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ADOPTION OF 'PUSH-PULL' BIOLOGICAL CONTROL OF STRIGA (*STRIGA HERMONTHICA*) WEEDS, AMONG SMALLHOLDER MAIZE FARMERS IN HOMA BAY, KENYA

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Abstract

Maize is the most important staple food for 96 percent of Kenya's population. However, maize productivity in Kenya is low averaging 1800kg/ha compared to a yield potential of over 6000kg/ha. Weed management has been attributed as one of the key factors affecting Maize yields. Among the weeds, striga (*Striga hermonthica*) is perhaps the most critical due to its ability to retard maize growth by competing for its nutrients with farmers reporting yield losses of up to 80 percent in infested fields. In recent times, the 'push-pull' biological method of striga weed control has been developed. The innovation controls striga and stem borers by using repellent (push) and traps (pull) plants. Although there is evidence showing that this method is effective and environmentally friendly, few farmers have adopted it in striga infested areas of Homa Bay, in Kenya. This article assesses factors that influence farmers' choice towards adoption of this push-pull innovation. A random sample of 96 smallholder farmers from Mbita and Homa Bay sub-counties were interviewed. Data analysis involved descriptive statistics, and probit regression model. Results show that the probability of adopting push-pull biological control increases with access to extension services ($p<0.01$); household size ($p<0.05$); returns from maize but decreases with limited access to markets ($p<0.05$). The findings suggest that addressing labour sourcing arrangements, enhancing the profitability of maize farming and putting in place the right institutional arrangements for extension and access to markets would enhance the adoption of the push-pull innovation.

Key words: Adoption, push-pull innovations, biological weed control, Striga weed, maize yields, probit, Kenya

1.0 Introduction

Maize is the most widely consumed food crop in Kenya and a staple food crop for 96 percent of the population (Omoyo et al., 2015). Maize has also been identified as a key crop in enhancing food security, income and poverty alleviation as it is grown in a range of agro-ecological environments and is consumed by people with varying food preferences and socio-economic backgrounds (Homann-Kee Tui et al., 2013).

Despite the importance of maize for both food security and livelihoods, current trends in maize production in Kenya shows that the average maize yield is about 1800kg/ha far below a yield potential of over 6000kg/ha (Schroeder et al., 2013). Additionally, growth in production in the country has not kept pace with demand, in a large part driven by changing food preferences and population growth, raising its import bill during the recent years (Ouma et al., 2014). This scenario has been attributed to a wide array of factors including the lack of productivity enhancing technologies, erratic climatic conditions, inadequate extension services, difficulties in accessing credit, poor marketing arrangements and high incidence of weeds, pests and diseases (Manana,2014). Among the weeds, striga has been reported to be the most critical (Khan et al., 2011), with farmers reporting losses ranging between 20 and 80 percent in infested fields (Teka, 2014) depending on severity of infestation.

In Western Kenya, a major maize producing zone, striga weed is one of the important challenges limiting maize production weed (Atera et al., 2013**)**. Western Kenya is used in this paper to refer to an area covered by ten counties namely: Kisii, Nyamira, Homa Bay, Migori, Kisumu, Siaya, Busia, Bungoma, Kakamega and Vihiga. Striga has infested over 217,000 ha of crop land, resulting in losses of 182,227 tons per year valued at US$ 53 million (Nzioki et al., 2016). Although a number of cultural, mechanical, chemical and biological practices have been recommended for striga control, such as crop rotation, intercropping, transplanting, soil and water management, use of fertilizer and hand weeding, (Teka, 2014), their effectiveness is limited possibly due to the large sizes of the infested areas, inefficient delivery systems and costs (Sibhatu, 2016).

Coupled with the need for sustainable intensification where production should strive to minimise chemical use (Khan et al., 2011), integrated approaches to striga weed control have been promoted as feasible alternatives (Dawud, 2017). One such innovation tried in Kenya is the push-pull innovation for the control of lepidopteran stem borers and striga weed in maize production (Khan et al., 2011). The innovation is based on stimulo-deterrent diversionary strategy (Miller and Cowles, 1990), where stem borers are repelled (push) from a harvestable crop and are simultaneously attracted (pull) to a trap crop (Cook et al., 2007). The innovation involves inter-cropping maize with a fodder legume, silverleaf desmodium (*Desmodium uncinatum*), and planting napier grass (*Pennisetum purpureum)* as a trap crop around the crop field. Desmodium inhibits (*pushes away stem borers*) and helps eliminate striga through a range of mechanisms such as nitrogen fixation, addition of organic matter into the soil, and smothering due to dense ground cover. The dense ground cover reduces soil temperatures and together with surrounding napier grass, protects the soil against erosion (Khan et al., 2011).

