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RESEARCH PAPER

Gross Margin Analysis of Adopted Imazapyr Resistant Maize in Eastern Uganda

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Abstract

Maize (Zea mays L.) is an East African region's major food and cash crop. However, the crop is susceptible to witchweed (*Striga hermonthica* (*Del*.) *Benth*.) and *Striga asiatica L.)* infestation causing yield losses of 60%. The weed is popularly controlled by Imazapyr, a non-selective herbicide that often destroys non-target plants including crops, and with some herbicide spillage effects leading to ecosystem erosion. Recent advances in biotechnology have led to the development of Imazapyr Resistant Maize (IRM) to address the key challenge of infestation in cereal crop production. Anecdote evidence also suggests that IRM is more profitable than local maize (LM) in *Striga* infested areas and is often preferred by farmers in Eastern Uganda. This study performed a comparable gross margin analysis of adopted IRM against LM for selected farmers under the *Striga* control project implemented in Eastern Uganda. The study used a sample size of 120 farmer households with 2 maize varieties. The data used was for 6 seasons of a 3-year project. The results showed a profit difference of Ug.sh 2,733,500 between IRM and LM in *Striga* infested area in 3 years. The adoption of IRM over LM was influenced by total variable costs, maize harvests, farm size, and level of education.

Keywords: Gross margin, Adoption, Imazapyr Resistant Maize, Local Maize, Witch weed

Introduction

In Africa, the witch weed (*Striga*) causes an annual grain loss of about 8 million tons and the most important among the *Striga* species in the continent are purple witch weed (*Striga hermonthica (Del.) Benth.*) and Asiatic witch weed (*Striga asiatica* L.) (Gethi *et al.,* 2005). The weed severely constrains maize production in the East African Region and infests about 40 million hectares of smallholder farmland and causes yield losses ranging from 20-80% together with other limitations like declining soil fertility, climate change, pests, and diseases (AATF, 2006). This reduction has greatly caused food insecurity with no income and profit. Maize yields under farmers' conditions in the region average 1.3 tons/ha or less than 25% of the potential yield of 5 tons/ha under rainfed conditions (Kanampiu *et al.,* 2018).

In Kenya, *Striga* infestation is most severe in the western province due to a continuous decline in soil fertility (Manyong *et al.,* 2008a). In the area, maize is a staple food and *Striga* has been identified by farmers as one of the most important problems in maize production. *Striga* control technologies entailing traditional and novel ones such as push-pull have been transferred to farmers over decades and have failed to contain the problem. With push-pull technology, cereals are commonly intercropped with legumes for example, cowpeas (*Vigna unguiculata (L.) Walp*.), mung bean (*Vigna radiata L.),* and Desmodium spp; Silver leaf desmodium (*Desmodium uncinatum*), Green leaf desmodium (*Desmodium intortum*) to reduce the number of *Striga spp*. plants that mature in an infested field. Such intercrops act as trap crops, stimulating suicidal *Striga spp*. germination or altering the micro-climate of the crop's canopy and soil surface to interfere with *Striga spp.* germination. This push–pull technology has been used to effectively manage *Striga hermonthica* in sorghum and maize-based cropping systems where maize is intercropped with a stem borer–repellent plant, *Desmodium uncinatum*, and an attractant host plant, Napier grass (*Pennisetum purpureum Schumach*.), is planted as a trap plant around the field (Khan *et al.* 2006).

The new technology known as IRM was introduced in the early 1990s involving coating maize seeds with a systemic herbicide called Imazapyr (Illa *et al.,* 2010) whereas, in Uganda, the crop is also constrained by the same parasitic weed and is of great socio-economic importance (Manyong *et al.,* 2008a) and remains the main source of food, income, livestock feeds for the majority of the smallholder farmers and with about 8-12% of the household harvests being exported to neighboring countries (MAAIF, 2011).

