

## Transgenic Cotton in Mexico

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We examine the farm-level impact of Bt cotton in Coahuila and Durango, Mexico. Bt cotton was introduced in Mexico in 1996. It has been an important tool in reducing pesticide use by more than 50% and generating annual benefits of US\$2.7 million. About 85% of benefits accrued to farmers and 15% to seed suppliers. Adopting farmers spent \$100 less on pest control and had \$295/ha higher net revenue than nonadopting farmers. The average holding of adopting farmers was 14 ha. Bt cotton has been a valuable technology for certain areas in Mexico. Cotton profitability and competitiveness have increased, and the risk of crop failure from insect infestation has been reduced. Victory over the pink bollworm, once the dominant insect pest, would not have been possible without Bt cotton. Because Bt cotton protects only against a certain spectrum of the pest population, national adoption stands at 33%.

**Key words:** adoption, biotechnology, Bt cotton, Mexico.

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### Introduction

In 1996, Mexico and the United States became the first two countries to plant Bt cotton commercially. Bt cotton area in Mexico reached 26,300 hectares (one third of the country's cotton area) during the 2000 growing season, with adoption varying from less than 10% in Sinaloa and Baja California to 96% in Comarca Lagunera. The same two Bt cotton varieties (NuCOTN 33B and NuCOTN 35B) that were introduced in the United States in 1996 through a strategic alliance between Monsanto and Delta and Pineland Co. (D&PL) have subsequently been marketed in five other countries, including Mexico.

In this paper, we summarize the impact of the introduction of Bt cotton in the Comarca Lagunera region in the northern states of Coahuila and Durango.<sup>1</sup> The cotton area in Comarca Lagunera peaked at 142,777 hectares in 1944 but fell to less than 1,000 ha in 1992 and 1993 because of price and exchange rate volatility, changes in government policy, and a scarcity of water for irrigation. In 1994, Mexico's federal government and the state of Coahuila created a fund to reactivate the cultivation of cotton in the region. This fund provided for subsidized credit to producers through producer associations. At present, cotton yields in the Comarca Lagunera stand at 125% of the national average, having increased from less than one ton/ha in the late 1980s to 1.6 tons/ha in 2000 (Figure 1). Yields had previously

peaked in 1984, then declined due to serious problems with pest control. Only 8,283 ha of cotton were planted in the Comarca in 2000.

### Insect Complexes, Adoption of Bt Cotton, and Chemical Pesticide Use

Seven important insect pests plague cotton in Mexico. The most damaging are pink bollworm (*Pectinophora gossypiella*), boll weevil (*Anthonomus grandis*), tobacco budworm (*Heliothis virescens*), and cotton bollworm (*Helicoverpa zea*), but fall armyworm (*Spodoptera exigua*), white fly (*Bemisia argentifolii*), and conchuela (*Chlorochroa ligata*) also cause crop damage and require treatment in some areas. Patterns of infestation levels and economic losses vary widely across the main growing regions and have been important determinants of the adoption of Bt cotton (Table 1). Bt cotton is 100% effective in controlling two major pests—pink bollworm and cotton bollworm—and is partially effective in controlling tobacco budworm and fall armyworm. These four pests are often referred to as the budworm-bollworm complex (BBWC). Although annual infestation levels are variable, the BBWC are most damaging in Comarca Lagunera and Tamaulipas.

Pest populations vary from year to year as a result of weather conditions, cultural practices, and cropping patterns. Each year the government Plant Health Authority locates several dozen insect traps around Comarca Lagunera to monitor pest pressure. Pest infestation levels, particularly of boll weevil and pink bollworm, have fallen during the 1990s. Neither the pink bollworm nor the boll weevil has important plant hosts other than cot-

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1. A more comprehensive discussion of Bt cotton in Comarca Lagunera can be found in Traxler, Godoy-Avila, Falck-Zepeda, and Espinoza-Arellano (2003).

