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An economic analysis of adopting new imazapyr resistant maize in eastern Uganda

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ABSTRACT

Witch weed (Striga) is a major constraint to maize production in Sub-Saharan Africa. New imazapyr-resistant maize (IRM) technology appears to be effective in controlling the weed. This study was conducted to analyze the economics of adopting IRM technology alongside local maize (LM) in Eastern Uganda based on sample size of 60 farmer households with two maize variety fields (IR and Local Maize). The data were collected for six seasons in three years of project implementation. The two commercially imazapyr resistant maize varieties in the trial were Longe 5H-IR and Victoria 3H-IR in comparison with local maize. Results showed a considerable difference in profit between IRM (Ug.sh 6,107,500) and local (Ug.sh 3,672,800) in Striga infested area. The Striga counts and maize variety yields were inversely related. The outcome of regression analysis showed that level of education by host farmers, distance to source IRM seeds, yields of a variety, Striga counts, land Striga status and food shortage were the major factors influencing adoption of IRM. Accordingly, there is need to have a well-defined system that links farmers, agro-dealers, and seed companies through which knowledge and experiences can easily be shared and allowing the players to become more efficient and productive.

Keywords: Adoption, Economic benefit, Imazapyr resistant maize, maize yield, *Striga* spp, Uganda

RÈSUMÈ

L'herbe-sorcière (Striga) est une contrainte majeure à la production de maïs en Afrique subsaharienne. La nouvelle technologie consistant à développer du maïs résistant à l'imazapyr (IRM) semble être efficace pour lutter contre les mauvaises herbes. La présente étude a été menée pour analyser les aspects économiques de l'adoption de la technologie IRM aux côtés du maïs local (LM) dans l'est de l'Ouganda. Un échantillon de 60 ménages d'agriculteurs a été utilisé avec deux champs de variétés de maïs (IR et maïs local). Les données ont été collectées pendant six saisons en trois ans de mise en œuvre du projet. Les deux variétés de maïs commercialement résistantes à l'imazapyr dans l'essai étaient Longe 5H-IR et Victoria 3H-IR par rapport au maïs local. Les résultats ont montré une différence considérable de profit entre l'utilisation de l'IRM (Ug.sh 6 107 500) et celle de la variété locale (Ug.sh 3 672 800) dans la zone infestée par le Striga. Les dénombrements de Striga et les rendements des variétés de maïs étaient inversément proportionnels. Le résultat de l'analyse de régression a montré que le niveau d'éducation des agriculteurs hôtes, la distance à la source des semences IRM, les rendements d'une variété, les dénombrements de Striga, le statut de Striga des terres et la pénurie alimentaire étaient les principaux facteurs influençant l'adoption de l'IRM. En conséquence, il est nécessaire d'avoir un système bien défini qui relie les agriculteurs, les agro-

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négociants et les entreprises semencières à travers lequel les connaissances et les expériences peuvent facilement être partagées et permettant aux acteurs de devenir plus efficaces et productifs.

Mots clés : Adoption, Avantage économique, Maïs résistant à l'imazapyr, Rendement du maïs, *Striga* spp, Ouganda

INTRODUCTION

Striga is commonly known as witch weed and with other different given local names in Sub Saharan Africa (SSA). The weed attacks cereal crops such as maize, sorghum, rice, finger millet and Napier grass species (Mignouna *et al*., 2011). Striga infests nearly 100 million hectares in SSA (Menkir *et al*., 2012b) and causes yield losses ranging from 20% to 80% with total crop failure in cases of severe infestation (Khan *et al*., 2006). In maize alone, the weed causes harmful effects whereby about 2.5 million hectares of land suffer grain losses of 30 to 80% (Makumbi *et al*., 2015). This leads to economic losses of US $1 billion annually. The efficiency and profitability of maize production is often constrained by Striga, especially *Striga hermonthica* Benth. In some cases, Striga infestation leads to complete loss of the local maize varieties and wide decline in soil fertility; the latter favours Striga proliferation (Kanampiu *et al*., 2018; Oswald, 2005).

Farmers use traditional Striga control methods and technologies such as uprooting, burning, manuring, and pug.sh-pull which have been transferred to farmers over decades but have failed to contain the problem. The continued attempts to combat Striga by uprooting and burning during weeding have not reduced the parasites infestation thus leading to an enormous seed bank in the soil (AATF, 2009; Menkir *et al*., 2010). However, use of imazapyr-resistant maize (IRM) technology which utilizes herbicide resistant maize seed, coated with the herbicide (imazapyr) have been put in place to control Striga without impacting intercrops when planted at 10 cm away from the maize hills. The adoption of this technology has become paramount in reducing yield loss caused by Striga to smallholder farmers in Eastern Uganda. The adoption of this technology varies among economic units, areas and attributes of the technology itself.

In Eastern Uganda, maize remains the main source of food and income for most farmer households. However, maize yields have reduced in the region due to infestation by the parasitic weed together with other constraints like declining soil fertility, climate change, pests and diseases. This reduction has caused food insecurity and less of income in the affected areas. As an intervention to reduce or control Striga in maize and increase yields, AATF and A2N introduced IRM technology to maize farmers in Eastern Uganda from 2015 to 2017. The IRM technology was deemed appropriate in providing economic benefits to farmers faced with the problems of Striga infestation.

