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Survey Study

Economic impact of maize stem borer (*Chilo partellus*) attack on livelihood of maize farmers in Pakistan

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Abstract

Maize is third important cereal in Pakistan after wheat and rice. The demand of maize is increasing due to poultry and other industries. However the maize crop is faced with number of challenges especially the attack of number of insect, pest and diseases. The maize stem borer is an important pest in Pakistan causing a damage ranging up to 30%. The current paper is based on comprehensive cross sectional data set collected through detailed field survey from 812 maize farmers across Pakistan. The losses are ordered into different categories depending upon the intensity and damaged caused. The analysis was carried out by employing a number of econometric models and approaches e.g. multivariate Probit model, Poisson regression model, as well as propensity score matching approach were employed. The empirical results indicated that as the intensity of losses increases the maize yield decreases. The reduction in maize yields leads to less income levels and higher poverty levels, hence inversely affecting household welfare. The current paper has key policy implications specifically institutional support needs to be provided to maize growers regarding effective control of the stem borer, which can help to enhance the maize yield and in turn the household welfare in Pakistan.

Keywords: Stem borer, Maize crop, Yield losses, Household welfare, Pakistan

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Introduction

Maize is the third important cereal after wheat and rice and is grown globally for food and feed purposes. For human consumption maize is used in a variety of ways e.g. porridge, boiled, roasted including as vegetable. In Pakistan maize is important cereal and covers 8.5 percent of the overall cropped area i.e. 1.33 million hectares with an average yield of 4.5 tons per hectares and with estimated annual production of 6 million tons (Economic Survey of Pakistan 2016-17). In Pakistan although maize is grown in all the four provinces including Azad Jammu and Kashmir and Gilgit Baltistan. About 97 percent maize of Pakistan is produced in Punjab and KPK provinces. Recently in Sindh province, the maize crop is picking up nicely.

Maize crop is attacked by number insect pest and diseases. Among all these insect pest and diseases, the damage caused by maize stem borer is more severe (Kumar et al., 1993; Pingali, 2001; James, 2003; Siddiqui and Marwaho, 1993). Maximum number of insect pest attack maize crop as compared to other

cereals. In Pakistan since last many years the maize stem borer is causing huge damage. According to various estimates about 20-30 percent of the maize yield is lost due to maize stem borer attack (Arabjafari and Jalali, 2007; Farid, 2007).

Globally large number of species of the maize stem borer exists and cause damage in different countries. However, the major species of the maize stem borer in Pakistan is *Chilo Partellus* (Swinhole) (spotted stem borer) and believed to be originated from India and spread to Africa. The maize stem borer injuriousness not only depend on infestation level but also on the plant development stage. Stem borer initially damaged the leaf tissues followed by stem and sometimes even the cobs. The yield losses due to maize stem borer attack can be up to 33 percent. Many factors contribute to the intensity of the maize stem borer attack e.g. cropping pattern and water stress situation (Moyal, 1995). Due to maize stem borer attack, not only maize yield is decreased but also the crop biomass is affected. The past research has shown that there was less attack of the maize stem borer on the low intensity cropping. The crop rotation can be an effective measure to control the stem borer attack (Agrios, 2005).

The stem borer attack can weaken the maize plant resulting in lodging as well as breaking and dead heart, which ultimately reduces maize yield (Davies and Pedigo, 1990; Tabashnik et al., 2003). Maluleke et al. (2005) compared stem borer attack on sole cropping as well as maize intercropping with legumes. They found that stem borer attack was more on sole maize crop as compared to intercropping. Berg (2017) carried out a comprehensive review on stem borer attack and found that number of host plant contribute in the survival of maize stem borer. Ahmed et al. (2007) worked on chemical control of maize stem borer in Pakistan. They concluded that beside stem borer, termites also needs to be controlled through different insecticide. Similarly Khan et al. (2004) argued that different insecticide needs to be used to prevent the attack of maize. Javed (2005) studied resistance in maize against stem borer and found that due to stem borer attack the resistance is greatly decreased. De-Groote (2002) studied maize stem borer attack in Kenya, and that maize yield was decreased up to 13 % which cost about 0.39 million tons of maize and its estimated value comes out to be US$ 76 million.