Advocacy for the best management practices and reward for environmentally friendly approaches including organic farming have gained traction (Polacek & Diekmann, 2013). The use of integrated weed management approaches to control notorious parasitic weeds such as witchweed (*Striga hermonthica*) is at the forefront of the African Agricultural Technology Foundation (AATF), National Agricultural Research Organization (NARO), government and independent agricultural research organizations such as International Maize and Wheat Improvement Centre (CIMMYT), Badische Anlin and Soda Fabrik (BASF) and USAID - Feed the Future with partnering for innovation approach. *Striga* management strategies such as uprooting during weeding, burning, and manuring have not reduced the parasite's infestation due to its enormous seed bank in the soil (Manyong *et al.,* 2008a). Other strategies like growing cereals in rotation with legumes, like maize and sorghum with cowpeas (*Vigna unguiculata (L.) Walp.*), mung bean (*Vigna radiata L*.) and also using desmodium species such as Silver -leaf desmodium uncinatum (*Desmodium uncinatum*), and Green leaf desmodium (*Desmodium intortum*) have also been used but are ineffective (Pittchar & Mbeche, 2008). Chemical control including the use of imazapyr, a non-selective herbicide has environmental concerns such as chemical spillage and ecosystem erosion effects (Aktar, 2009).

To mitigate these concerns, various biotechnologies have been used in the fight against weed. For instance, Uganda started the fight against *Striga* as early as 2011s with Kilimo Trust in collaboration with Integrated Soil Productivity Improvement through Research and Education (INSPIRE) by use of the push and pull technology (A2N-U, 2007). Later in 2014, Africa 2000 Network-Uganda (A2N-U) in partnership with INSPIRE introduced the growing of cereals in rotation with legumes to reduce *Striga* infestation and where the legume acted as a trap crop with the capacity to suppress *Striga* germination and the weed is unable to attack the host crops, thus resulting into suicidal germination of *Striga* (Gachene *et al.,* 2000). In 2015, AATF in partnership with Africa 2000 Network-Uganda (A2N-U) also came in and introduced IRM technology to farmers in Eastern Uganda under *Striga* control in maize project where IRM trials were set and proved to be effective in suppressing *Striga* (Tugeineyo, 2020). The continuous cultivation of cereals with low soil fertility has enhanced the growth of *Striga* where it is estimated that 62,000 ha of farmland is infested with the weed causing an economic loss of US $ 8 million a year. In spite of the high demand for rice and maize, their production volumes are still low mainly due to inherently low soil fertility and *Striga* infestation (Kamau *et al.,* 2020; Tugeineyo, 2020).

About 50-80% of farming in developing economies is for subsistence purposes (AGRA, 2015) with only 5% committed to commercial farming (Okezie *et al.,* 2012). In analyzing farm profitability, gross margin is the best method due to its simplicity and accuracy (Ahmad, 2004). It serves as the unit of analysis in evaluating the economic performance of an enterprise and gives an indicator of its feasibility of it and its potential contribution to household income (Masvongo *et al.,* 2013). Gross margins are usually computed per year or per cropping season (Zulu, 2011). Gross margins, however, should only be compared with figures from farms with similar characteristics and production systems. With this reservation in mind, the comparisons can give a useful indication of the production and economic efficiency of an enterprise (Kamau *et al.,* 2020).

In the theory of technology adoption, low agricultural technology adoption rates are caused by low levels of economic factors (Zavale *et al.,* 2015). Technology adoption takes a process that potential adopters go through to evaluate technical, economic, and socio-factors associated with the use of it (Mwangi and Kariuki, 2015). For hybrid maize in the analysis of farmers' decisions to adopt technological innovations, researchers always take different directions and various socio-economic or demographic variables have often been considered as a major constraint in reducing the rate of adoption (Tugeineyo, 2020).

