2004 BELTWIDE COTTON CONFERENCES, SAN ANTONIO, TX – JANUARY 5-9

TEMPORAL AND SPATIAL PRODUCTION OF BOLLWORM FROM VARIOUS HOST CROPS IN NORTH CAROLINA: IMPLICATIONS FOR BT RESISTANCE MANAGEMENT

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Abstract

Bollworm, *Helicoverpa zea* (Boddie), production from various host crops was measured in 2003 by weekly larval and adult monitoring in commercial crop fields to compare temporal and spatial production of bollworm from non-cotton crop hosts with that from Bollgard and nBt cottons. Pheromone trap catches demonstrated that bollworm larval production in localized areas had little impact on the number of moths collected from the local environment, which suggests a high level of movement by bollworm adults. Results from larval monitoring in commercial fields of corn, cotton, peanut, and soybean demonstrated the potential for alternate host crops to produce much higher numbers of bollworm compared to Bollgard® or nBt cottons. Thus, these results show that temporal and spatial production of bollworm by various host crops favor Bt resistance management and that alternate host crops can effectively supplement or replace the 5% unsprayed cotton refuge for Bollgard and Bollgard II® cottons in the diversified southeast U. S. agroecosystem.

Introduction

The general Bollgard® (Monsanto Co., St. Louis, MO) registration was granted a five-year extension in late 2001 by the U. S. Environmental Protection Agency. However, the 5% unsprayed refuge option will remain in effect only until the end of 2004, at which time it will be reviewed by EPA to determine whether or not this specific option will be continued. At that time, the EPA may require changes in refuge size, structure, and deployment. Previous reports from North Carolina had suggested that nBt refuge cottons did not produce enough susceptible bollworm, *Helicoverpa zea* (Boddie), adults to effectively delay Bt resistance evolution (Jackson et al. 2003a). However, Jackson et al. (2003b) proposed that the reason frequencies of Bt resistance alleles in the general bollworm population in North Carolina had not increased over a three year period was partially due to substantial production of bollworm adults from alternate crop hosts.

North Carolina agroecosystems are characterized by a high degree of host crop diversity. Diversity in this region is impacted by small field sizes relative to other production regions in the U. S. cotton belt. For example, the average cotton field in the area has been estimated at 15 acres by Boll Weevil Eradication personnel. Intercrop movement of bollworm adults is enhanced by the spatial heterogeneity imposed by small field sizes; thus, the probability of matings between moths produced on Bt and refuge crops is high in this region.

The objective of the study reported herein was to quantify temporal and spatial bollworm production from selected host crops (corn, cotton, peanut, and soybean) in targeted agroecosystems representative of North Carolina agriculture.

Materials and Methods

Bollworm production from various host crops during the 2003 growing season was measured using two methods: weekly monitoring of commercial crop fields for larval and adult production. Four cotton-producing counties were selected for monitoring of bollworm production in commercial crop fields. These four counties (Chowan, Edgecombe, Halifax, and Washington) were selected because of variation in production of Bollgard cottons and alternate host crops among counties. Bollworm larval and adult production was monitored in five areas within each county that consisted of an interface of a Bollgard cotton field with another crop host field (Bollgard cotton, nBt cotton, corn, peanut, or soybean). Two modified Harstack pheromone traps were placed along each crop interface with a minimum distance of 100 yards between traps and baited with Luretape® (Hercon Environmental Co., Emigsville, PA). Adult bollworms were collected each week from pheromone traps and counted to compare moth production at each interface. Bollworm larval sampling was also conducted on a weekly basis at each crop interface by sampling 100-row ft. within each crop at each interface. Each crop field associated with pheromone traps was sampled for large (L4-L5) larvae in order to estimate the proportion of moths produced by each crop at each interface and to determine whether moths captured in pheromone traps were produced locally. Larval sampling was initiated at the onset of the bollworm moth flight in mid-late July and terminated in mid-late September when all crops had reached maturity and no bollworm larvae were found.

All data were $\log_{10}$ transformed before being subjected to ANOVA using PROC GLM (SAS Institute 1990). Means for each treatment were separated ($P \leq 0.05$) using Fisher's Protected Least Significant Difference test.

Results

Extremely high populations of bollworm were found throughout eastern North Carolina in 2003, as indicated by larval sampling in commercial crop fields and pheromone trap collections (Figures 1-2). Bollworm larval numbers in commercial crop fields at each interface varied greatly across sample dates (Figure 1). Only field corn was found to produce large bollworm larvae on 14, 21, and 28 July. By 4 August, large bollworm larvae were found only in field corn, peanut, and soybean; however, numbers of larvae in these crops did not differ from Bollgard and nBt cottons. On 11 August, peanut and soybean were the only host crops to produce significantly higher numbers of bollworm larvae than Bollgard. However, numbers of bollworm larvae produced by field corn and nBt cotton were similar to that of soybean. By 18 August, field corn had ceased bollworm larval production, but production of bollworm larvae had peaked in peanut and soybean. Again, peanut and soybean were the only host crops to produce significantly higher numbers of larvae than Bollgard, as larval numbers produced by nBt cottons did not differ from that of Bollgard. On 25 August, larval production was less than half that of the previous week. Larval production was similar among all crop hosts with the exception of field corn. Production of bollworm larvae on 1 and 8 September was very low and limited to peanut and soybean only; however, significant differences in larval numbers did not exist among host crops.

