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TRANSGENIC COTTON IN MEXICO: A CASE STUDY OF THE COMARCA LAGUNERA

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Summary

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 change in cost of production. The result has been increased profitability and competitiveness, and a reduction in the risk associated with cotton production failures from insect infestations. A number of facts 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 be en 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.

Introduction

In 1999, transgenic cotton was grown in six countries on a total of some 3.7 million hectares, making it the world's third most common transgenic crop (Table 1). Bt cotton has been grown in Mexico since 1996 and was planted on one third of the country's cotton area during the 2000 growing season. A number of papers have now been published on the impacts of transgenic crops in the United States, but few empirical studies of transgenic crops in developing countries have appeared. In this paper we describe Mexico's experience with Bt cotton, focusing on the "Comarca Lagunera" region in the northern states of Coahuila and Durango, where Bt adoption reached 96% within three years of its introduction in 1997.

The Bollgard Bt gene was developed by Monsanto in the 1980s from a soil microorganism, *Bacillus thuringiensis kurstaki,* long known to produce a protein that is toxic to certain species of Lepidoptera when ingested. Two Bt cotton varieties, NuCOTN 33[B] and NuCOTN 35[B], were introduced in the US in 1996 through a strategic alliance between Monsanto and the dominant US seed cotton firm Delta and Pineland Co. (D&PL). These same D&PL varieties have subsequently been marketed in five other countries (including Mexico) under a similar business arrangement between the two firms Monsanto and D&PL maintain modest research presences in Mexico, primarily small programs of routine agronomic testing and pest monitoring. Seed sales and distribution are handled through regional agricultural input distributors. Monsanto provides sales support through a national office in Mexico City and through two technical representatives located in the main cotton growing areas.

An average of 200,000 hectares of cotton were grown in Mexico in the 1990s (Table 2). Nearly 95% of this area is Located in the northern states of Baja California, Sinaloa, Sonora, Chihuahua, Coahuila, Durango, and Tamaulipas. Ninety percent of the cotton area is irrigated. Production fluctuated during the 1990s due to volatility in price, exchange rate government policy, and water for irrigation. Just 79,581 ha were planted in 2000, due largely to the unavailability of surface water for irrigation.

In 2000, 26,300 hectares of Bt cotton were planted in Mexico. This represents nearly a third of the total acreage planted to cotton. Adoption varies from less than 10% in Sinaloa and Baja California to 96% in Comarca Lagunera (Table 3).

Refuge restrictions are the same as in the United States. Producers are allowed to plant either an 80%/20% or 96%/4% Bt/conventional cotton combinations as refuge alternatives for resistance management. Bt cotton is barred from the southern states of Chiapas and the Yucatan, where wild species of *Gossypium* (a native related to cotton) exist

Mexico has been a leader in the testing and approval of transgenic crops (GMOs). The country's first biosafety field trials, for Flavor Savr ™ tomatoes, were conducted in 1988. Mexico and Argentina are the only countries in Latin America to have approved GMOs for commercial use. Mexico possesses several key advantages over smaller countries in accessing benefits from agricultural biotechnology. It has a strong university system providing basic research capacity, a large national agricultural research system, experiences with biosafety procedures, and has seed markets of sufficient potential to attract private sector investment. Mexico has a three-stage biosafety testing and approval process. The first stage is permission to conduct field trials, the second is permission for "limited" commercial use, and the third is approval for full commercial use. There is no set definition of limited commercial use. Bt cotton is currently grown under a limited commercial use permit; only Flavor Savr™ tomatoes have been approved for full commercial use. Limited commercial plantings, ranging from 2 to 12.5 ha of transgenic tomato, melon, potato, and squash, have been planted in Mexico, as has 900 ha of herbicide resistant soybeans.

A total of 147 biosafety field trials GMOs have been conducted in Mexico, ranking it ninth worldwide in terms of total number of field trials (Table 4). Cotton has been the third most common crop to appear in field trials, after maize and tomato. A moratorium has been placed on field-testing of transgenic maize; out of concern for the effect that genetic drift might have on native teocintle (an ancestral maize plant). The private sector has dominated field-testing, with 80% of all trials (Table 5)

The Region

The Comarca Lagunera comprises parts of the states of Coahuila and Durango in north central Mexico. The region is in a semiarid subtropical agro ecological zone that used to flood during the rainy season. Floods have been controlled since the construction of the two regional dams. The Comarca Lagunera is located between 24° 05' and 26° 54' North latitude and between 101° 40' and 104° 45' West longitude, with an altitude of 1,120 meters above sea level and 240 mm of annual precipitation. The region is served by one research station of the National Agricultural Research Institute (INIFAP), Centro Experimental Comarca Lagunera, staffed with 32 research scientists, 13 of whom hold a Ph.D. degree, 16 with an M.S., and 3 with a B.S.

