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**Can Bt Technology Reduce Poverty Among African Cotton Growers? An Ex Ante Analysis of the Private and Social Profitability of Bt Cotton Seed in Mozambique.**

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*Contributed Paper prepared for presentation at the International Association of  
Agricultural Economists' Conference, Beijing, China, August 16-22, 2009*

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Can Bt Technology Reduce Poverty Among African Cotton Growers? An Ex Ante Analysis of the Private and Social Profitability of Bt Cotton Seed in Mozambique.

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**Abstract.** This paper presents an ex ante analysis of the private and social profitability of the introduction of Bt cotton for a major cotton producing area of northern Mozambique. Cotton is especially relevant to rural poverty reduction because smallholders often have few alternative cash earning activities, and yields are among the lowest in Africa. Multivariate regression is used to quantify the relationship between pest control and yield loss at farm level as a basis for estimating the expected yield gain from the introduction of Bt cotton. Partial budget analysis of technical packages with and without Bt cotton seed reveals a strong divergence between private (negative) and social (positive) profitability. The Mozambique case indicates that effective bio-safety and legal frameworks may be a necessary but not sufficient condition for Bt cotton technology adoption and poverty reduction. Policy changes to align private and social profitability of cotton production with Bt seed, as well as complementary improvements in crop management, especially timely planting and weed control, are also necessary for Bt technology to change the fortunes of Mozambican cotton growers. With improved policy and technology in place the adoption of Bt cotton varieties could result in a sizeable reduction in poverty as measured by the predicted change in squared poverty gap.

**Keywords:** Bt cotton, social profitability, poverty reduction, Mozambique.

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## **1. Introduction**

Africa is one of the world's largest cotton growing regions. Because most of Africa's cotton is produced by low-income smallholders, the crop can play a strategic role in the rural poverty reduction strategies of at least 17 Sub-Saharan African countries. The widespread introduction of Bt technology in many cotton producing countries outside Africa has led to rapid growth in average world cotton yields. Several developing countries have participated in the boom, notably China and India. But African countries have so far passed up the opportunity. Among them is Mozambique, where 200,000 families depend on cotton for a significant part of their cash income. Several *ex ante* studies have predicted significant yield improvement and income gains for African cotton growers if Bt cotton were to be introduced. One of the main barriers to the realization of these gains is considered to be the lack of effective bio-safety and legal frameworks (Boughton and Poulton 2009).

This paper conducts an *ex ante* analysis of the social and economic profitability of Bt cotton to evaluate the hypothesis that, with the requisite frameworks in place, the introduction of Bt cotton would improve the farm-level profitability of cotton and hence contribute to the Government's poverty reduction objectives. The next section briefly reviews the literature on Bt cotton prospects in Africa. Section 3 presents the data and methods used; section 4 discusses the results. Section 5 concludes as to the policy implications of the predicted strong divergence between private and social profitability of Bt cotton seed.

## **2. Literature Review**

Seventeen of the top 40 cotton-producing nations in the world are located in Africa (ICAC, 2005). Although Mozambique is not in the top echelon of producing countries in Africa, the importance of cotton should not be underestimated; cotton ranks second in merchandise exports (Osorio and Tschirley 2003).

Bt cotton has engendered several large success stories and has endured several smaller setbacks during its first decade in farmers' fields. Yet exporters in Sub-Saharan Africa (SSA) and in Central Asia and Pakistan figure prominently on the Bt cotton nonparticipation list. Because of the intensity, depth, and severity of poverty in SSA, the cost of not deploying Bt cotton could be very large (Eicher et al., 2006). Producers in non-adopting regions lose when technological change results in lower producer prices, and several modeling exercises show that cotton-growing households in Sub-Saharan Africa are no exception (Elbehri and Macdonald, 2004, Anderson et al. 2008, and Falck-Zepeda et al. 2007). Indeed, Anderson and Valenzuela (2007) estimate that the opportunity cost of not deploying Bt cotton in SSA is greater than the deleterious effects of subsidized production of cotton in the United States, Greece, and Spain on export earnings in SSA.

As many as 20 studies have assessed the impact of Bt cotton in SSA. The Republic of South Africa (RSA) released Bt cotton to farmers in 1998, where 14 impact assessments on Bt cotton have been carried out (Smale et al. 2006). The rest of the literature on the

impact of Bt cotton in Sub-Saharan Africa has centered on ex ante assessment in Francophone Africa where the major exporters of cotton in SSA are located. Yet cotton is also an important cash crop in several countries of Southern and Eastern Africa.