Dharmasena (2002) studied maize pest and climate relationship in developing countries. Khaliq and Mehmood (1991) studied six maize varieties for resistance against maize borer and found only one variety as resistant with 17.7% infestation. Oben et al. (2015) conducted a questionnaire-based survey administered in four villages of Fako division of Cameroon and found that majority of the farmers reported serious attack of stem borer on maize crop. Kfir et al. (2002) carried out a comparative study of different crop insects/pests i.e. maize, sorghum, millet, rice etc. and found that stem borer are the most injurious pest. Similarly, Muhammad and Khawja (2002) found that maize stem borer is most destructive pest causing up to 90-95 % of the total damage during Kharif season. Jalali and Singh (2003) also reported similar results.

The current paper is the first paper having comprehensively and systematically documented the impact of the maize stem borer on maize crop yield in Pakistan. Secondly the paper employs the propensity score matching approach i.e. still quite new on the growing literature on impact evaluation. For that, the rest of the paper is organized as follows; In section 2 methodology is presented. In section 3 data and description of variables are presented. The results and discussion are presented in section 4 and paper concludes in section 5 with some policy recommendations.

Material and Methods

The current study is based on comprehensive cross sectional data set collected through field survey from 812 maize growers across Pakistan. The empirical analysis was carried out by employing a set of econometric models and techniques. The multivariate Probit model was employed for the measures taken to control the stem borer attack. In the multivariate probit model the dependent variables are pest scouting, chemical control and crop rotation while a set of independent variables are included in the mode e.g. age education, land holding etc. Poisson regression model was employed for the number of acres affected by the maize crop. Propensity score matching approach was employed to estimate the impact of the attack on household welfare in Pakistan. Propensity score matching creates the condition of the randomized experiment and matches similar farmers affected by the maize stem borer attack with the similar farmers not affected by the maize stem borer attack.

Data and description of variables

Detailed comprehensive survey was carried out in the maize growing areas of Pakistan covering Punjab, Sindh, KPK, Balochistan, AJK and Gilgit Baltistan. Data was collected by employing detailed comprehensive questionnaire. A team of well trained enumerators carried out the survey. Before carrying out the formal survey the pre testing of the questionnaire was carried out and the questionnaire was refined in the light of pre testing results. The questionnaire included information on socioeconomic and farm level characteristics as well as sources of maize seed and maize production technology as well as major maize insect and diseases. In total 812 farmers were interviewed. Detailed information was collected on household and farm level characteristics. The description of variables is presented in table 1. The average age of the farmers was 43 years, the average education was 7 years of schooling, and mean farming experience was 22 years. Maize growing experience was 17 years. Approximately 75 % of the households have access to metal road. The mean distance to the basic health unit was 3.36 kilometers. The mean distance to the veterinary center was 6.4 kilometers and the mean distance to the agricultural extension office was about 12 kilometers. About 1.84 male family members has migrated and about 1.29 females' family members has migrated. The mean distance to the boy's school was 1.35 and the mean distance to the girls' school was 2.27 kilometers. The average distance to the bank was 8.20 kilometers. The average distance to the transport was 2.59 kilometers. The average distance to the input dealer was 7.6 kilometers; the average distance to the implement repair was 6.93 kilometers. Average distance to the NGOs office was 17 kilometers. About 27 % of the households have tractor ownership, 21 % have trolley ownership, 28 % have tube well ownership, and 7 % have zero tillage drill ownership. Approximately 18 % have MB plough ownership and 8 % have rota vator ownership and 2 % have laser land leveling ownership, about 19 % have car ownership and 52 % have motorcycle ownership and only 35 % have bicycle ownership. About 61 % have washing machine ownership and 52 % have refrigerator ownership. About 7 % have AC ownership and 12 % have room cooler ownership. About 79 % have iron ownership.TV as source of information and entertainment was owned by 78 % of the households. About 86 % of the households have spade ownership. The average numbers of buffaloes owned by the households are 4.59. The average numbers of cows owned by the household was 2.75 and the average numbers of horses and donkeys was very less and was less than 1 per household.

