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Farm Profits from Observed Yields of Bt and Non-Bt Cotton, with and without Spray Application, in the Mississippi Delta

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Abstract

Since 1996, the introduction of Bt cotton has demonstrated to have increased the profitability of farm operations in the Mississippi Delta. Using state budgeted costs, NASS prices and published yield data, net per acre returns for conventional (non-Bt) and Bt cotton were calculated for the Mississippi Delta. For the period 1997-2000, a comparative study of net per acre returns between non-Bt and Bt cotton varieties and total returns for an average-sized Mississippi Delta cotton farm that plants both Bt and non-Bt cotton was conducted. From the results, we find that mean per acre profits were higher with Bt than with non-Bt cotton. More importantly, those profits were higher for non-Bt cotton when an insecticide/pesticide spray was applied as compared to when it was not. When we consider relative risk, mean farm returns are found to be not only higher but also more stable (less risky) when spray was applied. Observed farm yields are found to be a driving force in this study in choosing Bt over non-Bt cotton and a spray application over non-application.

Introduction

Bacillus thuringiensis (Bt) is a soil bacterium that protects or provides high level of suppression in cotton plants from certain lepidopteran insect pests like tobacco budworms, pink bollworms, cotton bollworms, armyworms, loopers, and other leaf- and fruit-feeding caterpillar pests in cotton. When larvae feed on Bt cotton plants, the proteins protect the plants by reducing larval survival and plant-foliage damage. In most cases, the requirement for remedial insecticide treatments for these pests is either reduced or eliminated.

However, lepidopteran cotton pests have demonstrated an ability to develop resistance to many chemical insecticides. As a preemptive stewardship measure, Bt cotton should be managed with an objective of delaying resistance development. In this regard, the U.S. Environmental Protection Agency (EPA), in pursuance of its interest in the social welfare benefit of Bt cotton, has mandated an Insect Resistance Management (IRM) program that promises to preserve the benefits and insect protection of this technology. According to that mandate, growers planting Bt cotton are required to follow the IRM practices designed so that some lepidopteran populations are not exposed to the Bt protein so they can reintroduce susceptibility into the selected populations. Thus, insects must be provided a refuge that is a food source and that does not contain the Bt protein. In order to do that, farmers planting Bt cotton are required to simultaneously plant either 5% unsprayed or 20% sprayed non-Bt cotton as refuge. Comparison of the per acre net returns from Bt and non-Bt cotton will determine the importance or otherwise of the non-Bt cotton refuge requirements.

Data

The study broadly uses three levels of data: First, USDA data (1996 – 2003) – National Agricultural Statistics Service (NASS) data on marketing year (August to July) average price for Mississippi [from NASS online]:- http://usda.mannlib.cornell.edu/reports/nassr/price/zap-bb, and cost data from Mississippi State budget publications.
Second, state and county level on-farm data (1997 – 2000) on field trials for Mississippi. Third, economic threshold studies (1971, 1972) of *Heliothis spp*. larval infestation on cotton for Mississippi.

Objectives

In 2002, Bt cotton varieties represented approximately 46% of the entire U.S. cotton acreage and 74% of the cotton acreage in the state of Mississippi (USDA-NASS 2004). Farmers are interested in knowing the value of Bt cotton so they can make improved production decisions with low commodity prices and increased market uncertainty. As part of its quantitative benefit and risk assessment, the U.S. Environmental Protection Agency seeks the welfare benefit of Bt cotton to farmers. The broader objective of this study, which is part of an ongoing research, is to calculate farm-level returns based on simulated farm-level yields and attempt to arrive at a feasible minimum proportion of non-Bt (conventional) cotton that will provide the farmer with the maximum return in a given year or over a period of time. The immediate objective of this study (as embodied in this paper) was to see how net returns per acre and total for a cotton farm of average size compared between Bt and non-Bt, both with and without insecticide or pesticide spray application for non-Bt cotton over the period of our study – 1997 through 2000.

Methods and Procedures

1. Marketing year (August to July) average prices over 1996 through 2003 for Mississippi were obtained online from the NASS site: http://usda.mannlib.cornell.edu/reports/nassr/price/zap-bb.
   Lint Price was calculated as Max (Marketing Year Average, \$0.52), \$0.52 being the government program price. The average of this price series was used in the calculation of net returns to follow: \$0.5777625/lb. (approx. 58 cents per pound) for lint and \$0.0480625/lb. (approx. 0.05 cents per pound) for cottonseed.

2. Variable input costs (denoted by k and K's) used in the production of Bt and non-Bt cotton were assumed fixed at the 2002 level. They were obtained from the Mississippi state budgets.