Agriculture in the Region

Agriculture in the Comarca Lagunera is intimately tied to water availability. The main source of water in the region has been the regional dams that are fed by the Nazas River. Up to 1994, land irrigated with water captured in the regional dams and distributed by gravity represented 53% of cultivated area, whereas groundwater irrigation and rain-fed agriculture represented 32% and 16% of total surface, respectively. Since 1994, the percentage of land irrigated by gravity has fluctuated significantly depending on the amount of annual rainfall. Annual rainfall has been low over the last few years, and thus the amount of area planted for agricultural uses has declined.

The major agricultural products in the region are forages for dairy, horticultural products, fiber/industrial products, and fruits. The annual value of production during this period was around $100 million, of which alfalfa represents 24%, cotton 18%, and corn 7%.

During the year 2000, the Region Lagunera planted nearly 10% of the total Mexican cotton area. The cotton area in Comarca Lagunera reached a peak of 142,777 hectares in 1944, but fell to less than 1,000 ha in 1992 and 1993. 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 been increased from less than one ton/ha in the late 1980s to 1.6 tons/ha in 2000. Yields had previously peaked in 1984, and then declined due to problems with pest control.

Insect Complexes, Bt Cotton Adoption, and 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 6). 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, Comarca Lagunera and Tamaulipas are the most critically affected by the BBWC. The boll weevil is a serious pest in Tamaulipas and South Chihuahua. Pest damage in the other growing regions is more balanced among other insect complexes.

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 (Table 7). Neither the pink bollworm nor the boll weevil has important plant hosts other than cotton, so effective residue management and the high adoption rate of Bt cotton have been major factors in reducing pest populations in Comarca Lagunera. The government has provided support for pest control programs through the Regional Plant Health Committee (Table 8). 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. An active biological control program is also in place and has released some 40 million eggs of the beneficial insects *Trichograma* spp. against budworm and *Crysoperla* spp. against white fly.

The combined effect of the disappearance of the boll weevil, use of Bt cotton, and the reduced cotton acreage has been a dramatic falls in the use of chemical pesticides in Comarca Lagunera. The total amount of active ingredient (a.i) applied to cotton in 1999 was just 2% of the amount applied in 1988 falling from 670,709 kg to 11,842 kg (Table 9). Per ha pesticide use has fallen by more than 80%, from an average of nearly 14 kg/ha of active ingredient in the 1980s to about two kg/ha. The average number of pesticide applications for all insects has also fallen steadily (Table 10), led by the decline in applications to control BBWC. Pesticide use is lower on Bt than conventional cotton varieties (Table 11), but it seems clear that conventional cotton is under less pressure from BBWC 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 which they are becoming increasingly reluctant to use chemical pesticides for fear of upsetting the new equilibrium between beneficial an destructive insects.

Two resistance management plans are allowed under Monsanto's seed contracts-an 80% Bt, 20% conventional refuge and a 96/4% plan. Under the 80/20% plan, producers are allowed to apply any insecticide they wish (other than foliar Bt) to the refuge cotton. Under the 96/4% plan producers are prohibited from applying any pesticide for control of BBWC. By the 2000 season, most farmers in Comarca Lagunera utilized the 96/4% plan.

A number of studies of resistance development have been conducted in Mexico. In 1998 and 1999, Nava-Camberos, Sanchez-Galvan, and Lopez-Rios performed bioassays to evaluate the resistance of the pink bollworm to the CryIAc toxin contained in transgenic Bt cotton in the states of Coahuila, Durango, Baja California, and Chihuahua. Pink bollworm samples were taken from experimental trials in 1998; in 1999, samples from cornmercial fields were tested for survival. Bioassays indicated that only 2.5% of pink bollworm larvae survived beyond the third instar, and none survived to maturity at fourth instar. Survival occurred at a diagnostic concentration level of one microgram of toxin per milliliter of diet, a level of toxin lower that expressed in Bt cotton plants. The authors also monitored the development of fall armyworm *(Spodoptera exigua* Hübner), and damage from tobacco bollworm *(Heliothis zea)* and white fly *(Bemisia argentifolii),* finding no significant difference in the infestations of white fly between conventional and transgenic cotton. The transgenic cotton provided very good control of tobacco bollworm and partial control of fall armyworm.