Results and Discussion

The details about the stem borer attack are presented in table 2. About 76 % of the maize growers reported that maize crop is affected by the stem borer attack and the average loss due to stem borer attack was about 13 %.

To analyze the count data like numbers of acres affected by the stem borer attack, normally two types of models are estimated i.e. Poisson regression model and negative binomial logit model. In the current analysis normal distribution has been assumed for that Poisson regression model has been employed and the results are presented in table 3. The dependent variable is the number of acres affected by the maize stem borer attack while a set of independent variables is included in the model.

The age was included in number of years and the coefficient is positive and significant indicating that aged farmers face more stem borer attack as compared to young farmers. The education was also included in number of years and the coefficient was negative and significant indicating that educated farmers face less stem borer attack. Similarly, land holding was also positive and significant. The results for the village facilities were mostly non-significant. The results for the agricultural extension were negative and significant indicating that farmers having contact with agricultural extension services have less numbers of acres affected by the stem borer attack hence indicating the importance of agricultural extension services.

The results for the boys school, bank and transport were non-significant. The results for the input dealer were negative and significant. The results for the implement repair, NGOs, tractor, trolley and tube well were non-significant.

Table 1: Description of data and variables

Variable	Description	Mean	Std. Dev.
Age	Age of the farmer in number of years	42.65	13.09
Education	Education of the farmer in number of years	6.76	5.62
Experience	Experience of the farmer in number of years	22.41	13.58
Maize Growing Experience	Maize growing experience in number of years	16.61	11.85
Own Land	Number of acres owned by the farmer		
Metal Road	Average distance to the metal road in number of kilometers	0.75	1.06
BHU	Mean distance to the basic health unit in number of kilometers	3.36	3.84
Veterinary Center	Average distance to the veterinary center in number of kilometers	6.40	7.22
Agri. Extension	Average distance to the agricultural extension office in number of kilometers	12.26	16.32
Migrant Male number	Number of migrant male family members in the household	1.84	5.02
Migrant Female members	Number of migrant female family members in the household	1.29	3.64
Boys School	Average distance to the boys school in kilometers	1.35	2.85
Girls School	Average distance to the girls school in kilometers	2.27	5.22
Bank	Average distance to the commercial bank in kilometers	8.20	11.69
Transport	Average distance to the transport in kilometers	2.59	4.58
Input dealer	Average distance to the input dealer in kilometers	7.60	9.51
Implement repair	Average distance to the implement repair in kilometers	6.93	9.39
NGOs	Average distance from NGOs in kilometers	17.17	20.24
Tractor	1 if the household owns a tractor, 0 otherwise	0.27	0.20
Trolley	1 if the household owns a trolley, 0 otherwise	0.21	0.18
Tube well	1 if household owns a tube well, 0 otherwise	0.28	0.15
ZT drill	1 if the household owns Zt drill, 0 otherwise	0.007	0.05
MB Plough	1 if the household owns MB Plough, 0 otherwise	0.18	0.13
Rota vator	1 if the household owns rota vator, 0 otherwise	0.08	0.05
Laser Leveler	1 if the household owns laser leveler, 0 otherwise	0.02	0.06
Car	1 if the household owns a car, 0 otherwise	0.19	0.12
Motorcycle	1 if the household owns a motorcycle, 0 otherwise	0.52	0.18
Bicycle	1 if the household owns a bicycle, 0 otherwise	0.35	0.21
Washing machine	1 if the household owns washing machine, 0 otherwise	0.61	0.42
Refrigerator	1 if the household owns a refrigerator, 0 otherwise	0.52	0.39
AC	1 if the household owns an AC, 0 otherwise	0.07	0.19
Room cooler	1 if the household owns a Room cooler, 0 otherwise	0.12	0.20
Iron	1 if the household owns an iron, 0 otherwise	0.79	0.28
TV	1 if the household owns a TV, 0 otherwise	0.49	0.28
Spade	1 if the household owns a spade, 0 otherwise	0.86	0.27
Bullock	Average number of Bullock owned by the household	1.03	1.37
Buffalo	Average number of Buffalo owned by the household	4.59	9.57
Cow	Average number of Cows owned by the household	2.75	4.09
Donkey/Horse	Average number of donkey/horse owned by the household	0.04	2.14
Household Income	Approximately household income in rupees	45638	2751
Post-harvest losses	Approximate post-harvest losses in %age	4.34	3.94
Seed Source	1 if the seed is purchased from market, 0 otherwise	0.45	0.21
Punjab	1 if the farmer is from Punjab province, 0 otherwise	0.36	0.25
Sindh	1 if the farmer is from Sindh province, 0 otherwise	0.22	0.19
KPK	1 if the farmer is from KPK province, 0 otherwise	0.28	0.16
Baluchistan	1 if the farmer is from Baluchistan province, 0 otherwise	0.14	0.11

