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Vegetable Production and Pesticide Use in Ghana: Would GM Varieties Have an Impact at the Farm Level?

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Abstract

The objective of this study is to evaluate pesticide use as an important factor affecting potential adoption and farm level impact of genetically modified (GM) vegetable varieties in Ghana. Tomato is the most consumed vegetable and a food security crop. Cabbage is a vegetable of growing importance but limited cultivation and is produced in urban areas. Garden egg is a native African crop of wide consumption and importance for rural economies. Farm level information was collected in randomly selected sites in southern and central regions of Ghana. Partial budget analysis shows that investments in pesticides are rather low, especially for tomato and garden egg. Analysis of production using an abatement framework shows that insecticide amounts are significant in determining cabbage output levels only. Rate of returns of GM seeds however can still be high. GM varieties would need to show not only a high abatement rate and a high yield potential but mainly an affordable price, to reduce total costs and induce adoption

Keywords: Farm, Genetically modified, Ghana, Tomato

Introduction

Pesticide use in Ghana has increased over the years and it is particularly elevated in high value cash crops and vegetable production with concomitant environmental and health negative effects. The Diamond Back Moth (DBM) in cabbage, Tomato Yellow Leaf Curl Virus (TYLCV) in tomato, and the shoot and fruit borers (SFB) in garden egg are important biotic constraints for each of these crops. They are control with increasing levels of pesticides. According to experts resistance has already being developed in DBM against the main insecticides available in Ghana. In this context, could genetically modified (GM) tomato resistant to TYLCV, GM cabbage resistant to DBM or garden egg resistant to SFB be an alternative to farmers? Would farmers reduce the use of pesticide and be able to increase their production levels? There appear to be significant potential for capturing large economic, social, and environmental payoffs from the use of biotechnology products in the farming systems of Africa. Unfortunately, ex-ante impact evaluations of the adoption of GM crops in Africa are limited (Smale et al. 2006).

Tomato is a food security crop as it is the most consumed vegetable in Ghana. This crop is produced all over the country but the main producing areas are located in the Northern regions. Tomato demand however is higher than the supply and Ghana imports tomato at least 6 months of the year. Cabbage is a vegetable of growing importance but of limited production in the country. It is produced in urban areas for urban consumers in main cities. While it is an economic alternative for migrants and fills a gap for urban consumers, cabbage production also brings negative environmental and health externalities mainly related to high pesticide and water use. Garden egg is a native African crop of wide consumption in Ghana and economic importance for rural households in the southern and central regions on the country. Garden egg is not only particularly diverse in Ghana but it also has some export possibilities that can be better exploited.

Research Design

A set of three survey instruments were used to enable a) the calculation of partial budgets for representative growers; and b) simulation of partial budgets for scenarios with and without GM seed. The pesticide use and production function were later evaluated using a damage abatement framework. Production areas were selected based on prior information, by agro-ecological zone, region, and district. The regions and districts selected were: Greater Accra Region: Accra Metropolitan Area, Dangme East and Ga West; Central Region: Mfantseman; Ashanti Region: Kumasi Metropolitan Area, Mampong and Offinso; Brong-Ahafo Region: Techiman and Wenchi; Volta Region: Keta and Kpandu. With the help of the Agricultural Extension officers in each district, specific town and production areas were identified and weighted according to the number of producers per area. Finally, for each crop, a random sample of farmers was drawn after visiting the town and contacting producers.

Partial Budget Analysis

Farmers consider tomato, cabbage and garden egg production to be profitable activities in spite of the numerous constraints they face along the production and marketing chain. We estimated crop budgets and developed partial budget scenarios for evaluating impact of GM vegetable varieties. The limited information available on real damage levels and specific labor costs to control target pest however represents a serious limitation to this approach. The crop budgets showed that labor is by far the largest cost component in vegetable production in Ghana. Expenses on synthetic pesticides are relatively low, varying from 2% of total production costs in tomato and garden egg to 17% in cabbage production. Downside risk is considerably high. The percentage of farmers with net income below zero could be as high as 70% when there is no pest control. It is important to point out also that that Karate, a wide-spectrum insecticide, is the major pesticide used by vegetable producers. The costs reduction then would then also depend on the importance of secondary pest.

