Hans H. Ruthenberg-Graduierten-Förderpreis 2008/

Hans H. Ruthenberg Award for Graduates 2008

Anna Jankowski "Economics of Biological Control of Diamondback Moth in Vegetable Production in East Africa"

Leibniz University Hanover, 2007

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Summary

Background

In Eastern and Southern Africa, cabbage, *Brassica oleracea L. var. capitata*, is one of the most widely grown vegetables. For small-scale farmers it is an important source of vitamins, minerals and income. However, cabbage production is constraint by insect pest problems, among which the Diamondback moth (DBM), *Plutella xylostella* (L.), is considered as the most destructive worldwide and occurs wherever brassica crops are cultivated (Talekar and Shelton, 1993). In East Africa, most farmers use synthetic pesticides and solely depend on their use to minimize damage and output losses due to DBM (Varela et al., 2003).

Increasing difficulties in DBM control can arise because DBM possesses the ability to quickly develop resistance to any pesticides (Gelemter and Lomer, 2000). This constitutes a challenge in its control, and without alternatives, farmers tend to overuse chemicals by increasing pesticide quantity and spray frequency, as well as applying pesticide cocktails (Varela et al; 2003). Since chemical control measures are associated with negative external effects like build-up of resistance and negative impacts on human and environmental health, biological control is gaining attention (Hajek, 2004; Margni et al., 2002). Classical biological control (BC), i.e. the introduction of an exotic natural enemy into a new environment, involves releases of an appropriate BC agent, which spreads on its own and is ubiquitous when successfully established. Because the pest control is permanent and requires no investment from individuals, it is extremely appropriate for pests that affect resource-poor farmers (Hajek, 2004).

In several Asian countries, especially in the highly intensive vegetable production systems, problems in chemical control of DBM were reported. However, although BC programs of DBM were successful in several regions (Talekar and Shelton, 1993), evidence on their economic impact has not been documented. Even though the intensity of pesticide use in the vegetable production systems of East Africa is generally lower than in Asia, Kibata (1996) found that in Kenya pesticide resistance has developed in DBM. However, assessment of resistance is complicated due to heterogeneous pesticide quality caused by e.g. inappropriate storage, high temperatures and other factors.

To control DBM in the major cabbage producing areas of Kenya, Tanzania and Uganda, the BC agent Diadegma semiclausum (Hellen) was imported from Taiwan and introduced in highland areas by the International Centre of Insect Physiology and Ecology from 2001 onwards. For Kenya an economic ex-ante impact assessment was conducted during the pilot phase of the project. Based on a number of assumptions about the potential impact of the parasitoid, Macharia et al. (2005) calculated a benefit cost ratio of 24:1.

Objective of the study

This study aims to supplement the ex-ante analysis by verifying the assumptions and including Tanzania as project country. Representing a short to medium term ex-post impact assessment, specific questions, which are addressed in this study, are

(1) How does the introduction of the BC agent affect the output of cabbage production?

(2) Does it result in decreased pesticide use?

(3) Does the presence of the BC agent contribute to a reduction of negative externalities on household health via reducing pesticide use?

Methodology

Data

Study areas in Kenya and Tanzania were selected and data was collected following a "with and without the BC agent" survey design. Selected study sites were Central Province (Kiambu, Nyeri and Nyandarua District) in Kenya and Northern Zone (Arusha and Tanga Region; and within these regions Arumeru and Lushoto District respectively) in Tanzania. The survey followed a two-stage sampling procedure, which resulted in a total sample of 1,291 farmers covering two production seasons in both countries. Using the same structured questionnaire, data were collected trough face-to-face interviews, by a recall survey for a dry season (October 2004 to March 2005), and for a rainy season (March 2005 to July 2005) by season-long monitoring, involving three farm visits. For the analysis 1,250 complete data sets were retained.

Model I: Production function with integrated damage control function

For the analysis of the effect of the BC agent, the concept of damage abatement (see Lichtenberg and Zilberman, 1986) is used and a production function with integrated damage control function (using different functional forms) is estimated. One key feature in the concept is the distinction between inputs in standard factors of production (e.g. land, labor), which enhance productivity directly, and in damage control agents (e.g. pesticide, BC agent), which contribute indirectly to the output by preventing output losses. To analyze the effect of the damage control agents, presence of the BC agent, pesticide and interaction between these two control agents is incorporated in the damage abatement function.

A major problem in estimating production functions is that all production factors are treated as exogenous although farmers decide their level. Though the problem is apparent for all inputs, it is special for pesticide use. Due to the nature of potentially omitted variables and correlations, not accounting for endogeneity could bias parameter estimates (Huang et al., 2002). To solve this problem a two stage least square (2SLS) estimator is used and the pesticide variable is instrumented by estimating a pesticide use function. Thus, in the first stage a pesticide use function is estimated and then, in the second stage, the predicted values of pesticide use are used to estimate a production function. However, in this summary only the estimation results of a production function with in-build exponential damage abatement function are discussed.