Desmodium roots produce chemical compounds some of which stimulate striga seed germination while others inhibit attachment of striga roots to those of the maize resulting to suicidal germination (Midega et al., 2015). Being a perrenial crop, desmodium ensures continual depletion of striga seed bank when there is no cereal in the field. While there are numerous push-pull innovations that have been developed in a range of agricultural situations, only a few have been used successfully at a commercial level (Ratnadass et al., 2012). Although there is evidence showing that this method is effective and environmentally friendly, few farmers have adopted it in striga infested areas of Homa Bay, in Kenya.

The push-pull innovation for striga control was introduced in Western Kenya in 1997 (Murage et al., 2012). However, only about 60,000 households in the region had adopted push-pull biological control method by 2013 (Pickett et al., 2014). This represents only a very small percentange of the estimated 1.6 million maize farming households in the region (Ndwiga et al., 2013).

This paper analysed the determinants of adoption of push-pull biological control of striga in Homa Bay County, Kenya. The study is justified because understanding the drivers of adoption is important in enhancing interventions that will improve adoption of new agricultural innovations. Previous studies have shown that adoption of new technologies is conditioned by the dynamic interaction between charateristics of the technology itself and the array of conditions and circumstances (Mwangi and Kariuki, 2015). As a result, farmers' adoption of innovations could be explained by credit constraints, risk aversion, the farmer's landholding size, land tenure system, human capital endowment and supply of complementary inputs (Ogada et al., 2014).

2.0 Methodology

2.1 The study area and data collection

The study was conducted in Homa Bay County located in Western Kenya, one of the areas in Kenya with the highest incidences of striga weed in the country (Atera et al., 2013). Data for the study was collected from a cross sectional survey of smallholder maize farming households drawn from two sub-counties purposively selected from the study area (Mbita and Homa Bay). The data was collected in 2017 following a multi-stage random sampling procedure. The sampling approach started with a random selection of 5 enumeration villages in each of the two selected sub-counties, followed by preparation of a list comprising of the set of all the maize farming households in the sleeted villages. The process was finalized with a random selection of 96 households who were interviewed.

The survey collected data on various farm level characteristics, household demographic, socio economic characteristics and institutional variables and was complimented with key informant interviews and focus group discussions. The collected data was analysed both qualitatively and quantitatively. Data from household interviews were entered, processed and analysed using Stata version 14. In order to assess the determinants of adoption of push-pull biological control, both descriptive stastics and probit regression model were used.

Figure 1. *Map of Kenya showing location of the study area*

2.2 Empirical Model

In order to assess the determinants of adoption of push-pull biological control, we used probit model to generate maximum likelihood estimates. The household decision making behaviour was modelled as a choice between two alternatives, in this case the choice to either adopt or not to adopt push-pull innovation.

The binary random variable U_i therefore takes the value of 1 if the household adopt and zero otherwise.

$$U_i = \begin{cases} 1\ if\ adopts \\ 0\ otherwise \end{cases}$$

As utility is random, the household will select the alternative to adopt if $U_{i1}>U_{i_o}$. Thus, the probability of adopting push-pull innovation is given by equation 1:

$$Pr = P(U_{i1} > U_{i_o}) \ldots\ldots \quad (1)$$

The probability that a household adopts push-pull innovation is estimated empirically in equation 2 as:

$$\Pr(U_i = 1) = X_i\beta_i + \varepsilon_i \ldots\ldots \quad (2)$$

Where, X is a vector of variables related to household specific factors, technological, economic, and institutional factors that are hypothesized to influence adoption of push-pull innovation; β_i is a vector of parameters to be estimated while ε_i is the statistical random term specific to a household. This can also be presented in equation 3 as:

$$Pr = \Phi(\beta X_i) \ldots\ldots \quad (3)$$

Where $\boldsymbol{\Phi}$ is the cumulative distribution function of the standard normal distribution which yields the probit model which was applied in the analysis of the determinates of push pull innovation. Probit model best suited this study because it is based on the cumulative normal probability distribution which provides statistically significant findings of which factors increase or decrease the probability of adoption. The parameters β are estimated by maximum likelihood estimation.

2.3 Description and measurement of variables

The dependent variable in the adoption model is a dummy variable taking the values 1 if a household had adopted push-pull innovation and 0 if not. The explanatory variables expected to influence adoption of push-pull innovation included, age of the farmer, gender, education level, household size, farm size, access to market, returns from maize, access to credit, access to extension service and membership to a farmer's group or association (Table 1).