Rodriguez-Maciel and Aguilar-Medel performed bioassay analysis of the susceptibility of populations of *H. zea and H. virescens* collected in Chihuahua, Comarca Lagunera, Sonora, and Tamaulipas. They found that no larvae had developed to the third instar in any of the instances at the diagnostic level of 0.5 μ gram of toxin per milliliter of diet. This concentration thus becomes important in the detection of resistance to the endotoxin. The authors concluded that there is no tendency to develop resistance to the delta endotoxin in the sample populations.

Seed Prices, Contracts and Protecting Intellectual Property

The ability to protect intellectual property (IP) is a critically important consideration for the private sector biotechnology effort. When Monsanto/D&PL introduced Bt cotton in 1996 and Roundup Ready soybeans in 1997 in the US, it also introduced the use of seed licensing contracts, which farmers are required to sign upon seed purchase. Because cotton and soybeans are pure line crops, it is possible for farmers to save seed from their harvest and replant them the following year. The seed contract forbids farmers from saving seed and, in the case of Bt cotton, obligates them to follow a specified resistance management strategy. The contract requires farmers to forfeit rights to replant seed that they would normally have under national seed laws in most countries, including the US and Mexico. This effectively moves enforcement from the somewhat obscure realm of IP law to common contract law. The seed contracts have been effective in protecting IP in the US and Canada, but the ability to protect IP in developing countries has been a cause of concern. Monsanto has had difficulty protecting the IP from Roundup Ready soybeans in Argentina (United States General Accounting Office, 2000) and from Bt cotton in China (Pray *et al*., 2001).

The Bt cottonseed contracts in Mexico obligate farmers not only to refrain from saving seed, but also to have cotton ginned only at authorized gins and to contract an entomologist to supervise the farmer's compliance with biosafety standards. Within the contract the farmer must specify the total area to be planted, and agrees to allow Monsanto access to all of the farmer's holdings that are planted to cotton. Monsanto hires two seasonal field representatives in Comarca Lagunera to spot check cotton fields, and to investigate suspected 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. Farmers who are found to have exceeded their agreed acreage are required to reimburse Monsanto/D&PL for the value of seed that would have been required to plant the additional area, and to sign a "reminder contract" acknowledging that seed cannot be replanted. Representatives visit these farmers the following season to be sure that saved seed has not been planted. The contractually specified penalty for selling seed of 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. In Comarca Lagunera, suspected violations have been settled through negotiation between company representatives and the violators; no disputes have been taken to court. Monsanto obtained a positive judicial decision, through which it achieved payment for the technology fee plus an additional amount not divulged, in a 2001 court decision against a larger farmer in Sonora accused of selling Bt cottonseed. Farmers attempting to sell saved Bt seed can be sued for breach of contract. Buyers, on the other hand, may have never signed a contract and would be pursued under Mexican intellectual property law.

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. This has been simplified for Monsanto because 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. Farmers identified as requesting the return of the ginned seed are subject to field visits by Monsanto representatives the following growing season.

Total revenue from Bt cotton seed sales in Mexico in 2000 was approximately $1.5 million. Bt technology fees are collected on a per bag basis and have not increased between the 1998 and 2001 growing seasons. The price charged for Bt varies by growing region is shown in Table 12. 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.

Monsanto/D&PL has attempted to establish a stacked Roundup Ready Bt cotton variety, but has managed to sell seed sufficient to plant less than 400 ha during 2000. Weed control is not a serious problem in north central Mexico, so Roundup Ready cotton is not economical.

Materials and Methods

Financial Benefits of Bt Cotton in Comarca Lagunera

Because Mexico produces a relatively small share of total world cotton output, annual production fluctuations have no effect on world prices. In most years, Mexico is both an importer and an exporter of cotton, trading about 200,000 tons of cotton. Therefore, Bt cotton benefits can be modeled as occurring in a small open economy (Alston, Norton, & Pardey, 1995). In Comarca Lagunera, the availability of water for irrigation has placed a binding limit on acreage. As a result, farmers are unable to respond to reduced production costs by expanding area, and farmers' surplus will simply be the per ha increase in net revenue multiplied by the number of ha grown. 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. Recent studies have emphasized that monopoly profit must be included when measuring welfare changes (Falck-Zepeda *et al.*, 2000). The introduction of the new input is assumed to leave the perfectly competitive nature of the cotton lint and cottonseed markets unchanged. Therefore, the welfare calculations performed below have two components changes in farmer surplus and monopoly profits.

