Field evaluation of the impact of Bt-cotton on non-target soil arthropods in Colombia during 2003 to 2005

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INTRODUCTION

The incorporation of genetically modified (GM) crops in agriculture has been rapid and impressive (James 2008). During 2008 the global GM area reached 125 million hectares (308 millions acres). While it took ten years for this technology to be adopted across the first billion acres, the second billion acres were reached in only three years. At present, 25 countries have adopted the use of GM crops, of which 15 are developing countries and the others industrialized.

Colombia is not exempt from this situation. Since approval and commercial release of Bt-cotton (Nucotn 33B) in 2003, the area increased from 6,200 ha harvested in the 2003-2004 growing cycle, to 26,000 ha in 2008. Despite this level of acceptance by growers, the situation has generated a series of questions at the national level related to what benefits and costs the incorporation of new GM technologies will have for Colombian agriculture.

Among these concerns is the possible effect that the implementation of Bollgard® technology may have on non-target soil arthropods. For this reason, there is a need to conduct studies in cotton regions of Colombia to establish the possible effects of these technologies on non-target soil arthropods over time, based on rigorous scientific field studies.

OBJECTIVES

- Evaluate the long-term effect of Bollgard® technology on non-target soil arthropods in field plots.
- Generate information on the species richness of soil arthropods associated with transgenic and non-transgenic cotton in the Cauca Valley.

MATERIALS AND METHODS

In collaboration with ICA's division of Agricultural Regulation and Protection, we initiated field studies for the first cycle of cotton at the ICA research station in Palmira, located at 03°31'N, 76°19'W, 975 m elevation, annual precipitation 1295 mm, mean temperature 24ºC, relative humidity 76%, and corresponding to the Holdridge life zone of Dry Tropical Forest.

Evaluations were conducted within the methodology implemented by ICA to evaluate the effect of Bollgard® technology on arthropod populations in cotton crops grown in the departments of Tolima, Huila and Valle del Cauca.

The experimental units were plots measuring 225 m^2 (15 x 15 m) in a completely randomized block design. Each block had 6 plots for a total of 24 plots under evaluation. Plant material was (1) Bollgard® technology represented by the variety NuCotn 33B that contains the Cry1A(c), and (2) the conventional technology represented by variety DP 5415.

Sampling: Information was gathered from two types of samples: pitfall traps and soil cores extracted in berlese funnels. Pitfall traps were located between plants within the rows; eight were set out in each experimental plot (Fig. 1) and these were opened to sampling for a 24-hour period each week. In addition to the pitfall traps, a cup cutter was used to take soil samples every 2 weeks. The cup cutter had a diameter of 10 cm and the sample was taken to a depth of 10 cm in the row between plants (Fig. 2). Field samples were brought to the laboratory for their processing on the same day (Fig. 3).

Figure 1. (A) Fixed and removable components and (B) lid of the pitfall traps in the field.

Figure. 2. Field collection of samples using a "lever action hole cutter" for extraction of arthropods in berlese funnels.

Analysis of information: The statistical model used for data analysis was a completely randomized block design. With this design an ANOVA was used to test for differences in arthropod abundance between treatments.

In addition, the most abundant groups were analyzed by measuring the area under the population curve (accumulated insect-days) to determine differences betweeb treatments over the course of the trial. Various indices of taxonomic diversity, dominance and equity were also used to assess differences between treatments.

Figure. 3. Cleaning and storage of samples in the laboratory.

RESULTS

Arthropod Taxonomic Composition. During the three cycles of evaluation (2003-2005), 1,573,041 specimens were captured representing 22 orders and 10 taxonomic classes (Table 1, 2). The most abundant class was Aracnida with 59.0% total individuals captured (Table 1). Of all individuals captured, 50.4% of those were associated with Bt cotton and 49.6% with conventional cotton (Table 1). Of the 22 identified orders, the most abundant were Acari and Poduromorpha with 58.9 and 19.9%, respectively. During the three cycles differences between treatments are not evident for each of the taxa identified. Of taxa identified in the three cycles, only Chilopoda, Diplopoda, Diplura, Entomobryomorpha, Hymenoptera and Thysanoptera exhibit a significant difference in abundance between cycles. Of the 28 taxa identified during the three years (2003-2005), only 8 were more abundant during 2005.

