PRODUCTIVITY OF BT COTTON AND ITS IMPACTS ON PESTICIDE USE AND FARM RETURNS: EVIDENCE FROM PAKISTANI PUNJAB

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Introduction

Many countries including the developed and developing ones have experienced substantial declined pesticide use along with increased cotton production. USA, Australia, China, Mexico, Argentina, South Africa, and India are some examples who have allowed the cultivation of Bt cotton at commercial level and gained huge benefits in terms of lower level of pesticide use and higher yield (Qaim, *et al.*, 2006). Studies such as Thirtle, *et al.* (2003), Qaim and de Janvry (2005), Qaim and Matuschke (2005), Qaim, *et al.* (2006) and Bennett, *et al.* (2006) provide insights about benefits of Bt cotton seed in the developing countries. This reduction in pesticide use is associated with a substantial decline in cost of production.

However, limited research work has been reported in Pakistan on this issue. Mostly, studies have information of limited scope (Hayee, 2005; Sheikh, et al., 2008, Arshad, *et al*., 2007, Nazli, 2009, Nazli, et al., 2010, Ali and Abdulai, 2010), since cross sectional single year data have been employed. Since, the issue of trying to look at cross sectional single year data is questionable. Reasons may include variations in weather conditions and insect pest infestation during different years, thereby affecting cotton production. Therefore, one finds it difficult to separate effects of technology from these variations. Thus, a time series dimension is more appropriate to decide whether Bt cotton performs better than non-Bt cotton and how much economic benefits would be available to farmers when they use Bt cotton seed. Therefore, the present study makes the assessment of the performance of Bt cotton on farmers' field for a period of two crop growing seasons. The study presents an analysis of data collected from a large sample of farmers growing Bt cotton and non-Bt cotton seeds, providing an evidence whether adoption of Bt cotton has positive or negative impacts on productivity. It also provides an insight whether Bt cotton should be commercialized on large scale. It would also help researchers to initiate new research and development in evolving new Bt varieties which are more suited to geographical areas of Pakistan.

Pakistani cotton growers are experiencing rising cost of production, mainly due to increased use of pesticide, pointing out that there is a dire need to reduce cost of production of cotton growers so that the cotton growers could compete in the world market, especially in the era of trade liberalization and globalization. Adoption of *Bacillus thuringiensis* (Bt) cotton could help in this regard, since it provides resistance to bollworms. Bollworms are major pest problem in cotton production and farmers have to apply huge amount of chemicals to control these pests. Looking at statistics of pesticide use in Pakistani Punjab reveals that its use has substantially declined from 2004-05 to onward (Govt. of Pakistan, 2009). It is the time period when some organization started reporting planting of unapproved varieties of Bt cotton in Pakistan. This study provides valuable evidence in order to confirm the above statistics regarding pesticide use in cotton production.

Comparatively of the two types of cotton seeds, namely Bt cotton seed and non-Bt cotton seed are practiced in Pakistan. Bt cottonseed is supposed to give higher returns due to reduced use of pesticide. Reduction in pesticide use ultimately leads to higher profit in cotton production. Comparative economics of these two types of cotton seeds requires to be studied in the province of Punjab, being the main suppliers of raw cotton to textile industry in Pakistan. Bt cotton seed is available in the market with its given price, although it was unapproved at the time of data collection. Now farmers have the choice either to adopt Bt cotton at prevailing market price or not to adopt it. The first question is whether adoption of Bt cotton seed leads to decline in pesticide use in cotton production? Whether yield and revenue generated from Bt cotton is higher than yield and revenue from non-Bt cotton? Whether cost on inputs, such as fertilizer and irrigation water of planting Bt cotton is higher than that of non-Bt cotton, since increased application of fertilizer and irrigation water has potential environmental impacts. Based on the above research questions, objectives of the study include to determine whether adoption of Bt cotton has reduced pesticide use on the farmers' fields and to estimate the possible changes in yield and revenue for farmers who have adopted Bt cotton. Similarly, the study estimates the possible variations in application of inputs and their costs between Bt cotton and non-Bt cotton.

