Int. J. Agr. Ext. 05 (03) 2017. 131-143

Available Online at ESci Journals
International Journal of Agricultural Extension
ISSN: 2311-6110 (Online), 2311-8547 (Print)
http://www.escijournals.net/IJAE

IMPACT OF FIELD DAYS ON FARMERS' KNOWLEDGE AND INTENT TO ADOPT PUSH PULL TECHNOLOGY IN UGANDA

Girma Hailu*, Zeyaur R. Khan, Jimmy O. Pittchar, Nathan Ochatum
International Center of Insect Physiology and Ecology (icipe), Uganda.

A B S T R A C T

This study assessed farmers' knowledge and intent to adopt push-pull technology to control striga and cereal stem-borers based on a field day experience. The study utilized cross-sectional data collected during on- spot surveys conducted in 2014 and 2015 across seven districts of Uganda. 849 respondents, 474 in 2014 and 375 in 2015 participated in the study. Collected data was analyzed using STATA version 12. Findings unveiled that average age of the participants in 2014 and 2015 was 42.3±14.1 years. More male respondents 63% in 2014 and 65% in 2015 participated in the exercise. Over three-quarters of the farmers who participated in the field days both in 2015 and 2014 had the problem of striga and stem borer in their farms. More than three quarters (over 75%) of the interviewed farmers cite push-pull technology as effective in controlling striga and stemborer, improving both soil fertility and yields of cereals providing quality fodder. The effectiveness of field days during 2015 was considerably improved due to the improved training packages hence willingness to adopt or continue the technology uptake was significant. For knowledge, intensive technology such as push-pull the training packages need to be tailor-made to suit their farming practices and demonstrates the advantages over other pest and weed management approaches. The findings showed that the training components that demonstrate how push-pull can be integrated with other technologies and host farmers demonstrating that will improve the perception about the technology. It was evident that what the farmers saw for themselves has more value than what they were told. Further, through field days, training of farmers should focus on translating the science into a common and easy to understand language so that farmers can easily grasp how the technology works and embrace it as an alternative farming system.

Keywords: Agriculture, field days, maize, push-pull technology, sorghum, stemborer, striga, Uganda, perception.

INTRODUCTION

Improving agricultural productivity, profitability and sustainability is the main path to alleviate poverty among smallholder farmers (World Bank, 2008). Adoption of improved agricultural technologies may be viewed as a means of these transitions since new or improved agricultural technologies are central to transforming livelihoods (Besley & Case, 1993). In the agriculture sector development strategy and investment plan of Uganda 2010 – 2015, the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) acknowledged that farming in Uganda is characterized by low production and productivity across all sectors. Moreover, the strategy document states that pests, vectors, and diseases are the major causes of losses in agriculture (MAAIF, 2010). Eastern Uganda is characterized as the major cereal producing region in the country where 1,108,554 tonnes of maize, 106,838 tonnes of Finger millet, 128,195 tonnes of rice were produced (Uganda Agricultural Census report, 2008-09). The productivity of these crops is limited by major pests and weeds including parasitic weed striga (Striga hermontica Del.) and stemborers, Chilo partelius and Busseola fusca Ful. (De Grote, 2002; Odendo *et al.,* 2001; Karaya *et al.,* 2009). In a study conducted across four districts of Uganda, pests and diseases ranked as the number one limiting factors of maize production (Rosetti & Godfrey 2004). Moreover, other factors including loss of soil fertility (Henao & Baanante, 2006; Hossner & Juo 1999), erosion (Lulseged & Quang Bao le 2015), land tenure and land defragmentation (Tenaw *et al.*, 2009) are

* Corresponding Author:
Email: girmahailuus@gmail.com

contributing considerably to the poor yields registered by smallholder farmers. Push-pull, a novel technology developed by the International Center of Insect Physiology and Ecology (icipe) in collaboration with Rothamsted Research in the UK and Kenya Agricultural Research Institute (KARI) to control striga and stemborer is being disseminated in Uganda by the icipe Uganda team since 2013. The technology is based on a stimulo-deterrent diversionary strategy (Khan & Pickett, 2004; Miller & Cowless,1990) where insect pests are repelled from a harvestable crop and are simultaneously attracted to a 'discard' or 'trap' crop (Cook *et al.,* 2007). The technology works through intercropping cereals such as maize or sorghum with a repellent plant, Desmodium, and an attracting border plant, such as Napier grass or brachiaria grass (Cook *et al*., 2007). In push-pull technology, volatiles emitted by the desmodium silverleaf and desmodium greenleaf (Desmodium unicinatum and Desmodium intortum) repel the stemborer moths away from the maize field (push component), while those released by the Napier grass (Pennisetum purpureum) attract them (pull component).

Adoption of agricultural technology is affected considerably by the perception of farmers about the improvements the new technology renders (Adesina & Forson, 1995; Adesina & Zinnah, 1993). Moreover, demand for new technology is often driven by the subjective assessment of the attributes of a technology that is being promoted (Yapa & Mayfield, 1978; Nowak, 1992). For example, farmers who perceive striga as an important weed are likely to adopt a striga-control technology (Murage *et al.,* 2015). The success of technology transfer lies on the adoption of the trained farmers and further the voluntary uptake by fellow farmers. (Truong, 2002). This implies that the quality and suitability of information packaged and delivered to farmers' is a critical first step in planning their training. Push-pull technology is currently promoted in eight districts of eastern Uganda. One of the dissemination methods designed to reach more farmers is field days (Amudavi *et al.,* 2009). According to a report by the National Agricultural and Livestock Extension Program (NALEP) of Kenya, field days scored the highest in the effectiveness of information delivery both by the farmers and extension staff (NALEP, 2011). Field days comprise of training farmers about the technology followed by visits to host farmers' demonstration fields showcasing the effectiveness of the technology as well as utilization of companion plants as livestock fodder. Although farmers are often excited and show their willingness to adopt the technology, discouraging rates of adoption was reported in Uganda (Uganda Bureau of Statistics, 2007). Moreover, dropout rates are also on the higher side (Kijima *et al*., 2011). Taking into consideration the rate of adoption and dropouts in the past experience, was important to capture how much knowledge they gained and if this knowledge will be retained to make decision to adopt or not.