Large bollworm larvae were found in Bollgard cottons during a three-week period from mid- to late August. Production of bollworms from nBt crop hosts is most critical during this period because production from nBt host crops should be synchronous with that of Bollgard cottons in order for susceptible adults to mate with those from Bollgard cottons. Bollgard cottons contributed 0.8% of the total bollworm larval production during this time period. Field corn constituted only 1.1% while nBt cottons generated 4.4% of the total numbers of bollworm produced within this three-week period. Peanut and soybean were by far the major producers of bollworm larvae during the critical period with peanut and soybean contributing 56.3% and 37.4%, respectively, to the bollworm larval population.

During the 2003 period from 7 July to 15 September, bollworm moth numbers differed among host crop interfaces only during the first two weeks of collections (Figure 2). Higher numbers of bollworm moths were collected at the Bollgard/field corn interface than at interfaces of other host crops during these two weeks. Although moth numbers collected at the various host crop interfaces varied from week to week, numbers of moths collected within a given week remained similar among host crop interfaces.

Discussion

Field corn was the major producer of large bollworm larvae through early August in 2003. However, large bollworm larvae were collected from field corn as late as mid-August. These results confirm those produced by Jackson et al. (2003) in which commercial field corn produced large bollworm larvae through 21 August. Data of this nature are very important from a Bt resistance management standpoint because it had not been anticipated that field corn could serve as a refuge for Bt cottons this late into the season. From mid- to late August, when large bollworm larvae are typically found in Bollgard cottons, peanut and soybean produced numbers of large bollworm larvae well beyond that of any other host crop. Refuge contributions of peanut or soybean were 3X to 26X that of nBt cotton during mid- to late August when bollworm larvae were found in Bollgard cottons. Therefore, the importance of peanut and soybean as refuges for Bt cottons is much greater than that of nBt cottons in North Carolina.

Estimated crop acreages for North Carolina in 2003 were 2,251,000 combined acres for field corn, peanut, and soybean versus 658,000 acres for Bollgard cottons. Using these estimates to calculate bollworm production from these alternate host crops versus Bollgard, it was determined that field corn, peanut, and soybean produce anywhere from 154X to 951X more bollworm larvae than Bollgard cottons throughout the time period in which larvae were produced by Bollgard cottons. It was apparent that peanut and soybean were the major sources of susceptible bollworms during this time period; thus, alternate host crops in North Carolina appear to serve as adequate refuges for Bollgard cottons.

The similarities among pheromone trap catches in nine of eleven sampling weeks in 2003 suggest that bollworm production from crops within a particular localized area has little impact on the spatial occurrence of bollworm moths in the local environment. Pheromone trap catches differed among host crop interfaces only during the first two weeks of 2003. This was most likely due to the attractiveness of field corn that was at peak silking during these two weeks. Overall, the results suggest that movement of bollworm moths into and out of localized areas is much more significant than anticipated. Therefore, the requirement for a nBt cotton refuge to delay Bt resistance evolution seems unnecessary for the North Carolina agroecosystem that is characterized by a diversity of host crops that produce bollworms and small field sizes that enhance adult movement.

Although several assumptions of the refuge strategy for Bt resistance management are violated by bollworm, these violations may be overcome by favorable assumptions about other factors such as fitness costs, incomplete resistance, or large refuges of alternate nBt host crops (Carrière and Tabashnik 2001, Carrière et al 2002, Gould et al. 2002). Thus, refuges may be useful even though one or more key assumptions of the refuge strategy are violated (Tabashnik et al. 2003). The results provided herein demonstrate the ability of host crops such as field corn, soybean, and peanut to supplement or replace the 5% unsprayed nBt cotton refuge both temporally and spatially for effective Bt resistance management of bollworm.

Acknowledgments

The authors express appreciation to Monsanto Agric. Co. and USDA/ARS for providing project funding. Special thanks are given to Wayne Modlin, Ryan Kurtz, and Maria Marcus for technical assistance.