Materials and Methods

Study Area and Data

The Punjab province of Pakistan is usually divided into two areas, such as irrigated and non-irrigated areas. Irrigated area has been chosen for this study because cotton is commonly concentrated in this area, especially in Southern Punjab[1]. The survey data to be collected over two cotton growing seasons has been used to achieve above mentioned research objectives. It is more logical to take data for two crop growing seasons, since geographical and climatic conditions may vary year-to-year, subsequently the success of Bt cotton may vary. Moreover, the evolution of pest problems in specific areas could be a causal factor that would be difficult to identify with cross sectional data.

A three stage sampling technique was used for the present study. In the first stage, three districts were randomly selected, one from each cotton growing area. The second stage involved preparation of list of cotton growing farmers who purchased cotton seed (either Bt and non-Bt or both) from the registered private seed companies/input dealers during cotton growing season of 2008. There were some farmers who purchased both types of cotton seed. So choosing such farmers helped to make comparisons while controlling certain factors such as soil type, management practices, etc. This list represents our target population in each selected district. In the third sampling stage, respondents were taken from the list of cotton growers using a systematic simple random sampling technique. A systematic random sampling is used to select respondents from a target population. Thus 96 respondents from one selected district were enumerated. If one selected respondent refused to respond, left farming or was not available in the area after three visits to farm, other respondent next to this one in the list was considered. The total sample size from all selected districts was 288 respondents. The same respondents were interviewed during second crop season, 2009. However, three respondents could not be interviewed due to death, migration, etc. Thus, a total of 573 respondents were interviewed during two crop growing seasons of cotton in the Punjab province. Since, data of the study include two types of farmers, one group of farmers growing only Bt

[1] A few years ago, adoption of Bt cotton seed was not commonly practiced, however, partial adoption was there. The major reason is that Bt cotton was not allowed to be practiced during these years since no genetically modified seed was released or introduced officially in the market for commercial purpose. Some Bt cotton seed was smuggled by private company and growers. That smuggled seed was multiplied and distributed among cotton growers (Hayee, 2005). However, the Government of Pakistan has now allowed planting Bt cotton in the country.

cotton and other one planting both types of cotton seeds i.e. Bt and non-Bt cotton. Farmers belonging to the second category were asked to provide information on both type of cotton seeds. This makes it possible to make comparison with and without Bt cotton technology across and within farms. Thus the number of observations on plots is 801 which is larger than the number of respondents interviewed.

Empirical Analyses

Comparative statistics show that adopting Bt cotton significantly contributes in yield through reducing pesticide use especially against bollworms and it even comparatively performs well in the adverse conditions which is evident from the less decline in cotton yield on Bt plots when the country observe overall reduction in cotton production. Although more costs incurred on Bt cotton seed and irrigation, yield and pesticide reduction are enough high to compensate the higher cost of production and farmers experience higher monetary returns.

Pesticides are used against cotton insect and pests and so its use is not similar compared to other inputs such as fertilizer, seed and irrigation which imply direct impacts on yield. Thus pesticide use enhances yield indirectly through controlling cotton insects and pests, hence these inputs are considered as abating inputs. Taking pesticide as independent variable in the production function gives biased estimates. Lichtenberg and Zilberman (1986) argue that production function treating pesticide as traditional input fails to capture the damage control nature of pesticides[2]. Huang, et al. (2002) employed damage control framework based on the framework of Lichtenberg and Zilberman (1986) in estimating productivity of pesticide. Bt cotton is considered as an alternative to pesticide use, since its use can substitute pesticides. So, farmers can control certain pests either through employing pesticide or Bt cotton seed.

Consider here the Cobb Douglas type production function[3] of the cotton crop in order to estimate the impacts of pesticide use and Bt cotton seed on yield

$$Y = \delta \sum_{i=1}^{n} X_i \qquad (1)$$

Where Y is the quantity of cotton yield and X includes vector of farm inputs, such as seed, fertilizer, pesticide, irrigation and labour. As discussed earlier, the unique nature of pesticide and Bt cotton having damage control characteristics call for specifying different non-linear functional form for these two inputs. Following the work of Lichtenberg and Zilberman (1986), equation (1) can be written as

$$Y = \delta \sum_{i=1}^{n} X_i \, G(Z_i) \qquad (2)$$

Now Z denotes a vector of damage control agents such as pesticide and Bt cotton and X includes other farm inputs. Above function in equation (2) is the joint production function incorporating the damage control function of pesticide and Bt cotton and $G(Z_i)$ lies $0<G(Z_i)<1$. It means the proportion of potential cotton yield loss from pest attacks in the range of zero and unity. When $G(Z_i)=0$, it shows complete loss of the crop and