Table 2: Measures to control Maize Stem Borer

Variable	Description	Mean	Std. Dev.
Stem borer	1 if the maize crop is affected by stem borer attack, 0 otherwise	0.76	0.28
Stem borer loss	%age loss due to stem borer attack	12.95	12.97
Spray	Numbers of liters of spray to control stem borer	1.37	1.16
Pest Scouting	Frequency of pest scouting carried out to control pests	2.11	3.04
Resistant varieties	1 if the household have adopted resistant varieties, 0 otherwise	0.22	0.17
Biological control	1 if the household have carried out biological control, 0 otherwise	0.18	0.13

The results for the laser land leveling, car and TV were negative and significant. The results for the spade were positive and non-significant. The results for the bullock were positive and significant at 5 % level of significance. To account for regional heterogeneity the provincial dummies were also included in the model. The value of R^2 was 0.48 indicating that 48 % variation in dependent variable was due to independent variables included in the model. The LR χ^2 is highly significant at 1 % level of significance indicating the robustness of the variables included in the model.

Determinants of the Measures Adapted to Control Stem Borer Attack

The severity of the losses caused by the stem borer varies and very much depend on the management practices adopted by the farmers. For that multivariate probit model has been estimated and the results are presented in table 4. The measures included in the model were pest scouting, chemical control and crop rotation as dependent variables while a set of independent variables was included in the model. The cross equations correlations were positive and significant indicating the robustness of the model.

The age coefficient was positive and significant in case of pest scouting and crop rotation while negative and non significant in case of chemical control indicating that experienced farmers mostly adopt pest scouting and crop rotation practices while the young farmers mostly adopt chemical control measures.

Table 3: Intensity of Maize Stem borer attack (Poisson Regression Estimates)

Variable	Coefficient	z-values
Age	0.02*	1.83
Education	0.03***	2.65
Own Land	0.01***	2.82
Metal Road	-0.02	-1.27
BHU	-0.01	-2.06
Agri. Extension	-0.02**	-2.03
Boys School	0.01	1.24
Bank	0.03	1.33
Transport	0.01	2.88
Input dealer	-0.04**	-2.06
Implement repair	0.01	1.35
NGOs	-0.02	-1.22
Tractor	0.03	1.41
Trolley	0.02	1.33
Tube well	-0.03	-1.48
Laser Leveler	-0.02***	-2.47
Car	-0.01*	-1.73
TV	-0.02***	-2.64
Spade	0.01	1.20
Bullock	0.02**	2.03
Punjab	0.02	1.52
Sindh	0.03	1.39
KPK	0.02	1.28
Constant	0.02	1.46
Number of Observations	822	
Value of R^2	0.48	
LR χ^2	265.32	
Prob> χ^2	0.000	

