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IMPACTS OF BT COTTON ADOPTION: WHAT STATE-LEVEL DATA CAN AND CAN'T TELL US

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Abstract

This study reports on differences in means and variances of pest damage, insecticide use, and pest control costs between Bt and non-Bt acreage using state-level data. Some statistically significant differences are as follows. Insecticide applications for both target pests and all pests were lower on Bt acreage. Yield losses from target and all pests were lower on Bt acreage. The variance of yield losses from target pests was lower for Bt cotton. The hypothesis that means or variances of overall pest control costs, including Bt fees, were equal on Bt and non-Bt acreage could not be rejected. Results should be treated with caution because state-level data represent "uncontrolled" experiments subject to confounding influences.

Introduction

Most of the empirical findings regarding the performance of Bt cotton are based on small-scale, experimental or plot–level farm studies. Performance measures include yield, boll damage from target pests, insecticide applications, and pest control costs. Means of these variables are compared between Bt and non-Bt plots. An advantage of this design is that they control, largely, for differences other than seed variety choice. When comparing means from plots with the same soil type, weather, insect pressure, or grower attributes, the use of Bt seed is a treatment and its impact can be isolated. A limitation of this approach is that for policy purposes, decision-makers often want measures of more aggregate impacts of Bt cotton adoption. It is difficult to assess how representative these plot-level results are. This raises questions about the reasonableness of extrapolating small-scale results to state or national impacts.

Representative farm surveys and state-level statistics, in contrast, can more readily provide representative or aggregate measures of Bt cotton adoption impacts. They also reflect responses to real agronomic and economic conditions, rather than experimental ones. Comparisons of means from farm surveys, state, or regional statistics, however, represent uncontrolled experiments. Differences in means of yield or insecticide use can be affected by many confounding factors such as pest pressure, weather, irrigation, grower attributes, or participation in a boll weevil eradication program.

By failing to account for these confounding factors, simple comparison of means can provide biased and misleading results (Fernandez-Cornejo and McBride, Heimlich, et al.). Growers are not assigned randomly to treatment (Bt cotton adopter) and control (non-adopter) groups. Rather they choose whether or not to adopt Bt cotton based on factors that also influence yield and insecticide use. Failure to account for this can lead to sample selection bias. Consider one example. Growers who expect to face higher pre-treatment densities of target pests are more likely to adopt Bt cotton, while those in areas with low pest pressure will not adopt. Simply comparing means between the two groups does not account for the fact that non-adopters (on average) face less target pest pressure. This will bias tests toward failing to reject a null hypothesis that Bt cotton has no impact on insecticide use. Now consider another example. Growers with higher potential yield, because of better land, management skills, etc., may be more likely to adopt Bt cotton because the expected dollar value of yield gains will be higher. In this case, Bt adopters may have higher yields for other underlying reasons, quite apart from Bt adoption.

Results from Carlson, Marra and Hubbell are consistent with both these effects. Their study compared yields and insecticide applications of Bt adopters on their Bt plots, Bt adopters on their non-Bt plots, and non-adopters. They found that, on their Bt plots, Bt adopters applied fewer insecticides than non-adopters. They also found adopters applied more insecticides on their non-Bt plots than did non-adopters. This suggests that adopters faced greater underlying pest pressure. They also found that adopters had higher yields on their Bt plots than non-adopters, but also higher yields on their non-Bt plots. This suggests that other factors, aside from Bt cotton, also account for some yield advantage.

Methods

With these warnings in mind, we report on some simple hypothesis tests concerning differences in means and variances of pest damage, insecticide use, and pest control costs between the Bt and non-Bt acreage using state-level data. We considered separately effects from the target pests and effects from all pests. The three main target lepidopteran pests we consider are cotton bollworm (*Helicoverpa zea*), tobacco budworm (*Heliothis virescens*), and pink bollworm (*Pectinophora gossypiella*). Simple one-tailed t-tests were used to test differences in means. For example, the null hypothesis that insecticide applications were equal for Bt and non-Bt acreage was tested against the alternative that applications were greater on non-Bt acreage. Non-parametric methods, not reported here (i.e. the Wilcoxon / Mann-Whitney test) gave similar results. An F-test was used to test differences in variances.

Data

State-level data come from the Cotton Crop Loss database maintained by Mississippi State University (Williams). Some state coordinators have begun reporting data separately for acres planted to Bt and non-Bt varieties. These include Arizona (1999-2002), Louisiana (1999-2002), Tennessee (1999, 2002), North Carolina (2000-2002), Georgia (2002), and South Carolina (2002). Pooled together, there are 30 observations, 15 Bt observations and 15 non-Bt observations.