3. Per acre returns for Bt and non-Bt cotton (respectively) were calculated separately following Hurley et al. (2004), with minor revisions to include cotton seed along with lint:-

   Bt: $\pi_b = (p^L - k)y_b^L + p^S y_b^S - K_b - T$ (1)

   non-Bt: $\pi_c = (p^L - k)(1-\lambda)y_c^L + p^S(1-\lambda)y_c^S - K_c + [(p^L - k)\lambda_s^L y_c^L + p^S \lambda_s^S y_c^S - c_s]\tau$ (2)

   where p^L = price of cotton lint, fixed at \$0.58 (approx.),
   p^S = price of cotton seed, fixed at \$0.05 (approx.),
   k = per acre cost of production depending on harvested yield
   = cost of gin and haul, fixed at \$0.10 per pound of lint,
   y_b^L = observed per acre farm yield for Bt cotton lint,
   y_b^S = observed per acre farm yield for Bt cotton seed = 1.55 * y_b^L,
   K_b = per acre cost of production of Bt cotton not depending on harvested yield but exclusive of cotton acreage costs, fixed at the 2002 level, \$345.54,
   T = non-random cost per acre of Bt cotton, i.e., the technology fee, fixed at the 2002 level, \$26.80,
   λ = proportional yield loss due to uncontrolled pests, obtained from on-field trials in 1972 by Joe Reed Townsend, Jr., fixed at 45%,
   y_c^L = observed per acre farm yield for non-Bt cotton lint,
   y_c^S = observed per acre farm yield for non-Bt cotton seed = 1.55 * y_c^L,
   K_c = per acre cost of production of non-Bt cotton not depending on harvested yield but exclusive of cotton acreage costs, fixed at the 2002 level, \$399.92,
   λ_s^L = proportion of non-Bt cotton lint yield saved by an insecticide/pesticide application, obtained by subtracting percentage reduction in lint yield due to bollworm/budworm (from annual reports/publications on cotton losses in Reports on Cotton Insect Research and Control section of Beltwide Cotton Conferences Proceedings) from total reduction due to all pests (λ),
   λ_s^S = proportion of non-Bt cotton seed yield saved by an insecticide/pesticide application = 1.55 * λ_s^L,
   c_s = per acre cost of insecticide/pesticide application(s), also obtained from annual reports/publications on cotton losses in Reports on Cotton Insect Research and Control section of Beltwide Cotton Conferences Proceedings, and
   τ = indicator variable for insecticide/pesticide application,
   = 1 when applied, and
   = 0 otherwise.

4. Farm totals: Following Hurley et al. (2004), total returns for a representative farm that typically plants both Bt and non-Bt cotton are given by

$$\pi = A[z\pi_c + (1-z)\pi_b] - C(A) \qquad (3)$$

where A = average cotton farm size in acres per farm in the Mississippi Delta, taking into account irrigated, partly irrigated and non-irrigated land, obtained from USDA-NASS 2002 Census of Agriculture, fixed at 725 acres (approx.),
z = proportion of non-Bt cotton planted per farm on average, and
C(A) = per farm average of irrigated and non-irrigated acreage costs (rent) of land in the Mississippi Delta, obtained from Doane's Agricultural Report, fixed at the 2004 level, $51,852.37.
Note: The terms within brackets vary while those outside are fixed.

5. Total farm returns were calculated for different scenarios: viz.,
   a. $z = 0\%$, $\tau = 0$,
   b. $z = 1\%$, $\tau = 0$,
   c. $z = 5\%$, $\tau = 0$,
   d. $z = 10\%$, $\tau = 0$,
   e. $z = 20\%$, $\tau = 0$,
   f. $z = 26\%$, $\tau = 0$,
   g. $z = 1\%$, $\tau = 1$,
   h. $z = 5\%$, $\tau = 1$,
   i. $z = 10\%$, $\tau = 1$,
   j. $z = 20\%$, $\tau = 1$,
   k. $z = 26\%$, $\tau = 1$.

Note 1: The omitted case of $z = 0\%$, $\tau = 1$ would give us identical results as $z = 0\%$, $\tau = 0$, as shown in Table 2, because in equation (3) when $z = 0$ (no conventional cotton), the first term within brackets becomes zero, and hence it becomes irrelevant if $\tau = 0$ or 1 (see equation (2)).

Note 2: The sum of actual proportions (0.16 and 0.58, respectively) of insect-resistant (Bt) and stacked gene varieties observed in 2003-4 was 0.74. Choosing this to be the proportion of Bt cotton, the proportion of non-Bt cotton is the difference of the Bt proportion from unity (i.e., $z = 1-0.74 = 0.26$) (USDA-NASS, 2004). Hence the arbitrary inclusion of the cases when $z = 26\%$ above.