Table 1. Number of individuals and composition of arthropod classes caught in Pitfall traps and Berlese funnels in cotton, during 2003 to 2005 in the Cauca Valley, Colombia.

class	DP5415	%	NuCotn 33B	%	Total	%
Aracnida	483,577	61.9	445,608	56.2	929,185	59.0
Chilopoda	1,680	0.2	1,595	0.2	3,275	0.2
Collembola	184,375	23.6	241,399	30.5	425,774	27.1
Diplopoda	1,327	0.1	1,562	0.2	2,889	0.2
Diplura	2,024	0.2	1,751	0.2	3,775	0.2
Insecta	100,286	12.9	94,458	11.9	194,744	12.4
Malocostraca	215	0.0	253	0.0	468	0.0
Pauropoda	1,382	0.1	1,194	0.1	2,576	0.2
Protura	220	0.0	176	0.0	396	0.0
Symphyla	5,382	0.7	4,577	0.6	9,959	0.6
Total	**780,468**	**100**	**792,573**	**100**	**1,573,041**	**100**

Table 2. Abundance of arthropods (mean ± S.E. number of individuals caught per evaluation date) associated with cotton, during 2003 and 2004 in the Cauca Valley, Colombia.

Taxa	Between treatments		Between samples		Between cycles		
	DP 5415	NuCotn	Pitfall	Berlese	2003	2004	2005
Acarina	59.8±1.7a	55.2±1.6a	14.5±0.4b	272.5±5a	30.2±1.0c	82.7±3.2b	78.4±2.3a
Aranae	0.1±0.0a	0.1±0.0a	0.1±0.0a	0.1±0.0a	0.1±0.0c	0.2±0.0b	0.2±0.1a
Blattaria	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0b	0.0±0.0b
Chilopoda[1]	0.2±0.0a	0.2±0.0a	0.0±0.0b	1.2±0.0a	0.0±0.0b	0.3±0.0a	0.4±0.0a
Coleoptera	0.4±0.0a	0.4±0.0a	0.1±0.0b	1.5±0.1a	0.4±0.0b	0.4±0.0a	0.4±0.0a
Dermaptera	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0b	0.0±0.0a	0.0±0.0a
Diplopoda[1]	0.2±0.0a	0.2±0.0a	0.0±0.0b	1.0±0.1a	0.0±0.0c	0.1±0.0b	0.5±0.0a
Diplura[1]	0.3±0.0a	0.2±0.0a	0.0±0.0b	1.4±0.0a	0.1±0.0c	0.3±0.0b	0.5±0.0a
Diptera	0.2±0.0a	0.1±0.0a	0.1±0.0b	0.6±0.0a	0.2±0.0c	0.1±0.0b	0.2±0.0a
Entomobryomorpha	7.5±0.3a	6.4±0.3a	0.9±0.0b	37.4±1.0a	6.1±0.3c	7.2±0.4a	8.0±0.4b
Hemiptera	0.0±0.0a	0.0±0.0a	0.0±0.0b	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
Homoptera	0.5±0.0a	0.5±0.0a	0.5±0.0b	1.0±0.1a	0.5±0.0b	1.0±0.0a	0.2±0.0c
Hymenoptera	11.2±0.5a	10.6±0.5a	10.1±0.4b	14.6±1.3a	21.9±0.8a	1.9±0.2b	1.2±0.3c
Isopoda	0.0±0.0a	0.0±0.0a	0.0±0.0b	0.1±0.0a	0.1±0.0a	0.0±0.0b	0.0±0.0b
Lepidoptera	0.0±0.0a	0.0±0.0a	0.0±0.0b	0.2±0.0a	0.1±0.0a	0.0±0.0a	0.0±0.0a
Mantodea	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0b	0.0±0.0a	0.0±0.0b
Neelipleona	0.0±0.0a	0.0±0.0a	0.0±0.0b	0.2±0.0a	0.0±0.0a	0.0±0.0b	0.0±0.0b
Neuroptera	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
Orthoptera	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0b	0.0±0.0a	0.0±0.0a	0.0±0.0a
Pauropoda[1]	1.0±0.1a	0.9±0.1a	0.0±0.0b	1.0±0.0a	0.5±0.1c	0.4±0.0b	1.8±0.1a
Poduromorpha	15.3±1.9a	23.5±2.6a	21.9±1.9b	6.7±0.3a	31.6±3.0a	17.3±2.9a	1.0±0.1b
Protura[1]	0.0±0.0a	0.0±0.0a	0.0±0.0b	0.1±0.0a	0.0±0.0b	0.0±0.0a	0.1±0.0a
Psocoptera	0.0±0.0a	0.0±0.0a	0.0±0.0b	0.1±0.0a	0.0±0.0b	0.0±0.0a	0.0±0.0a
Strepsiptera	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
Symphyla[1]	0.7±0.0a	0.6±0.0a	0.0±0.0b	3.7±0.1a	0.7±0.0c	0.8±0.0a	0.4±0.0b
Symphypleona	0.0±0.0a	0.1±0.0a	0.0±0.0b	0.1±0.0a	0.1±0.0a	0.0±0.0b	0.0±0.0a
Thysanoptera	0.0±0.0a	0.0±0.0a	0.0±0.0b	0.1±0.0a	0.0±0.0b	0.0±0.0a	0.0±0.0c
Thysanura	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
Unidentified	0.0±0.0a	0.0±0.0a	0.0±0.0b	0.2±0.0a	0.0±0.0a	0.1±0.0b	0.0±0.0c