Results

Bt acreage suffered less damage from bollworm, budworm and pink bollworm than non-Bt acreage. Non-Bt cotton averaged yield losses of 4.1 percent or 0.9 bales (43.1 pounds) per acre, while Bt cotton averaged yield losses of 0.91 percent or 0.2 bales (8.6 pounds) per acre. (Table 1). Growers treated Bt acreage less extensively and less often for bollworm, budworm and pink bollworm. While 75.6 percent of non-Bt acres infested with these pests were treated, less than 53 percent of infested Bt acres were treated. Applications per total cotton acres were 2.31 for non-Bt cotton and 0.73 for Bt cotton. Non-Bt cotton received 3.28 applications per treated acre compared to 1.09 applications for Bt cotton. The statistical significance of all these differences was high using a one-tailed t-test assuming unequal variances. The difference in acres treated as a percent of acres infested was significant at the 2 per cent level, while all the other differences were significant at a less than 0.1 percent level.

Similar results obtain for differences in damage and applications to control all cotton pests. Yield loss on non-Bt acres averaged 7.43 percent or 0.17 bales (82.8 pounds) per acre, while yield loss on Bt acres averaged 4.75 percent or 0.11 bales (53.3 pounds) per acre. There was less of a difference in mean applications for all pests between Bt and non-Bt cotton. Still, non-Bt acre averaged 5.15 applications per total acres versus 3.77 applications for Bt cotton. Using a one-tailed t-test, either assuming unequal variances or not, the differences were all significant at the 5 percent level.

The variances of damage and insecticide use variables were lower for Bt cotton than non-Bt cotton, with the exception of applications per total cotton acres for all pests (Table 2). We fail to reject the hypothesis that the variances are equal for variables related to all cotton pests, using an F-test. For variables related to bollworm, budworm and pink bollworm, we reject the hypothesis of equal variances for percent yield loss and bales lost per acre at a less than 0.1 percent significance level. We reject the hypothesis of equal variances for applications per total acre at the 5 percent level.

Pest control costs, including Bt technology fees, were slightly higher on Bt acres than non-Bt acres, $86.55 compared to $82.13 (Table 3). The variance of pest control costs was lower for Bt than non-Bt cotton. We failed to reject the hypotheses, either of equal means or equal variances, however.

Discussion

The above results suggest that pest damage and insecticide use are different on Bt and non-Bt acreage. Because they do not control for confounding factors, however, one cannot say how much of these differences are attributable to Bt cotton. We could not reject the hypothesis that means and variances of pest control costs were equal on Bt and non-Bt acreage. Again, confounding factors may bias results. Bt cotton adopters are likely to face higher pest pressure than non-adopters. A simple comparison of means of state-level data cannot answer the counterfactual question of, "What would yield losses and insecticide applications have been had Bt cotton not been adopted?" Results should be viewed as preliminary and complementary to multiple regression analysis to control for confounding factors. An interesting line of research would be to estimate the impact of Bt cotton adoption on variability of pest damage.

References

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Table 1. Comparison of pest damage and insecticide use, Bt vs. non-Bt cotton, pooled years and states.

	Non-Bt	Bt	t value	Significance level*
All cotton pests				
Percent yield loss	7.43	4.75	2.87	0.004
Bales lost per acre	0.17	0.11	2.40	0.012
Applications per total cotton acres	5.15	3.77	1.81	0.041
Bollworm, budworm, and pink bollworm				
Percent yield loss	4.10	0.91	5.20	0.000
Bales lost per acre	0.09	0.02	6.49	0.000
Applications per total cotton acres	2.31	0.73	4.60	0.000
Acres treated as % of acres infested	75.60	52.98	2.15	0.021
Applications per treated acre	3.28	1.09	5.20	0.000

* Significance level of one-tailed t-test of difference in means.

Table 2. Comparison of variances of pest damage and insecticide use variables , Bt vs. non-Bt cotton, pooled years and states.

	Variance Non-Bt	Variance Bt	F statistic	Significance level*
All cotton pests				
Percent yield loss	8.34	4.76	1.75	0.15
Bales lost per acre	0.007	0.003	2.29	0.07
Applications per total cotton acres	4.08	4.69	1.15	0.40
Bollworm, budworm and pink bollworm				
Percent yield loss	5.11	0.54	9.54	0.0001
Bales lost per acre	0.0016	0.0002	8.29	0.0002
Applications per total cotton acres	1.26	0.51	2.48	0.05
Acres treated as % of acres infested	1157.78	508.66	1.69	0.17
Applications per treated acre	1.50	0.69	2.17	0.08

* Significance level of one-tailed F-test of difference in variances

Table 3. Comparison pest control costs, Bt vs. non-Bt cotton, pooled years and states.

	Non-Bt	Bt	Significance level
Mean pest control costs per acre	$82.13	$86.55	0.352[a]
Variance of pest control costs per acre	1176.37	829.51	0.261

a. Significance level of t-test of difference in means.
b. Significance level of F-test of difference in variances.