According to Bandiera and Rasul (2006), the theory of the Technology Acceptance Model (TAM) is the most used framework in predicting information technology adoption. TAM helps to analyze factors affecting adoption intentions beyond perceptions of convenience and usefulness. This model indicates that the profitability of adoption is uncertain and exogenous when farmers discover the true profitability of adopting the new technology and they are more likely to adopt it. At first, farmers may not take up a new technology because of imperfect knowledge about its management; however, adoption finally occurs following their own and neighbors' experiences. The understanding of farmers' perceptions of a given technology is thus crucial in the generation and diffusion of new technologies (Alomia-Hinojosa *et al.,* 2018). For IRM technology to be adopted its beneficiaries must be fully conceptualized within the farming systems and resource limits (Tugeineyo, 2020). However, there is no empirical research that has analyzed smallholder farmers' gross margins on the production of the IR and LM and the factors affecting profitability, yet the technology appears lucrative in providing economic gains to farmers faced with the problem of Striga infestation.

Previous studies on IRM have focused on management options for *Striga* infestation and maize grain yields (Kanampiu *et al.,* 2018) and *Striga* control technologies and their dissemination (Oswald, 2005). However, management options, agronomic, and dissemination results alone do not provide complete direction when assessing the benefits of a given technology. More insights from an economic point of view are crucial to enable farmers to make decisions based on the profitability of the technology. Other factors like production costs, season harvests, sources of farm inputs, and markets for the produce affecting profitability are vital. It is against this background that the study sought to conduct a gross margin analysis of IRM technology in Eastern Uganda.

Methodology

Project and Study Area Profile

Striga control in the maize project started on a 3 years' timeframe plan (i.e 2015-2017). Prior to commencement, a sequence of baseline surveys was conducted in greater Eastern Uganda in the early 2011s. The project was objectively implemented on (i) evaluation and commercialization of the usage of IRM seeds by smallholder farmers, and (ii) increasing production of maize and income through the use of IR maize seeds. The project was implemented in the region with 6 districts of Mbale, Bugiri, Sironko, Iganga, Tororo, and Mayuge where *Striga* infestation was majorly a problem.

Plant Materials

There were two types of maize varieties with different characteristics of resistance and susceptibility to *Striga* attack in the field. The two varieties were the imazapyr IRM (Longe 5H-IR) and local maize, the farmer's most preferred Open-Pollinated Variety (OPV) in comparison as a control check.

Imazapyr Herbicide and Agronomic Practices

Small quantities of Imazapyr (as little as 30g/ha) act before or at the time of Striga attachment to the maize root and so prevent the phytotoxic effect of Striga on the maize plant, thus enabling the plant to grow to its full potential. Additionally, Imazapyr that is not absorbed by the maize seedling diffuses into the surrounding soil and kills ungerminated Striga seeds. The low-dose herbicide seed dressing used in the technology controls Striga without impacting sensitive intercrops when planted 10cm away from the maize hills. This allows smallholder farmers who practice intercropping to incorporate this technology in their farming systems. In deployment of Striga management agronomic practices, farmers are encouraged to incorporate soil fertility practices such as use of legume rotation and intercrops and fertilizer additions to replenish soil nutrients and optimise crop yields.

Sampling and Data Collection

The project was implemented for 3 years and benefited many farmers affected by *Striga* weed. For accuracy reasons, only 120 farmers were used for the study. The study employed a purposive sampling design in selecting both farmers and districts where the project was implemented. This design was chosen because the researcher already knew all farmers that were consistently growing both IR and LM on the same field trials in comparison for 3 consecutive years of project implementation and districts. Purposive sampling of 20 smallholder farmers from each district out of six districts was done thus making a total sample size of 120 farmer households. Data was collected by known partner Field Extension Workers under the guidance of the Project Officer (Researcher) on variables such as prices, maize yields, production costs, maize sales, and adoption determinant factors. Data were collected by the use of interviews, focus group discussion and observation methods, and a structured questionnaire tool.