Following Falck-Zepeda *et al.* (2000), monopoly profit was calculated as QBt (PBt- c), where QBt and PBt are the quantity and price of Bt seed, and c is the marginal cost of producing seed. Once a commercial transgenic variety has been created, the seed reproduction process is nearly identical for transgenic and conventional varieties. 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, or IPR enforcement costs were deducted, these figures do not represent true surplus estimates, but rather represent gross Bt revenue. The issue of whether or not to deduct development costs from the firm’s net return is not answered definitively in the literature. We assumed that development costs were sunk, and did not enter into the pricing decision. That is, if Monsanto/D&PL were to expand the market for Bt seed by another 100,000 hectares, the only variable cost would be seed production.

Cotton Costs and Revenues

The estimate of the cost reduction induced by the introduction of the new technology is crucial to the economic surplus calculation, and is often the most difficult variable to measure accurately. We base our estimates on information from farmer surveys.

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 average size ejido holding is 2-10 ha, that of the small landholders 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 is comprised of 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. SEREASA is one of the largest of the 14 associations in Comarca Lagunera. In 1997, this association had a total of 638 producers awning 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 for SEREASA small landholders was 20 ha. The mean size cotton acreage was 15 ha in 1997 and 8 ha in 1998.

Results and Discussion

The Bt variety NuCOTN 35[B] (DP35B) was grown on 52% of SEREASA cotton area in 1997, while two conventional varieties accounted for 48% of area (Table 13). Yields were about the same for both types of cotton, but conventional cotton graded slightly higher, reflected in a $65/ton higher average price. As a result, conventional cotton produced nearly $501ha higher revenue than the Bt variety. Less pesticide, however, was used on the Bt cotton. Conventional cotton averaged 1.57 applications for pink bollworm, while no growers sprayed Bt cotton. Conventional cotton required more than twice as many pesticide applications to control cotton budworm, and slightly more applications for 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 pesticide costs were $153.91 1ess 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 also 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 advantage profit advantage for Bt cotton in 1998 was $626.74. The large difference in profitability of Bt cotton between 1997 and 1998 is 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 (seeTable 7).

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. Nonetheless, if pest populations fallow enough, conventional cotton may begin to appear profitable, and farmers may be tempted to abandon Bt cotton as a means of reducing production expenditures. In other words, there will be pressure for farmers to reduce their contribution to the common good of pest suppression.

Benefit Distribution Between Monsanto/D&PL and Cotton Producers

The estimated surplus distribution between Monsanto/D&PL and producers is given in Table 14. After subtracting the estimated cost of seed production, we estimate that Monsanto/D&PL were left with a net revenue of roughly $100 per 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 ha 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.

Conclusions

It is risky for to speculate on how the private sector might view their experience in Mexico, but we will do so because of the importance of this issue in trying to understand the future of transgenics in developing countries.

The $1.5 million revenue from seed sales, from which seed distributor compensation, administrative and marketing costs must be deducted, is not a large sum for a company such as Monsanto, with $5.49 billion in annual revenue. Yet it is worth noting that 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 fanners. 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. Yet biosafety testing of transgenic maize has been indefinitely suspended. So, biosafety procedures can be a source of considerable uncertainty, even in experienced countries.

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Table 1. Transgenic cotton area by country 1999.

Country	Area (ha)
United states	3,200,000
China	245,000
Australia	125,000
Mexico	20,000
Argentina	10,000
South Africa	10,000

Source : James 2000.

Table 2. Bt cotton area and adoption in Mexico, 1996-2000.

Year	Total cotton area	Bt Cotton area (ha)	% Bt cotton area
1996	314,768	900	<1%
1997	214,378	15,000	7%
1998	249,602	37,000	15%
1999	144,995	17,000	12%
2000	79,581	26,106	33%

Table 3. Area planted to Bt cotton by state, 2000.

State (area)	Bt Area	Total Cotton Area	%Bt
Comarca Lagunera	7,932	8,263	96%
North Chihuahua	8,387	22,000	38%
South Chihuahua	1,500	4,500	33%
North Sonora	1,445	2,248	64%
South Sonora	1,270	5,500	23%
Baja California	1,110	14,500	8%
Tamaulipas	4,332	11,741	37%
Sinaloa	130	1,177	7%
Mexico	26,106	79,581	33%

Table 4. Field trials by crop, 1988-1999.