The purpose of the study was to determine the impact of field days on knowledge of push-pull technology (PPT hereafter) by farmers in eastern Uganda and their intent to adopt the technology.

MATERIALS AND METHODS

Study area and Sampling procedure: International Center of Insect Physiology and Ecology (icipe) promotes Push-pull technology to control striga and cereal stem borers in seven districts (Bugiri, Bukedea, Busia, Iganga, Mbale, Pallisa and Tororo) of eastern Uganda (Table 1). Eastern Uganda has a bimodal rainfall pattern with the main rain season running from March to June and the Short rain season running from August to October. Crops such as maize, sorghum, beans, cassava as well as fruits, vegetables and tuber crops are cultivated and livestock such as cattle, goats, sheep, pigs and poultry are reared by some households.

From the surveyed districts, sub-counties were selected using cluster sampling technique. Sub-counties were clustered based on proximity to the next sub-county and area of PPT dissemination by icipe. Therefore, the number of sub-counties in each district varied depending on the coverage of the program. In each Sub County, between one and three parishes were chosen purposively as this are areas of PPT dissemination. Villages were data was collected from were also selected purposively as these are villages were striga is prevalent and icipe is implementing the push pull technology. A total of 14 villages in 2014 and 13 villages in 2015 were selected (Table 1).

Research design and Data: The study utilized a cross-sectional design from which data was collected through on spot surveys during field days conducted in 2014 and 2015. A cross-sectional design looks at a phenomenon by taking a cross-section of it at one time (Kumar, 2005). This design is best suited to studies aimed at finding out the perceptions of people towards a situation or issue by taking a section of the population at a given point in time

(Mugenda & Mugenda, 1999). This design helped in exploring technology adoption by farmers while presenting the knowledge and perceptions of farmers towards adoption of PPT from the perspective of PPT and non PPT farmers obtained through the field day events.

The field days were organized and conducted on farm where host farmers are showcasing their farm and associated benefits of the technology. 27 field days were conducted, 14 during 2014 and 13 in 2015 across seven districts. At the commencement of each field day, about 30 to 35farmers were randomly selected from the field day attendees. The total number of participants who took part in this study over two years was 849. Among which, 474 farmers participated in field days conducted in 2014 and 375 farmers in 2015. Knowledge of the farmers about stemborer and striga infestation and the push-pull technology being promoted were recorded in a short survey structured questionnaire. The questionnaire used was a well-designed standard tool used by icipe for examining perception and knowledge about PPT. The interviews were conducted by designated technicians and training facilitators. The interview design was standardized across all sites for the two years of field day evaluation.

Table 1. List of locations and dates where field days were conducted in eastern Uganda in 2014 and 2015.

District	Sub-county	Parish	Village	Date
Bugiri	Buwunga	Magola	Kayandhakato	23/7/2014
	Kapyanga	Nakavule	Izira	19/11/2014
	Budhaya	Mayuge	Mayuge west	21/7/2015
	Kapyanga	Kapyanga	Isagaza	18/08/2015
Busia	Sikuda	Tiira	Tiira	22/7/2014
	Buteba	Abochet	Abochet	31/7/2014
	Busitema	Chaiwo	Buwuchi	20/11/2014
	Busitema	Busitema	Namayenje	28/7/2015
Bukedea*	Kachumbala	Aligoi	Aligoi	22/7/2015
	Namungalwe	Namukanga	Namukanaga	10/12/2014
Iganga	Makuutu	Makandwa	Makandwa	25/6/2015
	Nawandala	Nawandala	Kiringa	23/7/2015
	Makuutu	Makuutu	Kasozi	8/12/2015
Mbale	Bukasakya	Tsabanyanya	Tsabanyanya	9/12/2014
	Bukasakya	Marale	Kisenyi	3/7/2015
Pallisa	Agule	Morukokume	Pasia	24/7/2014
	Agule	Odusai	Odusai	26/11/2014
	Puti-puti	Limoto	Katome	16/12/2014
	Apopong	Apopong	Katukei	1/7/2015
	Opwateta	Aputon	Aputon	14/8/2015
Tororo	Rubongi	Nyangole	Maguria	14/1/2014
	Rubongi	Panyangasi	Papel	30/7/2014
	Mukuju	Kwapa	Opolia	6/8/2015
	Mulanda	Mulanda	Magoro	9/7/2015
	Magola	Magola	Paloto	4/12/2014
	Iyoiwa	Ojilai	Fungwe	7/8/2014
	Osukuru	Kayoro	Abur B	13/11/2014

*Bukedea is a newer addition to the other districts where *icipe* disseminates push-pull technology.

Data analysis: The questionnaire items coded were designed in an epidata entry template (version 3.2). The data entered was exported to STATA (Version 12) from which data cleaning and analysis was done. The data were subjected to univariate, bivariate and multivariate analysis. The univariate analysis involved the use of "sub program frequencies" utilized to generate means, frequency count, standard deviations and percentage scores of respondents for each of the variables of interest.

The bivariate analysis involved running cross-tabulations between farmer's willingness to adopt push-pull technology and some variables of interest including the level of education, familiarity with the technology, prevalence of striga and cereal stem borers, etc. as well as testing associations and relationships between the bivariate items. The chi-square test was used to measure the association between the variables. The paired sample t-test was used to test for significant differences in yields of maize and sorghum over the different seasons of adoption of PPT. The multivariate analysis involved running a regression model to predict the composite adoption of PPT as a function of their perceptions and understanding of PPT as well as other demographic variables such as age, education level, and gender among others.

