

Commentary

Does expression of Bt toxin matter in farmer's pesticide use?

Jikun Huang¹, Ruijian Chen^{1,2}, Fangbin Qiao^{3,*}, Honghua Su⁴ and Kongming Wu⁵¹Center for Chinese Agricultural Policy, Chinese Academy of Sciences and Institute of Geographic Sciences and Natural Resource Research, Beijing, China²Foreign Economic Cooperation Center, Ministry of Agriculture of the People's Republic of China, Beijing, China³China Economics and Management Academy, Central University of Finance and Economics, Beijing, China⁴School of Horticulture and Plant Protection, Yangzhou University, Yangzhou, Jiangsu, China⁵State Key Laboratory for Biology of Plant Diseases and Insect Pests, Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing, China

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*Correspondence (Tel: (0086)10 62288295;

fax: (0086)10 62289376;

email fangbin.qiao@gmail.com)

Summary

Despite the widespread adoption of Bt cotton, farmers still spray excessive pesticides in their cotton fields. In contrast to scientists who always use high quality seeds in the laboratory and/or experimental fields, farmers may plant low quality seeds with a low expression of Bt toxin. How does the expression of Bt toxin influence farmers' pesticide use? On the basis of a plot-level survey and laboratory test data, this study shows that pesticide use on one cotton plot is influenced not only by the expression of Bt crops in this plot, but also by the average expression in the village in the early stage of the cotton growing season. In other words, high expression of Bt toxin benefits not only the farmers who plant the varieties but also all the other villagers.

Keywords: Bt toxin expression, plot-level survey, laboratory test, pesticide use, Bt cotton.

Introduction

Despite the widespread adoption of Bt cotton, field observations show that Chinese farmers still spray excessive amounts of pesticide on their cotton fields. Although farmers significantly reduced their pesticide use after the adoption of Bt cotton (for example Pray *et al.*, 2001; Qaim and de Janvry, 2003), empirical studies show that Chinese farmers continue to overuse pesticides in their Bt cotton fields (Huang *et al.* 2002; Pemsil *et al.*, 2005; Yang *et al.*, 2005).

Why do Chinese farmers continue to overuse pesticides? Is the Bt cotton efficient in controlling pests? Bt plants control target pests, which leads to chemical pesticide reduction and yield increase (Pray *et al.*, 2001; Qaim and de Janvry, 2003). Efficacy of Bt cotton depends on the expression level of Cry genes and the synthesis of insecticidal proteins (Gutierrez *et al.*, 2006). High expression of Bt toxin means high efficiency of Bt crops in controlling pests, and *vice versa*. Therefore, low expression of Bt toxin should lead to high pesticides use.

Is the expression of Bt toxin really important in pesticide use in practice? Does low expression of Bt toxin lead to high pesticide use? Is low expression of Bt toxin causing overuse of pesticides? To the best of our knowledge, there have been no studies that have empirically estimated the impact of Bt toxin expression on farmers' pesticides use in agricultural production.

The overall goal of this study was to empirically address the above questions by estimating the impact of Bt toxin expression on pesticide use in the field. To achieve this goal, we selected Bt cotton in the Yellow River valley, the largest cotton production area and the largest Bt cotton production area in China.

Expression of Bt toxin and farmers' pesticide use

Two types of data sets were used in this study: data from a household farm management survey and data from laboratory tests. The household farm management survey data were

collected from 813 plots belonging to 240 households in the Yellow River valley. To increase the accuracy of data collection, we provided each farmer with a notebook and pens and asked them to record all farm management activities (such as pesticide use) for each plot. For the laboratory tests, we collected cotton leaves from each sample plot three times (in June, July and August) and analysed them in the laboratory for the expression of Bt.

Our results showed no clear relationship between the expression of Bt toxin and the amount of pesticide used in each plot which suggests that farmers' pesticide use in a single plot is unrelated to the expression level of Bt toxin.