Empirical Model Estimation

Gross Margins of IRM and LM Farmers

Gross Margin Analysis (GMA) method was applied to determine the profit levels of two maize varieties used in the *Striga* control project. In the field trial, the method was considered the best due to the nature of data collected, simplicity, and accuracy (Kasonga, 2018, Tugeineyo and Hella, 2011). One of the objectives of the study is to establish income and profit levels generated from two maize varieties grown by farmers, the method helps to evaluate the profitability performance of two crop varieties and gauges the potentiality to generate income for farmers. The difference between total revenue (TR) and total variable costs (TVC) and returns to factors of production refer to the gross margin as explained by Johnsen (2003). It was stated and computed as follows;

$$GM_i = V - C = PQ - \sum^{n} P_i Q_i \quad \text{.............................} (1)$$

Where:

Σ = Summation sign, V = Value of production, C = Total cost of production, P = Price of the produce, Q = Total production, pi = Price of inputs per unit and qi = Quantity of inputs per unit

Factors Affecting Adoption of IRM and LM Varieties

The binary logistic regression model was used. The model was preferred due to its potential to describe the nexus between dependent and independent variables and also the type of variables. The adoption is a dummy dependent variable (Y) with two limits of values (0) if the farmer remains on local maize production for no gain and (1) if the farmer adopts IRM for gain under Striga infested area. The independent variables were; gender of farmer, age of farmer, level of education, gross margin, farming experience, farm size, total variable costs, and total harvests. Data on all variables were subjected to Statistical Package for Social Sciences (SPSS) (2008). The model was stated as follows:

$$Logit(Y_1) = \ln\left[\frac{P(Y_1 = 1)}{1 - P(Y = 1)}\right] = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + ... + \beta_n X_n + \varepsilon^i \quad (2)$$

Where:

$P(Y_1 = 1)$ is the probability of adoption of IRM divided by the probability of adoption of LM (1 if the farmer found IRM profitable and 0 if the farmer found no profits in local maize), α = constant coefficient, x1-xn = independent variables and ei= error term.

Results

Descriptive Analysis of Striga Control Project Farmers

The study used 120 *Striga* control project farmers based on farming households. Among the interviewed farmers, 60% were female and 40% were male. Farmers (36.7%) were aged between 31-40 years and 18.3% of farmers were of the age group 19-30 years as summarized in Table 1.

Table 1: Results of age, education, marital status, and gender of farmers

Variables	Frequency (n)	Percent (%)
Age bracket (years)		
19-30	22	18.3
31-40	44	36.7
41-52	28	23.3
53-64	26	21.7
Total	120	100
Education		
Informal education	20	16.7
Primary education	71	59.2
Secondary education	28	23.3
Post-secondary education	1	0.8
Total	120	100
Gender		
Female	72	60.0
Male	48	40.0
Total	120	100

Results also showed that 16.7% of the farmers had informal education, 59.2% for primary education, 23.3% had secondary education, and 0.8% of the farmers had post-secondary education.

Gross Margins of IRM and LM Farmers

The results of the gross margin analysis of farmers for 3 years of project implementation are shown in Table 2 below. The gross margin for each farmer per annum over of three years showed considerable differences between IRM and LM in *Striga*-infested areas. The IRM had a higher average GM of Ug.sh 7,717,500 compared to LM with Ug.sh 4,794,000). The TVC for IRM were Ug.sh 2,080,000 and Ug.sh 1,890,000 for LM for 3 years. The net profit was Ug.sh 5,637,500 for IRM while Ug.sh 2,904,000 was for local maize.

