2005 Beltwide Cotton Conferences, New Orleans, Louisiana - January 4 - 7, 2005

NINE YEARS OF TRANSGENIC COTTON IN MéXICO, ADOPTION AND RESISTANCE MANAGEMENT RESULTS

Jose L. Martinez-Carrillo
INIFAP
Ciudad Obregon, Sonora,
Nicolas Diaz-Lopez
Monsanto
Mexico. D. F., ME

Abstract

Transgenic Bt cotton has been well accepted in Mexico since 1996, when it became available to growers. Even though, cotton hectareage has decreased during the last ten years due to different factors such as international fiber price, drought, high production costs, lack of federal government support, fiber importation and others; transgenic cotton has increased from 0.3% in the 1996 season to 60.6% in 2004, of the total cotton area established in Mexico. Cotton is produced under irrigated conditions in the states of Chihuahua, Sonora, Baja California, Coahuila, Durango, and northern Tamaulipas, all located in northern Mexico., In the 2003-2004 growing season, Chihuahua planted 49.04% transgenic cotton of the 107, 346 ha established in Mexico, Sonora, 17.82%, Baja California 16.49% and Comarca Lagunera (region that includes the states of Coahuila and Durango) 14.48%. Since 1999, transgenic Bt cotton plus the herbicide resistant gene is been used by farmers in Mexico. This technology has also been well adopted and this season the area planted with this dual gene was 16.14%. Resistance management strategies include the use of refuges planted with conventional cotton; these should be around 20% of the area in any production system. Monitoring of resistance is mandatory and has been performed since 1997, on cotton bollworm, tobacco budworm and pink bollworm. Results of this program have not shown any change in response of these insect populations to the CryIAc toxin present in the Bollgard® materials established in Mexico.

Introduction

Worldwide adoption of transgenic crops continues to grow. It was estimated that 67.7 million hectares were planted in 2003, and 7 million farmers in 18 countries used this technology. Almost one-third of the area planted with transgenic crops has been established in developing countries. It is estimated that in the next five years 10 million growers in 25 countries will grow 100 million hectares of transgenic crops (James C, 2003). Transgenic plants with insecticide properties represent a new tool for insect pest management. Mexico has adopted this new technology and since its release in 1996, Bt (Bollgard®) cotton has been used by farmers interested in obtaining better yields, reduction in the use of pesticides and in production costs. After nine years, transgenic cotton reached 60.6% of the 107, 346 hectares planted this season. In some areas more than 70% was planted to transgenic cotton. Since 1999, transgenic (Bollgard® SF) cotton, which contains Bt cotton plus the herbicide resistant gene is been used by growers in Mexico. It has also been well accepted and this season the area planted with this dual gene was 16.14%.

The area planted to cotton has been variable in the last ten years, influenced by the international fiber price, drought, high production costs, lack of subsides, fiber importation, and others. In 1993 there were planted only 42,539 hectares, mainly due to whitefly outbreaks in the early 1990´s (Martinez-Carrillo, 1994). In 1994, 175,375 hectares were established, and reached a maximum of 314,776 in 1996. This situation was mainly influenced by an increase in the fiber price which reached 92.72 cents per pound in 1994; thereafter, it decreased as did cotton area in Mexico. This trend continued and by the season 2001-2002 there were planted only 40,483 hectares, the lowest cotton hectareage established in Mexico up to day. In 2003, the increase in fiber price, and better federal government support stimulated cotton growers and 62,892 hectares were planted, this year the area increased to 107,346 hectares (Table 1). Growers have been motivated by good yield and better pest control, consequently, an increase in area is expected for the next cotton season.

Cotton is produced under irrigated conditions in the states of Chihuahua, Sonora, Baja California, Coahuila, Durango, and northern Tamaulipas, all located in northern Mexico., all located in northern Mexico. This 2003-2004 cotton season, Chihuahua planted 49.04% of the 107, 346 established in Mexico, Sonora, 17.82%, Baja California 16.49% and Comarca Lagunera, (region that includes the states of Coahuila and Durango) 14.48% (Table 3).