[1]Taxonomic Class (Including for analysis)

For each row, means followed by different letters are statistically different at P<0.05 (Tukey-Kramer test for multiple comparisons)

Pitfall traps: Over all three cycles (2003-2005), 650,777 individuals were captured, representing 19 orders and 4 classes of arthropods (Table 3). Of all individuals captured, 54.8% were from Bt cotton and 45.2% from conventional cotton. Of the 19 orders, the most abundant were Poduromorpha, Acari and Hymenoptera with 45.3, 30.0 and 20.9% of total captures, respectively (Table 3). Abundance, in terms of individuals per order, was 1.2 times greater in NuCotn 33B; of all orders, 10 were more abundant in DP5415 (Table 3). Only the orders Chilopoda, Diptera and Isopoda exhibited a significant difference in abundance between treatments. While Chilopoda and Isopoda were more abundant in NuCotn 33B, Diptera was more abundant in DP5415 (Table 3).

Berlese funnels. Over all three cycles (2003-2005), 922,841 individuals were captured, representing 22 orders and 6 classes of arthropods (Table 3). Of all individuals captured, 52.8% were from conventional cotton and 47.2% from Bt cotton. The most abundant order was Acarina, with 79.3% of total captures; this order was 1.1 times more abundant in DP5415.

Only the orders Coleoptera, Diplura, Entomobryomorpha and Hemiptera exhibited a significant difference in abundance between treatments; they were all more abundant in DP5415 (Table 3).

Arthropod Taxonomic Diversity: The species richness and Shannon indices were not significantly different between the treatments NuCotn 33B and DP5415. The Simpson index showed dominance for one species, presenting the same value (0.4) for DP5415 and NuCotn 33B. Finally, in the comparison of diversity across the three cycles (2003 to 2005), no significant differences were observed in richness based on the taxa identified. The Simpson index did not differ across the three cycles of evaluation. The value of the equality index showed a tendency for greater diversity in the surveys conducted in 2003.

Table 3. Number of individuals and composition of arthropod orders caught in Pitfall traps and Berlese funnels in cotton, during 2003 and 2004 in the Cauca Valley, Colombia.

Taxa	Pitfall traps		Berlese funnels	
	DP 5415	NuCotn 33B	DP 5415	NuCotn 33B
Acarina	96,590a	98,845a	385,783a	345,865a
Aranae	1,057a	774a	147a	124a
Blattaria	45a	39a	21a	12a
Chilopoda	9b	28a	1,671a	1,567a
Coleoptera	1,010a	966a	2,176a	1,863b
Dermaptera	33a	34a	18a	23a
Diplopoda	92a	111a	1,235a	1,451a
Diplura	33a	26a	1,991a	1,725b
Diptera	668a	402b	934a	711a
Entomobryomorpha	5,252a	61,77a	55,017a	4,5348b
Hemiptera	113a	110a	75a	38b
Homoptera	3,076a	2,980a	1,322a	1,335a
Hymenoptera	70,976a	65,083a	19,035a	20,124a
Isopoda	50b	119a	165a	134a
Lepidoptera	59a	52a	292a	305a
Mantodea	3a	2a	0a	1a
Neelipleona	0a	0a	259a	202a
Neuroptera	12a	16a	1a	0a
Orthoptera	76a	67a	9a	9a
Pauropoda	0a	0a	1,382a	1,194a
Poduromorpha	114,529a	180,336a	9,145a	8,738a
Protura	1a	0a	219a	176a
Psocoptera	47a	24a	70a	79a
Strepsiptera	0a	0a	1a	0a
Symphyla	30a	28a	5,352a	4,549a
Symphypleona	99a	533a	74a	65a
Thysanoptera	91a	74a	121a	108a
Thysanura	0a	0a	2a	1a
Unidentified	0a	0a	282a	295a
Sum	**293,951**	**356,826**	**486,799**	**436,042**

CONCLUSIONS

- These studies have identified a high abundance and diversity of soil-active and surface-active fauna associated with cotton crops under the conditions of the Cauca Valley, Colombia.
- Pitfall traps are an appropriate method for measuring the abundance of surface-active arthropods and comparing their activity and diversity across treatments.
- Extracting soil cores with berlese funnels is an appropriate method for measuring the abundance of soil-active arthropods and comparing their activity and diversity across treatments.
- No significant differences were observed in abundance between the treatments during three evaluation cycles.
- 17 of the identified taxa did not exhibit a significant difference in abundance across cycles (2003-2005).
- Although abundance and diversity differences may exist in response to GM technology, it is important to determine whether the magnitude of those differences is ecologically relevant, i.e. have an effect on ecological function or overall soil health.

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