Table 2: Profit margins for IRM and LM varieties/farmer/year (Ug.sh)

Variables	IR Maize			Local Maize		
	Year 1 (Ug.sh)	Year 2 (Ug.sh)	Year 3 (Ug.sh)	Year 1 (Ug.sh)	Year 2 (Ug.sh)	Year 3 (Ug.sh)
Sales						
Maize flour	493,400	510,000	612,000	-----	-------	-------
Maize grains	751,000	845,000	915,000	645,000	690,000	492,000
Maize fresh cobs	72,500	610,000	710,200	681,000	580,000	446,000
Maize fodder	186,500	204,500	265,000	------	------	-------
Maize cob husks	196,000	210,500	270,000	495,000	380,000	385,000
Maize mash	273,500	282,000	310,400	-------	-------	-------
Sub Gross Margin	1,972,900	2,662,000	3,082,600	1,821,000	1,650,000	1,323,000
Gross Margin			7,717,500			4,794,000
Variable Costs						
Cost of seeds	24,000	24,000	24,000	6000*	6000*	6000*
Land opening	120,000	100,000	90,000	120,000	100,000	90,000
Planting cost	30,000	30,000	30,000	30,000	30,000	30,000
Fertilizers	96,000	96,000	96,000	96,000	96,000	96,000
Pest control	60,000	60,000	60,000	60,000	60,000	60,000
Disease control	60,000	55,000	50,000	60,000	65,000	66,000
Transport for seeds	50,000	50,000	50,000	----	------	------
Weeding	35000	30000	27000	40,000	40,000	40,000
Harvesting	45000	50,000	55000	40000	36000	34000
Threshing	60,000	70,000	80,000	40,000	36000	32000
Storage materials	70,000	85,000	100,000	65,000	60,000	50000
Maize loss	40,000**	38,000**	40,000**	80,000**	100,000**	120,000**
Sub Total Costs	690,000	688,000	702,000	637,000	629,000	624,000
Total Costs			2,080,000			1,890,000
Net Profit			5,637,500			2,904,000

**The varied estimated maize losses per farmer/year/variety, * the estimated cost of local maize seed per year, -- no sales and costs on LM, and Ug.sh-Ugandan Shillings

In the cost and profit context, on local maize variety; some variable costs such as costs of seeds for planting were estimated (denoted value*) while costs for transporting seeds for planting from sources were not incurred. Additionally, on the sales side, maize mash (i.e partialy milled maize grains, commonly used for poultry birds, pigs and dairy animals as feeds), flour, and fodder were not sold due to little or no surplus for sale that is why the net profit margin of local maize remained far below 50% more than that of imazapyr-resistant maize. Other variables like weeding and harvesting of the IRM and LM varied significantly due to different availing field conditions. For instance, under IRM field, costs for weeding reduced gradually from year 1 to 3 as aresult of the canopy of IRM in a *Striga* free environment which helped to suppress the growth of weeds as opposed to local maize with less canopy because of *Striga* infestation problems. On the other hand, more harvesting happened in *Striga* free fields hence more harvesting labor costs incurred as opposed to LM fields. Fertilizer usage could not be the same in both fields because during project implementation, the two fields and two maize varieties were subjected to similar conditions and treatment in order to capture realities in the two fields under *Striga* infestation.

Factors Affecting Adoption of IRM and LM Farmers

The factors affecting the adoption of IRM and LM varieties in *Striga*-infested areas were determined by the binary logistic regression model in SPSS version 16 of 2008. Of the eight variables: gender of the farmer (1), age of the farmer (2), level of education (3) gross margins (4), farming experience (5), farm size (6), total variable costs (7), and total harvests (8) entered in the logistic regression model, only five variables: level of education, gross margins, farm size, total variable costs, and total harvests were statistically significant in influencing IRM and LM's adoption. The variables that were statistically insignificant and unrelated were dropped from the former equation of eight variables and formed the later equation that contains five variables: level of education (3), gross margins (4), farm size (6), total variable costs (7) and total harvests (8) as follows;

$$Logit(Y_1) = \ln\left[\frac{P(Y_1 = 1)}{1 - P(Y = 1)}\right] = \alpha + X^3 + X^4 + X^6 + .X^7 + X^8 \quad ..3$$

Model Estimation

The full binary logistic regression model containing all variables was statistically significant at p<0.05. The model summary statistic value was 14.563 at -2 log-likelihood. The Cox & Snell R^2 was 0.614 and Nagelkerke R^2 was 0 .815. Accuracy prediction of 81.5% was recorded in identifying variables affecting the adoption of IRM and LM with only 18.5% representing variables that were unrelated and insignificant. The results are summarized in Table 3.