Key insect pests vary in each region, for Chihuahua, pink bollworm, stink bugs, whiteflies, bollworm and tobacco budworm are important pests in the north part of the state, while boll weevil is the key pest in the rest of the state. In 2001, a suppression program for pink bollworm and boll weevil was initiated at the state level. This program is conducted in cooperation with the Department of Agriculture of the United Stated (USDA). Results are encouraging and sprays for control of the key insect pests have been reduced considerably.

The state of Sonora has two main cotton production areas, with different characteristics. In the northern region were climatic conditions change from arid to semiarid includes Caborca and Sonoyta, cotton is produced through well irrigation. Key insect pests are sucking insects such as lygus bugs and whiteflies. Pink bollworm, cotton bollworm and tobacco budworm have been reduced due to the increasing use of Bt transgenic cotton. In south Sonora, climate is semiarid; cotton is now irrigated by water obtained from wells, due to drought affecting this area. The key pest is boll weevil *Anthonomus grandis*, followed by a complex of sucking insects such as lygus bugs, cotton fleahopper *Pseudatomoscelis seriatus*, and whitefly *Bemisia argentifolii*, The bollworm-tobacco budworm complex *Helicoverpa zea* and *Heliothis virescens* is another important problem during fruit production.

In the Mexicali Valley, located in the state of Baja California, pink bollworm *Pectinophora gossypiella*, lygus bugs *Lygus hesperus*, *L. lineolaris* y *L. elisus*., silverleaf whitefly *Bemisia argentifolii*, and bollworms-tobacco budworm complex *Helicoverpa zea* and *Heliothis virescens* are the main pests.

Comarca Lagunera, region which integrates parts of the states of Coahuila and Durango, had in the past serious problems with pink bollworm. Currently the main problems are sucking insects like stink bugs *Chlorochroa ligata* and *Nezara viridula*, whiteflies, aphids and cotton bollworm which continues to be a problem, however, spraying has been reduced to only two per season (Sánchez 2000, Nava et al. 2002).

In northern Tamaulipas, cotton is irrigated whereas the south is rain feed. The key pest is boll weevil which is sprayed 5 times in the northern part of the state and 15 times in the southern. Other entomological problems include cotton bollworm, tobacco budworm, beet armyworm, whiteflies, and fleahoppers. Farmers spray two or three times during the cotton season for these insects. This year there was not cotton planted in southern Tamaulipas.

In Mexico, as in other parts, there is a concern that resistance could evolve in those insect populations subjected to selection pressure by these toxins (Gould et al. 1995). The mode of action of the toxins responsible for insect control and its high expression in plants makes them candidates to select insect populations for resistance, thus resistance management strategies have been implemented and involve mainly refuges of conventional cotton close to areas planted with Bollgard® and Bollgard® SF (Solución Faena) wich is the herbicide resistant cotton. A resistance monitoring program has been implemented to detect any shift in response of Cotton Bollworm *Helioverpa zea*, tobacco budworm (TBW) *Heliothis virescens*, and pink bollworm *Pectinophora gossypiella* populations, to the CryIAc toxin present in the Bollgard® varieties,

Materials and Methods

Statistics. Data of area planted to cotton in Mexico since the introduction of transgenic cotton was obtained from Sistema de Información Agropecuaria de Consulta (SIACON) http://www.siap.sagarpa.gob.mx. Data of the area planted to transgenic cotton in Mexico, was obtained form Monsanto Comercial S.A. de C. V.

Resistance Monitoring. This program is performed by three laboratories in Mexico, each one evaluates the response to one of the key insect pests under selection pressure. Tobacco budworm resistance to the CryIAc toxin is monitored in the INIFAP, Entomology Laboratory of the Yaqui Valley Field Experimental Station, located in Cd. Obregón, Sonora. Cotton Bollworm in the laboratory of Plant health in Colegio de Posgraduados, Mexico and pink bollworm in the laboratory of INIFAP located in La Laguna Field Experimental Station in Torreón Coahuila. Monitoring is performed under standard techniques and has been previously described (Martinez-Carrillo 2000, Martinez-Carrillo, et al. 2003).