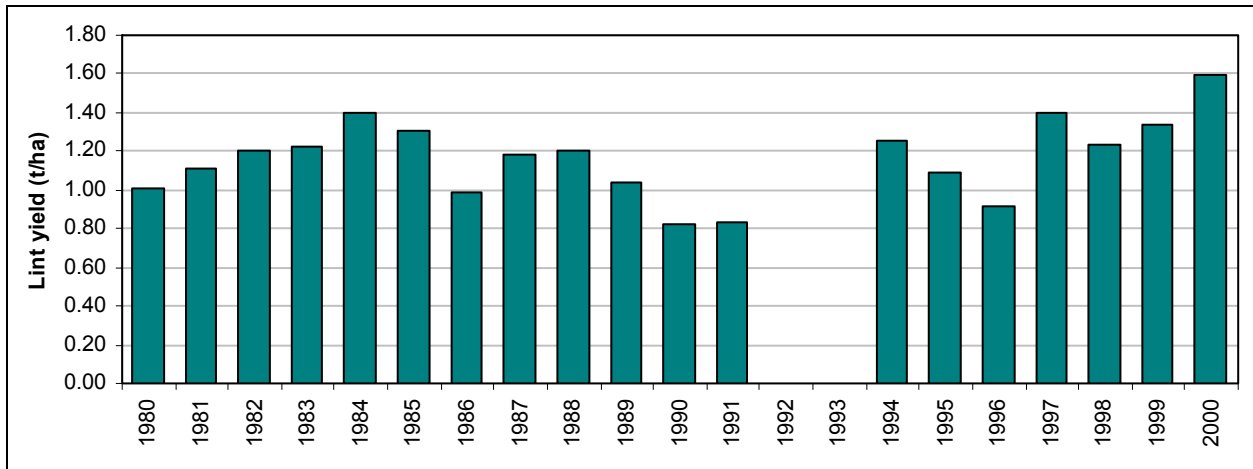


Figure 1. Cotton lint yields, Comarca Lagunera, Mexico, 1980–2000.

Table 1. Geographic distribution of pest problems in Mexico's major cotton areas.

Pest	Bt effective-ness (%)	Alternate plant hosts	Seriousness of problem <sup>a</sup>					
			Laguna	Tamaulipas	North Chihuahua	South Chihuahua	Sonora	Baja California
Pink bollworm	99	none	highest	none	minor	medium	medium	medium
Cotton bollworm	90:70 <sup>b</sup>	maize, tomato	high	high	medium	medium	minor	minor
Tobacco budworm	95	maize, tomato	medium	high	medium	medium	medium	minor
Fall armyworm	20 or less	many	minor	high	medium	medium	minor	minor
Boll weevil	0	none	eradicated	highest	minor	highest	minor	none
White fly	0	many	minor	none	none	none	highest	highest
Conchuela	0	many	high	none	minor	minor	minor	minor
2000 Bt adoption	—	—	96%	37%	38%	33%	6%	1%

<sup>a</sup> Highest requires multiple applications annually, potentially heavy crop damage; high: 2-3 applications required most years, some crop damage; medium: 1-2 applications required most years, minor crop damage; minor: not necessary to spray most years, some crop damage.

<sup>b</sup> Pre-bloom stage effectiveness: Blooming stage effectiveness

ton, so effective cotton residue management and the high adoption rate of Bt cotton have been major factors in reducing pest populations in Comarca Lagunera. The near elimination of cotton during the 1992 and 1993 growing seasons has nearly eliminated the boll weevil. The government has provided financial support averaging \$24/ha from 1998 through 2000 for pest control programs through the Regional Plant Health Committee. The focus has varied through the years, but programs have been carried out in extension, field pest pressure monitoring, post harvest control of cotton residue, and for subsidizing the adoption of Bt cotton.

The combined effect of the disappearance of the boll weevil, use of Bt cotton, and the reduced cotton acreage has been a dramatic fall in the use of chemical pesticides

in Comarca Lagunera. The total amount of active ingredient (AI) applied to cotton in 1999 was just 2% of the amount applied in 1988, falling from 670,709 kgs to 11,842 kgs. Per-hectare pesticide use has fallen by more than 80%, from an average of nearly 14 kgs/ha of active ingredient in the 1980s to about two kgs/ha. The average number of pesticide applications for all insects has also fallen steadily (Figure 2), led by the decline in applications to control BBWC. Pesticide use is lower on Bt than conventional cotton varieties, but it seems clear that all cotton is under less pressure from BBWC than in the past, perhaps because of the widespread adoption of Bt cotton. This suggests that a new low-infestation level pest dynamic may be emerging in the region. Producers are still adjusting to a new approach to pesticide use, in