Model 2: Health model

The health model investigates whether the reduction in pesticide use as a result of the presence of the BC agent can be translated into improvements in the health status of the farm household. For this purpose the number of self-reported pesticide induced acute illness symptoms within a household is used as a proxy for the health status. Since the dependent variable is a count variable, the most appropriate model, which explicitly deals with characteristics of count outcomes, is the Poisson Regression Model (PRM). It has the characteristic that the mean of the count outcome is equal to the variance. However, in the underlying data the variance exceeds the mean, and the number of zeros in a sample exceeds the number predicted by the PRM. These problems are amended by using a non-linear zero-inflated Poisson (ZIP) regression model.

Results

Model 1: Estimation of production function with exponential damage abatement function

As first stage of the 2SLS, the estimated pesticide use function (dependent variable: pesticide expenditure in US$ per ha; adj. R^2 = 0.44) shows that presence of the BC agent decreases ceteris paribus pesticide expenditure by 34%. Further, operating in an environment, in which the farmer considers the pest pressure (average pressure of insect pests and plant diseases) to be above normal level, a higher pesticide price as well as the use of a higher number of different pesticide products increase pesticide expenditure significantly. The district dummies depict that farmers from Nyeri spend more on pesticide compared to farmers from both districts of Tanzania.

The second stage estimation results show that the production function (dependent variable: cabbage revenue in US$ per ha) has a sound explanatory power with adjusted R^2 value of 0.24, which is acceptable for cross-sectional data. The significantly positive coefficients of the inputs seed, fertilizer and labor indicate that higher spending on seed, higher input of organic and/or inorganic fertilizer and higher aggregated labor costs for different crop management activities increase the cabbage revenue. The negative coefficient of the season dummy shows that the cabbage revenue is lower in the rainy season. Regarding the districts, Nyeri farmers have significantly lower cabbage revenue compared to other surveyed districts.

Analyzing the impact of damage control agents on cabbage revenue is not straightforward, since the interaction term needs to be considered. The negative coefficient of the interaction term indicates that there is a negative relationship between pesticide use and the presence of the BC agent. This relationship can be explained since most pesticides used are toxic for the parasitoid thereby interfering and reducing the effectiveness of BC to prevent output losses. Computing the partial effect of pesticide on cabbage revenue results in a positive coefficient with and without presence of the BC agent, i.e. pesticide use increases revenue whether the parasitoid is present or not. Regarding the impact of the BC agent, the estimation results show that the solely dependence on the parasitoid has a positive effect on cabbage revenue, i.e. when no pesticide are used the presence of the BC agent increases revenue. However, the results also indicate that farmers using pesticides as well as having the BC agent present obtain significantly lower cabbage revenue. This suggests that the economic benefits of the BC project in Kenya and Tanzania could be more limited than expected based on the ex-ante impact assessment.

The effect of the parasitoid on cabbage revenue depends highly on the level of establishment and maintenance of the parasitoid in the field, which is hampered by the commonly used broad-spectrum pesticides. Several studies on the effect of insecticides on the pest and natural enemies in the maize system showed an increase of the pest after partial removal of BC agents by applying sub-lethal dosages of pesticides (Cugala et al., 2006; Kfir, 2002). Sub-lethal doses, typically applied by farmers without the necessary training, can cause higher mortality among natural enemies, which are more susceptible than the pest. Thus, they may lead to high output losses. This situation may be aggravated further if DBM builds up resistance to pesticides and by poor quality of pesticides. Unfortunately, for this study no information on these issues is available, and hence the low cabbage revenue in areas with BC might be explained by either of these factors.

Model 2: Estimation of health model

The PRM and ZIP model show that households from areas where the BC agent is present have fewer health symptoms compared to households from areas without the parasitoid. The presence of the BC agent decreases the expected number of health symptoms ceteris paribus by 20%. The pesticide quantity of extremely, highly and moderately hazardous pesticides; the number of other crops grown and eating in the field are found to significantly increase the number of symptoms in a household. While factors such as washing hands after pesticide application, higher education level of the household head and growing cabbage in the rainy season significantly contribute to a lower number of pesticide-related health hazards. Although the finding of the variable protective clothing is surprising, the positive impact of using more protective clothing can be explained and is supported by findings of other studies.

If small-scale farmers are facing situations of financial constraints the use of pesticide could be limited to very low levels, if even affordable at all. In the case where no pesticides are being used the presence of the BC agent demonstrates its positive impact on cabbage revenue and thus its potential to contribute to poverty alleviation. However, in such situations stakeholders need to be informed of the negative relationship between chemical control and the natural enemy and that using both strategies, especially broad spectrum pesticides, may lead to output losses. In sum, although a positive impact of the BC agent on cabbage revenue is not found, the health model shows that BC has a positive impact on the household health status. Because non-market effects are difficult to translate into monetary terms, the economic magnitude of the impact is unknown.

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