As per technology adoption theory, the causes of low agricultural technology adoption rates have elicited a large economic literature. Many researchers agree that technology adoption is a process that potential adopters go through to evaluate technical, economic and socio factors associated with the use of technology. Technological adoption models initiated by pioneering work on adoption of hybrid maize in the analysis of farmers' decision to adopt technological innovations took a different direction (Zavale *et al*., 2015). Various socio-economic, structural or demographic variables have often been considered as a major factor reducing the rate of adoption of any kind of innovation (Mwangi and Kariuki, 2015).

The theory of Technology Acceptance Model (TAM) is the most used framework in predicting information technology adoption (Paul *et al*., 2003). Lee and Jun (2007) argued that TAM should be able to analyze factors affecting adoption intentions beyond perceptions of convenience and usefulness. Though TAM had received much support, it focused on the effects of perceptions of the technology's usefulness and convenience on adoption intentions (Lai and Zainal, 2015). The use model of learning indicates that the profitability of adoption is uncertain and exogenous when farmers discover the true profitability of adopting the new technology, they are more likely to adopt the technology. Initially farmers may not adopt a new technology because of imperfect knowledge about management of it; however, adoption eventually occurs due to own experience and neighbours' experience (Bandiera and Rasul, 2006). The understanding of farmers' perceptions of a given technology is thus crucial in the generation and diffusion of new technologies and information dissemination (Alomia-Hinojosa *et al*., 2018). Therefore, this paper analyses the economic effects of adopting IRM varieties under Striga control project in Eastern Uganda. From 2015 to 2017, evaluations of IRM field trials were conducted during field days and post-harvest activities in villages of; Nakaloke, Bukasacha, Nagongera, Rubongi, Busenda, Kityerera, and Igombe in Eastern Uganda. Participatory evaluation data were collected from farmers and other stakeholders namely extension workers and project officers. Seed companies also did performance evaluation at production sites which encouraged promotion of the outputs through seed multiplication. The technical dimensions in adaptation trials were cross-evaluated by the National Agricultural Research Organization (AATF and A2N, 2017).

Research Approach:

Striga control project and its commercialization strategies. Striga control project started in 2015 and ended in 2017 after a series of socio-economic baseline surveys conducted from early 2011s in Eastern Uganda. The surveys identified five constraints affecting maize production in the region. The constraints included; i) reduced maize yields, ii) increased costs of Striga control, iii) increased food insecurity, iv) reduced soil fertility and v) reduced maize sales. The major objectives of the project were to; i) evaluate and commercialize the usage of IRM seeds to smallholder farmers, ii) increase production of maize while controlling Striga, and iii) increase on smallholder farmers' income through the use of IR maize seeds. The project used experimental field approach to market its IRM varieties to the farmers in the region. The project was implemented in six districts namely; Bugiri (0.573099 N 033.745863 E), Tororo (0.705952 N 034.184210 E), Iganga (0.609549 N 033 719261 E), Mayuge (0.457629 N 033 480532 E), Mbale (1 080146 N 034 185460 E) and Sironko (1 231040 N 034 249178 E) where Striga infestation was a major problem.

Plant materials. Three types of maize varieties with dissimilar traits of herbicide (imazapyr) resistance, and susceptibility to Striga were used in the study. The two commercially herbicide (imazapyr) - resistant maize varieties in the field were Longe 5H-IR and Victoria 3H-IR locally known as "Kayongo go, EKayongo and Emoto" whereas the farmers preferred variety (local maize), an open pollinated variety (OPV) was selected as a susceptible check in the project area.

On-Field trials. Naturally infestated fields were selected from farmers' land that were purposively identified and known to be highly affected by Striga problem. Field extension workers and Project Officer managed the fields with the help from the selected host farmers. The host farmers were the key caretakers of the fields in providing agronomic activities of fertilizer application, weeding, thinning, spraying and harvesting based on the guidance from the Field Extension Workers and Project Officer. Weeding was done at three weeks after planting (WAP) and thereafter, hand pulling was done to remove weeds other than Striga. Fertilizer was also applied to the fields especially Diammonium Phosphate (DAP) which was used during planting at a rate of 50 kg N and 128 kg P_2O_5/ha, and top-dressing was done at six weeks after planting (WAP) with Urea at a rate of 50 kg N/ha.

Data collection. The number of germinated Striga plants was recorded at 8, 10, and 12 WAP/season. The summation of Striga plants per field for the three years of project implementation was done and expressed as Striga counts per hectare. At harvest, maize stands were counted and cobs were handpicked from net field while excluding maize plants from the first two rows by all sides. Damaged ears were also excluded to have a representative sample for ears to be shelled in order to determine maize grain weight (tones/ha). Grain moisture at shelling was tested (13%) by using moisture content machine. The total sample size of farmer households selected for the study was 60 (i.e; only farmers who consistently grew both IR and LM per season per year for the three years) respondents and were randomly picked from six districts. The data were collected from the same 60 farmers every season from 2015 to 2017 growing both IR and LM under Striga infestation.

Host farmers' selection criteria and dimension of experimental sites. Prior to the commencement of the Striga control project in Eastern Uganda, key beneficiaries (farmers) of the project were selected to become hosts of the field sites (demo sites) under three criteria, i.e; i) Participatory research selection criterion, ii) Participatory varietal selection criterion, and iii) Participatory plant breeding selection criterion as described below.