Model specification: Shakya & Flinn (1985) provide that, univariate and multivariate logit and probit models including their modified forms have been used extensively to study the adoption behavior of farmers and consumers and this can be a basis for modeling adoption behavior. The probit model has been recommended for functional forms with limited dependent variables that are continuous between 0 and 1 and logit models for discrete dependent variables. In analyzing farmers' perceptions about push-pull technology and the intent to adopt the technology (by non-adopters), the responses recorded are discrete (Mutually exclusive and exhaustive). Therefore, a univariate logit model was used to analyze the willingness of a farmer to adopt the push-pull technology.

The dependent variable was measured by dichotomous variables, i.e. farmers who were willing to adopt the technology and those not willing to adopt the technology. The definitions and measurement of variables are presented in the Table 2.

The probability of adoption (Yi) is specified as a function of factors that are associated with push-pull technology represented as follows:

$$Yi = f(X1, X2, \ldots, Xn) + Ui \qquad \text{(equation 1)}$$

Where;

Ui, is the random disturbance assumed to be normal with mean zero and constant variance 1.

Table 2. Definition of variables in the logit regression model.

Variables	Description of variable
Dependent variable	
Yi	Farmers' willingness to adopt push-pull technology which takes the value 1 if he/she is willing to adopt, and 0 otherwise
Independent variables	
Age (X1)	Age of the farmer measured in years
Sex (X2)	Farmers gender (1=Male, 0=Female)
Education level (X3)	Farmer education level (0=None, 1=Primary, 2=Secondary)
Ever seen push-pull (X4)	If a farmer has ever seen a push-pull field (1=Yes, 0=No)
Striga (X5)	If farmer has striga problem (1=Yes, 0=No)
Stem borer (X6)	If a farmer has stem borer problem (1=Yes, 0=No)
Striga effect (X7)	If a farmer clearly understood the striga effect (1=Yes, 0=No)
Stemborer effect (X8)	If a farmer clearly understood the stem borer effect (1=Yes, 0=No)
Control using PPT (X9)	If a farmer clearly understood the control of striga & stemborer using PPT (1=Yes, 0=No)
Utilization of PPT (X10)	If a farmer clearly understood the utilization of PPT (1=Yes, 0=No)

The logit model assumes that the underlying motivation (Ii) is a random variable that predicts the probability of push-pull technology adoption

$$Pi = \frac{e^{Ii}}{1+e^{Ii}} \qquad \text{(Equation 2)}$$

Conceptually, the behavioral model used to examine factors influencing the farmers' willingness to adopt 'push-pull technology" is given by

$$Yi = g(Ii) \qquad \text{(Equation 3)}$$

$$Ii = \beta o + \sum \beta jXji \quad \text{(Equation 4)}$$

Where;

Yi is the observed response for the ith observation (i.e. the binary variable, Yi = 1 for an adopter, Yi = 0 for non-adopter).

Ii is an underlying stimulus index for the ith observation

(Generally, there is a critical threshold {Ii *} for each farmer, if Ii < Ii*, the farmer is observed to be non-adopter and if Ii≥=Ii*, the farmer is observed to be adopter);

g is the functional relationship between the field observation (Yi) and the stimulus index (Ii) which ideally determines the probability of the farmer's willingness to adopt push-pull technology).

I = 1, 2,…, k are observation on variables for the adoption model; k is the sample size;

Xji is the jth explanatory variables for the ith observation and j = 1, 2, 3,…, n;

βj is an unknown parameter, j = 0,1, 2,…, n, where n is the total number of the explanatory variables

Therefore, for the ith observation (an individual farmer)

$$Ii = In\frac{Pi}{1-Pi} = \beta o + \sum \beta jXji \quad \text{(Equation 5)}$$

Which is a logit model (Engleman, 1981).

Hence the empirical logit model specification for push-pull technology adoption will take the form of equation 6

$$Yi = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4x4 + \beta 5X5 + \beta 6X6 + \beta 7X7 + \beta 8X8 + \beta 9X9 + \beta 10X10 + ui \quad \text{(Equation 6)}$$

RESULTS AND DISCUSSION

Demographic attributes of the respondents: Data mentioned in Table 3 depicted that average age of the participants over two years was 42.3±14.1 years with a minimum age of 16 and maximum of 82 years. No significant association between age of the farmer and being a push-pull farmer was observed (chi^2=5.387, p>0.05). There was non- significant association between gender of a participant and being whether one is a push-pull technology adopter or not (chi^2=0.135, p>0.05). Male respondents' participation was prominent in both years. Most of the participants are literate. Chi^2 analysis also unveiled significant relationship between educational level of respondent and whether one is a push-pull farmer or not (chi^2=14.184, p<0.01).

Table 3. Demographic attributes of the respondents.

Attributes	2015 (n=375)		2014 (n=474)		Chi^2
	Frequency	%	Frequency	%	
Age group (years)					
<=30	83	24.1	117	24.8	
31-45	124	36.1	182	38.6	5.387
>45	137	39.8	173	36.6	
Sex					
Male	235	62.8	312	65.8	0.135
Female	140	37.3	162	34.2	
Education level					
None	18	5.3	23	4.9	
Primary	125	36.8	210	44.7	14.184**
Secondary	158	46.5	154	32.8	
Tertiary	39	11.5	83	17.7	