Note: The results are significant at ***,**,* 1,5 and 10 % levels respectively

The education coefficient was positive and significant indicating that educated maize growers try to adopt all the three control measures as compared to less educated farmers. The coefficient land ownership was also positive and significant indicting that larger farmers adopt more measures to control maize stem borer attack and the small farmers adopt less measures. The access to metal road was included as dummy variable and the coefficient is positive. The access to agricultural extension services was also included as dummy variable and the coefficient is positive and significant indicating that households having access to agricultural extension services

mostly adopt pest scouting, chemical control as well as crop rotation. Other variables like village infrastructure, the variables like access to boys school, access to bank facility, transport, input dealer and NGOs indicates mix results as some coefficient are positive while others are negative. The results for the farm level as well as household assets like tractor, tube well, laser land leveling, car, washing machine, refrigerator and TV were mostly positive and significant. However, the results for the livestock ownership like Bullock are negative and non-significant.

Impact of the Maize Stem Borer Attack

The Impact of the maize stem borer was estimated on maize yield, pesticide spray and household income levels. The impact was estimated by employing the propensity score matching approach. The PSM is implemented by employing two different matching algorithms i.e. Nearest Neighbour Matching (NNM) and kernel based matching (KBM). STATA software 14 was used for the analysis.

Depending upon the intensity of the losses the maize stem borer losses were categorized into three different categories i.e. less than 10 %, 10-30 % and more than 30 %. The PSM results were presented in table 5. The empirical findings indicated that as the intensity of the losses increases the maize yield and household income levels decreases accordingly while the demand for the pesticide increases.

Table 4: Determinants of the control measures adopted at farm level (Multivariate Probit estimates)

Variable	Pest Scouting	Chemical Control	Crop Rotation
Age	0.01*(1.66)	-0.05(-1.26)	0.02***(3.10)
Education	0.01***(3.26)	0.07*(1.93)	0.04**(1.99)
Own Land	0.04*(1.95)	0.04**(2.016)	0.009(1.38)
Metal Road	0.03(1.34)	0.03(1.29)	0.08***(2.75)
Agri. Extension	0.02**(2.23)	0.02**(2.15)	0.03*(1.70)
Boys School	0.05*(1.92)	0.03**(2.37)	0.04*(1.66)
Bank	0.07**(2.05)	0.04**(2.34)	0.05**(2.18)
Transport	0.04(1.22)	0.06(1.34)	0.09(1.53)
Input dealer	0.01(1.36)	0.03*(1.96)	0.07*(1.82)
NGOs	0.02***(2.16)	0.04(1.33)	0.01(1.42)
Tractor	0.02(1.37)	0.04(1.59)	0.03(1.39)
Tube well	0.01(1.63)	0.03(1.44)	0.04*(1.72)
Laser Leveler	0.02*(1.84)	0.02**(2.16)	0.03*(1.86)
Car	0.03**(2.19)	0.03(1.56)	0.01(2.04)
Washing Machine	0.03(1.36)	0.05(1.39)	0.01(1.22)
Refrigerator	0.04*(1.91)	0.03(1.22)	0.04**(2.13)
TV	0.03**(2.10)	0.03(1.44)	0.03(1.28)
Bullock	0.02(1.25)	0.02(1.57)	0.04(1.38)
Punjab	0.01**(1.36)	0.03***(2.84)	0.02**(2.23)
Sindh	0.03*(1.55)	0.03(2.11)	0.04(1.37)
Constant	0.02**(2.17)	0.04***(2.13)	0.03**(2.17)
Cross Equation Correlations	ρ_{12} 0.21*(1.84)	ρ_{13} 0.28**(2.35)	ρ_{23} 0.17*(1.93)
Number of Observations	812		
Value of R^2	0.31		
LR χ^2	178.64		
Prob> χ^2	0.000		

Note: The results are significant at ***, **,* 1, 5 and 10 % levels respectively.