Results

Each year (1997-200) per acre returns obtained from Bt cotton were found to be slightly higher than that obtained from non-Bt cotton with insecticide or pesticide application(s), which in turn were found to be considerably higher than the returns from non-Bt cotton without insecticide or pesticide application(s). Standard deviations (Std. Dev.) and coefficients of variation (C.V.) (= Mean / Std. Dev.) followed the exact same comparison. These results are shown in Table 1 below, followed by a graphical depiction in Figure 1. Note: All returns calculated in this analysis are net returns (after subtracting all relevant costs), even if not noted.

Table 1. Per acre returns ($) from Bt and non-Bt (conventional) cotton in the Mississippi Delta, 1997-2000.

		non-Bt returns	
Year	Bt returns	with spray application	without spray application
1997	419.51	384.28	161.29
1998	374.62	277.87	89.08
1999	322.07	293.61	106.79
2000	310.50	279.29	82.71
Mean	356.67	308.76	109.97
Std. Dev.	330.29	328.46	229.42
C.V.	1.08	0.94	0.48

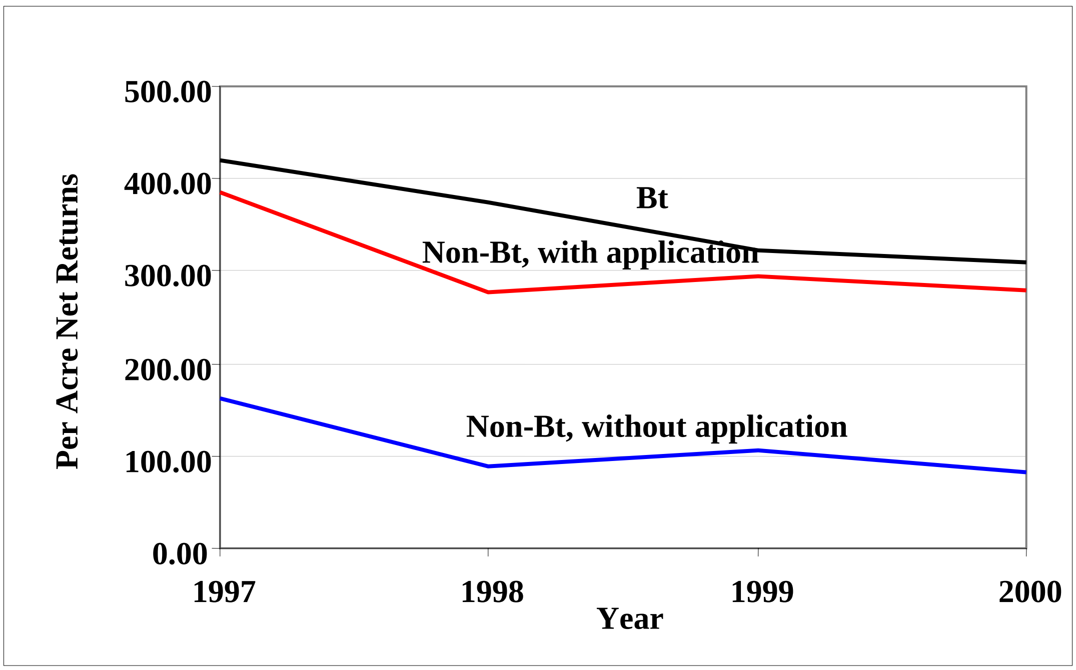

Figure 1. Per acre net returns ($) from Bt cotton, and non-Bt cotton, with and without spray application, in the Mississippi Delta, 1997-2000.

Mean-Variance Analysis

Regime 1 (Table 2, first half): $\tau = 0$ (scenarios a through f): z = 0% gives more mean net return and standard deviation (positive square root of variance) than for z = 1%, which in turn gives more net return and standard deviation than when z = 5%, and so forth. So, lower the z, higher are mean return and standard deviation, though the differences in means and standard deviations between series (i.e., between 0% and 1%, 1% and 5%, and so forth) are not statistically significant at the 5% level of significance. C.V. falls consistently as z (the refuge level) rises.

Regime 2 (Table 2, second half): $\tau = 1$ (scenarios g through k): z = 1% gives more mean net return and standard deviation than for z = 5%, which in turn gives more net return and standard deviation than when z = 10%, and so forth. So, lower the z, higher are mean return and standard deviation, though the differences in means and standard deviations between series (i.e., between 1% and 5%, 5% and 10%, and so forth) are not statistically significant at the 5% level. C.V. remains more or less constant.