***p<0.01*

Awareness of farmers about Striga, Stemborer and Push-pull technology: Among the respondents who started PPT in 2014, 31% were still practicing while among those who started in 2015, 42% continued practicing PPT (Table 4). Of the respondents who are not practicing PPT in 2015, more than a quarter (39.2%) had ever seen a push-pull field while only 2% of the farmers in 2014. There are two types of PPT; the Conventional and the climate-smart. The conventional PPT involves intercropping maize with silver leaf desmodium (push) and Napier grass (pull) while the climate smart PPT involves intercropping maize with green leaf desmodium (push) and brachiaria (Mulato II) grass (pull). Farmers can practice any or both of the PPT types. More than half of the push-pull farmers in 2015 (60%) and in 2014 (56%) practiced the conventional type while 40% in 2015 practiced the climate-smart push-pull type. Slightly more than a quarter of the farmers in 2014 practiced the climate-smart push-pull type. 17% of the push-pull farmers in 2014 practiced both the climate-smart and conventional PPT (Table 4). Interestingly both types performed very well in eastern Uganda. The results further show that farmers acknowledge striga and stem borer as production constraints. Over three-quarters of the farmers who participated in the field days both in 2015 and 2014 had the problem of striga and stem borer in their fields. The level of severity varied from farmer to farmer. Close to three-quarters of the respondents in 2015 cited striga as being severe. Furthermore, 20% and 11% stated striga as being very severe and moderately severe respectively. In 2014, slightly more than half of the participants (51%) cited striga as very severe with more than a quarter (28%) citing it as being moderately severe. Similarly, in 2015, 81% of the farmers cited stem borer as severe with only 15% citing it as being moderately severe. In 2014, 37%, 28% and 34% of the participants cited stem borer as being very severe, severe and moderately severe, respectively (Table 4). Moreover, farmers were able to recognize the benefits of the technology in reducing striga and stemborers as well as improving soils and provision of fodder. This finding was similar to the study conducted in Kenya (Khan *et al.*, 2007).

Table 4. Awareness and perception of field day attendants about striga, stemborer and push-pull technology.

Variable	2015		2014	
	Frequency	%	Frequency	%
Push-pull farmer				
Yes	116	30.9	197	41.7
No	259	69.1	276	58.3
Ever seen a push-pull garden				
Yes	147	39.2	8	1.7
No	228	60.8	466	98.3
Push-pull type farmer has adopted				
Climate smart	46	40.0	48	27.5
conventional	70	60.0	109	55.5
Both climate smart and conventional	0	0.0	34	17.0
Has a problem of striga				
Yes	332	88.5	463	97.7
No	43	11.5	11	2.3
Level of severity of striga				
Very severe	66	19.9	238	51.4
Severe	231	69.6	96	20.7
Moderately severe	35	10.5	129	27.9
Has a problem of stem borer				
Yes	315	93.7	397	85.0
No	21	6.3	70	15.0
Level of severity of stem borer				
Very severe	12	4.0	162	37.1
Severe	240	80.8	124	28.4
Moderately severe	45	15.2	151	34.5
Clearly understood striga effect				
Yes	340	90.7	394	83.1
No	35	9.3	80	16.9
Clearly understood stem borer effect				
Yes	317	84.5	371	78.3
No	58	15.5	103	21.7
Clearly understood control using PPT				
Yes	302	92.6	393	86.6
No	24	7.4	61	13.4
Understood utilization of push-pull fodder				
Yes	248	82.1	375	82.8
No	54	17.9	78	17.2

Note: missing cases are excluded from analysis

Perception of farmers about effectiveness and adoption of push-pull technology: Over 80% of the participants who attended the field day rated push-pull technology as being effective in controlling striga and cereal stemborers, improving soil fertility, providing fodder and improving maize and sorghum yields (Table 5). There was no significant association in the way participants perceived push-pull in controlling striga, stem borer, improving soil fertility, providing fodder or improving yields. This finding was similar to push-pull practicing farmers and others who are not practicing. This could be because of the training during the field day, the situation in the demonstration farm and testimonies from fellow farmers who practiced the technology. In 2014, participant's perception of the effectiveness of push-pull technology in providing fodder was significantly associated with adoption of push-pull technology (chi^2=6.67, p<0.01). Overall, the farmers' perception on the effectiveness of push-pull technology could not significantly be associated with whether he/she was a push-pull practicing farmer or not (Table 5). Similar findings were reported from Kenya where farmers stated that the technology helps improve yield and diversifies agricultural products (Khan *et al.,* 2008b).

Majority (98%) of PPT adopters in 2015 and 81% in 2014 exhibited their willingness to continue practicing the technology. Similarly, 96% non-adopters in 2015 and 96% in 2014 stated their willingness to adopt the technology. There was a significant (P<0.001) association between PPT adopters to continue the practice and non PPT adopters to take up the technology (Table 5). Among adopters, only 2% in 2015 and 19% in 2014 were not willing to continue practicing PPT. This discouragement was associated with inadequate land, failure to utilize companion plants, desire for crop rotation, as well as lack of technical backstopping. Comparison between 2014 and 2015 clearly showed a difference in the decision to discontinue PPT due to the improvements made in the training program and follow-up guidance by technicians. Thus most of the observed values showed a positive impact where PPT adopters who opted to discontinue the technology reduced from 19% in 2014 to about 2% in 2015 (Table 5).

Table 5. Comparisons of push-pull technology adopters and newly trained farmers' perception on effectiveness of the technology and willingness to adopt.

Effectiveness of push-pull technology	2015			2014		
	Push-pull practicing farmer	Nonpush-pull farmer	Chi^2	Push-pull practicing farmer	Nonpush-pull farmer	Chi^2
Striga control						
Effective	92 (89.3)	198(90.0)	0.04	162(84.4)	239(87.9)	1.17
Not effective	11 (10.7)	22 (10.0)		30 (15.6)	33 (12.1)	
Stem borer control						
Effective	92 (90.2)	197(92.5)	0.48	164(85.4)	243(89.7)	1.91
Not effective	10 (9.8)	16 (7.5)		28 (14.6)	28 (10.3)	
Improving soil fertility						
Effective	92 (91.1)	198(93.4)	0.53	154(80.2)	231(85.2)	2.03
Not effective	9 (8.9)	14 (6.6)		38 (19.8)	40 (14.8)	
Providing fodder						
Effective	97 (95.1)	200(94.3)	0.08	157(82.2)	245(90.4)	6.67**
Not effective	5 (4.9)	12 (5.7)		34 (17.8)	26 (9.6)	
Improving cereal yields						
Effective	94 (92.2)	203(94.4)	0.60	158(82.7)	238(87.8)	2.38
Not effective	8 (7.8)	12 (5.6)		33 (17.3)	33 (12.2)	
Willingness to adopt						
Yes	114(98.3)	249(96.1	1.18	160(81.2)	264(95.7)	25.79***
No	2 (1.7)	10 (3.9)		37 (18.8)	12 (4.3)	

***p<0.001, **p<0.01, *p<0.05, missing cases are excluded from analysis.

Whole numbers are frequencies; percentages are in parenthesis.