This ex ante assessment adds to the literature in four important ways. First, we provide one of the few examples of ex ante Bt cotton assessments in Southern and Eastern Africa outside South Africa. A second addition to the literature is the use of multivariate regression analysis to estimate the potential productivity impact of Bt cotton. Third, we assess profitability using both financial and economic values to compare expected private and social profitability of the technology. Fourth, in view of the observed divergence between private and social profitability in the Mozambique case, we estimate the effect on poverty reduction if barriers to private profitability could be overcome.

### **3 Data and Methods**

We use a data set of 316 cotton-growing households collected by Strasberg in the mid-1990s from two outgrower schemes in Monapo District, Nampula Province, and Montepuez District, Cabo Delgado Province. Farmers were visited five times during the growing season to gather detailed information on the cost of production. Additionally, we interviewed entomologists and other crop specialists to shed light on farmers' pest management practices (MADER 2003). Discussions with scientists reconfirmed our thinking on the timing and targets of insecticide applications. Sprays that occurred in the first eight weeks of the crop were targeted at sucking and piercing insects such as aphids,

jassids, and other non-Lepidopteran pests; applications later than eight weeks were aimed at the bollworm complex.

### **3.1 Explaining the Variation in Yield with a Simple Multivariate Model**

The analysis focuses on the determinants of yield in a simple regression that emphasizes the interaction between plant protection and productivity. Yield is posited to be a function of crop management, plot characteristics, perceived weather, perceived pest infestation, and village effects. The data for the regression analysis are summarized in Table 1. By global standards, seed cotton yield was low and variable across farmers. Seed cotton yield averaged about 800 kgs/ha and ranged from about 50 to 1950 kgs/ha across the 215 observations in the 17 cotton-growing villages. Most of the independent variables pertain to aspects of crop management. Sprays were divided into two types: early applications targeted to sucking pests and later applications targeted to chewing pests of the bollworm complex. The majority of households did not apply pesticides during the first eight weeks of the growing season; only about one farmer in ten made more than two applications during this period. Some of the non-applying households may have been cultivating ‘hairy’ varieties with a low yield potential. The hairy trait is associated with less damage from jassids and aphids.

We expect to see a positive response to spraying, particularly for applications targeted to the bollworm complex since all varieties are susceptible. Although pesticide use is somewhat subsidized by outgrower schemes in the form of access to backpack sprayers and modest reductions in the market price of pesticides, cotton farmers are poor.

Independent variables that complete the expected determinants of seed cotton yield in Table 1 are perceived soil quality, rainfall, and pest infestation level. Most farmers felt that their fields were fertile or fairly fertile, that the 1994-95 cropping season was a normal rainfall year, and that pest infestation was not excessive.

The determinants of yield are modeled with a Cobb-Douglas specification in terms of logarithms of the dependent and continuous independent variable which is days of weeding labor. All the other independent variables, including village effects, are specified as binary 0-1 variables. Aside from ease of interpretation, the normalization of the dependent variable is one of the attractive features of a Cobb-Douglas specification as yields are often non-normally distributed. A damage recovery model along the lines of Lichtenberg and Zilberman (1986) was not estimated because data on pesticide active ingredients were not available. Moreover, the emphasis in the analysis is to let the data express itself in as discontinuous a fashion as possible to generate more information on the productivity prospects of Bt cotton. Modeling sprays as additive dummy variables accommodates that emphasis. Nor was a two-stage process entertained where predicted pesticide use was included in a subsequent multivariate analysis on the determinants of yield to address simultaneity bias. Such an analysis is complex for first-stage categorical variables and could be a topic for further research with this data set. These assumptions are in the spirit of the Shankar and Thirtle (2005) analysis that shows a marked but gradually narrowing difference in recovery of yield potential with the adoption of Bt cotton by level of insecticide use. At the 0-level of spraying, our results diverge from their analysis.



## **4 Results and discussion**

### **4.1 Interpreting the Estimated Coefficients**

The model explains about 60% of the variation in yield across the 215 cotton farmers. In terms of cross-sectional data on commodity productivity in rainfed agriculture, capturing 55-60% of the variation in yield is a more than adequate performance. Moreover, the signs of almost all the estimated coefficients in Table 2 are consistent with expectations in Table 1.