[2] For more details about damage control specification for pesticide use in agriculture, Lichtenberg and Zilberman (1986), Jha and Regmi (2009)

[3] Other functional forms such as quadratic and translog were employed but these functional forms did not give the better results compared to Cobb Douglas production function

$G(X_i)=1$, it means perfect control of pests. Taking log of both sides in equation (2) and using modified exponential form[4] give the following form

$$lnY = \delta + \beta \sum_{i=1}^{n} lnX_i + \propto A_i + \left[1 - e^{\{-\gamma_1(Pest_{quantity}) - \gamma_2(Bt)\}}\right] \qquad (3)$$

Where lnY is log of cotton yield in kg per hectare. X_i include a vector of farm inputs and A_i shows socio-economic characteristics of the farms and farmers and geographical variables.

$Pest_{quantity}$ is log of the amount of pesticide use in cotton production in liter per hectare, Bt is the dummy variable for Bt cotton and it is 1 if farmers planted Bt cotton, 0 otherwise. Summary statistics of the variables is detailed in Table 1.

Results and Discussion

An interview-based survey was conducted to gather information about input-output and others characteristics in cotton cultivation for two cropping seasons-2008 and 2009. Some Bt adopters were cultivating conventional (non-Bt cotton) crop at the same time, so they were asked the same questions for both their Bt and non-Bt crops. This allows us to make comparison of technology with and without situation more easily across and within farms as well.

Economic Performance of Bt Cotton

Bt cotton has been developed to provide resistance to certain cotton bollworms. Thus this resistance results in less use of pesticide in order to control insect pests of cotton. Bollworms are major pests in Pakistan and cotton growers have to make huge amounts of pesticides to control cotton bollworms (*Lepidopteron* species). In addition to cotton bollworms, there are other pests (sucking pests and mealy bug) in Pakistan against which Bt cotton does not provide resistance. Therefore, farmers have to spray pesticide in order to control these pests. Even farmers use pesticide to control bollworms in the late cropping season when pest infestation is very high (Qaim and de Janvry, 2005). So, Bt cotton does not guarantee 100 percent elimination of pesticide use, it only reduces pesticide use against certain bollworms in cotton production.

We use mean difference to estimate comparative performance of two technologies i.e. Bt cotton and conventional cotton (non-Bt cotton) on plot basis[5]. We estimate mean difference in two ways. At first, we compare non-Bt plots with all Bt plots for each cotton season, 2008 and 2009 separately. In the second case, we compare non-Bt plots with Bt plots of those growing Bt cotton and non-Bt cotton at their farms. We use paired t-test to compare inputs and returns on the farms where both types of cotton seeds are planted. Although t-test does not control for difference between fields on the same farm, managerial ability and practices remain the same. Table 2 shows pattern of the use of pesticide and other inputs along with yield and returns of Bt cotton and conventional cotton for the two cropping seasons. First column for each cropping season contains information about mean values for non-Bt cotton plots, second

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[4] Other forms such as logistic and Wiebull were also estimated but these forms did not give significant results for our data. Jha and Regmi (2009) also estimated damage control function using modified exponential form

[5] Information is available on the basis of hectare for each type of plot.

column shows means values for all Bt plots[6] whereas mean values for Bt plots of those growing Bt cotton and non-Bt cotton are given in column three. First we make comparison between first and second columns, and then between first and third columns.

First type of comparison shows that according to our priori expectation, cost of seed on Bt plots is relatively higher (76 percent during cropping season 2008 and 69 percent during 2009) compared to non-Bt plots. However, quantity of seed is less on Bt plots compared to non-Bt plots during both cropping seasons as farmers apply costly inputs with more care and in an efficient manner. However, cost of Bt cotton seed in the present study is very low compared to other studies conducted in India (Bennett, et., 2006, Morse, et al., 2007). However, estimates of cost of Bt cotton seed by Nazli (2009) and Nazli, et al., (2010) show that Bt cotton seed is highly costly in the range of 67 to 71 percent. Fertilizer use is another important input in cotton production. It is commonly expected that its use increases in Bt cotton. However, results of the present study do not confirm this presumed use of fertilizer. Fertilizer use on Bt plots is substantially less, thereby indicating that farmers allocate the more fertile plots to Bt cotton and geographical difference also matters in this case, since our study data are collected from semi-arid region of the Punjab province[7]. However, Bt plots are more frequently irrigated showing more water requirements. Although it is not significant, labor use on Bt plots is little lower during both cropping seasons. This labor saving is the outcome of reduced amounts of pesticide applied on Bt plots.