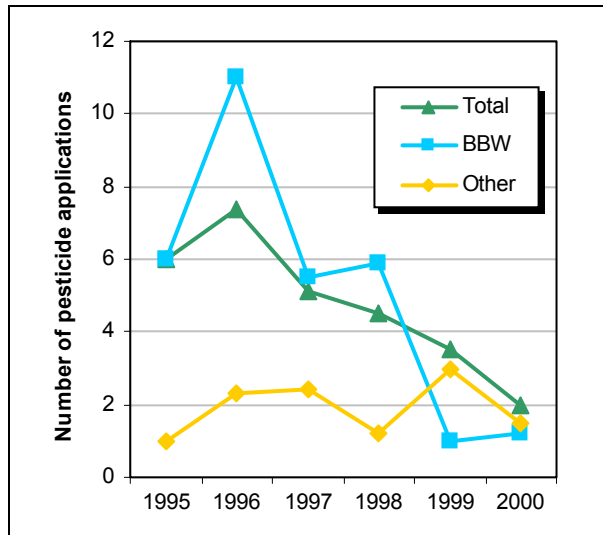


Figure 2. Average number of chemical pesticide applications, Comarca Lagunera, Mexico, 1995–2000. Data from Sánchez-Arellano, 2000.

which they are becoming increasingly reluctant to use chemical pesticides for fear of upsetting the new equilibrium between beneficial and destructive insects.

### Financial Benefits of Bt Cotton in Comarca Lagunera

Bt cotton benefits in Mexico were modeled as occurring in a small open economy (Alston, Norton, & Pardey, 1995; Falck-Zepeda, Traxler, & Nelson, 2000). As holder of a patent on the technology, Monsanto/D&PL has a monopoly on the sale of Bt cotton, giving the firm the power to set seed prices above its marginal cost of production. Therefore, the welfare calculations performed below have two components—changes in farmer surplus and monopoly profits. Monopoly profit was calculated as  $Q_{Bt} (P_{Bt} - c)$ , where  $Q_{Bt}$  and  $P_{Bt}$  are the quantity and price of Bt seed and  $c$  is the marginal cost of producing seed. We assumed that the market for conventional seed cotton is competitive, so that the market price represents the marginal seed production cost,  $c$ . Because no administrative, marketing, research and development, or intellectual property rights enforcement costs were deducted, these figures do not represent true surplus estimates, but rather represent gross Bt revenue.

### Bt and Conventional Cotton Cost and Revenue Differences

Producers in the region are generally classified as falling into two groups: ejidos and small landholders. The ejido producers (or *ejidatarios*) are very small producers

whose holding was formed during one of Mexico's several land reforms. The size of the average ejido holding is 2–10 ha and that of the small landholders is 30–120 ha. The ejidos and small landholders are organized into farmer associations for the purpose of obtaining credit and technical assistance. The associations have centralized accounting, management, and technical staff. Each association comprises a number of smaller groups that farm together. Each farmer group is assigned a technical consultant, who makes most of the production decisions for the fields of all members of the group. In most cases, the individual landholders have relatively little involvement with actual production on their smallholding, deferring to the judgment of the consultant. Because of the link that the associations provide with credit provision, they serve as a very effective conduit for information about new technologies and have undoubtedly served to speed the adoption of Bt cotton varieties.

We collected survey information on yields, revenue, and pest control costs for the first two years that Bt cotton was widely grown in Mexico (1997 and 1998). The data were collected from the technical consultants working for the association SEREASA, one of the largest of the 14 associations in Comarca Lagunera. In 1997, this association had a total of 638 producers owning 4,789 ha of land. Of this, 2,265 ha were planted to cotton in 1997 and 2,023 ha in 1998—about 12% of the cotton area in the Comarca. The members of the association are probably representative of medium to small landholders in terms of size of holding. The median size holding of SEREASA ejido members was 3.5 ha, while that of SEREASA small landholders was 20 ha (Figure 3). The mean cotton acreage was 15 ha in 1997 and 8 ha in 1998.

The Bt variety NuCOTN 35B was grown on 52% of SEREASA cotton area in 1997; two conventional varieties accounted for 48% of the area (Table 2). Yields were about the same for both types of cotton, but conventional cotton graded slightly higher, which is reflected in a \$65/ton higher average price. As a result, conventional cotton produced nearly \$50/ha higher revenue than the Bt variety. Less pesticide, however, was used on the Bt cotton. Conventional cotton averaged 1.57 applications for pink bollworm, but no growers sprayed Bt cotton. Conventional cotton required more than twice as many pesticide applications to control cotton budworm, and slightly more applications for armyworm and other insects. All growers used biological control against cotton bollworms. Bt cotton growers averaged 2.26 fewer total pesticide applications than conventional cotton growers did. Total chemical pesti-