Participatory research is one of the criteria that was used in this project. The beneficiaries of the project were first involved in pre-suggested activities before the project started. Generally, it was the type of research where users or beneficiaries (farmers) got involved in the design and not merely in the final testing or adopting of a new technology, thus received tips on the project. In this case, maize farmers from six Striga affected districts were reached through local council ones (LC1s) leadership mobilization. As project implementers, maize farmers' production constraints were already known via research and experiences and in such community meetings, experiences were shared and this enabled introducing the project idea to farmers at the beginning of the Striga control project in the area. At this stage in time, farmers were free to accept or not accept the idea. Those who were willing to participate were registered for initial stages. This criterion was also earlier used by Yazici and Bilir (2017) in the development of appropriate crop production technologies for sites in Ethiopia.

Participatory plant breeding selection criterion was also used in the project. Before the project kicked off in the target Striga infested areas, the project implementing team first conducted consultative meetings with farmers, extension workers, seed producers, agro dealers and other NGOs to participate and collaborate in the development of new varieties. The full participation gave a clear yardstick and direction on whom to select or not as host farmer for this project. It was through these meetings that the fore mentioned people shared detailed information about prospective farmers and profiling other factors qualifying them as hosts. This criterion is also supported by earlier studies of Yazici and Bilir (2017) who explained that selecting farmers on their own fields or near-finished plots for learning and production is crucial and has different impacts on biodiversity.

Participatory variety selection criterion was also applied. Before the project started, farmers were first told that to qualify as host, one must have preferred local seed variety at home to be compared with IRM varieties in demonstration sites prepared. This criterion also considered possession of land infested with Striga and the condition that before being considered the host, they agreed to monitoring by project implementing staff. This criterion was earlier used by Yazici and Bilir (2017) who confirmed that it is a simple way for field extension workers to learn which varieties perform well on-farm and preferred by farmers. Participatory varietal selection criterion helps to identify farmers' needs; search for suitable material to test with farmers; and experimentation on farmers' fields. It is further articulated that participatory variety selection criterion can be effectively used to identify farmers acceptable varieties that are better than old and obsolete varieties with which farmers stick for long period. It is also vital that the adoption of new seed is much faster than under the formal crop improvement and also the spread of varieties from farmer-to-farmer through the local seed system can be very fast, thus guaranteeing higher.

Dimension of experimental sites. As per the Striga control project, experimental sites were called demonstration or field sites and were prepared by host farmers under the guidance of field extension workers while following demonstration establishment protocol set by the funding agency. While following the establishment protocol, the demo size was set at 40 m x 20 m (800 m^2). Each demonstration had two plots, one plot for IRM and the other for LM. The plot size was 20 m x 20 m (400 m^2). Planting seed rate was at three seeds per hill with standard spacing of 75 cm x 60 cm. Each plot had 28 rows with 33 hills/row and one metre was left between two plots.

Analytical approach. A number of different methods were used including; logistic regression analysis, gross margin analysis and t-test analysis as described in subsequent sections below.

Regression analysis. Logistic regression analysis was carried out to determine factors influencing adoption of IRM by farmers. The Logit model is based on the plausible assumption that a farmer makes the decision to adopt technology to certain level only if it maximizes its perceived utility. The decision to adopt or not to adopt a technology or innovation is a discrete choice. There are several discrete choice models that can be used to analyze farmers' technology choice decisions. These include Logit, Tobit and Probit models (Abebaw and Belay, 2001). In theory, the discrete decision of whether to or not adopt a new technology is modeled as utility maximization function (Awotide *et al*., 2016) and it is specified as follows;

$$\text{Max } (U)=U(FF_{ji},TA_{ji} \ldots\ldots\ldots\ldots \quad (1)$$

Where; U (.) is the non-observable utility function that ranks the preference of the i^{th} farmer for the j^{th} technology ($\forall_j$ =1, 2); 1 is for IRM whereas 2 is for LM varieties, respectively. The FF is defined as the field and farmers' attributes and TA is defined as other attributes of technology that may be unobserved by the author but observed and acted upon by the decision makers (farmers). Therefore, the relationship between the utility derived from j^{th} technology is a function of FB, TA and a disturbance term with zero mean. It follows that equation (1) can be presented as;

$$U_{ji}=\alpha_j F_i(M_i,A_i)+e_{ji} \ \forall \ (j=1,2;\ i=1,2,\ldots,n)\ldots\ldots\ldots\ldots(2)$$

Since utilities U_{ji} are randomized, the i^{th} farmer will select alternative j= 1 when $U_{1i} > U_{2i}$ or the non observable (latent) random variable $Y^* = U_{1i} - U^2_i > 0$. The probability that Yi=1(i.e., the farmer adopts IRM is function of independent variables and is represented as:

$$\begin{aligned}
P_i &= pr(y_i=1)=pr(U_{1i}>U_{2i}) \\
&= pr[\alpha_j F_i(M_i,A_i)+e_{1i}>\alpha_j F_i(M_i,A_i)+e_{2i}] \\
&= pr[e_{1i}-e_{2i}>F_i(M_i,A_i)(\alpha_2-\alpha_1)] \ldots\ldots\ldots \quad (3) \\
&= pr[u_i>F_i(M_i,A_i)\beta] \\
&= F(X_i\beta)
\end{aligned}$$

Where x is the n x k matrix of the explanatory variables and B is a k x 1 vector of parameters to be estimated, Pr(.) is a probability function, ui is the error term and F (xi,B) is the cumulative distribution function for ui evaluated at xiβ. The specifications in equation (3) indicate that the probability that farmers will adopt an IRM is a function of the vector of explanatory variables and error term.