The main concern of this study is to estimate impact of Bt cotton technology on pesticide use. As it was expected, Bt cotton reduces pesticide sprays against all pests by 2 times during cropping season 2008 and 1.42 times during cropping season 2009. However, this reduction in pesticide sprays comes from the less use of pesticide against bollworms whereas sprays against sucking pests are on higher side on Bt plots. Similarly, pesticide amounts on Bt plots decline by 35 percent in the cropping season 2008 and 37 percent in the cropping season 2009. Overtime pesticide use also declines on Bt plots and non-Bt plots as well, still pesticide use on Bt plots is on lower side. Reduction in pesticide use in the present study is far lower compared to studies in the neighboring countries, such as India and China (Pray, et al., 2001, Huang, et al., 2002, Crost, et al., 2007). However, the estimates of the present study are far higher than those studies conducted in Pakistan (Nazli, et al, 2010 and Ali and Abdulai, 2010). Findings of our study show that adopting Bt cotton gives substantial reduction in pesticide use in the country and, therefore, its adoption has two types of benefits. The reduced pesticide use can decrease cost of production to farmers and the country's import bill on pesticide will go down due to less demand of pesticides, since cotton crop accounts for around 58 percent of total area treated with plant protection in the Punjab province (Government of Pakistan, 2009).

Regarding per hectare yield is concerned, it is substantially higher on Bt plots (15% during cropping season 2008 and 19% during 2009), although the increase in yield is considerably very low when we compare it with studies of Crost, et al. (2007), Morse, et al. (2007) and Subramanian and Qaim (2009).. The higher yield on Bt plots is the result of less crop loss due to healthy crop, since Bt cotton provides resistance against bollworms. Comparatively less pesticide sprays results in lower cost of pesticide on Bt plots, however, this lower cost is not enough to compensate higher cost on other inputs, such as seed, pesticide spray for sucking

[6] All Bt plots include Bt plots of those growing only Bt cotton and those growing both types of cotton on their farms

[7] District level comparison confirms that less fertilizer is used on Bt cotton plots in Mianwali where only Bt cotton is practiced.

pests and irrigation. Higher yield on Bt plots gives substantially huge gross income, and therefore, gross margins are large enough to compensate high variable cost incurred on Bt plots during the both cropping seasons (Table 2). However, yield on Bt plots and non-Bt plots has declined in the second crop season, mainly due to unfavorable climatic conditions during this year. Nevertheless, larger decline in yield on non-Bt plots is estimated. It shows that Bt plots performs comparatively well even in the adverse conditions. Gross revenue is significantly different between Bt plots and non-Bt plots in both cropping seasons, which in turn results into substantially higher gross margin on Bt plots. These findings suggest that adoption of Bt cotton seed provide considerable financial incentives to farmers to go for adopting Bt cotton seed.

We also compare mean values of various inputs and returns for Bt plots and non-Bt plots of those growing both types of cotton seed on their farms. Such comparison helps in estimating impact of Bt cotton while certain characteristics such as managerial abilities and farm practices. So cotton plots of the same farmers are compared using paired t-test. Results of Table 2 indicate that farmers use lower amount of Bt cotton seed compared to non-Bt cotton seed and it makes sense that farmers use less of inputs that are more costly. However, seed cost is on higher side, mainly as a result of higher purchase price of Bt cotton seed in 2008. Seed cost on Bt plots declines on Bt plots in the following year. The reason for the decreased cost of Bt cotton plots is a result of the use of seed saved from the previous year. Similarly we estimate the more use of irrigation and fertilizer on Bt cotton plots compared to non-Bt cotton plots and these estimates are relatively higher from the above mentioned comparison. The use of pesticide is substantially low on Bt cotton plots during 2008 and 2009, although this pattern can be found during 2009 but with less intensity. Yield on Bt plots are significantly higher compared to non-Bt plots during both cropping seasons (Table 2). Yield on both types of cotton plots decreases during the crop season 2009, however, higher decline for non-Bt cotton is estimated. The positive externality of Bt cotton is the reduced insecticide use.