Before turning to the estimated spray coefficients that are our center of attention, we briefly review several of the estimated effects of some of the other independent variables. As expected, the use of weeding labor is positively and significantly associated with yield. A proportional 1% increase in weeding labor, results in a 0.45% increase in seed cotton yield. The potential for weed damage to reduce yield is also reflected in the estimated coefficient on herbicide use. *Ceteris paribus*, the herbicide package conferred a hefty 71% advantage in yield. The estimated effect of the fertilizer package was less but was still a sizeable 41%. Late planting diminished yield by 30%. If the outgrower scheme in Montepuez selected better farmers to make fertilizer and herbicide available to, then these effects are overestimated because of selectivity bias. Nevertheless, taken together, these results suggest that there is ample scope to intensify yield in Mozambican cotton production if the access to inputs improves on a timely basis.

The estimated coefficients on applications targeted at sucking pests indicated a positive response to spraying once, but more intensive spraying was not associated with

significantly higher yields. The pattern of the estimated coefficients on the five bollworm spray variables is particularly interesting. The estimates in Table 2 tell us that farmers who sprayed once had the lowest yields. Their yields were 41% less than farmers who did not spray. Intensifying from one to four or more sprays was associated with an almost linear increase in yield. The higher yield of the no spray farmers suggests lower levels of bollworm infestation. Many of these farmers did spray for sucking pests as the correlation between the two types of sprays was not statistically significant. In any case, the farmers who sprayed three or more times were characterized by significantly higher yields than those who engaged in one or two applications. Additionally, the small minority of farmers who believed that pest infestation was heavy suffered a 33% decline in yield, signaling that they were not able to cope with this event.

Our regression results in Table 3 signal yield advantages from adopting Bt cotton for farmers who sprayed 1-3 times; they obviously had a problem in controlling chewing-pests as their yields were not significantly lower than or not significantly different from farmers who did not spray. With well-adapted varieties of Bt cotton, farmers in these three groups should be able to achieve a level of control equivalent to farmers who sprayed four times. This assumption is equivalent to a yield increase of 94%, 60%, and 22% for farmers who sprayed one, twice, and thrice. In the same spirit, farmers who sprayed 4 times should be able to begin to approach yields of farmers who sprayed 5 or 6 times. We assume that adoption of Bt cotton will increase yields by 50% of the difference between these two groups which is equivalent to a 20% increase in yields for farmers who sprayed 4 times. We further assume that the most intensive users of

pesticide (those in the 5-6 sprays group) will not derive a significant yield benefit from Bt cotton. Overall, the yield advantage of Bt cotton is estimated at 25%, equivalent to about 200 kg/ha of seed cotton.

#### **4.2 Estimating on-farm profitability**

For varietal change, a 25% yield increase is very respectable and rivals the productivity gains from the initial maize hybrids at the turn of the 20<sup>th</sup> century and from the semi-dwarf rice and wheat varieties at the beginning of the green revolution. But the increased costs of Bt cotton are considerably higher than either of these other two revolutionary developments in plant breeding. Is our best estimate of a 25% yield increase sufficient to drive the adoption of Bt cotton in Mozambique?

We analyze the on-farm profitability of Bt cotton from financial and economic perspectives in Table 4. The financial calculation is based on: increased yield evaluated at \$0.21/kg (Poulton et al. 2009); a reduction in 1.5 sprays, and total technology costs assigned at \$50.00. The savings in sprays is evaluated at a subsidized cost of \$3.31/application. Another cost is the maintenance of resistance which is equivalent to a production loss from a 5% unsprayed embedded refuge (USDA, 2001). From the financial viewpoint of the farmer, an assumed 25% yield advantage and a relatively small savings in subsidized pesticide costs equivalent to 1.5 sprays does not generate enough revenue to cover the technology fee of \$50.00/ha (Table 4). To satisfy the marginal rate of return adoption threshold criterion of 100% the yield advantage to Bt cotton in Mozambique would have to approach 70% at a base yield level of 800 kgs/ha. Low

output prices and the relatively high technology fee place the technology outside the grasp of poor cotton farmers.

From the viewpoint of society, the value of Bt cotton is considerably higher. The economic perspective in Table 4 factors in all costs and benefits and uses undistorted international prices to reflect scarcity value.