Empirical model. In the study where the dependent variables are qualitative in nature, regression modeling approaches are used. These include Logit, Probit and Tobit models (Gujarati, 2004). The Tobit model is used to estimate linear relationships where a threshold level is involved thus censuring below or above while Probit and Logit models are similar in that they are both binary response regression models. Woodridge (2003) and Gujarati (2004) also explained that the decision to adopt or not to adopt new technology is evaluated as a non-linear function for dependent variable and the explanatory variables. It is against this background therefore, that the stated model specification is as follows;

Let Y= 1, the probability of dependent variable adopting, Y=0, the probability of not adopting. This relationship (Y=1) can be presented as;

Pi= E (Y=1/Xi) or P (Y=1/xi), where E denotes expectation. Y=0 can be expressed as;

P (Y=0)/xi or as (1-Pi).

The odds ratio (likelihood) in favour of Y=1 are given as (Pi/ 1-Pi)..............................(4)

If (1) >1, then it implies increased odds; when (1)<1, then it means reduced odds and when (1)=1, then it indicates the equally likely odds. Thus taking natural log of equation (4) above logit Y is as follows;

ln P (Y=1/xi)/P (Y=0)/xi
= ln (Pi/1-Pi),

$$\text{Logit}\,(Y_i) = \ln\left[\frac{P(Y_i = 1)}{1 - P(Y_i = 1)}\right] = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon_i \quad \text{..................................(5)}$$

Where Yi is the dependent variable, Xi-n are explanatory variables, the probability of the dependent variable when all explanatory variables are zero; β1-n are coefficients estimated in the analysis.

Model justification. Binary logistic regression model was adopted due to the fact that the dependent variable was dummy. The regressors of the model were; the distance to source IRM seeds, age of farmer, price of IRM seeds, extension services, food shortage, farmers awareness, Striga control, maize sales, yield of a variety, gender, farmer's education, household size, land Striga status, and maturity period of the variety. The model was selected to determine the relationship between these fore mentioned factors and adoption of IRM because i) the coefficients can be interpreted in terms of odds ratios, ii) it is one of the mostly preferred regression methods that can be applied in modeling binary dependent variables, and iii) there is no precondition in the logistic regression regarding the distribution of independent variables.

Gross Margin Analysis. Assessing the profitability of two maize varieties grown by farmer using Gross Margin Analysis (GMA) technique involves estimation of total revenue and total variable costs. The difference between the two gives the gross margin, which is a measure of profit and reflects the returns to factors of production (Johnsen, 2003; Phiri, 1991). An enterprise can be considered profitable if the total revenue is greater than the total variable costs. Such an estimate provides a guide to the farmers" investment decision. Maize growing involves costs such as land preparation, planting, weeding, fertilizer application, harvesting, shelling, storage and transportation like, in other investments. Total revenue is the product of total output and price in Uganda shillings (1US $=3600 Ug.sh). The gross margin analysis provides a simple method for comparing performance of different crop varieties on farms of farmers for a given period of time (year). The variable costs relate to production at a given level of output and it was predicted that in growing both IR and local maize, costs were incurred due to Striga infestation problem. It was calculated as in Eq. (6):

$$GM_i=TR_i-TVC_i \ldots\ldots\ldots\ldots (6)$$

Where,
GM_i is the gross margin,
TR_i is total revenue,
TVC_i is the total variable costs (U_iL_i) for i=1, 2,…, n
Ui is unit cost of given input, Li is the level of input use like labour, seeds, fertilizers, storage materials, transportation, and harvesting tools.

The t- test analysis. In studies where two sample means are in comparison by difference, paired t-test method is applied (Kothari, 2006). As per this study, the whole study of Striga control project in Eastern Uganda was treated as a population. The population was grouped into two equal samples defined as IRM (sample 1) and local maize (Sample 2) grown by farmer per season per year. The t- statistic to test whether the means of two samples were different was computed as in Eq. (7):

$$t = \frac{X_1 - X_2}{sX_1X_2\sqrt{\frac{2}{n}}} \ldots\ldots\ldots\ldots (7)$$

$$sX_1X_2 = \sqrt{\frac{1}{2}(S^2x_1 + S^2x_2)}$$

Where
sX_1X_2 is the pooled standard deviation, 1 = group one (IRM), 2 = group two (Local maize). and are the unbiased estimators of the variances of the two samples. The denominator of t is the standard error of the difference between two means.