Crop	Number of field trials
Maize	34
Tomato	30
Cotton	27
Soybean	13
Other veg.	11
Fruits	11
Potato	5
Wheat	5
Tobacco	4
Canola	2
Rice	1
Flowers	1
Alfalfa	1
Other	2
Total	**147**

Source:biosafety comitee, taken from website http://www.sagar.gob.mx/users/conasag/

Table 5. GMO field trials in Mexico by type of institution, 1988-1999.

Type of institution	Number of trials	Percent of trials
Multinational firms	113	77%
Mexican firms	5	2%
Universities	1	---
Ag. Research institutes	28	19%
Total	147	

Source:biosafety comitee, taken from website: http://www.sagar.gob.mx/users/conasag/

Table 6. Geographic distribution of pest problems in Mexico's major cotton areas.

			Seriousness of problem[a]					
Pest	**Bt effectiveness**	**Alternate plant hosts**	**Laguna**	**Tamaulipas**	**North Chihuahua**	**South Chihuahua**	**Sonora**	**Baja California**
Pink Bollworm	100%	none	highest	none	minor	Medium	medium	medium
Cotton BoIlworm	100%	maize, tomato	high	high	medium	medium	minor	minor
Tobacco budworm	partial	maize, tomato	high	high	medium	medium	minor	minor
Fall armyworm	partial	many	minor	high	medium	medium	minor	minor
Boll weevil	none	none	eradicated	highest	none	highest	none	none
white fly	none	many	minor	none	none	none	highest	highest
Conchuela	none	many	high	none	minor	minor	minor	minor
2000 Bt adoption	-	-	96%	37%	38%	33%	6%	1%

[a] 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.

Table 7. Insect captures in Comarca Lagunera.

Year	Pink Bollworm[a]	Boll Weevil[b]	% Bt Adoption
1994	3.7	Na	0
1995	216	112	0
1996	356	2	0
1997	52	158	26
1998	74	0	80
1999	33	0	97
2000	30	0	97

[a] Highest weekly average per trap capture during growing season in Comarca Lagunera
[b] Total number of insects captured in all traps during growing season in Comarca Lagunera
na : data not available.
Source: Plant Health Authority, Torreon, Coahuila, Mexico.

Table 8. Government expenditures on pest control programs in Comarca Lagunera, 1998-2000.

Activity	1998 ($US)	1999 ($US)	2000 ($US)
Bt cotton subsidy	46,678	33,247	0
Beneficial insects	52,933	12,612	0
Technical Assistance	79,399	84,845	0
Control of field residue	0	0	334,718
Total	$179,009	$130,704	$334,718

Source: Plant Health Authority, Torreon, Coahuila, Mexico.

Table 9. Amount of pesticide active ingredient applied to cotton in Comarca Lagunera, 1982-1999 Activity.

Year	Total a.i applied (KG)	Area (ha)	Avg. Kg. a.i./ha
1982	581,438	38,570	15.1
1983	349,828	30,566	11.4
1984	515,693	30,626	16.8
1985	593,656	39,752	14.9
1986	579,127	39,702	14.6
1987	na	na	na
1988	670,709	40,770	16.5
1989	407,698	37,790	10.8
1990	308,452	52,280	5.9
1991	na	27,427	na
1992	na	385	na
1993	na	842	na
1994	na	6,483	na
1995	na	2,300	na
1996	na	4,900	na
1997	na	2,600	na
1998	11,072	6,954	1.6
1999	11,842	5,687	2.1

Source: Plant Health Authority, Torreon, Coahuila, Mexico.

Table 10. Average number of insecticide applications targeted to principal cotton pests in the Comarca Lagunera, 1995-2000.

Year	Pink Bollworm	Tobacco Budworm	Conchuela	Fall Armyworm	White Fly	Total[a]
1995	3	2	0	1	1	6
1996	7	2	0.3	2	2	7.35
1997	1.5	2.5	2	1.5	0.4	5.1
1998	2.5	1.3	1	2.1	0.2	4.5
1999	0	0	2	1	1	3.5
2000	0	1	1.5	0.2	0	2

[a] Totals do not equal row sums because multiple pests are targeted in some applications.
Source: Sanchez-Arellano, 2000. Data from Plant Health Authority pesticide use records.

