean percent boll grazing by 2-d and 5-d old *Spodoptera frugiperda* larvae after 5d on non-Bt, Bollgard, Bollgard II, or WideStrike cotton flowers.

Genotype	2-d old	5-d old	Mean
Non-Bt	70.0 a	70.0 ab	70.0
Bollgard	45.0 a	75.0 a	60.0
Bollgard II	70.0 a	35.0 bc	52.5
WideStrike	60.0 a	20.0 c	40.0
Mean	61.3	50.0	

Means within the same column or row followed by the same letter are not significantly different, LSMEANS, (*P*≤0.05).

Table 4. Mean percent boll penetration by 2-d and 5-d old *Spodoptera frugiperda* larvae after 5d on non-Bt, Bollgard, Bollgard II, or WideStrike cotton flowers.

Genotype	2-d old	5-d old	Mean
Non-Bt	40.0	60.0	50.0 a
Bollgard	35.0	55.0	45.0 a
Bollgard II	20.0	10.0	15.0 b
WideStrike	20.0	10.0	15.0 b
Mean	28.8 a	33.8 a	

Means within the same column or row followed by the same letter are not significantly different, LSMEANS, (*P*≤0.05).

Table 5. Mean percent survival of 2-d and 5-d old *Spodoptera frugiperda* larvae after 5d on non-Bt or VipCot cotton flowers.

Genotype	2-d old	5-d old	Mean
Non-Bt	58.3	86.7	72.5 a
VipCot	14.2	13.3	13.8 b
Mean	36.3 a	50.0 a	

Means within the same column or row followed by the same letter are not significantly different, LSMEANS, (*P*≤0.05).

Table 6. Mean percent bract feeding by 2-d and 5-d old *Spodoptera frugiperda* larvae after 5d on non-Bt or VipCot cotton flowers.

Genotype	2-d old	5-d old	Mean
Non-Bt	73.3	73.3	73.3 a
VipCot	43.3	30.0	36.7 b
Mean	58.3 a	51.7 a	

Means within the same column or row followed by the same letter are not significantly different, LSMEANS, (*P*≤0.05).

Table 7. Mean percent boll grazing by 2-d and 5-d old *Spodoptera frugiperda* larvae after 5d on non-Bt or VipCot cotton flowers.

Genotype	2-d old	5-d old	Mean
Non-Bt	56.7	66.7	61.7 a
VipCot	16.7	3.3	10.0 b
Mean	36.7 a	35.0 a	

Means within the same column or row followed by the same letter are not significantly different, LSMEANS, (*P*≤0.05).

Table 8. Mean percent boll penetration by 2-d and 5-d old *Spodoptera frugiperda* larvae after 5d on non-Bt or VipCot cotton flowers.

Genotype	2-d old	5-d old	Mean
Non-Bt	53.3	63.3	58.3 a
VipCot	0.0	0.0	0.0 b
Mean	26.7 a	31.7 a	

Means within the same column or row followed by the same letter are not significantly different, LSMEANS, ($P \leq 0.05$).