However, the relationship changes if we analyse it at the village level. Cotton bollworm moths have a strong flying ability, and their density can be monitored in small plots (for example Wu and Guo, 2005). Hence, it is reasonable to assume that both moth and larval density are the same throughout a village. This assumption has been used in many studies, including that of Livingston *et al.* (2002) and Qiao *et al.* (2008). Therefore, we might need to check the relationship between farmers' pesticide use and the expression of Bt toxin at the village level.

Table 1 shows the negative relationship between farmers' pesticide use and the expression of Bt toxin at the village level. If we list all four sample villages in the Shandong Province according to the average expression level of Bt toxin in descending order, we find that farmers in the village with highest expression level of Bt toxin sprayed the least amount of pesticide (columns 1–4). We obtain similar results if we revisit this question in Hebei and Henan Provinces.

Estimation results of models

The descriptive analysis might be biased because farmers' pesticide use is affected by many factors. To isolate the impact of Bt toxin expression, we adopted a multivariate function approach and estimated the model using plot-level data. Our

Table 1 Expression of Bt toxin and pesticide use in controlling cotton bollworm at the village level

	Shandong Province				Hebei Province				Henan Province			
	Amount of Bt toxin		Pesticide use in controlling cotton bollworm		Amount of Bt toxin		Pesticide use in controlling cotton bollworm		Amount of Bt toxin		Pesticide use in controlling cotton bollworm	
	Quantity (ng/g)	Rank	Quantity (kg/ha)	Rank	Quantity (ng/g)	Rank	Quantity (kg/ha)	Rank	Quantity (ng/g)	Rank	Quantity (kg/ha)	Rank
Village 1	943	1	3.3	4	1070	1	7.9	4	1195	1	1.4	4
Village 2	891	2	7.4	1	1025	2	26.6	1	1109	2	5.7	1
Village 3	872	3	5.0	2	1024	3	10.7	3	1005	3	2.9	2
Village 4	841	4	4.1	3	1014	4	22.3	2	953	4	1.7	3

Source: author's survey.

objective was to estimate the *net* impact of Bt toxin expression on farmers' pesticides use. To do so, we needed to hold constant the effect of many factors, such as plant and household characteristics, when estimating statistical models.

The estimation results are shown in Table 2. In general, the models perform well in all estimations. The R-squared values range from 0.59 to 0.61, which are high for cross-section data analyses. The signs of most of the coefficients estimated were as expected. For example, the estimated coefficients of plant age were positive and significant in all models, which indicates that the earlier the cotton is planted, the greater is the amount of pesticide that is sprayed.

Consistent with the descriptive analysis, the estimation results show that the village average expression of Bt toxin has a significant negative impact on farmers' pesticide use, although the impact of the expression level of the plot is insignificant. The estimated coefficient of the village average expression of Bt toxin is negative and significant (column 2, row 1). If we replace the average expression by the expression levels of June, July and August in the village, the estimated coefficients of June and July are still significant and negative, even though the estimated coefficient of August is not significant (columns 3–4, rows 2–4). In other words, the estimated results show that the higher the village average expression levels of Bt toxin in June and July are, the less pesticide farmers spray. However, the estimation results show that the expression level of each plot is insignificant (column 1, row 5).

Cotton bollworm moths have the ability to fly high and they prefer older plants. A high expression level of Bt toxin is efficient in controlling pests, which contributes to the nutritional status of plants. For cotton bollworm moths, these plants are more attractive. As a result, the pest density on these plants is also higher. Consequently, farmers should also spray more pesticide on these plants. This is the so-called externality. In this sense, the seeming unrelated relationship (as shown in column 1) might be caused by the existence of this externality.

To control for externalities, we re-ran the models by adding the expression of Bt toxin of a plot relative to the village average. After adding the expression levels of Bt toxin in June, July and August, we also add three dummy variables: (i) the first dummy variable equals 1 if the expression level of the plot is higher than the village average in June; (ii) the second dummy variable equals 1 if the expression level of the plot is higher than the village average in July; and (iii) the third dummy variable equals 1 if the expression level of the plot is higher than the village average in August. The value of each of the three dummy variables was 0 if

the condition was not met. The estimation results are shown in the last column of Table 2.