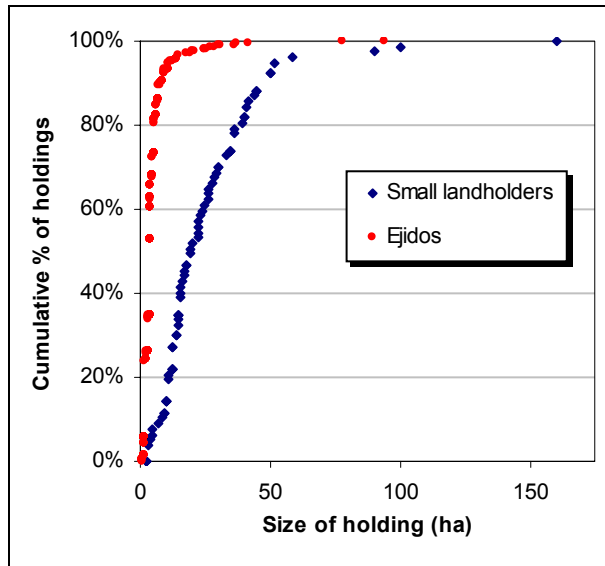


Figure 3. Size distribution of SEREASA land holdings, 1997.

cide costs were \$153.91 less for Bt cotton, and total pest control costs, including seed costs, were \$92.66 less. The net difference in profitability was a \$44.15 advantage for Bt cotton.

Adoption of Bt cotton varieties increased to 72% in 1998, and average Bt yields were 0.29 t/ha higher than for conventional varieties. Lint quality was higher for Bt cotton, giving it a \$543.56/ha revenue advantage. An average of two fewer pesticide applications were used on Bt than conventional cotton, and total seed and pesticide costs were \$83.19 less. The net profit advantage for Bt cotton in 1998 was \$626.74. The large difference in relative profitability of Bt cotton between 1997 and 1998 is likely explained by differences in pest infestation levels. The yield advantage of Bt cotton increases in parallel to infestation levels, and 1997 was a very light year for pink bollworm compared to 1998. By historical standards, even 1998 was not a heavy pink bollworm year.

With more than \$600/ha net benefit during years of pest pressure, and slightly higher profits in low pest years, Bt cotton provides growers a valuable insurance against pest infestation. The profit from 1998 would cover technology fees for several years.

### Benefit Distribution Between Monsanto/D&PL and Cotton Producers

The estimated surplus distribution between Monsanto/D&PL and producers is given in Table 2. After subtracting the estimated cost of seed production, we estimate

Table 2. Estimates of economic surplus distribution in Comarca Lagunera, 1997 and 1998 (\$US).

	1997	1998	Average
Conventional seed price per kg	2.21	2.21	2.21
Cost per ha to produce Bt seed	30.94	30.94	30.94
Monsanto/D&PL Bt revenue per ha	101.03	101.03	101.03
Monsanto/D&PL net revenue per ha <sup>a</sup>	70.09	70.09	70.09
Farmer change in variable profit per ha	44.15	626.74	335.40
Bt area in Comarca Lagunera	4,500	8,000	6,250
Monsanto/D&PL total net revenue <sup>a</sup>	315,405	560,720	438,063
Total farmer surplus	198,675	5,013,920	2,096,250
Total surplus <sup>a</sup> produced	514,080	5,574,640	2,534,313
Monsanto/D&PL share of total surplus <sup>a</sup>	61%	10%	17%
Producer share of total surplus	39%	90%	83%

<sup>a</sup> Monsanto/D&PL net revenue calculated before administrative and sales expenses and before any compensation to Mexican seed distribution agents.

that Monsanto/D&PL were left with a net revenue of roughly \$70/ha. Expenses related to field research, providing technical assistance to farmers, for monitoring contract compliance, or compensation to local seed distribution agents were not subtracted because we do not have this information available. The per-hectare change in variable profit accruing to farmers varied widely between the two years, with an average figure of \$335.45. Therefore, for the two years, we estimate that a total of more than \$6 million in surplus was produced, of which about 86% accrued to farmers and 14% to Monsanto/D&PL; but again, not all of the amount attributed to Monsanto is true surplus, because some costs were not accounted for.

### Seed Prices, Contracts, and Protecting Intellectual Property

When Monsanto/D&PL introduced Bt cotton in 1996 and Roundup Ready soybeans in 1997 in the United States, it also introduced the use of seed licensing contracts, which farmers are required to sign upon seed purchase. The seed contract forbids farmers from saving seed and, in the case of Bt cotton, obligates them to fol-

low a specified resistance management strategy, to refrain from saving seed, to have cotton ginned only at authorized gins, and to contract an entomologist to supervise the farmer's compliance with biosafety standards. Monsanto hires two seasonal field representatives in Comarca Lagunera to spot check cotton fields and to investigate suspected intellectual property (IP) violations. These representatives are equipped with field kits that test for the presence of the Bt gene at a cost of less than \$5 per test. The contractually specified penalty for selling seed—120 times the purchase price—appears to be high enough to have prevented large-scale violations, although some transfer among small farmers is rumored in Comarca Lagunera area.