Table 5: Impact of the Stem Borer Attack

Matching Algorithms	Outcome	Caliper	ATT	t-values	Critical Level of Hidden Bias	Numbers of Treated	Numbers of Control
Less than 10 %							
NNM	Maize Yield	0.02	-2.37	-1.35	-	185	216
	Pesticide Spray	0.5	0.82	1.48	-	185	216
	Household Income	0.06	-2352	-1.22	-	185	216
KBM	Maize Yield	0.02	-2.56	-1.52	-	185	216
	Pesticide Spray	0.008	0.89	1.57	-	185	216
	Household Income	0.06	-2679	-1.63	-	185	216
10-30 %							
NNM	Maize Yield	0.05	-2.84*	-1.73	1.25-1.30	203	249
	Pesticide Spray	0.04	1.03**	2.15	1.45-1.50	203	249
	Household Income	0.03	-2760***	2.78	1.60-1.65	203	249
KBM	Maize Yield	0.06	-3.05**	-2.18	1.20-1.25	203	249
	Pesticide Spray	0.007	1.26**	1.99	1.15-1.20	203	249
	Household Income	0.04	-3175***	2.85	1.25-1.30	203	249
>30 %							
NNM	Maize Yield	0.03	-3.14***	2.82	1.05-1.10	327	298
	Pesticide Spray	0.5	1.62**	2.19	1.20-1.25	327	298
	Household Income	0.004	-4064***	3.24	1.15-1.20	327	298
KBM	Maize Yield	0.007	-3.29**	2.06	1.25-1.30	327	298
	Pesticide Spray	0.03	1.84*	1.75	1.35-1.40	327	298
	Household Income	0.02	-3872***	3.22	2.10-2.15	327	298

Note: ATT stands for the average treatment affect for the treated. The results are significant at ***,**,* 1, 5 and 10 % levels respectively.

When the maize stem borer attack is less than 10%, the average treatment affect for the treated (ATT) results for the maize yield were negative in the range of 2.37-2.56 maunds per acre although non-significant. Similarly the households income levels were negative although non-significant. However the ATT results for the pesticide spray were positive and non-significant.

The second category of losses categorized from 10-30 % of losses indicated that as a result of stem borer attack the maize yields were less in the range of 2.84-3.05 maunds per acre and the results were significant. Similarly household income levels were less in the range of rupees 2760-3175. The results for the pesticide spray were positive and significant.

The results for the third category of the losses i.e. more than 30% indicates that ATT results for the maize yield were negative and highly significant indicating reduced maize yields in the range of 3.14-3.29. The households income levels were less in the range of rupees 3872-4064.

The demand for pesticide spray was higher in the range of 1.62-1.84. Similar results were reported by past studies like Ali and Abdulai (2010) and Ali and Sharif (2011).

The empirical findings indicated that as the intensity of losses increases the maize crop yield levels as well as household income levels decreased while the demand for the pesticide spray increased. The policy makers and researchers needs to directly focus on the minimization of the losses due to stem borer attack as it adversely affect the rural household welfare in Pakistan. After matching the matching quality was checked by employing different balancing tests and the results were found robust.

Conclusion

Current paper employs a comprehensive data set collected through field survey from maize growing areas of Pakistan. For the empirical analysis a number of econometric models and approaches were used. At farm level the maize farmers adopt a number of measures to control for the stem borer attack like chemical spray, crop rotation as well as pest scouting. The empirical results indicated that as the intensity of

losses increases the maize yield and household income levels decreases while the poverty level increases. The household welfare is badly affected when the maize yield losses reached up to 30 % due to maize stem borer attack.

Based on the empirical findings the current paper has important policy implications like more awareness regarding control measures needs to be created by various stakeholders especially agricultural extension department. More focus needs to be on the intensity of the losses as the empirical findings indicated inverse relationship hence it's very important that the intensity of losses to be minimum for the sustained household welfare. The awareness, capacity building and extension services can help farmers to minimize the losses due to maize stem borer attack.

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Contribution of Authors

Ali A: Conceived Idea, Data Collection, Data Analysis, Statistical Analysis, Literature Review, Manuscript Writing

Issa ARB: Designed Research Methodology, Data Interpretation, Manuscript final reading and approval

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