The calculations in the economic column of Table 4 differ from those in the financial column in four ways. First, and most importantly, we increase the price of seed cotton to US\$0.29 per kg. Mozambique is characterized by the lowest seed cotton prices in the region. Tanzania, with a fully liberalized output market and transport costs probably comparable to Mozambique, has recently paid US\$0.28 per kg of seed cotton (Poulton et al 2007). By 2003-04, prices in Mozambique had rebounded from their all-time lows of 2001-2002 as farmers received US\$0.25 per kg. Although estimates vary considerably by study, subsidies to producers, mainly in the United States and the EC, are reckoned to depress international prices by around 10% (Baffes, 2005). Given the higher level of regional prices and the effects of subsidy payments in developed countries, an economic price of US\$0.29 per kg of seed cotton seems reasonable. Although this price is considerably higher than its financial counterpart in Table 4, it is important to point out that this economic price level is inferior to that specified in any other ex ante or ex post study on Bt cotton.

Secondly, we value pesticide at international market prices. Without subsidies, pesticide cost increase and, consequently, the pesticide savings rise from US\$5/ha to US\$14/ha.

Thirdly, we recognize that pesticide savings generate a health benefit. According to Maumbe and Swinton (2003), pesticides pose health hazards that impose hidden costs on African cotton growers. They found that in Zimbabwe, acute pesticide-related illnesses impose costs equivalent to at least 45% to 83% of annual pesticide expenses by smallholder cotton farmers. We assume, modestly in view of the rudimentary protection measures used in Mozambique, that health costs savings are equivalent to 50% of the value of cost savings on insecticides. Given the labor intensity of cotton production in Mozambique, farmer's health status is an important determinant of planted area and productivity.

In a social pricing application, we could improve the odds that Bt resistance is sustainable and increase the refuge costs over and above the 5% area allocated in the financial budget. But we do not believe that an additional expenditure is warranted for two reasons. First, cotton production in Mozambique takes place in spatially dispersed fields in the bush in an environment that seems especially hostile to the development of resistance. Secondly, the advent of stacked Bt varieties leads to reduced refuge requirements and potentially results in enhanced returns to producers and seed companies. In essence, this thinking emphasizes the potential for natural refuges to substitute for crop refuges (Qiao, 2006; and Piggott and Marra, 2007).

As reported in Table 4, the estimated social profitability of Bt cotton adoption of US\$22.5/ha is dramatically higher than estimated financial loss of US\$10/ha. In the next section we evaluate the importance of this difference for poverty reduction among cotton growing families.

### **4.3 Bt Cotton and Poverty in Mozambique**

Conventional wisdom suggests that producers of cash crops are likely to be better off in terms of consumption, income, and assets than other rural households in developing countries. Analysis of national survey data indicates that conventional wisdom is rejected in Mozambique: cotton growers are not richer than other rural households. In a national rural income survey conducted in 2002, 6-7% of the 4908 sample households grew cotton. A multivariate regression analysis showed that household income of cotton producers was not significantly different from income of other rural households (Walker et al. 2004). These surveys and their related regression analyses provide a basis for developing a profile of cotton growers in Mozambique.

The expected impact of the adoption of Bt technology is simulated with the 2002 national rural household income data for the 316 cotton-growing households. The benefit from adopting the technology is valued at \$30.00 per hectare (equivalent to the level of social profitability achieved in Table 4, increased by one third to allow for modest improvements in crop management). The methodology is described in Walker et al. (2006) and features the evaluation of changes in the intensity, depth, and severity of poverty that correspond to the head count index, the poverty gap, and the squared poverty

gap, respectively. Of these, the squared poverty gap is the preferred measure of poverty because it places more weight on outcomes accruing to the poorer of the poor.

Using a price \$0.21/kg of seed cotton (Table 4), the baseline squared poverty gap was 0.36. With the adoption of Bt cotton, the estimated average squared poverty gap falls by about 25% to 0.27 for the 316 cotton-growing households. The observation that such a seemingly small difference in household income can leverage such a large relative change in income poverty underscores the severity of poverty among cotton producers in central and northern Mozambique. The vast majority fell below the poverty line which was equivalent to only about US\$0.25 per person per day in 2002 prices. Bt cotton does not make a large dent in national rural poverty because of the small proportion (6-7%) of households that grow cotton.