Cited reasons for not planting push-pull include; it is expensive, lack of land and no time to invest in push-pull since it requires a lot of time.

Comparisons of female and male farmers' perceptions on effectiveness of push-pull technology: More than 75% of the respondents in 2014 and 2015 cited push-pull technology as effective in the listed parameters (Table 6). As a general trend, more positive impressions about the technology were observed from responses of 2015 compared to responses in 2014. This probably was linked to the delivery of the training. Furthermore, in 2015 some of the respondents already practiced the technology for more than two seasons and were able to understand well how the technology works and witnessed the benefits.

Striga and cereal stemborers being landscape level problems, the damage they cause is equally known by male and female respondents. The perception on the effectiveness of PPT was relatively the same which explains why differences were not significant (Table 6).

Table 6. Perception of female and male adopters of push-pull technology on its effectiveness in eastern Uganda.

Effectiveness of push-pull technology	2015			2014		
	Female adopters	Male adopters	Chi^2	Female Adopters	Male adopters	Chi^2
Striga control						
Effective	31 (83.8)	61 (92.4)	1.86	53 (82.8)	109(85.2)	0.18
Not effective	6 (16.2)	5 (7.6)		11 (17.2)	19 (14.8)	
Stem borer control						
Effective	31 (88.6)	61 (91.0)	0.16	55 (84.6)	109(85.8)	0.05
Not effective	4 (11.4)	6 (9.0)		10 (15.4)	18 (14.2)	
Improving soil fertility						
Effective	32 (91.4)	60 (90.9)	0.008	50 (76.9)	104(81.9)	0.67
Not effective	3 (8.6)	6 (9.1)		15 (23.1)	23 (18.1)	
Providing fodder						
Effective	32 (91.4)	65 (97.0)	1.54	53 (82.8)	104(81.9)	0.02
Not effective	3 (8.6)	2 (3.0)		11 (17.2)	23 (18.1)	
Improving cereal yields						
Effective	31 (88.6)	63 (94.0)	0.95	53 (82.8)	105(82.7)	0.005
Not effective	4 (11.4)	4 (6.0)		11 (17.9)	22 (17.3)	

***p<0.001, **p<0.01, *p<0.05, missing cases are excluded from analysis.

Whole numbers are frequencies, percentages are in parenthesis; Cited reasons for not planting push-pull include; it is expensive, lack of land and no time to invest in push-pull since it requires a lot of time.

Difference in maize and sorghum yield outputs over four seasons due to PPT adoption: According to the data presented in Table 7, significant increase in maize and sorghum yield over different seasons between baseline yields (no push-pull technology) and the current yield (with push-pull technology) is self-evident. Farmers who had practiced push-pull for 1 season registered a difference of 148.6kg of maize yield (diff=148.6, P<0.05). Over two seasons, farmers registered a difference of 177.2kg of maize yield (diff=177.2, p<0.05). Over three seasons, there was a difference of 136kg of maize yield (diff=136, p<0.05) and over four seasons, farmers registered a difference of 266kg of maize yield (diff=266, p<0.05). Onfarm study by Hasanali *et al.* (2008) showed that the PPT significantly improved maize yields and controlled striga and stem borers and this had a direct influence on adoption of the technology. Similarly, Khan *et al.* (2008a) have associated the PPT with significant increases in maize height and higher grain yield from 0.5t/ha to 5.8t/ha in different locations of western Kenya where PPT is being disseminated. Furthermore, significant increases over different seasons were observed for sorghum yields when farmers adopted push-pull technology. Farmers who had practiced push-pull technology for one season registered a significant difference of 72kg of sorghum yield (diff=72.4, p<0.01). Over two seasons, farmers registered a significant difference of 76kg of sorghum yield (diff=75.5, p<0.05). As seen in table 7, during the fourth season, farmers registered a significant increase in sorghum yields by 83 kg (diff = 83.3, P<0.05).

Table 7. Summary of maize and sorghum yield outputs over four seasons of push-pull technology adoption.

Grain yield (Kg/acre)	-	season one	season two	Season three	Season four
Maize yield (PPT)	Mean	208.6	231.8	217.0	390.0
Baseline maize yield (no PPT)	Mean	62.0	54.6	81.0	124.0
	Mean diff	148.6*	177.2*	136*	266.0*
Sorghum yield (PPT)	Mean	122.7	98.2	109	113.3
Baseline sorghum yield (no PPT	Mean	50.3	22.7	58	30.0
	Mean diff	72.4**	75.5	51.3	83.3*

** p<0.01 *p<0.05, Mean diff=Mean difference, comparison of average yields computed using paired sample t-test with unequal variances assumed.

Prospects of adoption of push-pull technology by non-adopters: The results of the univariate regression analysis documented in Table 8 revealed that in 2015, the female were two-fold at increased odds of adopting PPT as compared to the male participants (OR=2.51, 95% CI 0.5-12.1). In 2014 however, the odds of the female adopting PPT decreased by 0.51 (OR=0.51, 95% CI 0.2-1.6) implying that females were up to 49% less likely to adopt PPT as compared to the male farmers.