The contracts with gin owners are another legal initiative taken by Monsanto to protect their revenue from Bt cotton. Because cottonseed can only be separated from the lint by ginning, the gins are a logical focal point for Monsanto to capture the Bt cottonseed. Of the 34 cotton gins in Comarca Lagunera that existed in 1990, only 12 remain. In the contract, the gins are offered the opportunity to become “authorized Monsanto cotton gins” by agreeing to refrain from selling or using Bt seed obtained through the ginning process. Given the 96% adoption of Bt cotton in Comarca Lagunera and that the producers' contract calls for ginning only at Monsanto-authorized gins, it is not surprising that all gins have signed Monsanto's contract. The gins also agree to open their facilities and transaction records to inspection by Monsanto. This allows Monsanto to be informed of any producers who have requested their seed back from the gin.

Total revenue from Bt cottonseed sales in Mexico in 2000 was approximately \$1.5 million. The price charged for Bt varies by growing region. For example, the technology fee is three and half times higher in Northern Tamaulipas than it is in Southern Sonora, where BBWC problems are the lightest. The differential pricing strategy is based on differences in the marginal value product of Bt cottonseed caused by differences in pest pressure and seed application rates. Monsanto/D&PL have attempted to thwart spatial arbitrage by working with the distributors in each region. Distributors are simply asked to refrain from selling Bt cotton to producers from outside of their region. For example, attempts are made to prevent farmers from buying low-cost seed in Chihuahua for planting in neighboring Comarca Lagunera. This appears to have been effective because of the relatively small acreage involved (about 16,000 ha total in Chihuahua and Comarca Lagunera) and the

desire of distributors to maintain good relations with Monsanto/D&PL.

## Summary and Conclusions

Cotton production in the Comarca Lagunera has undergone a transformation over the past decade. The most notable changes are a reduction in pesticide use and the corresponding reduction in the cost of production. The result has been increased profitability and competitiveness, and a reduction in the risk associated with cotton production failures caused by insect infestations. A number of factors have been important in ushering in this new era in cotton production, including the availability of Bt cotton varieties, reduced cotton acreage, and government support for farm credit and integrated pest management.

Bt cotton varieties are in many ways a nearly ideal innovation for the Comarca Lagunera. The region's victory over the pink bollworm—once the dominant insect pest—would not have been possible without Bt cotton. At an average of less than two total chemical pest control applications per season, cotton has become a low-pesticide crop, benefiting both farmers and residents of the region. Bt cotton varieties have been a tremendously useful tool for the Comarca Lagunera, but because they only protect against a certain spectrum of the pest population, they are not a cure-all for cotton production in all regions, as demonstrated by low adoption in other Mexican states.

How relevant for other countries is Mexico's experience with Bt cotton? First, it must be recognized that Mexico is an atypical developing country in several respects. It is large in terms of total agricultural area, the size of its national agricultural research system, and the capacity of its university-based basic research establishment. Mexico also began setting the stage for the use of biotechnology earlier than most countries. It began approving biosafety trials in 1988 and has now accumulated a significant amount of experience with the regulation of transgenics. Cotton production in Comarca Lagunera is also intensive; 95% of cotton is irrigated, yields are high by world standards, infrastructure is well developed, and material, financial, and intellectual inputs are readily available. All of these factors favor the successful adoption of a new technology. Of particular importance in Comarca Lagunera were the key government interventions of credit for financing the purchase of Bt cottonseed combined with technical assistance for small landholders and the implementation of an effective integrated pest management program.

Monsanto has been largely successful in enforcing IP protection in Mexico. The small size of the market and the fact that the Bt gene was introduced into a crop in which seed saving can be monitored through activities at 14 gins and through registers of producer field locations contributed to successful enforcement. Clearly, IP enforcement would be more difficult for other self-pollinating crops, such as wheat, rice, or soybeans, and for crops such as maize, which are grown by more dispersed small farmers. The experience in Mexico suggests, however, that relevant conditions for transferring biotechnology to developing countries through the private sector activities may indeed exist in some situations.

A final point that is worth noting is that despite Mexico's positive experience with Bt cotton, constraints on other biotechnologies do exist. Mexico has about 7.5 million ha of maize, compared to 0.2 million ha of cotton, and would be an attractive market for transgenic maize. However, biosafety testing of transgenic maize has been indefinitely suspended. Therefore, biosafety

procedures can be a source of considerable uncertainty, even in experienced countries.

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