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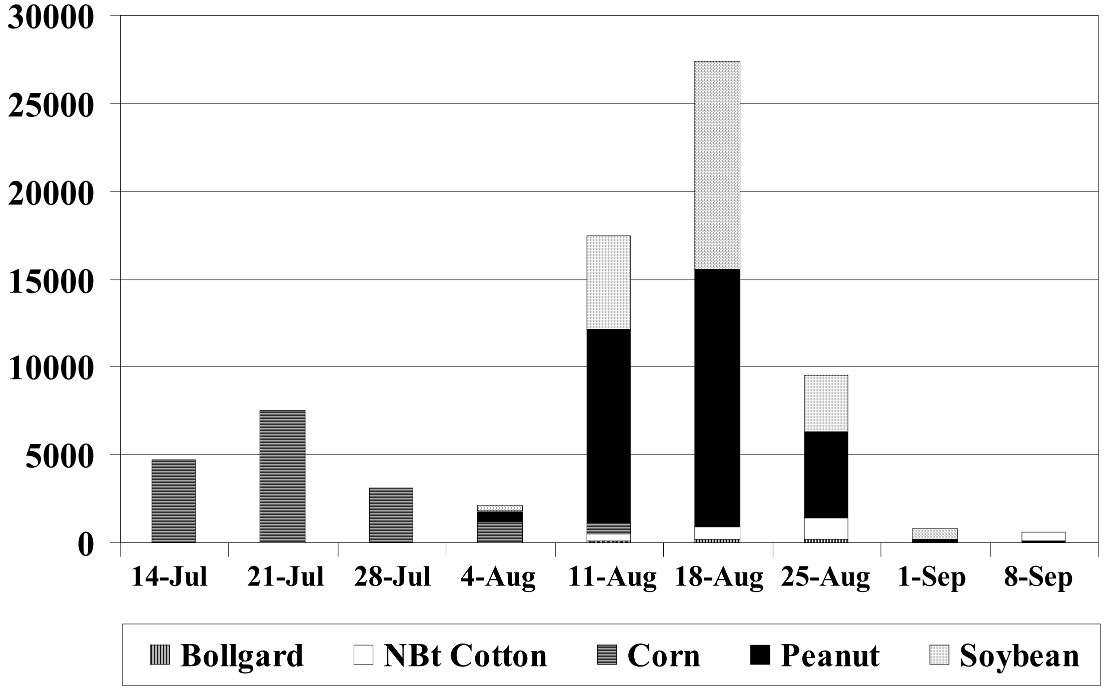

Figure 1. Mean numbers of *Helicoverpa zea* larvae (L4-L5) produced per acre on various host crops averaged across four counties within nine sample weeks in North Carolina in 2003.

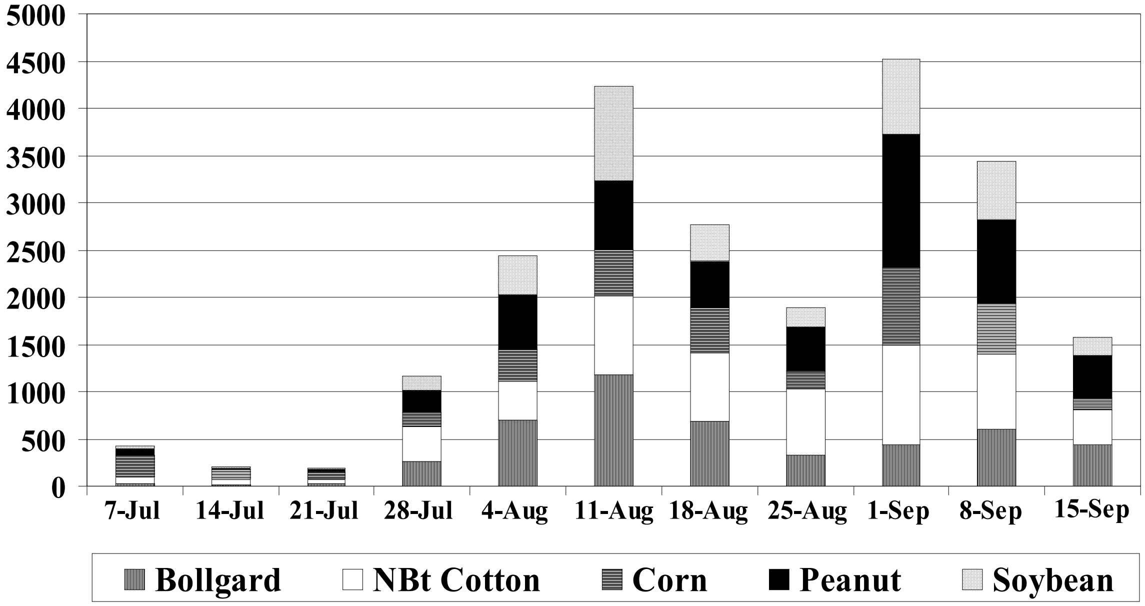

Figure 2. Mean numbers of *Helicoverpa zea* adults per two-trap set week at various crop host interfaces averaged across four counties within eleven sample weeks in North Carolina in 2003.