Table 1: Definition and Measurement of variables applied in the Probit Model

Variables	Defination of variables
Dependent:	
Adoption of push-pull innovation	Dummy=1 if household head had adopted push-pull innovation; 0 otherwise
Independent:	
Age	Age of the smallholder maize farmer in years
Household size	Number of dependents and young children
Farm size	Total amount of farmland owned by the farm household (acres)
Distance to market	Distance from the farm to the market center in kilometers
Distance to main road	Distance from the farm to the main road in kilometers
Returns from maize	Difference between the gross returns and the variable inputs in ksh per acre per season in the preceeding year
Gender	Dummy= 1 if household head is a male; 0 otherwise
Education	Dummy; D_1=1 if household head had attained education up to primary level; 0 otherwise D_2= 1 if household head had attained education up to secondary level; 0 otherwise D_3= 1 if household head had attained education up to tertiay level; 0 otherwise
Extension service	Dummy=1 if household head received extension service within the preceeding year; 0 otherwise
Membership to social groups	Dummy= 1 if household head belonged to a farmer's group or association; 0 otherwise
Access to credit	Dummy= 1 if household head had access to credit during the preceeding croppping season; 0 otherwise

3.0 Results and Discussion

3.1 Household characteristics and behaviour

Table 2 below shows the descriptive statistics disaggregated by their adoption status for surveyed maize farmers in Homa Bay County in Western Kenya.

Table 2: Descriptive statistics of farm households on adoption of push-pull biological control

Characteristics	Total (N=96)		Adopters (N=32)		Non-adopters (N=64)		Difference
Continuous variables:	Mean	SD	Mean	SD	Mean	SD	
Age	36.0	9.88	34.0	6.19	37.0	11.20	-3.0(.090*)
Household size	6.3	1.98	7.1	1.67	5.8	1.99	1.3(.001***)
Total cultivated land (acres)	3.7	2.38	3.3	1.43	3.9	2.72	-.60(.221)
Distance to market (km)	2.0	1.57	1.8	0.73	2.1	1.31	-.30(.092*)
Distance to main road (km)	1.9	1.39	1.4	0.53	2.1	1.62	-.70(.002***)
Returns from maize (Ksh)	34093.9	23394	38961.6	26463.38	31660	21508.43	7301.6(0.050**)
Categorical variables:							
Gender: 1=male; 0 otherwise (%household head)	0.50	0.50	0.63	0.49	0.44	0.50	.19(.085*)
Education:1=primary;0 otherwise	0.13	0.33	0.09	0.30	0.09	0.30	.00(0.194)
Education:2=secondary;0otherwise	0.37	0.48	0.31	0.47	0.38	0.47	-.07 (0.767)
Education:3=tertiary;0 otherwise	0.50	0.50	0.59	0.50	0.52	0.50	.07(0.669)
Received extension service(% households)	0.48	0.50	0.75	0.44	0.34	0.48	.41(.000***)
Access to credit (% households)	0.59	0.49	0.78	0.42	0.50	0.50	.28(.005***)
Membership to social groups (% households)	0.46	0.50	0.59	0.50	0.39	0.49	.20(.064*)

***** significant at p<0.01; ** significant at p<0.05; * significant at p<0.1**

Table 2 indicates that the mean age for the sampled households was 36 years. Adopting households had a lower mean age of 34 years than the non-adopting households (37 years). This observation suggests that as farmers grow older they are less likely to adopt push-pull innovation. The average household size for the sampled household was 6.3 persons per household. Adopting households had larger households (7.1 persons) than the non-adopting households (5.8 persons) which was significantly different at (p=0.001). The average land holding was 3.3 acres and 3.9 acres for adopters and non-adopters respectively. The difference in the average land holding was insignificant.

Access to market is measured by capturing distances to the market and the main road. The average distance to the market was 2 kilometres. Adopting households had a significantly shorter distance (1.8km) to the market, than non-adopting households (2.1 km). The average distant to the main road was 1.9 kilometres and adopting households had significantly shorter distance (1.4km) than non-adopting households (2.1 km), which suggests that market access can has an effect on the adoption status of farm-households. The average returns from maize for the adopters was Ksh.38961.6 while for the non-adopters was Ksh.31660. The results indicate that the difference in their means is significant (p=0.050).

Overall, 50% of the sampled households were male headed, and the proportion of male-headed households was higher among the adopters of push-pull innovation (63%) than the non-adopters (44%). The difference was significant at (p=0.085). This observation suggests that adoption of push-pull innovation is highly preferred by the male headed households. The highest level of education was tertiary education for both the adopters and non-adopters representing 59% and 52% respectively (p=0.669).