Production function

Table 3 shows typical Cobb-Douglas production function, Hausman test to determine endogeneity of pesticide variable and modified exponential production function. In estimating production function, theoretical knowledge demands for explanatory variables as being exogenous variables, otherwise estimated coefficients are not consistent. This endogeneity problem is common for all farm inputs, it is more important for pesticide use, since farmers apply pesticide in response to insect and pest attacks. In order to solve this problem, instrumental variables are used when the problem is more severe. If endogeneity is less severe issue, the least square estimator is more efficient than instrumental estimator. A variant of Hausman test was used to determine endogeneity of pesticide. For this purpose, we estimate pesticide use function by regressing pesticide quantity on different variables, namely prices of output and pesticide, Bt dummy variable, cropping season, regional dummies and socioeconomic variables. Second column of Table 3 shows Hausman test. The residual value from pesticide use function was included in the Cobb Douglas production function. Its coefficient was insignificant, implying that there was not severe enough problem of pesticide endogeneity resulting biased estimates, so pesticide variable is used instead of instrumental variable in the production function.

Results of Cobb Douglas (column 1 of Table 3) and modified exponential function form (column 3 of Table 3) show that all variables have expected signs in both production functions except labor variable. Labor coefficient is negative and statistically significant. It may be due to the use of Bt cotton seed, since Bt cotton seed reduces labor demand for pesticide application and such farmers may be applying labor more efficiently. Although statistically insignificant, pesticide coefficient is positive. It may be due to the fact of inefficient use of pesticide in cotton production and farmers may be applying pesticide less than optimal level. Crost, et al. (2007) conclude that insignificant pesticide variable is due to inefficient utilization of pesticide against cotton insect and pests in India. The most important variable in the present study is Bt cotton seed. Its coefficient in both production functions is statistically significant. It implies that farmers are able to obtain higher yield by using Bt cotton seed. However, magnitude of Bt cotton coefficient is larger in modified exponential form. Regional differences and cropping season are also significantly positively related with cotton yield.

Conclusions and Suggestions

The present study has estimated economic performance of Bt cotton in the Punjab province of Pakistan. We have collected panel data for a period of two cropping seasons, 2008 and 2009 from three districts of the province. The Punjab province is the largest producer of cotton crop in the country. This study is different from other studies conducted in Pakistan by collecting data on two cropping seasons. It accounts for year-to-year variability in yield and helps to understand the change in input use and output while controlling many factors, such as farm and farmer related characteristics. Results of the study have proved that Bt cotton brings huge benefits to farmers in the form of pesticide reduction, considerably higher yield and substantially higher monetary returns. Moreover, yield of both types of cotton has decreased from the cropping season 2008 to the cropping season 2009. But the decline in cotton yield is relatively higher on non-Bt plots, showing that Bt cotton performs well even when conditions are not suitable to cotton production. However, pesticide use against sucking pests has increased on Bt plots in the cropping season, 2009. It alarms that secondary pests can be a serious problem in future cotton production. Future research and development needs to focus on the issue of secondary pests of Bt cotton seed in the country.

Econometric analysis show that Bt cotton contributes significantly in cotton yield, however, statistically insignificant pesticide hints that cotton growers were not able to apply pesticide efficiently due to lack of awareness, financial constraints and timely availability of pesticide products. Similarly, gross margin analysis confirms that Bt cotton seed substantially contributes in earnings of farmers growing cotton crop. The reason for higher returns is that the farmers growing Bt cotton are able to apply less pesticide use, resulting in low cost and healthy cotton crop.

The wide spreading of technology demands for formalization of Bt cotton in the country, so farmers may be able to get true benefits of the technology, since it will create a incentive based environment for research and development in private and public sector organizations. Currently cotton growers are facing the problems of non-availability of quality Bt cotton seed in the market. Unapproved Bt varieties with different names are available in the market creating mess for farmers during the selection of appropriate varieties.