The main reduction in costs from the use of GM seed is expected in insecticide and labor required for insecticide spraying. Seed costs on the other hand are expected to increase.

Conservative assumptions were used to reproduce the scenarios: damage abatement efficiency of 50 and 100%, and an average 25% reduction in labor and insecticide costs. Seed prices were increased in the same proportion to formal/informal seed price ratio. Yield losses were elicited from farmers based on their years of experience. Expected yield losses vary from 21% in garden egg, 24% in tomato and 27% in cabbage. Since it is difficult to single out the effect of one individual pest, yield losses might have an upward bias. In all the scenarios the rate of returns to GM seed use was moderate to high (above 100%) across crops. Given the limited information on detailed input use and possible upward bias in yield losses these results have to be taken with caution.

Modeling production

Lichtenberg and Zilberman (1986) were the first to propose the use of the damage abatement framework to estimate a production function. Since then the model has been widely used and extended (Babcock, et al., 1992, Carrasco-Tauber and Moffitt, 1992, Saha, et al., 1997). The framework consider that agricultural inputs have two main effects on agricultural production: 1) direct yield effect, and 2) damage abatement effect.

Yield effect is caused by inputs like fertilizers, labor or seed type that can have a direct effect on the performance of the crop. Damage abatement effect is defined as the proportion of the destructive capacity of the damaging agent eliminated by applying a given level of a control input. Control or damage abatement inputs could be pesticides, labor, cultural practices, a crop variety, or any other input that controls the potential impact of the pest and diseases.

Zhengfei et al. (2006) proposed a similar framework with a more broad characterization of the inputs: growth and facilitating inputs. The first ones are the inputs directly involved in the biological and agronomic processes of crop growth. Facilitating inputs are used to help create favorable growth conditions. Lichtenberg and Zilberman (1986) as well as Zhengfei et al. (2006) start from the same principle: if all inputs are treated as directly increasing output the productivity effect of some inputs is likely to be overestimated. The damage abatement framework not only provides a good framework to estimate the effect of inputs on yield but also the interaction effect among inputs.

Econometric Specification

There are different specifications that can be used to model a production function. Cobb-Douglass functions are commonly used to account for the effect of productive inputs. Cobb-Douglas functions are less complex but imposed more restrictions on the estimation. The main advantage of this specification is that it can be linearly estimated after a simple logarithmic transformation. This function has however important limitations: 1) the inputs are not necessarily use in a proportional way as the Cobb-Douglas implies; and 2) Cobb-Douglas leads to exclusion zero input observations because their logarithm is not defined. Quadratic and translog specifications have been used to overcome these limitations (Oude Lansink and Carpentier, 2001, Qaim and Janvry, 2005). For the purposes of this study we use a quadratic function of the form:

$$Y = \alpha + \Sigma \beta_i Z_i + \Sigma \Sigma \theta_{ij} Z_i Z_j + \gamma H + \varepsilon \qquad (1)$$

Where, Y is crop yield/output, Z represent a vector of productive inputs used (in per \$/Ha terms), and H are household characteristics that affect the production.