More adopters (75%) agreed to having received extension services than non-adopters (34%). 78% of the adopting households reported having access to credit than non-adopting households (50%). Membership in social groupings was more evident among adopters (59%) than non-adopters (39%) suggesting a positive correlation between adoption and membership in a social group.

3.2 Factors influencing the adoption of push-pull biological control

Table 3, present results of the probit regression model for assessing the determinants of adoption of the push-pull biological control for striga in Homa Bay County. The results of the estimated marginal effects from the model are presented below.

Table 3: Marginal effects on probability of adoption of push-pull biological control

Variable	Coefficient (dy/dx)	Std error	P>|z|
(Constant)	0.264	1.522	0.862
Gender	-0.084	0.157	0.593
Age	-0.016	0.014	0.246
Returns from maize	9.180*	0.000	0.078
Extension service	0.643***	0.175	0.000
Distance to the main road	-0.238**	0.116	0.041
Distance to market	-0.069	0.156	0.658
Credit	0.021	0.268	0.937
Membership to social groups	-0.283	0.281	0.313
Household size	0.102**	0.046	0.026
Farm size	-0.073	0.085	0.387

Significant ***p<0.01, **p<0.05,*p<0.1

From the results in table 3, the findings show that returns from maize, extension service, household size and market access are critical determinants of adoption of push-pull biological control. Among these variables, market access was the only variable with a negative influence on adoption of push-pull biological control.

Extension service positively and significantly (p=0.000) influenced adoption of push-pull innovation. Increase in access to extension service increases the likelihood of adoption of push-pull innovation by 0.643. This implies that farmers who have access to extension service have a higher probability of adopting push-pull innovation. These findings are in agreement with Obayelu et al., (2017) who in their study stated that access to extension services helps to spread information about new agricultural technology leading to adoption.

Similarly, returns from maize positively (9.18) and significantly (p=0.078) influenced adoption of push-pull innovation by non-adopters of push-pull innovation. An increase in returns from maize by adopters increases the probability of non-adopters adopting push-pull innovation by 9.18. This also suggests that farmers who have adopted push-pull innovation are more likely to continue using the innovation. In their study, Khan et al., (2011) found that push-pull innovation had increased maize grain yields by three-to four –folds enabling a typical family of six to come from a situation of food insecurity to food sufficiency. This finding is supported by Mizab and Falsafian, (2017) who found that profitability from Saffron production had a positive effect on the probability of farmers' willingness to accept Saffron planting.

Market access showed a negative relationship with farmers' decision to adopt push-pull biological control method. The results indicated a 0.238 decrease in probability to adopt push-pull innovation at (p=0.041). This implies that a one kilometre increase in distance to the main road reduces the likelihood of adoption of push-pull innovation by 0.238. This is explained by a daunting set of generic problems on rural areas in developing countries which include poor roads, thin markets for agricultural inputs, outputs and finance, business environment characterized by weak information on prices and new technologies resulting into high transaction costs which expose the farmers to coordination risks and risks of opportunism (Kydd and Dorward, 2004). This finding is supported by Ogada et al., (2014) who found that households which were one kilometre closer to the input market had one per cent higher chance of adopting use of both inorganic fertilizer and improved maize varieties.

Household size was significant (p=0.026) and positively (0.102) related to adoption of push-pull innovation. An increase in the household size increased the likelihood of adoption of push-pull innovation by 0.102. This could be explained by family labour that dominates labour inputs in many low-income countries which tends to be mostly small, family-owned enterprises that are more labour-intensive, have low earnings, and are either not subjected to or do not comply with the existing labour market regulations which offers less favourable wages and conditions (Ahmed and Campbell, 2012). This finding is consistent with Benmehaia and Brabez (2017) who found that household size had a strong positive effect in assets acquisition in different farming systems.

4.0 Conclusion

The purpose of this study was to assess factors that influence farmers' choice towards adoption of push-pull biological control method. The study showed that only (33.3%) of the sampled smallholder maize farmers had adopted push-pull biological control compared to (66.7%) for the non-adopters. This low rate of adoption was mainly attributed to the following variables which affected the level of adoption either positively or negatively.

Extension service, returns from maize, and household size which gave a positive coefficient regarding adoption of push-pull biological control while market access showed a negative coefficient. This clearly indicates that the probability of adopting push-pull biological control increases with access to extension services; household size; returns from maize but decreases with limited access to markets.

Therefore, there is need to address labour sourcing arrangements through provision of trainings on skilled farm labour that will enhance agricultural output. Agricultural innovations with low cost of production should also be embraced in enhancing profitability of maize farming. There is also need of putting in place right institutional arrangements for extension services and access to markets that will avail farmers with information on effectiveness of push-pull innovation and market access with respect to input and output prices.

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