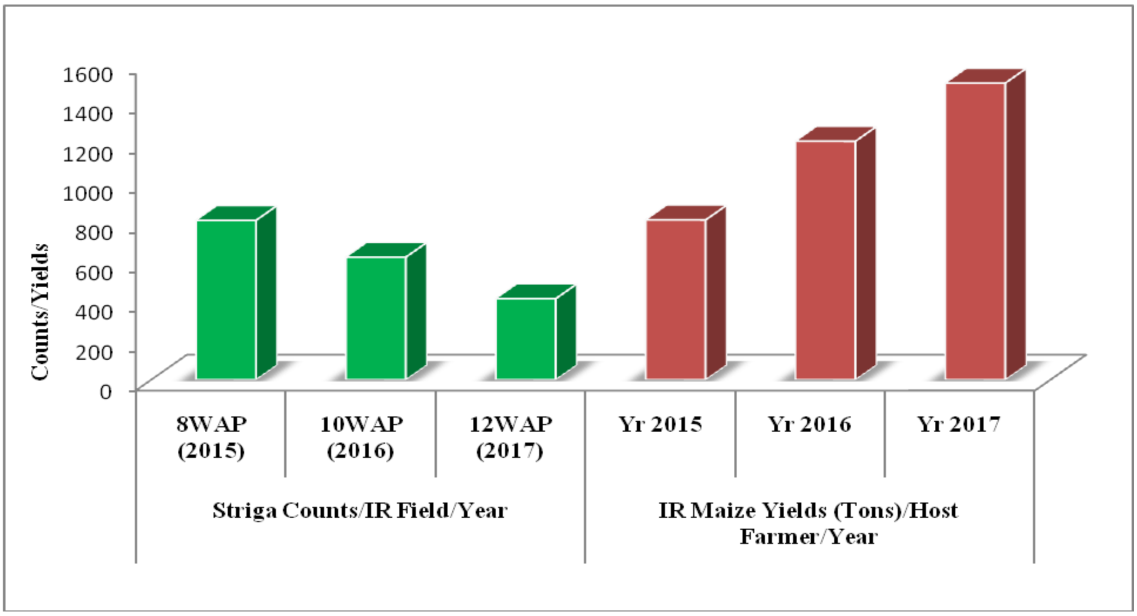
RESULTS AND DISCUSSION

Relationship between Striga counts and maize yields. Striga plants were uprooted from the fields at 8WAP, 10WAP and 12WAP per season of the year for all seasons within the three years of project implementation for IR and local maize and counted as they emerged to determine Striga counts. The local checks had the highest Striga counts and IR maize field had the lowest Striga counts. During the three years of project implementation, maize stands and cobs were counted, harvested and shelled from both fields (IR and Local) to determine the yield (kg) obtained from each field per season. There were highly significant differences between the maize stands, cob numbers and grain yield in each season of the year for both IR and local maize. Results on maize yield for each year for both IR and local maize were plotted against Striga counts for each year in order to determine the relationship. There was an inverse relationship between two variables (Striga counts and maize yields) for IR and local maize varieties (Fig.1).

The implication of this was that the decrease in the number of stands and cobs contributed to the decrease in kilograms of yield for local maize variety due to Striga parasitism that caused stunted and withered growth of most of the maize plants. Contrary, constant maize stands and cobs of IR maize as per planting hills in sustainably maintained high maize grain yields (kg) while the yield of local maize decreased with an increasing Striga counts in the fields.

Gross margin analysis of IR and Local maize varieties of farmer. The results of the analysis indicated that the profit margin of two maize varieties had significant difference under Striga infestation. The average profit margin per farmer per hectare for three years in IRM production was Ug.sh 6,107,500 much higher than Ug.sh 3,672,800 on local maize field. The average variable costs per farmer per hectare for three years of production were Ug.sh 3,160,000 for IR maize variety greatly higher than Ug.sh 2, 488,000 for local maize field as in Table 1.

a) IR Maize Field



b) Local Maize Field

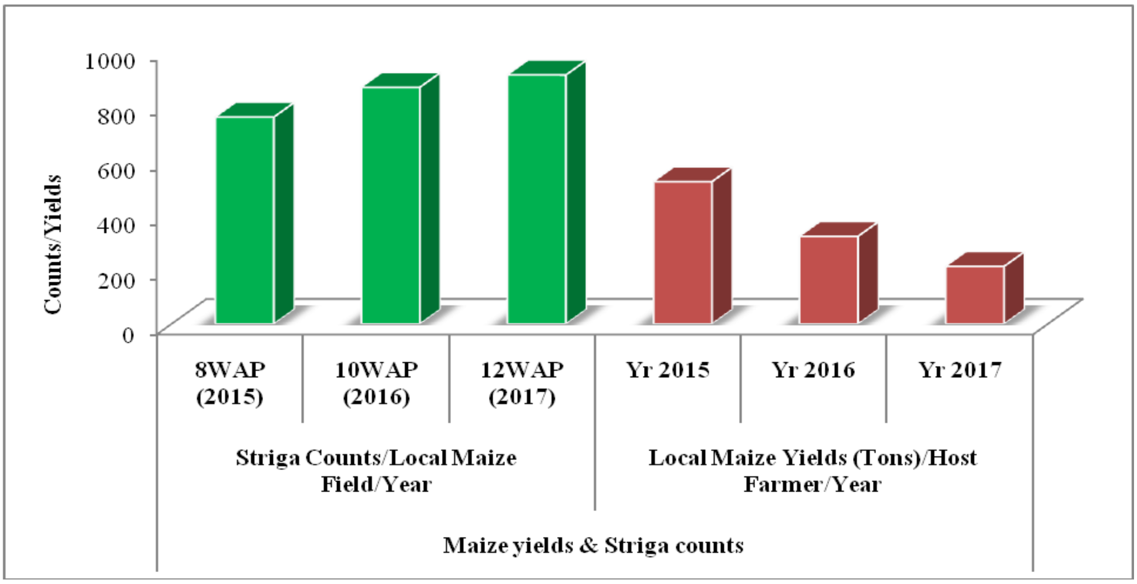


Figure 1. *Striga* counts Vs Maize yields in IR and local maize fields

Table 1. Profit margins for IR and local maize varieties in Uganda Shillings/ farmer/hectare/year