Table 3: Results on determinant factors of IRM and LM adoption

Variables	Standardized Coefficients of the Model				
	B	S. E	Wald	Sig	Exp(B)
Gender of a farmer (1)	-0.045	0.721	0.104	0.160	0.956
Total harvest (8)	8.346	4.117	6.314	0.012***	0.000
Gross margin (4)	0.032	0.012	6.900	0.009***	0.969
Total variable costs (7)	0.391	0.138	8.070	0.005***	0.676
Age of farmer (2)	1.273	0.764	2.774	0.196	3.571
Farming experience (5)	6.055	9.691	1.932	0.263	0.443
Farm size (6)	5.115	1.039	0.708	0.000***	4.924
Level of education (3)	0.982	0.473	0.216	0.047**	2.076

Note: B-Beta, S.E-Standard Error, Sig-Significance (p-values), Exp (B)-Expected Beta
***, **,* - Statistically significant at 1%, 5% and 10% respectively

Discussion

Descriptive Analysis for Striga Control Project Farmers

Striga control in maize project was implemented in Eastern Uganda and a region that largely attracts both male and female farmers to grow cereal crops, particularly maize. The rationale for considering gender balance in the project and technology adoption too relates to agricultural productivity, food security, poverty reduction, and employment. Gender dimensions in this project were put into account because gender balance affects decision-making on the choice of crop and allocation of resources for production and especially the heads of households highly influence this process. This finding is in line with the former findings of Karane (2016) who states that men are attracted to agricultural activities which generate sizeable income. This means men had the potential for taking up IRM in generating high incomes for their families.

The average age of the farmers interviewed was 42 years. This is considered an active and vibrant age that probably reflects an aspect of innovations for profit. This finding is almost similar to earlier findings of Singh *et al*. (2014) who explained that age has a significant effect on experience, wealth, and decision making and affects how one works thus influencing individual productivity. Onyango (2010), similarly had his findings explained that the young farmers in the age group of 15-64 years are regarded as economically productive and farmers in the age bracket of 65 years and above have deteriorating productivity.

The farmers with different levels of education were interviewed. Education is an important factor in any economic activity and increases farmers' ability to adopt innovations because they are able to take up new farming techniques and compare their impact easily. This is similar to earlier findings of Mbata, (1994) who argued that agricultural development requires abroad educational base in order to prosper.

Gross Margins of IRM and LM Farmers

The gross margin analysis results for each farmer per annum over three years showed considerable differences between IRM and LM in *Striga*-infested areas (Table 1). Results of the study indicated that adopted IRM generated greater average gross margins than LM annually per farmer in comparison. The IRM also had higher average GMs and production costs compared with LM. The low gross margins for local maize variety were a result of little and/ or no sales of maize flour, little fodder and mashes out of seasonal harvests due to the *Striga* attack and low yields were obtained to satisfy consumer demands thus implying that the farmer had no surplus for sale. Additionally, under *Striga* infestation conditions, maize plants tend to be weak and susceptible to drought, pest, and disease stress. The postharvest constraints such as excessive rainfall, breakages, leakages, and thieves result in a reduction in maize quality and yields. The farmers would establish their profitability efficiency of two maize varieties in *Striga*-infested areas if the total gross margins are divided by total variable costs.

Most farmers have not been motivated to increase the use of hybrid maize seeds regardless of the entangled *Striga* infestation problem in their maize farms. They have continuously concentrated on the use of large gardens for production with less attention to productivity dimensions that entail innovations for high yields. Low production adversely affects the output and profitability of the maize crop. It was observed that the more sales products IRM farmers had, the higher the profits compared to LM farmers. This implies that the good use of IRM seeds leads to high profits to high yields produced as opposed to local maize. These finding lines well with the earlier findings of Mogedi (2014) who states that when farmers access good innovations, production is also pushed higher thus gaining good gross margins in the end.