Using a variation of this same methodology, Minot and Daniels (2002) estimated that the 40% slump in cotton prices in 2001 and 2002 increased consumption expenditure poverty (as measured by the squared poverty gap) by about three-fold among cotton producers in Benin. Although the estimated levels of the squared poverty gap are not comparable because the Mozambique application focuses on per capita income and the Benin application addresses per capita consumption expenditure, both applications underline the sensitivity of poverty outcomes to changes in price and yield of a cash crop. Like many cash-crop producers in SSA, cotton farmers in Mozambique are characterized by less diversified sources of income than other households. Less diversification translates into

large changes in rural welfare when income from the cash crop is affected by fluctuations in yield and price and by technological change.

## **5. Conclusions, Policy Implications, Suggestions for Further Research, and Study Limitations**

Our analysis suggests that Bt cotton is not a highly attractive opportunity at this time in Mozambican agriculture. Expected profitability is eroded by the low existing yield levels, low output prices, the expected cost of the technology, and assumed low levels of bollworm infestation compared to other cotton producing countries. It is hard to recover yield if the potential for recovery is low. The results underscore the need for improvements in weed management to intensify productivity potential to enhance the prospects for Bt cotton. The testing and evaluation of pre-emergent herbicides is a priority in the short-term; the introduction of animal traction is a longer term priority. Higher yielding cultivars would also enhance the desirability of Bt technology. We also documented that fertilizer has a positive role to play in intensifying cotton production, but for now the emphasis needs to be improved weed management.

Suggesting actions that will have favorable consequences on low seed cotton prices is a more difficult undertaking. Mozambican prices have been lower than other countries in the region for a variety of reasons, including ineffective regulation of the regional monopsony arrangements for ginning, poor cotton quality, and low lint yields (Boughton et al., 2003). Greater transparency in cotton pricing, the adoption of varieties with higher ginning out-turn ratios, the deepening of road infrastructure, and the development of



cash-cropping alternatives, such as sesame, are all small steps to more remunerative seed cotton prices.

Our findings are based on several strong assumptions. Perhaps the greatest area of uncertainty concerns the yield advantage of Bt cotton for a significant minority of farmers who did not spray and who had significantly higher yields than those who sprayed once. We assumed that low levels of infestation were partially responsible for the absence of pesticide application and argued that, because of the spatially dispersed location of bush fields, infestation levels from bollworm species could be lower than in more conventional contiguous cultivation. The spatial and temporal incidence of bollworm infestation warrants more research. At a minimum, anecdotal information and expert opinion should be compiled on the incidence of infestation to better predict the expected productivity effects of Bt cotton across concessionaires in Mozambique and across cotton-growing countries in SSA.

The absence of a ringing economic endorsement for Bt cotton in this ex ante assessment does not mean that Mozambique should ‘go slow’ on bio-safety regulations which are characterized by inertia in their development. We showed that the social profitability of Bt was likely to be substantially higher than its private profitability. Although bio-safety working groups have been convened and consensus recommendations have been reported, these recommendations have not been legislated and enacted. The import of Bt maize in food relief is still the center of attention in bio-safety recommendations. Because of its negligible expected risk, other countries, such as China and India, have

‘fast-tracked’ Bt cotton long before the release of Bt food-crop varieties which are still under deliberation. For example, Mexico approved Bt cotton for field testing as early as 1988 (Traxler and Godoy-Avila, 2004). The example of these countries points to the priority for taking a sequential approach to bio-safety regulations to allow forward movement on fiber-Bt cultivars before a full bio-safety framework is in place for food-Bt cultivars. Our analysis is only indicative. Field testing is a first and necessary step to determining the contribution these varieties can make to cotton productivity, export expansion, and poverty alleviation.

We also argued on-going technological change is very likely to make Bt transgenic varieties more effective and perhaps even more affordable. The rapid emergence of China in general and RSA in particular as major importers of cotton is a favorable development for Mozambique. Both of these importers have released Bt cotton varieties and targeting exports towards them diminishes the need for a ‘coexistence’ production system that separates the output of conventional and transgenic varieties at all stages of production and marketing (Pehu and Ragasa 2007).

Low output prices and high technology fees may block the entry of Bt cotton to the 16 important producers (excluding RSA) in Africa particularly in the weaker economies. Expected profitability is particularly sensitive to assumptions about the technology fee. The present impasse of 12 years and still waiting is untenable for millions of poor farm households in Africa. But there does not seem to be any viable alternative to a private sector solution. Attention is now focused on Burkina Faso in the hope that Bt cotton is

finally released after years of field testing and that it can make a transparent contribution to the welfare of poor people. Positive results in Burkina Faso could provide the basis for a domino effect in the rest of Francophone Africa (Vitale et al. 2007).