Results and Discussion

Adoption of transgenic Bollgard® cotton which expresses the toxin CryIAc of *Bacillus thuringiensis kurtaki* Berliner has been cultivated since its introduction in Mexico in 1996; at that time, 896.8 ha were planted in southern Tamaulipas. This technology became better known and 16,677 ha were planted in 1997. Reduction of pink bollworm populations and sprays in Comarca Lagunera, was key to rapid adoption of Bollgard® cotton. This region which integrates parts of Coahuila and Durango, use to have serious problems with pink bollworm, they sprayed up to seven times against this pest. Through the use of Bt cotton, pink bollworm and other insect pests such as tobacco budworm, have been reduced drastically. Currentl, the main problems are sucking insects like stink bugs *Chlorochroa ligata* and *Nezara viridula*, whiteflies, aphids and cotton bollworm which continues to be a problem, however, applications have been reduced to only two per season (Sánchez 2000, Nava y et al. 2002).

In 1998, Bt cotton was grown in 35 630 ha reaching 14.3% of the 249, 602 ha planted, then in 1999 Bollgard® SF (Solución Faena) became available establishing 24.5 ha, total transgenic cotton was 12.5%. In 2000 there was an increase in both Bollgard® and Bollgard® SF adoption with 33.4% of the total cotton hectareage planted in Mexico. Since then adoption has increased reaching 60.6% of the 107,346 ha planted in 2004 (Table 1)

Adoption has been variable trough the different cotton-producing areas of Mexico. This variation is the result of diverse conditions of the production systems (Tables 2 and 3). Baja California has pink bollworm as a key pest, however they have had a good cultural control and spray an average of 1.8 to 2.0 times, thus transgenic cotton is not a real solution to their problem. In the 2004 cotton season there were planted 3,429 ha Bollgard® and 915 ha Bollgard® SF out of 17, 697 established. This represents 24.55% of transgenic cotton.

Northern Sonora has a similar situation and in 2004, there were planted 868 ha Bollgard® and 361 ha Bollgard® SF, which represented 20.75% of the 5,921 ha planted. The transgenic cotton area in southern Sonora reached 74.50% of the 13, 204 ha planted. This year, Bollgard® and Bollgard® SF were appreciated due to high tobacco budworm populations present in the area. However, lygus bugs and other plant sucking insects needed to be sprayed. Nevertheless, good yields encouraged growers to demand transgenic cotton for the next cotton season.

Chihuahua is the largest state in Mexico and the major producer of cotton. During the 2004 cotton season 52, 645 ha were planted, that is 49.04% of the total area established in Mexico. They have a suppression program for pink bollworm and boll weevil at the state level, in cooperation with the Department of Agriculture of the United States (USDA). They are using Bollgard® and Bollgard® SF as part of the suppression program. This 2003-2004 season 26,254 ha were Bollgard® and 11,574 Bollgard® SF, representing both 71.85% of the cotton area in the state.

Resistance Management strategies in Mexico are based in leaving refuges of conventional cotton close to areas planted to transgenic cotton. There are two options, in the first, 80% should be transgenic cotton and 20% conventional refuge in the second one 96% should be transgenic cotton and 4% conventional. In the first option growers are allowed to spray for insect control but not Bt´s and in the second pesticides are not permitted for insect pest control. In order to detect any change in susceptibility of the populations under selection pressure for the CryIAc toxin, monitoring of resistance is performed through bioassays utilizing diagnostic dosages for each insect pest. Susceptibility is measured through the evaluation of mortality, growth inhibition, and larval development to the third instar. A colony is established from populations collected in each cotton production area of Mexico and compared to a susceptible colony that has been reared in laboratory since 1982 without selection pressure. Results up to now indicate that those populations that have been evaluated are susceptible to the CryIAc toxin expressed in transgenic cotton used in Mexico (Martinez-Carrillo et. al. 2003).

Conclusions

Adoption of transgenic crops continues growing worldwide. In Mexico this technology has been accepted and has increased from 0.3% in 1996 to 60.6% in 2004 of the total cotton area planted. Since 1999 a new variety has been introduced which contains besides the CryIAC toxin of *Bacillus thuringiensis kurstaki*, a gene that codifies for resistance to the herbicide glifosate. Increase in fiber price, and better federal government support stimulated cotton growers to grow more than 100, 000 hectares of cotton this past season, good yield and better pest control has

motivated them, consequently an increase in area and therefore in transgenic cotton is expected for the next season. No change in susceptibility to the CryIAc toxin has been detected.