A study by Asfaw & Admassie (2004) indicated that female headed households are less likely to adopt new technologies due to lack of information and risk aversion compared to the male headed household. A similar observation made by Tenge & Hella (2004) also points out that women may have restricted access to information, land, and other resources due to traditional social barriers and therefore were less likely to adopt soil and water conservation measures. This was also in agreement to our findings in 2014 where female respondents were less likely to adopt PPT. Contrary to this however, the data for 2015 showed a greater likelihood of adoption of PPT by female farmers than the male farmers.

The result of the age of the participants shows that in 2015, there was a twofold increase in the odds of participant's age over 45 years adopting PPT as compared to participants less than 31 years. Participants aged 31 – 45 years were 50% highly like to adopt PPT as compared to participants less than 31 years. Similarly, in 2014, there was a twofold increase and a nine-fold significant increase in the odds of participants aged 31 – 45 years and over 45 years respectively adopting PPT as compared to participants less than 31 years (Table 8). This finding implies that over the two years, the older farmers were much more willing to adopt the technology as compared to the younger farmers. This might be related to the fact that controlling striga and stemborer using a cost-effective and environmentally friendly approach is critical to them on account of their longer-term experience. Moreover, land ownership and decision-making capacity might also be higher within this age group than the younger farmers. In a similar study by Khan *et al.* (2008b) in western Kenya, where age was used as a proxy for farm experience, results suggest that the older farmers were more likely to adopt and invest in PPT, and this was linked to greater appreciation of loss of farm productivity. Contrary to the results of this study are the findings of Polson & Spencer (1992) and Onyewaky & Mbuba (1991) who suggest that the younger farmers have been found to be knowledgeable about new agricultural practices and at the same time willing to take risks than older farmers and hence were highly likely to adopt new technologies. However, on the other hand, studies on agricultural technology adoption by Gbetibouo (2009) and Adesina & Forson (1995) observe that there is no consensus in literature as to the exact effect of age in the adoption of farming technologies because the age effect is generally location or technology specific and hence, an empirical question. He argues on one hand, age may have a negative effect on the decision to adopt new farming technologies simply because older farmers may be more risk-averse and therefore, less likely to be flexible than younger farmers while on the other hand, age may have a positive effect on the decision of the farmer to adopt because older farmers may have more experience in farming and therefore, better able to assess the features of a new farming technology than the younger farmers.

The results further show that in 2015, participants who attained secondary level education were significantly (11 fold) at increased odds of adopting PPT as compared to participants with no education. Participants who attained tertiary education were seven-fold at increased odds of adopting the technology. In 2014, participants who attained primary level education were 3 fold at increased odd of adopting PPT as compared to participants who did not have any education. Those who attained secondary level education were 74% highly likely to adopt PPT as compared to those without any education (Table 8). These findings reveal that the likelihood of adoption of PPT increases for farmers who have attained some formal education. The results are consistent with the findings of Nyengena (2007) who argue that farmers with more education are more likely to have enhanced access to technological information than poorly educated farmers. Furthermore, Igoden *et al.* (1990) in a study of maize farmers in Lake basin of Nigeria and Lin (1991) in a study with hybrid farmers in china observe a positive relationship between the education level of the household head and the adoption level of improved technologies and climate change adaptation. PPT is knowledge intensive; understanding the dynamics and science of PPT will be easy for someone with some level of formal education. It is highly possible that the non educated farmers were not able to understand clearly how the technology works during the field day exposure. Thus technicians need to be observant of this phenomenon and target those farmers with more illustrative training methods during the follow-up trainings. These results therefore suggest that farmers with some level of education can easily understand the technology and have a tendency to take risks and adopt the technology

The results also reveal that in 2015, participants who had seen a push-pull field were significantly 4 fold at increased odds of adopting PPT as compared to participants who had not seen a push-pull field (OR=4.97, 95% CI 10.-23.9, P<0.05). In 2014 however, participants who had seen a push-pull field were significantly up to 90% less likely to adopt push-pull technology as compared to participants who had not seen a push-pull field (OR=0.10, 95% CI 0.02-0.6, p<0.01), moreover only 2% of the non-adopters who were willing to adopt PPT had ever seen a push-pull field (Table 8).

With regard to having striga and stem borer problem, in 2015, participants with a striga problem were significantly 14 fold at increased odds of adopting PPT (OR=14.74, 95% CI 3.9-56.1, P<0.001) and were 3 fold at increased odds of adopting PPT for participants who had striga in 2014 as compared to participants who did not have a striga problem (OR=3.91, 95% CI 0.4-35.3). Further, participants with the stem borer problem in 2015 were 3 fold at increased odds of adopting PPT as compared to participants without the stem borer problem (OR=3.50, 95% CI 0.4-33.3). In 2014, participants with the stem borer problem were up to 41% highly likely to adopt PPT as compared to participants without the stem borer problem (OR=1.41, 95% CI 0.3-6.8). This suggests that farmers who have been affected by these constraints had a higher propensity to adopt the technology.

With regard to the understanding of push-pull technology, participants in 2015 who clearly understood the effect of striga on cereal crops were significantly (17 fold) at increased odds of adopting PPT as compared to participants who did not understand the damage caused by striga (OR=17.18, 95% CI 4.5-65.9, P<0.001). Similarly, participants who clearly understood the stem borer damage were significantly (9 fold) at increased odds of adopting PPT as compared to participants who did not understand the stem borer effect. (OR=9.48, 95% CI 2.5-35.4, P<0.001). On the other hand, in 2014, participants who clearly understood the striga effect and stem borer effect respectively were 46% and 86% highly likely to adopt PPT as compared to participants who did not understand the striga and stem borer effect respectively (Table 8). Further, participants who clearly understood control of striga and stem borer using PPT during the 2015 field days were six fold at increased odds of adopting PPT as compared to participants who did not understand the striga and stem borer control using PPT. Also, participants who understood the utilization of PPT for fodder were significantly five-fold at increased odds of adopting PPT as compared to participants who did not understand this concept. In 2014 however, there was a 27% and 13% high likelihood of adopting PPT for participants who clearly understood PPT in controlling striga and stem borer and for participants who clearly understood PPT in providing fodder respectively as compared to participants who did not understand these respective concepts. Moreover, Khan *et al.* (2008b) suggests that farmers in Trans Nzoiar and Vihiga districts of western Kenya appreciate the fodder component of the technology and hence choose to adopt the practice. It was therefore clear, that understanding the constraints and the effectiveness of Push Pull Technology (PPT) was an important determinant of push-pull adoption and its sustained use.