Variables	IR Maize (.000Ug.sh/ha)			Local Maize (.000Ug.sh /ha)		
	Project Timeframe (Yrs)					
Sales	Year 1	Year 2	Year3	Year 1	Year 2	Year 3
Maize flour	542,000	650,000	840,000	132,000*	146,000*	14,800*
Maize grains	926,000	1,050,000	1,150,000	850,000	700,000	510,000
Maize fresh cobs	66,500	700,000	810,000	710,000	620,000	560,000
Maize fodder	200,000	245,000	350,000	94,000*	95,000*	110,000*
Maize cob husks	230,000	240,000	300,000	550,000	430,000	400,000
Maize mash	300,000	328,000	340,000	72,000	80,000	87,000
Sub Gross Margin	2,264,500	3,213,000	3,790,000	2,408,000	2,071,000	1,681,800
Total Gross Margin		9,267,500	6,160,800			
Variable Costs						
Seeds for planting	48,000	52,000	56,000	10,000*	15,000*	18,000*
Land opening	120,000	180,000	200,000	60,000	80,000	100,000
Fertilizers	160,000	220,000	280,000	160,000	220,000	280,000
Pest control	60,000	76,000	85,000	60,000	65,000	75,000
Disease control	60,000	78,000	95,000	60,000	70,000	85,000
Transport for seeds	70,000	70,000	70,000	10,000*	10,000*	10,000*
Weeding	80,000	100,000	140,000	80,000	90,000	125,000
Harvesting	100,000	120,000	130,000	60,000	70,000	90,000
Storage materials	80,000	90,000	100,000	70,000	85,000	90,000
Maize loss	90,000**	80,000**	70,000**	100,000**	110,000**	130,000**
Sub Total Costs	868,000	1,066,000	1,226,000	670,000	815,000	1,003,000
Total Costs			3,160,000			2,488,000
Net Profit			6,107,500			3,672,800

* Low income and implicit costs on local maize, ** Varied estimated maize losses per farmer/year/ variety/hectare

** 1 Us$=3600 Uganda shillings

The total average profit margin for local maize was lower probably due to higher subsequent estimated total losses of Ug.sh 340,000 per hectare (for three years of project implementation) per farmer compared to Ug.sh 240,000 for IRM. The low gross margins on local maize could have been due to low sales of maize flour, fodder and mashes. It was however noted, that under Striga infestation with no control, the output of maize was consistently low at harvest with very little surplus for sale and the estimated maize losses were higher for local maize than IRM, thus increased. The values marked with * were associated with varying factors for instance, the cost of planting seed for local maize was treated as implicit because as per host farmers selection criteria of Striga control project, farmers were required to have their own preferred-reserved local seed. However, it was also thought that reservation time could have been associated with costs as well (Table1). Furthermore, transportation of seeds was also treated as implicit cost because IR seeds were supplied to host farmers by seed companies free of charge while local seeds were reserved by host farmers from previous seasons. However, farmer could have incurred some costs may be from residence to the field during planting and this was also estimated with value as above.

Efficiency in production is a vital factor. It was therefore, important to consider total revenue (TR) in relation to total variable costs (TVC) in order to establish economic efficiency of the two maize varieties under Striga infestation. Economic efficiency was calculated using TR/TVC ratio procedure. The ratio was 2.9 on IRM compared to 2.2 on local maize. The ratio of 2.9 on IRM was considerably desirable and efficient given the level of variable inputs in maize production compared to 2. 2 on local maize.

The annual yields of IR and LM varieties per farmer. The farmers' fields were under natural infestation of Striga. Data collected from six seasons of three years of project implementation was subjected to paired t-test method of compared means. The results revealed a significant difference in yield between IR maize variety and farmers' local maize. The comparable yield mean of two maize varieties per individual farmer in subsequent years of 2015, 2016 and 2017 was statistically significant ($p<0.001$) with a lower limits of 772.1 kg, 487.2 kg and 1717.9 kg for local maize/ha/farmer as opposed to 1339.6 kg, 966.8 kg and 1852.9 kg of IR maize/ha/farmer respectively (Table 2).

In Eastern Uganda, maize is a very important staple food and thus provides socio- economic benefits. Striga has been considered by farmers as one of the major problems limiting maize production. This study derived its justification from the fact that maize was/is the main source of food for rural farmers' households in the study area. However, there had been a decreasing trend of maize production in the area over the last decade due to Striga infestation. The study data indicate that for the last three years of the project implementation using IRM technology, there was increased maize production. In Uganda, the introduction of IRM technology has been more important for maize than any other cereal crops. This could provide lessons for increasing maize production in Striga infested areas in other parts of Uganda. An assessment of farmers' economic benefits resulting from IRM technology adoption revealed improved farmers' livelihoods in terms of food, income, nutrition and asset acquisition.

There was significant difference between IR variety and local maize during both short and long rain seasons. The most important factor that affected maize yield was Striga infestation, thus the suppression of Striga using

Table 2. Comparable yields IR and Local maize during the years 2015, 2016 and 2017

Variables	Paired Differences							
				95% CI of the Diff				
	Mean	Std. Dev	SE Mean	Lower	Upper	t	df	Sig. (2-t)
Pair 1 Yield of IRM (2015)								
Yield of LM (2015)	1.03083E3	1195.297	154.312	722.055	1339.611	6.68	59	.000***
Pair 2 Yield of IRM (2016)								
Yield of LM (2016)	7.27000E2	928.2447	119.835	487.208	966.791	6.06	59	.000***
Pair 3 Yield of IRM (2017)								
Yield of LM (2017)	1.78540E3	261.2352	33.7253	1717.915	1852.884	52.93	59	.000***

IRM-Imazapyr Resistant Maize; LM-Local Maize; *** Significant at 1%

high yielding IR-maize, and an increase in the overall yield of the crop. The average mean yield obtained from IR-maize was up to 3 tonnes per ha/farmer/season. It was also observed that the higher number of cobs for IR maize gave more maize grain yields. The higher number of IRM cobs was due to higher numbers of IRM stands which suppressed Striga infestation. This in return resulted into increased production as opposed for local maize which was affected by Striga infestation.