Acknowledgements

We acknowledge the collaboration of personnel from Monsanto Comercial S.A de C.V for collecting the biological material and personnel from the Entomology Laboratory in the Yaqui Valley Experimental Station for their assistance during the development of bioassays. Appreciation is also expressed to Dr. Miguel Camacho Casas and Dr. Guillermo Fuentes Davila for comments to the manuscript.

References

Gould, F., A. Anderson, A. Reynolds, L. Bumgardner, 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.

James; C. 2003. Preview: Global Status of Commercialized Transgenic Crops: 2003. ISAAA. Briefs No. 30. ISAAA:Itaca, NY.

Martínez-Carrillo J. L. 1994. Problemática Fitosanitaria causada por la Mosquita Blanca en México. **In**: Memoria de la Segunda asamblea anual del CONACOFI. 14-15 de noviembre. Montecillo, Edo de México. pp. 77-88.

Martínez-Carrillo, J. L., Urbano Nava Camberos and Mariano Berdegue. 2000. Monitoring for tolerante to CryIA(c) in populations of Heliothis virescens from Mexico. Procc. Beltwide Cotton Conferences. Vol. 2:1017-1019.

Martinez-Carrillo, J. L., U. Nava-Camberos and C. Rodriguez M. 2003. Monitoring Resistance in Mexican Populations of TBW, CBW and PBW for response to CryIA(c) ttoxin of *Bacillus thuringiensis*. Resistance Pest Management Newsletter. Vol 13 No. 1 (Fall 2003).

Nava Camberos, U., E. Valenzuela Herrera, y E. López Ríos. 2002. Efectividad del algodonero transgénico para el manejo integrado del gusano rosado en la Comarca Lagunera, México. Entomología Mexicana Vol. 1. 356-361.

Sánchez, A. J. 2000. Situación Actual de la Campaña contra las plagas del algodonero en la Región Lagunera. **In**: Memorias de la 7ª. Reunión Anual del CONACOFI. 24-25 de octubre. Puebla, Pue. pp. 146-147.

Table 1.- Total Area Planted to Bollgard® and Bollgard® SF cotton, and percent adoption since the introduction of transgenic cotton in Mexico

Year	Total Cotton Area* Ha	Bollgard® ** ha	Bollgard® SF ha	Percent Transgenic Cotton
1993	42539			
1994	175375			
1995	294512			
1996	314776	896.8		0.3
1997	214378	16677		7.8
1998	249602	35629.7		14.3
1999	149299	18653.0	24.5	12.5
2000	80166	26299.5	460.5	33.4
2001	91899	23392.5	1818.5	27.4
2002	40483	13960.0	1235.0	37.5
2003	62892	23897.0	2160.8	41.4
2004	107346	47679.0	17326.6	60.6

* Source: Sagarpa (SIACON) ** Source: Monsanto Comercial S. A, de C. V.

Table 2. Adoption of Bollgard® and Bollgard® SF cotton in each cotton-producing area in Mexico. 2003-2004 season.

REGION	Bollgard®	Bollgard® SF	TOTAL
Baja California	3429	915	4344
Northern Sonora	868	361	1229
Southern Sonora	7230	2608	9838
Sinaloa	0	6.6	6.6
Chihuahua	26254	11574	37828
Comarca Lagunera	9898	1862	11760
Total	**47679**	**17326.6**	**65005.6**

Table 3. Planted cotton in each region, percent of the total area and percent transgenic cotton by region in the 2003-2004.season.

REGION	Cotton Planted	Percent Total Cotton	% Transgenic Cotton
Tamaulipas	2043	1.90	0.00
Baja California	17697	16.49	24.55
Northern Sonora	5921	5.52	20.75
Southern Sonora	13204	12.30	74.50
Sinaloa	294	0.27	2.04
Chihuahua	52645	49.04	71.85
Comarca Lagunera	15542	14.48	75.66