Table 8. Prospects of adoption of push-pull technology by nonadopters based on field day exposure in eastern Uganda.

Wiliness to adopt PPT	2015		2014	
Variables	Count (%)	OR (95% CI)	Count (%)	OR (95% CI)
Age group (years)				
<=30	58 (25.0)	1	71 (26.9)	1
31-45	87 (35.0)	1.50 (0.3-7.7)	99 (37.5)	2.44 (0.7-8.7)
>45	87 (35.0)	2.25(0.4-13.9)	94 (35.6)	9.27*(1.1-77.0)
Sex				
Male	153(61.5)	1	175(66.3)	1
Female	96 (38.5)	2.51(0.5-12.1)	89 (33.7)	0.51 (0.2-1.6)
Education level				
None	12 (5.3)	1	13 (4.9)	1
Primary	92 (40.4)	-	137(52.1)	3.02 (0.6-14.1)
Secondary	95 (41.7)	11.88**(1.8-78.4)	79 (30.0)	1.74 (0.4-8.2)
Tertiary	29 (12.7)	7.25 (0.7-76.7)	34 (12.9)	-
Ever seen a push-pull garden				
Yes	138(55.4)	4.97*(1.0-23.9)	5 (1.9)	0.10**(0.02-0.6)
No	111(44.6)	1	259(98.1)	1
Has a problem of striga				
Yes	226(90.8)	14.74***(3.9-56.1)	258(97.7)	3.91 (0.4-35.3)
No	23 (9.2)	1	6 (2.3)	1
Has a problem of stem borer				
Yes	210(93.3)	3.50 (0.4-33.3)	228(86.4)	1.41 (0.3-6.8)
No	15 (6.7)	1	36 (13.6)	1
Clearly understood striga effect				
Yes	229(92.0)	17.18***(4.5-65.9	215(81.4)	1.46 (0.4-5.6)
No	20 (8.0)	1	49 (18.6)	1
Clearly understood stem borer effect				
Yes	215(86.4)	9.48*** (2.5-35.4)	208(79.8)	1.86 (0.5-6.4)
No	34 (13.6)	1	56 (21.2)	1
Clearly understood control using PPT				
Yes	204(81.9)	6.80** (1.8-25.1)	209(79.2)	1.27 (0.3-4.3)
No	45 (18.1)	1	55 (20.8)	1
Understood utilization of PPT fodder				
Yes	173(69.5)	5.31* (1.3-21.1)	204(72.3)	1.13 (0.3-4.3)
No	76 (30.5)	1	60 (22.7)	1

***p<0.001, **p<0.01,*p<0.05, OR=Odds ratio, CI=Confidence Interval, Percentages and confidence intervals are in parenthesis.

CONCLUSION AND RECOMMENDATION

Level of education, knowledge of striga and stem borer damage to cereal crops, as well as understanding the control measure using PPT and the added advantage in terms of fodder and soil fertility improvement were among the significant variables that influence the likelihood of adoption. Organizing the training packages in a suitable to the farmers need and encouraging active participation of the farmers throughout the field day will increase knowledge retention and encourage uptake of PPT. Since farmers are facing complex problems, showcasing how PPT can be linked with other technologies to enhance productivity and improve their livelihood is a key component to factor in while conducting field days. Further studies are required to determine factors affecting uptake and retention of the technology and what needs to be done to encourage voluntary uptake of the technology by farmers beyond the reach of technicians and or other extension staff.

ACKNOWLEDGMENTS

The authors are grateful to the generous financial support of DFID and Biovision. The contribution of field technicians in Uganda, the host farmers of field days and the respondents are highly appreciated. The authors would also acknowledge the contribution of the anonymous reviewers.

Conflict of interest: The authors do not have any current or potential conflicts of interest.

REFERENCES

Adesina, A.A. & Forson, J. B. (1995). Farmers' perceptions and adoption of new agricultural technology: Evidence from analysis in Burkina Faso and Guinea, West Africa. Agricultural Economics, 13,1–9.

Adesina, A.A & Zinnah, M.M. (1993). Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. Agricultural Economics,9,297-311.

Asfaw, A., & Admassie, A. (2004). The role of education on the adoption of chemical fertilizer under different socioeconomic environments in Ethiopia. Agricultural Economics,30(3),215-228.

Besley, T. & Case, A. (1993). Modeling technology adoption in developing countries. The American Economic Review, 83,2. Papers and proceedings of the Hundred and Fifth Annual Meeting of the American Economic Association.

Cook, S.M., Khan, Z.R, Pickett, J.A. (2007). The use of 'push–pull' strategies in integrated pest management. Annual Review of Entomology, 52, 375–400.

David, M. Amudavi, Khan, Z. R., Wanyama J. M., Midega, C. A. O. Pittchar, J., Hassanali, A. Pickett, J.A. (2009). Evaluation of farmers' field days as a dissemination tool for push-pull technology in Western Kenya Crop Protection, 28, 225–235.

De Groote, H. (2002). Maize yield losses from stem borers in Kenya Insect Science Applications. 22:89-96.

Hassanali, A., Herren, H., Khan, Z.R., Pickett, J.A., Woodcock, C.M., (2008). Integrated pest management: the push–pull approach for controlling insect pests and weeds of cereals, and its potential for other agricultural systems including animal husbandry. Philosophical Transactions of the Royal Society of Biological Sciences. 363, 611–621.

Gbetibouo, G. A. (2009). Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability: The Case of the Limpopo Basin, South Africa.