Factors influencing adoption of IRM technology. The data collected from six seasons of three years of Striga control project implementation was subjected to binary logistic regression of SPSS. The analysis showed an overall statistical significance ($P<0.001$). The model summary statistic value was 18.856 at -2 log likelihood. This value statistically indicated how best the model predicted the correlation between regresand (Adoption) and regressors (factors affecting IRM technology). The Cox & Snell R^2 was 0.707 whereas Nagelkerke R^2 was 0 .943 which implied that the model predicted correctly at 94.3% of the variables entered with only 5.7% representing variables that were not entered and equally to those entered and tested insignificant and uncorrelated. The results showed that 12 out of 14 variables were correlated and significant at different levels. The results further indicated that some variables in the model had both positive and negative coefficients. Some had positive relationship and strong significance levels whereas others revealed negative relationship and significance levels as well. Some variables which were completely insignificant and unrelated to adoption of IRM technology were neglected and ignored in the discussion of the results. The outcome of this model is also supported by earlier findings of Kothari (2006) who indicated that the smaller the statistic value, the better the model results (Table 3).

Table 3. Results of binary logistic regression analysis

Variables	Parameter Estimates				
	Standard Coefficient (B)	Standard Error (SE)	Wald	Sig	Exp(B)
Age of farmer (Years)	0.045	0.721	0.004	0.000	0.956
Gender (1-Male)	10.346	4.117	6.314	0.062*	0.003
Household size	0.032	0.012	6.900	0.285ns	0.969
Education of farmer (Years)	0.391	0.138	8.070	0.000***	0.676
Price of IR seeds (Shs)	-1.273	0.764	2.774	0.052*	3.571
Distance to source IR seeds (km)	-2.254	0.021	2.269	0.001***	0.724
Yield of variety (kg)	3.844	1.070	0.004	0.000***	0.956
Striga control (Counts)	0.006	0.002	6.314	0.001***	0.402
Sales (Shs)	1.358	0.557	6.900	0.054*	0.969
Food shortage (Months)	-1.235	0.563	8.070	0.028**	0.676
Land Striga status (1-Infested)	0.047	0.015	2.774	0.002***	3.571
Maturity period of the variety (Days)	-1.216	0.590	4.117	0.039*	1.570
Awareness (1-Aware)	-1.004	0.478	6.534	0.036**	1.821
Extension services (1-Yes)	0.533	0.486	2.321	0.273ns	0.436

-2 log likelihood = 18.856a , Cox & Snell R Square = 0.707, Nagelkerke R Square = 0 .943; **Significance at 1%, **Significance at 5%, Significance at 10%, Dependent variable (1 = adoption, 0 = Otherwise)

The results of the model revealed that the age of the farmer was positively correlated with adoption and this was significant. The coefficient of age showing positive relationship was 0.045 with statistical significance of $p<0.001$. The positive log odds of 0.045 were converted into odd ratio of 0.956 (Exp B) implied that older farmers' marginal propensity to adopt IRM was higher than that of young farmers. In production, labour is one of the fundamental factors and it is within the capacity of young farmers that active and cheap labour is provided for most agricultural activities. However, the old farmers play a principle role in decision making about adoption of new technologies as opposed to young farmers. Additionally, in commercial farming, experience plays a vital role and this is supported by the fact that aged farmers who were engaged in Striga control project from inception up to its completion accumulated much experience for IR maize production in Striga infested areas compared to new adopters of approximately one year in production.

The regression coefficient of gender of farmers was 10.346. Gender of the farmers engaged in IRM adoption was a dummy variable (1 = man, 0 = woman). The results of the model indicated that gender was positively related to IRM adoption and was statistically significant ($P<0.1$). The positive log odd of 10.346 with a converted odd ratio of 0.003 (Exp B) justified a positive relationship between adoption and gender of the farmers. It was clearly observed that gender balance in agricultural sector had a strong attachment towards production as it involved who makes decisions on IR usage, planning, accessibility and control. The results indicated that the male farmers took decision in the household on which technology could be taken up by the family as opposed to females except where the household was female headed.

The model showed that education was crucial and had a regression coefficient of 0.391 which was revealed positively correlated with IRM adoption. The variable was statistically significant (P<0.01). Having a positive coefficient implied that the increased level of education by farmer in terms of years of formal education exposure at them to understanding the concept of adoption of IR and its associated benefits. Education is a very important socio-economic factor that increases a farmer's ability to obtain, process and use information relevant to adopt and how one technically performs an activity.

The price of IRM seeds showed a regression coefficient of -1.273. It was negatively correlated to IRM adoption but statistically significant (P<0.05). The price is a key factor of demand and supply in any business undertaking and this implied the higher price (Ug.sh 5,000-6,000/ kg) imposed on IRM seeds by seed companies led to negative inverse relationship of imperfect demand by farmers and thus lowering adoption. Economically, one would expect the higher the current market price, the greater the supply of IRM seeds but lower demand. It was also noted that price varied from district to district in relation to seed company agents, stockiest and agro dealers. Therefore, higher prices discouraged farmers' adoption.