Damage Abatement Framework

In a damage control framework a production function has the following specification (Lichtenberg and Zilberman, 1986): Y = F [Z, G(X)], where Z represents directly productive inputs. The abatement function G(X) takes values between [0, 1]. If there is no control of the damage (G(X) = 0) then Q = F [Z, 0], while if there is complete control of the damage (G(X) = 1) then Q = F [Z, 1]. In the literature, the abatement function has been commonly expressed using exponential or logistic distributions rendering robust results (Babcock, et al., 1992, Pemsl, et al., 2005, Qaim and Janvry, 2005). A quadratic production function with a logistic abatement function can expressed as:

$$Y = (\alpha + \Sigma \beta_i Z_i + \Sigma \Sigma \theta_{ij} Z_i Z_j + \gamma H) * [1 + \exp(\mu - \sigma X)^{-1}] \qquad (2)$$

While G(X) is unobservable, the use of control agent X is susceptible to direct estimation. The estimation of this model requires the use of non-linear least square (NLSQ) methods. The abatement input X can be expressed in a variety of units, depending on the type of input. The use of a dummy variable is the easiest alternative when quantitative data is not available. In the case of pesticides both, the total amount per hectare or the total value have been equally employed (Shankar and Thirtle, 2005, Zhengfei, et al., 2005).

Dealing with Endogeneity of Insecticide Use

Endogeneity is a potential problem. Endogeneity refers to the fact that an independent variable included in the model is potentially a choice variable, correlated with unobservables relegated to the error term. Insecticide use, our abatement input (X), is a response to high pest pressure. If the farmers use chemical products to control pest it would be useful to determine an insecticide use function to test for possible endogeneity (Hausman test), as suggested by Qaim and De Janvry (2005) and Shankar and Thitle (2005).

The residues of the insecticide use function would be then added to the production function as an additional regressor:

$$Y = F(Z) [1 + \exp(\mu - \sigma X^{pred})]^{-1} \qquad 4)$$

If the residuals are not significant pesticide use is not endogenous to output levels and it is better to use the real pesticide values. Qaim and De Janvry (2005) found that in Argentina there is a strong correlation of pesticide use and cotton production while Shankar and Thirtle (2005) concluded that pesticide use in South Africa is still too low and restricted to be endogenous to cotton production. In our study when regressed against household characteristics variables (age, gender, education, and experience with the crop, training in the use of pesticides) and production variables (use of other chemical and damage control inputs like biopesticides and fungicides) the residues were significant only in the case of garden egg. Tomato and cabbage are more susceptible to pest attacks and farmers prefer to use preventive control measures. Garden egg as a native crop has a higher adaptability to local conditions including a number of pests and/or farmers set a higher economic threshold for this crop. Thus, predicted values of the insecticide function were used instead of the real values for the case of garden egg.

Production Determinants and Insecticide Damage Abatement

The regression results of the production function show strong differences across vegetables (Table 1). In tomato production labor, fertilizer and experience with the crop are main yield determinants. Seed and labor are main determinants to cabbage production. Cabbage production is dependent on water availability and is significant in both cases. The variable water reflects more accessibility to water and labor costs involved in carrying the water from the source to the plot, hence the negative relationship. Garden egg plots and tomato plots are located mainly under rainfed conditions. Access to credit, seed and fertilizer are significant factors affecting garden egg production. As expected, insecticide use is significant in cabbage production. In tomato and garden egg production insecticide does not have a significant effect. The reasons are different in each case. While in tomato the applications are mostly preventive, the amounts applied are still not sufficient to control the pest attacks. Garden egg in contrast has the higher tolerance to pests and the limited amount of insecticides applied is effective in controlling partly the insect attacks. Results are comparable using a quadratic specification where insecticide use is significant in cabbage production but its effect is overestimated.