This implies that farmers in the innovation take the higher value of markets for their crop and earn more from it.

Factors Affecting Adoption of IRM and LM Varieties

The binary logistic regression analysis shows that the adoption of IRM and LM is affected by the level of education, gross margins, farm size, total variable costs, and total harvests. Accuracy prediction of 81.5% implies that the researcher suitably identified relevant variables affecting the adoption of IRM and LM with only 18.5% representing a few irrelevant variables.

The study established that the total harvests obtained from IRM and LM by a farmer have a significant influence on adoption. From farmers' perspective, farming is done purposely for food and just a small surplus for sale. However, on occasions where a farmer harvests extremely high quantities of produce, big volumes of harvests are sold off for income and thus profits are realized from big sales. Notably, most farmers who consistently grew IRM and LM concurrently for 3 years of project implementation, obtained higher profits from IRM due to big harvests per annum compared to lower profits from LM due to low harvests in *Striga*-infested areas.

During *Striga* control project implementation, each farmer was encouraged to have at least a 20m by 20m ($400m^2$) field for IRM and LM placed alongside each other on *Striga*-infested land. It is commonly observed that most farmers are planting local seeds on less than an acre. Therefore, planting in a field of $400m^2$ was taken by farmers as an increase in farm size to an average of 0.09 acres which is one of the factors positively affecting both yield output and sale returns of maize. Therefore, the bigger the size of the field, the higher the maize yields obtained holding other factor constant.

The study found that the total variable costs have a strong influence on the production and adoption of both IRM and LM. It was established that the cost of production for both IRM and LM was high thus eroding farmers' gross margins and profits per annum. The intensity of costs adversely affecting adoption was higher for LM due to low gross margins obtained per season. The sales of LM were also low thus generating low gross margins being affected by costs.

The analysis finds that the education level of a farmer is an important factor influencing the adoption of both IRM and LM. The regression coefficient of the level of education was 0.982 which showed a positive correlation between IRM and LM adoption. The variable was statistically significant at a p-value of 0.047. Education makes a farmer innovative and has a strong ability to understand the concepts of adoption from various pieces of training on new technologies and innovations. Education is a very important socio-economic factor than any other economic factor in determining and increasing farmers' ability to obtain, process, and use information relevant to technology adoption (Tugeineyo and Hella, 2011) and how one technically performs an activity (Mbata, 1994).

Conclusion

Striga invasion being a major problem in low productivity of cereal crops like maize, sorghum, rice and pearl millet in East African Countries, introduction of herbicide resistant crops is one of the effective management techniques when used in integration with other agronomic approaches. However, precautions need to be taken to minimize the negative effects of transgenic crops on long term basis. The whole Eastern Region of Uganda is largely dependent on cereal crops as the main source of food and income. The cereal crops (maize, millet, sorghum, and rice) and farmers are vulnerable to *Striga* infestation and imazapyr-resistant herbicide has come become a solution to farmers operating under this condition. The costs, gross margins, total harvests, farm size, and level of education are the main factors influencing the adoption of this adoption.

It is recommended that smallholder farmers with *Striga* on ther land should adopt Imazapyr Resistant technology to reap higher output and profits. Farmers should be well-linked to agro-dealers, and seed companies to sustainably supply inputs, knowledge, or experience in order to remain operational even at the end of the project's work.

To the funders (USAID-Feed the Future) and key initiators of the project-AATF, there is a need to first harmonize with all relevant key stakeholders particularly government ministries and other private sector actors to facilitate sustainable input supply chains even after the project's completion. This is because many times, project stakeholders are supported only for a specific timeframe like 3 years, and thereafter, they remain stuck with no alternative source of inputs to carry on on their own.

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Statement of No-Conflict of Interest

The author declares that there is no conflict of interest in this paper.

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