Table 11. Average number of insecticide applications on conventional and transgenic Cotton, Comarca Lagunera, 1999-2000.

	Number of applications of insecticide			
	Transgenic		**Conventional**	
Pest	**1999**	**2000**	**1999**	**2000**
Pink Bollworm	0	0	4	0
Tobacco Budworm	1	0.5	1	1.5
Conch	2	1.6	1	2
Fall Armyworm	0.5	0.2	1	0.5
White Fly	1	0	1	0
Total	3.5	2	6	3

Source: Sanchez-Arellano, 2000. Data from Plant Health Authority pesticide use records.

Table 12. Price for Bt seed by growing region.

Region	**Bt seed price ($us/bag)**
Comarca Lagunera	105.45
South Tamaulipas	179.26
North Tamaulipas	80.05
South Chihuahua	90.45
North Chihuahua	61.81
South Sonora	50.40
North Sonora	105.45
Sinaloa	59.95
Baja California	85.05

Table 13. Summary of survey information by San Pedro region of Comarca Lagunera, 1997 and 1998.

	Bt 1997	**Conv. 1997**	**Bt 1998**	**Conv. 1998**
lint Yield (mt/ha)	1.58	1.54	1.11	1.42
lint Price ($US/mt)	1,425.85	1,490.74	1,555.60	1,530.52
lint Value/ ha ($US/ha)	2,257.72	2,296.07	2,656.44	2,171.98
Seed Yield (mt/ha)	2.24	2.29	2.53	2.21
Seed Price ($US/mt)	203.11	203.11	184.44	184.44
Seed Value ($US/ha)	454.96	465.11	466.71	407.61
lint + Seed Value ($US/ha)	2,712.67	2,761.18	3,123.15	2,579.59
Bt-Conv. Value ($US/ha)	(48.51)		543.56	
Seeding Rate (kg/ha)	14.00	18.00	12.00	14.00
Seed Price ($US/ha)	35.93	39.78	30.80	30.94
Technology Fee ($US/ha)	65.10	0.00	55.80	0.00
Pink Bollworm (# appl.)	0.00	1.57	0.00	1.66
Pink Bollworm ($US/ha)	0.00	58.14	0.00	48.80
Budworm (# appl)	1.32	2.77	0.84	2.04
Budworm ($US/ha)	21.92	71.92	13.43	51.18
Conchuela (# appl.)	1.64	0.68	0.70	0.63
Conchuela ($US/ ha)	14.06	15.02	7.61	8.47
Armyworm & Other (# appl)	0.02	0.22	0.01	0.27
Armyworm & Other ($US/ha)	0.27	8.55	0.86	7.57
Biol. Control (# appl)	2.00	2.00	0.00	0.00
Biol. Control ($US/ha)	6.57	6.60	0.00	0.00
Total Chemical Appl./ha	2.98	5.24	1.55	4.60
Total Chemical Cost ($US/ha)	42.82	160.22	21.91	116.02
Bt-Conv. Seed & Pest Cost Difference ($US/ha)	(56.15)		(38.45)	
Bt-Conv. Profit Difference ($US/ha)	7.64		582.01	
Total Area	1121	1051	1466	557
Percent Area	52%	48%	72%	28%
Number of Producers	59	93	155	87
Avg size Holding (# ha)	19	11	9.5	6.4
Varieties Grown	DP 35B	DP 5409, Sure Grow 125	DP 35B	DP 5690

Table 14. Estimates of economic surplus distribution, Comarca Lagunera, 1997 and 1998.

	1997	**1998**	**Average**
Conventional Seed Price/kg	2.21	2.21	2.21
Cost /ha lo Produce BI Seed	30.94	30.94	30.94
Monsanto/D&PL Bt Revenue/ha	101.03	101.03	101.03
Monsanto/D&PL Net Revenue/ha[a]	70.09	70.09	70.09
BI Brea in Comarca Lagunera	4,500	8,000	6,250
Monsanto/D&PL Total Net Revenue[a]	315,420	560,747	438,083
Producer Change in Variable Profit/ha	7.64	582.01	294.83
Total Producer Surplus	34,382	4,656,091	2,345,237
Total Surplus Produced	349,801	5,216,838	2,783,320
Monsanto/D&PL Share of Total Surplus	90%	11%	16%
Producer Share of Total Surplus	10%	89%	84%

[a] Net revenue calculated before administrative and sales expenses and before any compensation to Mexican seed distribution agents.