Table 1. Estimated damage abatement functions

	Tomato (N=139)		Cabbage (N=74)		Garden Egg (N=144)	
	Coef.	t	Coef.	t	Coef.	T
Household characteristics						
Age	21.56	0.53	127.44	0.86	-100.74	-2.02
Gender (fem =1)	640.23	0.54	1370.11	0.20	-193.26	-0.13
Education	2.10	0.02	47.49	0.12	252.33	1.43
Crop exp.	166.48	2.48 **	-134.44	-0.46	15.97	0.16
<u>Productive Inputs</u>						
Credit	9.77	1.35	-4.54	-0.31	33.01	3.08 ***
Sq. Credit	-0.01	-1.03	0.00	0.64	-0.03	-2.48 ***
Labor	12.69	3.45 ***	10.05	2.08 **	4.56	1.50
Sq. Labor	-0.01	-2.82 ***	0.00	-1.54	0.00	-1.12
Land	-18.72	-0.65	-149.59	-1.22	87.51	1.13
Sq. Land	0.07	1.19	0.60	0.70	-0.64	-0.88
Seed	17.92	0.27	247.61	3.40 ***	91.54	1.75 *
Sq. Seed	-0.54	-0.99	-0.70	-2.70 ***	-0.58	-1.96 **
Fertilizer	17.85	2.08 **	-30.19	-1.07	62.71	3.29 ***
Sq. Fertilizer	-0.01	-1.13	0.04	1.43	-0.11	-2.16 **
Water	-70.08	-1.52	-60.99	-2.13 **	-46.76	-1.21
Sq. Water	0.00	0.84	0.00	1.68 *	0.12	1.11
<u>Damage Abatement</u>						
μ	-5.54	0.00	-4.36	0.00	37.98	0.58
σ	-0.01	-0.13	0.00	1.82 ***	-0.34	-0.57
Adjusted R2	0.69		0.72		0.70	

Conclusion

Our findings indicate that while farmers currently tend to use higher than recommended doses of pesticides, the reduction in pesticide use may not be as great as expected with the introduction of GM varieties. This is not only because farmers' investments in pesticides are low for tomato and garden egg but also because insecticides are not significantly abating damage. Only in the case of cabbage is the prospect of reducing the costs of pesticide use through growing GM crops likely to be a critical determinant of adoption. Since in large, pesticides seem to be underused in vegetable production in Ghana due to their high costs, GM vegetable seed price would determine adoption. In general, any technology that will reduce yield variability or yield losses from damage will contribute to long-term poverty reduction among vulnerable groups. Further research on damage estimations due to target and detailed input use is needed.

References

Babcock, B. A., E. Lichtenberg, and D. Zilberman. "Impact of damage control and quality of output: Estimating pest control effectiveness." *American Journal of Agricultural Economics* 74, (1992): 163 - 172.

Carrasco-Tauber, C., and L. J. Moffitt. "Damage control econometrics: Functional specification and pesticide productivity." *American Journal of Agricultural Economics* 74, (1992): 158 - 162.

Lansink, A. O., and A. Carpentier. "Damage control productivity: An input damage abatement approach." *Journal of Agricultural Economics* 52, no. 3(2001): 11 - 22.

Lichtenberg, E., and D. Zilberman. "The econometrics of damage control: Why specification matters." *American Journal of Agricultural Economics* 68(1986): 261 - 273.

Pemsl, D., H. Waibel, and A. P. Gutierrez. "Why do some Bt-cotton farmers in China continue to use high levels of pesticides?" *International Journal of Agricultural Sustainability* 3, no. 1(2005): 2005.

Qaim, M., and A. d. Janvry. "Bt cotton and pesticide use in Argentina: economic and environmental effects." *Environment and Development Economics* 10(2005): 179 - 200.

Saha, A., C. R. Shumway, and A. Havenner. "The economics and econometrics of damage control." *American Journal of Agricultural Economics* 79, (1997): 773 - 785.

Shankar, B., and C. Thirtle. "Pesticide productivity and transgenic cotton technology: the South African smallholder." *Journal of Agricultural Economics* 56, no. 1(2005): 97 - 116.

Smale, M., Zambrano, P., Falck-Zepeda, J., and Gruère, G.. (2006) Parables: Applied economics literature about the impact of genetically engineered crop varieties in developing economies. Washington DC, IFPRI Library, pp. 83.

Zhengfei, G., Lansik, A. O., van Ittersum, and M., Wossink, A. "Integrating agronomic principles into production function specification: A dichotomy of growth inputs and facilitating inputs." *American Journal of Agricultural Economics* 88 (1) (February 2006): 203 - 214.