After controlling for externalities, we found that farmers did spray more pesticide in plots with relatively high expression levels of Bt toxin. As shown in the last column of Table 2, the estimated coefficient of 'Higher than village average dummy in June' was positive and significant, which showed that if the expression level of Bt toxin in a plot was higher than the village average in June, farmers sprayed more pesticide on the plot. This finding is consistent with the expectations of entomologists (for example, Wu and Guo, 2005). The estimated coefficients of 'higher than village average dummies in July and August' were not significant, which suggests that we cannot reject the null hypothesis that expression levels in the middle and late growing seasons have no impact on farmers' pesticide use.

The estimation results show that the Bt toxin expression in each plot has a negative impact on farmers' pesticide use. As shown in the last column, the estimated coefficient of the expression level of Bt toxin in June is negative and statistically significant (row 6). The estimation results show that if the expression level of Bt toxin in June increased by 100 ng/g, farmers decreased their pesticide use by 0.2 kg/ha. Similar to that of the dummies variables, the estimated coefficients of expression in July and August are insignificant (rows 7 and 8), suggesting that the expression of Bt toxin has no impact on pesticide use later in the growing season.

Discussion

The use of Bt crops that express Cry genes and synthesize insecticidal proteins can lead to a reduction in chemical pesticide use (Gutierrez *et al.*, 2006). In this study, we empirically examined the impact of Bt toxin expression on farmers' pesticide use. By analysing plot-level data collected in the Yellow River valley, we showed that pesticide use is affected not only by the expression of Bt toxin in the plot, but also by the average expression of Bt toxin in the village early in the growing season. Therefore, a high expression of Bt toxin benefits not only the farmers who plant these varieties, but also the other farmers.

Results from this study may have important policy implications. After the implementation of the Household Responsible System (HRS), millions of small households became the basic production unit in China's agricultural production. Even though implementation of the HRS has contributed significantly to agricultural development in China, it has also led to the failure of activities that require collective action. For example, due to the existence of

Table 2 Impact of expression of Bt toxin on farmers' pesticide use

	Pesticide use in controlling cotton bollworm (kg/ha)			
	Model (1)	Model (2)	Model (3)	Model (4)
Village average of expression of Bt toxin				
Average		−0.016 (4.21)***		
In June			−0.005 (3.45)***	−0.003 (1.72)*
In July			−0.011 (1.71)*	−0.011 (1.83)*
In August			−0.005 (0.93)	−0.004 (0.72)
Expression of Bt toxin in a plot				
Average	0.001 (1.06)			
In June				−0.002 (2.89)***
In July				0.001 (1.01)
In August				0.000 (0.19)
Higher than village average in June (Yes = 1)				2.318 (3.83)***
Higher than village average in July (Yes = 1)				0.128 (0.20)
Higher than village average in August (Yes = 1)				−0.084 (0.14)
Plant age (day)	0.066 (1.78)*	0.097 (3.08)***	0.095 (2.78)***	0.119 (3.13)***
Plot size (ha)	−0.955 (0.72)	−0.932 (0.64)	−1.127 (0.77)	−1.189 (0.84)
Education of household head	−0.105 (1.39)	−0.043 (0.56)	−0.047 (0.58)	−0.034 (0.41)
Age of household head	0.076 (2.69)***	0.069 (2.53)**	0.067 (2.38)**	0.06 (2.15)**
County/village dummy	Yes	Yes	Yes	Yes
Constant	−6.135 (2.05)**	32.002 (6.99)***	36.712 (3.90)***	34.783 (3.74)***
Observation	814	814	814	814
R ²	0.61	0.59	0.60	0.60

The figures in the parentheses are robust *t*-statistics.

***, **, *Significance at 1%, 5% and 10%, respectively.

the externalities, promotion of the Integrated Pest Management (IPM) failed in China and in other countries where there are millions of small households. This study provides empirical evidence of the externality in pest management and the need for government intervention in providing subsidies to farmers planting crops with high expression of Bt toxin and technical services to increase the expression of Bt toxin.

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