Note: Within a given regime, the differences in mean returns between successive levels of z are not of significant amounts. For the same level of z, these differences are larger across regimes (though not statistically significantly different). That is, it is more important whether or not a spray application is allowed than what portion of the planted acreage is non-Bt cotton (refuge).

Table 2. Total returns ($) for an average farm planting Bt and non-Bt (conventional) cotton in the Mississippi Delta, 1997-2000, under different scenarios.

z[1]	1997	1998	1999	2000	Mean	Std. Dev.	C.V.
	(τ = 0)[2]						
0%	260,645.28	229,908.30	188,166.37	177,313.32	214,008.32	33,324.71	6.422
1%	258,772.65	227,837.53	186,605.19	175,661.36	212,219.18	33,180.22	6.396
5%	251,282.11	219,554.44	180,360.44	169,053.56	205,062.64	32,607.92	6.289
10%	241,918.94	209,200.59	172,554.50	160,793.80	196,116.96	31,905.79	6.147
20%	223,192.60	188,492.89	156,942.63	144,274.29	178,225.60	30,549.57	5.834
26%	211,956.80	176,068.26	147,575.50	134,362.59	167,490.79	29,769.51	5.626
	(τ = 1)[3]						
0%	260,645.28	229,908.30	188,166.37	177,313.32	214,008.32	33,324.71	6.422
1%	260,389.81	229,206.59	187,959.98	177,087.00	213,660.84	33,254.50	6.425
5%	259,367.92	226,399.78	187,134.42	176,181.71	212,270.96	32,984.95	6.435
10%	258,090.55	222,891.27	186,102.46	175,050.11	210,533.60	32,673.90	6.443
20%	255,535.83	215,874.24	184,038.54	172,786.91	207,058.88	32,141.21	6.442
26%	254,002.99	211,664.03	182,800.19	171,428.98	204,974.05	31,880.81	6.429

[1] Proportion of non-Bt cotton planted as refuge.
[2] A spray application does not occur.
[3] A spray application occurs.

Conclusions and Further Research

Because prices and costs were assumed fixed, we may conclude that higher farm yields for Bt over non-Bt cotton were a driving force in our study that caused higher returns. For non-Bt cotton itself, higher yields with application of insecticides/pesticides resulted in higher returns over non-Bt cotton without application.

From our mean-variance results, we see that whether $\tau = 0$ or 1, the rule of thumb is: lower z (refuge) gives higher mean returns even for a short period of time, such as four years, for which on-farm data on yield were available. However, standard deviations (and hence variances) associated with lower z's are also higher, signifying higher risks. However, when coefficients of variation are considered, risks are as expected relative to mean returns. Comparing across regimes, for any positive z, a spray application ($\tau = 1$) provides higher mean returns but higher standard deviations (risks) over no application ($\tau = 0$). Considering relative risk, as given by a C.V. comparison between regimes, for any positive z, returns are not only higher but also more stable when spray is applied. However, if there were no restrictions on refuge requirements and no concern for risk, with or without spray application, a lower z would be preferred.

But how low is low enough? That is, what is the optimum z (say z^*)? We do not know that from this discrete analysis with too few data. The ongoing research in this area will attempt to address this issue. However, there is a caveat that needs mentioning here: The Environmental Protection Agency (EPA) stipulates the minimum proportion of refuge (conventional/non-Bt cotton) the farmer is allowed to plant along with Bt cotton is 5% if unsprayed or 20% if sprayed. Refuge levels below 5% are not allowed, and refuge levels between 5% and 20% are not allowed to be sprayed. So, for $\tau = 1$, i.e., when spray is applied, if z^* comes out to be less than 20%, our research will suggest the need to change the existing policy.

One limitation of this current study is the lack of availability of farm yield data over a longer period of time so to enable us a time-series analysis. A way out is to simulate farm data using data at the county or district (region) level from NASS and the deviations in yield between farm and region (Coble et al., 2001; Miller et al., 2003). Assuming constant relative risk aversion, a certainty equivalent mean value of returns for each scenario will provide us with a more comprehensive picture of the comparison between returns from Bt and non-Bt cotton, with and without application, under different scenarios.

Additionally, assuming the farmer is optimizing his/her profits, we may want to look at the farm-level marginal welfare effects of changing allocation arrangements between Bt and non-Bt cotton. Another option would be to adopt the willingness-to-pay approach and observe how farmers' willingness to pay would change in response to a 1% reduction (from both the 20% and 5% marks) in requirement to plant refuge cotton.

Unlike past studies estimating the *ex post* value of Bt cotton to farmers, proving the benefit of these refuge requirements, the ongoing study will incorporate an *ex ante* expected value approach and is an attempt to show how planting Bt cotton affects farmer risk and welfare.

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