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Table 1: Summary Statistics of variables in the production function and profit function

Variable	Mean	SD	Minimum	Maximum
Age of the respondents (years)	44.20	11.85	19	72
Farming experience of the respondents (years)	19.74	11.19	2	55
Farm size (hec)	18.97	22.84	0.81	224
Seed (kg/hec)	18.68	4.93	9.38	32.12
Fertilizer (NPK kg/hec)	249.30	79.91	1.32	600.44
Irrigation (No.)	9.80	3.12	3	16
Pesticide (Liter/hec)	4.32	2.20	0.41	16.89
Labor (Rs/hec)	7754.28	2205.48	1086.40	18585.200
Yield (kg/hec)	2394.54	751.84	296.52	5930.32
Gross margin (Rs/hec)	49784	26632	-19389	151880
Price of cotton output	34.44	5.30	20.53	53.38
Price of pesticide	1662	880	175	4927
Price of fertilizer	37.40	7.78	5.71	72.21
Price of seed	97.28	57.96	8.21	492.73
Bt dummy	0.71	0.45	0	1
Cropping season 2009	0.47	0.49	0	1
R Y Khan	0.40	0.49	0	1
Mianwali	0.24	0.43	0	1
Number of observations	801			

Table 2: Input use, output and returns on per hectare basis in cotton production

Items	**Cropping season 2008**			**Cropping season 2009**		
	Non-Bt plots	All Bt plots	Bt plots of those growing Bt and non-Bt	Non-Bt plots	All Bt plots	Bt plots of those growing Bt and non-Bt
Seed (kg)	20.16	18.38***	19.89	19.44	18.02***	19.73
Cost of seed (Rs)	1132.47	1997.58***	1997.58***	1176.32	1990.67***	1967.35***
Fertilizer (NPK kg)	253.71	231.62***	264.41	281.13	254.14***	285.86
Irrigation (No.)	9.19	10.13***	11.47***	9.76	9.78	11.00***
Pesticide (No.)	7.42	5.42***	5.72***	7.06	5.64***	6.21***
Sucking sprays (No.)	3.16	3.39*	3.43*	3.08	3.37**	3.63***
Chewing sprays (No.)	4.26	2.03***	2.29***	3.98	2.26***	2.58***
Pesticide (Liter)	5.93	3.83***	3.91***	5.62	3.57***	4.13***
Pesticide (Rs)	6504.37	5331.22***	5376.38***	7791.47	6594.07***	6820.29**
Labour (Rs)	7768.53	7407.08	6314.69	8106.06	7980.22	6882.92
Variable cost (Rs)	30096	31804***	31688**	32869	34306*	33896
Yield (kg)	2271.81	2610.51***	2574.97***	1993.75	2372.83***	2383.57***
Gross revenue (Rs)	69807	79883***	78871***	76824	92726***	92149***
Gross margin (Rs)	39710	48078***	47183**	43955	58420***	58252***
Number of observations	288	134	134	99	280	95

*****, ** and * are level of significance at 1%, 5% and 10% respectively*

Table 3: Estimation of Cobb-Douglas, Pesticide Endogeneity Test and Modified Exponential function

Variable	**Cobb-Douglas**		**Hausman**		**Modified Exponential**	
	Coefficient	**Standard error**	**Coefficient**	**Standard error**	**Coefficient**	**Standard error**
Constant	7.488	0.434***	7.516	0.452***	7.479	0.430***
Bt	0.179	0.030***	0.173	0.039***		
Pesticide	0.044	0.028	0.048	0.032		
Seed	0.048	0.047	0.049	0.047	0.048	-0.047
Fertilizer	0.072	0.036**	0.072	0.036	0.073	0.036**
Irrigation	0.139	0.045***	0.138	0.045	0.138	0.045***
Labor	-0.092	0.045**	-0.092	0.045	-0.092	0.045**
R Y Khan	0.073	0.028***	0.074	0.028***	0.073	0.028**
Mianwali	0.203	0.048***	0.201	0.048***	0.202	0.048***
Cropping season	-0.108	0.024***	-0.109	0.024***	-0.108	0.024**
Age	-0.003	0.001**	-0.003	0.001**	-0.003	0.001**
Farming experience	0.005	0.001***	0.006	0.001***	0.005	0.001***
Farm size	0.001	0.0005***	0.001	0.0005***	0.001	0.000***
Residual			-0.003	0.016		
Damage control						
γ_1					0.220	0.049***
γ_2					0.058	0.040
R^2	0.132		0.132			0.132

*****, ** and * are level of significance at 1%, 5% and 10% respectively*