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**Table 1. Summary Statistics and Expected Signs of the Variables Used in the Regression Model in Northern Mozambique.**

Variable	Summary Statistics		Expected signs <sup>b</sup>
	Description	Mean or frequency <sup>a</sup>	
Yield (kg/ha)	Dependent variable	801	
Pesticide Applications (0-1):			
0 sprays	Sucking pests	61%	R
1 spray	Sucking pests	29%	+
2-4 sprays	Sucking pests	10%	+
0 sprays	Bollworm complex	23%	R
1 sprays	Bollworm complex	8%	+
2 sprays	Bollworm complex	13%	+
3 sprays	Bollworm complex	33%	+
4 sprays	Bollworm complex	19%	+
5-6 sprays	Bollworm complex	4%	+
Fertilizer (0-1)	No use	79%	R
	Use	21%	+
Herbicides (0-1)	No use	73%	R
	Use	26%	+
Weeding labor	Total adult equivalent days	50	+
Planting date (0-1)	On time	65%	R
	Late	35%	-
Soil quality (0-1)	Fertile	61%	R
	Fairly fertile	32%	-
	Less fertile or infertile	7%	-
Perceived rainfall (0-1)	Normal	81%	R
	Abnormal	18%	-
Perceived pest infestation (0-1)	Normal	93%	R
	Excessive	7%	-

<sup>a</sup> Means for continuous variables and frequencies for (0-1) variables.

<sup>b</sup> R indicates the reference levels for the (0-1) variables.

Note: 16 village dummy variables are not included.

**Table 2. Estimated Coefficients and Statistical Significance of the Independent Variables Explaining Cotton Yield in Northern Mozambique**

Independent variable	Coefficient	t-value	[95% confidence interval]	
Bollworm 1 spray	-0.41	-2.43	-0.74	-0.08
Bollworm 2 sprays	-0.22	-1.56	-0.50	0.06
Bollworm 3 sprays	0.05	0.42	-0.08	0.27
Bollworm 4 sprays	0.26	2.04	0.01	0.50
Bollworm 5-6 sprays	0.59	2.81	0.18	1.01
Sucking Pests 1 spray	0.22	2.14	0.02	0.43
Sucking Pests 2-4 sprays	0.19	1.24	-0.11	0.48
Ln total weeding labor	0.45	5.05	0.27	0.62
Fertilizer use	0.41	2.03	0.11	0.80
Herbicide use	0.71	3.47	0.31	1.11
Soil less fertilizer	-0.11	-1.26	-0.29	0.07
Soil least fertilizer	-0.24	-1.46	-0.56	-0.08
Heavy pest infestation	-0.33	-2.16	-0.64	-0.03
Abnormal rain	0.01	0.13	-0.18	0.22
Late planting	-0.29	-3.07	-0.48	-0.10
Constant	4.61	12.30	3.87	5.35

Dependent variable is ln cotton yield in kg/ha.

$R^2 = 0.64$ , adjusted  $r^2 = 0.58$ ;  $F(30, 184) = 10.67$

Village effects are included in the analysis, but are not presented.

**Table 3. Distribution of spraying frequency and estimated yield effects**

Number of insecticide sprays	Frequency (%) <sup>a</sup>	Estimated yield effect (%) <sup>b</sup>
0	23	-
1	8	-41*
2	13	-22
3	33	5
4	19	26*
5-6	4	59*

<sup>a</sup> Based on 215 observations

<sup>b</sup> Relative to 0 sprays

\* Statistically significant at the 0.05 level

**Table 4. Financial and economic appraisal of the expected profitability of Bt cotton in \$/ha.**

Item	Profitability	
	Financial	Economic
Additional benefits		
Yield (\$/ha)	42.00	58.00
Increased production (Kg/ha)	200	200
Seed cotton price (\$/Kg)	0.21	0.29
Savings in insecticide cost (\$/ha)	5.00	14.00
Health (\$/ha)	0.00	7.00
Total	47.00	79.00
Additional costs		
Seed (\$/ha)	50.00	50.00
Refuge (\$/ha)	2.50	2.50
Harvesting (\$/ha)	5.00	5.00
Total	57.50	57.50
<b>Net benefit (\$/ha)</b>	<b>-10.50</b>	<b>22.50</b>

Source: Authors' computations