The distance to source IRM seeds showed a coefficient of -2.254 with negative relation to the adoption and this was statistically significant (P<0.01). The negative sign for distance implied that the long distance to access IRM seeds limited adoption in the area. Hypothetically, rural farmers have limited income to purchase farm inputs like seeds and fertilizers and worse still most seed companies are situated in Kampala, about 180 kilometres away from the project area with no agents in respective districts. Farmers gave reasons of high transport costs, fear of counterfeit seeds and lack information for limited adoption on usage of IR maize in trying to access seeds. Close proximity to the seed source enables the farmers to incur less transport costs and easy access to product information. The longer distances to the seed companies, the lower profit margin between a farmer and buyer.

The coefficient of maize yield (kg) produced was 0.306. The results indicated that quantity produced by IR and local maize varieties by the farmer was positively and significantly related to adoption (P<0.001). The positive log odds of 0.306 which were converted into odd ratio of 0.642 (Exp B) implied that an increase in the amount of maize yield produced per field of a variety encouraged a farmer to adopt IRM instead of growing local cultivar. In economic terms, larger quantities of a product produced greatly determine the level of surplus for sale to the market. Therefore, the farmers in this project obtained higher income levels from IRM sales than for local maize justifying adoption of IRM.

Awareness is an important factor for any innovations that producers particularly farmers may want to integrate themselves into their process and membership of farmer groups and associations. The coefficient of awareness was -1.004. The negative log odds of -1.004 were converted into odd ratio of 1.821 (Exp B) had negative relationship which was significant (P< 0.05) and uptake of other related technologies affected adoption of IRM. The negative coefficient implied that farmers' awareness was low to contribute to uptake of the technology and its benefits. Therefore, awareness through farmer groups, associations and organizations carries higher multiplier effects with greater likelihood of adopting IRM which in the long run results in more adoption using availed innovations.

Striga is a serious constraint to the productivity of maize. The regression coefficient of Striga control was 0.006. The Striga control was positively related to adoption of IRM and this was statistically significant (P<0.01). The positivity of the coefficient implied that farmers who had been affected by Striga infestation were willing to adopt the use of IRM. Having realized that IRM seeds were resistant to Striga attacks, their propensity to adopt IRM technology was higher than for local maize cultivar.

Results of regression showed coefficient of 1.358 for maize sales. The positive coefficient indicated that maize sales were positively related to adoption of IRM and this was statistically significant (P<0.1). This positivity of maize sales could be attributed by the fact that maize sales increased significantly when most farmers adopted the use of IRM. It is important to note that maize production in Eastern Uganda greatly depends on use of improved and hybrid seeds especially IRM. Therefore, good IRM seeds positively affect maize yields produced in highly Striga infested areas which in turn create maize yield surplus for sale.

Food availability and access are important for one to avoid hunger. The coefficient of food shortage was -1.235. The negative log odds of -1.235 were automatically converted into odd and had significant negative correlation to adoption of IRM. The negative coefficient implied that farmers experienced seasonal hunger with food shortage due to Striga infestation in their fields which left them with no or limited harvest. It was also established that farmers who had food shortage before due to Striga problem had high probability of adopting the use of IRM. Indeed, IRM technology was identified as the only viable in the management of Striga.

Results of regression showed a coefficient of 0.047 for Striga status in the field. Land Striga status was positively correlated to IRM adoption and was statistically significant (P<0.01). This was expected that since more the land is infested with Striga, the lower the land productivity in terms of maize production. This implies that to sustain and ensure high maize productivity, many farmers need to adopt the IRM technology in Striga infested areas.

Maturity period of a crop variety is one of the factors influencing farmers to grow a particular crop. Results of regression revealed coefficient of -1.216 which was statistically significant (P<0.1). The negative coefficient indicated that the more days the maize variety takes to reach its physiological maturity, the lower the adoption rate by farmers. Agronomically, most maize varieties especially open pollinated ones reach maturity stage at 100- 105 days while hybrid ones (like Longe 5H-IRM) take 110-120 days to mature. This negativity of maturity period could be attributed to the fact that IR maize takes long to mature as compared to local maize thus giving a negative perception to farmers towards adoption.

CONCLUSIONS

Maize is a major food and cash crop in Uganda but with gradual declining trends in profits. This study was conducted to analyze economic effects of adopting new imazapyr resistant maize alongside local maize cultivar under Striga infestation conditions. The study revealed higher profits from growing IRM than local maize. The profit margin differences of the two maize varieties was mainly influenced by high sales of maize grains, maize fresh cobs and maize flour accompanied by low losses on IRM while on local maize (LM) side, sales on grains, fresh cobs and flour were low and accompanied by high losses caused by Striga problem. The relationship between Striga counts and maize yields was inverse. The key factors that influenced adoption of IRM included level of education by host farmers, distance to source IRM seeds, yields of a variety, Striga counts, land Striga status and food shortage. This study recommended that farmers with land infested with Striga should be equipped with more information about IRM technology in order to reap higher yields and profits. There is need for well-collaborated system that links farmers to agro-dealers, and seed companies through which knowledge and experiences can easily be shared to allow the players to become more efficient and productive.

For the key initiators of the project, AATF and A2N, there is need to first harmonize interventions with the respective ministries and institutions especially Ministry of Agriculture, Animal Industry and Fisheries, Crop Research Institutes and Seed Companies like NASECO and Victoria in Uganda on consistent and sustainable production of IRM seeds or other planting materials in order to have smooth seed flow chains to farmers even after projects' completion. This is because farmers complained that projects always come with good benefits but when they complete their operations, farmers can no longer access the same inputs to use and continue 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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