Henao, J. & Baanante, C. (2006). Agricultural production and soil nutrient mining in Africa: Implication for resource conservation and policy development. IFDC Tech. Bull. International Fertilizer Development Center (IFDC). Muscle Shoals, Al. USA.

Hossner, L.R., Juo, A.S.R (1999). Soil Nutrient Management for Sustained Food crop Production in Upland Farming Systems in the Tropics. Juornal of Soil and Crop Sciences Department College Station Tennessee 77843, USA. Retrieved from http//www.agnet.org.

Igoden, C., Ohoji, P. & Ekpare, J. (1990). Factors associated with the adoption of recommended practices for maize production in the Lake Basin of Nigeria. Agricultural Administration and Extension, 29 (2), 149–156.

Karaya H, Njoroge K, Mugo S, Nderitu, H. (2009). Combining Ability among Twenty Insect Resistant Maize inbred lines Resistant to *Chilo partellus* and *Busseola fusca* Stem borers. International Journal of Plant Production, 3(1), 210-223.

Khan, Z. R., & Pickett, J. A. (2004) The 'Push-pull' strategy for stemborer management: a case study exploiting biodiversity and chemical ecology. *In*: Ecological Engineering for Pest Management: Advances in Habitat manipulation for arthropods (ed) GM. Gurr, SD Wratten and MA Altieri,154–164.

Miller, J.R., Cowless, R.S. (1990) Stimulo-deterrent diversion: a concept and its possible application to onion maggot control. Journal of Chemical Ecology, 16, 3197-3212.

Khan, Z.R., Midega, C.A.O., Amudavi, D.M., Hassanali, A., Pickett, J.A. (2008a). On-farm evaluation of the 'push–pull' technology for the control of stemborers and Striga weed on maize in western Kenya. Field Crops Research,27(6), 976-987.

Khan, Z. R., David M. Amudavi, Charles A.O. Midega, Japhether M. Wanyama, John A. Pickett., (2008b). Farmers' perceptions of a 'push–pull' technology for control of cereal stemborers and *Striga* weed in western Kenya. Crop Protection, 27, 976–987.

Kijima, Y., K. Otsuka and D. Sserunkuuma. 2011. "An inquiry into constraints on a green revolution in Sub-Saharan Africa: The case of NERICA rice in Uganda". World Development, 39(1),77-86.

Kumar, R. (2005). Research methodology: A step-by-step guide for beginners. London: Sage publications Ltd, Second edition. Retrieved from http://www.sociology.kpi.ua/wp-content/uploads/2014/06/Ranjit_Kumar-Research_Methodology_A_Step-by-Step_G.pdf

Lin, J. (1991). Education and innovation adoption in agriculture: evidence from hybrid rice in China. American Journal of Agricultural Economics, 73 (3), 713–723.

Lulseged, T. & Quang Bao le. (2015). Estimating soil erosion in Sub Saharan Africa based on landscape similarity mapping using the universal soil loss equation (RUSLE). Nutrient Cycling Agroecosystem,102,17–31.

Ministry of Agriculture, Animal Industry and Fisheries (2010). Agriculture for Food and Income Security. Agriculture Sector Development Strategy and Investment Plan: 2010/11-2014/15

Mugenda M. Olive. and Mugenda G. Abel 1999. Research Methods: Quantitative and Qualitative approaches. Nairobi: Acts Press

Murage, A.W., Midega C.A.O., Pittchar J.O., Pickett J.A., Khan Z.R. (2015). Determinants of adoption of climate-smart push-pull technology for enhanced food security through integrated pest management in eastern Africa. Food Security, 7, 709–724.

National Agricultural and Livestock Extension Program (NALEP). (2011). A guide to effective extension method for different situations.

Nowak, P. (1992). Why farmers adopt production technology. Journal of Soil Water Conservation, 47, 14-16.

Nyangena, W. (2008). Social determinants of soil and water conservation in rural Kenya. Environment, Development and Sustainability, 10(6), 745-767.

Odendo, M, De Groote, H & Odongo, O.M. (2001). Assessment of farmers' preferences and constraints to maize production in moist mid-altitude zone of Western Kenya. Paper Presented at the 5th International Conference of the African Crop Science Society (ed. by H. Malika), 21–26 October, 2001, pp. 1–12. Nigeria, African Crop Science Society, Kampala, Uganda.

Onyewaku, C.E & A.C. Mbuba. (1991). The adoption of seed-yam Minisett multiplication technique by farmers in Anambra state, Nigeria. The Nigeria Jouranl of Agricultural Extension, 6(1&2).

Rosetti N. & G. Bahiigwa. (2004). Agricultural productivity constraints in Uganda. International Food Policy Research Institute IFPRI. pp22

Shakya, P.B. & J.C. Flinn (1985) Adoption of modern varieties and fertilizer use on rice in the Eastern Tarai of Nepal. Journal of Agricultural Economics, 36, 409-419.

Tenaw, S., Islam, K. Z., & Parviainen, T. (2009). Effects of land tenure and property rights on agricultural productivity in Ethiopia, Namibia and Bangladesh. University of Helsinki, Helsinki.

Tenge, D. G. & Hella, J.P. (2004). Social and economic factors affecting the adoption of soil and water conservation in West Usambara highlands, Tanzania. Land Degradation and Development, 15 (2), 99–114

Truong, T.N.C & Ryuichi Y., (2002): Factors affecting farmers' adoption of technologies in farming systems: A case study in Omon district, Cab Tho province, Mekong Delta. Omonrice, 10,94-100.

Uganda Bureau of Statistics (2007). Uganda National Household Survey 2005 – 2006: Social Economic Report, Kampala, Uganda Bureau of Statistics

WorldBank (2008), World development report 2008: Agriculture for development. Technical report, WorldBank.

Yapa L.S. & Mayfield R.C. (1978) Non-adoption of innovations: evidence from discriminant analysis. Economic Geography, 54,145-156.