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REVIEW ARTICLE

ADOPTION OF INTEGRATED PEST MANAGEMENT (IPM) TECHNOLOGIES IN UGANDA: REVIEW OF ECONOMIC STUDIES

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Abstract

Following the development and dissemination of new agricultural technologies to farmers by the IPM CRSP in Uganda, there has been an increase in the number of economic studies on adoption of IPM technologies over the last 10 years. This study was set to review empirical evidence on adoption determinants of IPM technologies and identify possible policy implications and the most promising areas for future research. The review of the empirical evidence shows that socio-economic and institutional factors are important determinants of farmers' adoption decisions. Income was found to positively influence adoption while the finding that amount of land owned negatively influenced adoption of land improvement technologies may be due to fear of the disadvantages associated with asset specificity. The finding that tenure security positively influences adoption implies that efficiently functioning land markets that enhance allocation and accessibility of land by smallholder farmers who are efficient producers will enhance adoption of improved technologies. The positive influence of farmers' organizations emphasizes the continued role of social capital. Market based reforms geared towards elimination of imperfections in credit, labor and agricultural information systems for the smallholder farmers are likely to enhance technology adoption while increased awareness of farmers through enhancing the extension delivery systems, research and outreach programs will increase multiple adoption. Finally, IPM technologies were found to reduce pesticide use intensity. This finding has implications for environmental and technology transfer policies designed to reduce environmental pollution. Research should focus on the dynamics of the adoption process.

Introduction

Despite the importance of the agricultural sector in Uganda's poverty reduction strategies, its productivity is still challenged by declining soil fertility, pests and diseases resulting from low intensification, limited knowledge and skills on appropriate and/or improved agronomic practices, lack of access to input and output markets, poor service delivery and infrastructure among others (DSIP, 2010). The above challenges have resulted in realization of low yields and incomes from agricultural production resulting into increased food insecurity and poverty of the smallholder farmers. In order to escape such poverty traps, there is an urgent need for growth and development of the agricultural sector not only because it is a major source of livelihood but also for the forward and backward linkages it provides to other sectors of the economy. Agricultural growth and development can only be achieved with technology development and adoption of yield enhancing options that can sustain and support the eco-systems for improved livelihoods. This is because merely expanding the area under cultivation (Kassie *et al*., 2011) as shown by the resource exploitation model to meet the ever increasing demand for agricultural commodities is no longer sufficient and sustainable.

Agricultural research for improved technologies and technology adoption can significantly influence the level and distribution of income and poverty among the population. Technology adoption for example can lower per unit-costs of production, increase the supply of food, and raise incomes of adopting producers leading to improved welfare. Additionally, the out-ward shifts in supply resulting from increased technology adoption can lower food prices to the benefit of the net buyers of food (Moyo *et al*., 2007) while increased productivity may stimulate the demand for labour; that is because the poor tend to supply off-farm labour, this may stimulate demand for labour thereby translating into increased employment, wages, and earnings for them (Kassie *et al*., 2011).

The potential of agricultural development in food security, poverty alleviation and economic development in Sub-Saharan Africa (SSA) has therefore triggered researchers, donor agencies, governments, policy makers and development partners to invest in the development of new agricultural technologies with a potential of sustaining African livelihoods. However, as demands grow for scarce funds, evidence is needed to demonstrate that agricultural research and technology development when adopted generates attractive returns compared to other alternative investments (Moyo *et al*., 2007).

This has stimulated many economists to evaluate research programs in a bid to justify research investments. Following the development and dissemination of new agricultural technologies to farmers by the IPM CRSP in Uganda, there has been an increase in the number of economic studies on adoption of IPM technologies for over the last 10 years. Such studies (Bonabana-Wabbi and Taylor, 2012; Mugisha *et al.,* 2004; Bonabana *et al.,* 2013 among others) have based their analysis on an economic theory perspective that farmers adopt technologies from which they can maximize their utility and profits. These studies have variously analyzed the determinants of adoption of IPM technologies and have each found various factors to significantly influence the adoption of IPM in Uganda.

However, it is not yet known on an aggregate/overall level which factors among the socio-economic, institutional and technology categories have come out the most among the various adoption studies to significantly influence the adoption of IPM CRSP technologies in Uganda. The thrust of this study is therefore to review all IPM CRSP adoption studies in Uganda and aggregate the factors significantly influencing the adoption of IPM technologies in Uganda and thereafter provide recommendations and policy implications on how IPM technology dissemination and transfer to the smallholder farmers could be fostered.

Theoretical framework

Feder *et al.*, (1985) defined adoption as the degree of use of a new technology in a long run equilibrium when a farmer has full information about the new technology and its potential. Adoption can also be defined as the application of technology as it is recommended (Ashby, 1991). In its simplest form, Rogers (1962) describes adoption as a process of willingly accepting innovation by members of a social system. When a new innovation is introduced, farmers go through periods of becoming knowledgeable about the new technology, to forming positive or negative attitudes toward the technology, and ultimately to deciding whether to adopt the technology or not. Adoption process can be classified into three phases namely, information collection, whether or not to adopt and how much to adopt.

Numerous household, community, and institutional factors affecting the farmer influence this decision process. Adoption at the farm level describes the realization of farmers' decision to apply a new technology in the production process. On the other hand, aggregate adoption is the process of spread or diffusion of a new technology within a region. Some studies have concentrated on the theory of adoption processes. Another avenue of study has focused on identifying significant characteristics associated with adopters and non-adopters. Other studies took a novel approach to combine both approaches by investigating not only the presence or absence of adoption, but also the influencing factors. Although studies on adoption of agricultural innovations are many, there is still an overriding need to investigate factors driving adoption of farming practices (e.g IPM practices).

Factors influencing the adoption of new agricultural technologies can be divided into three major categories: farm and farmers' associated attributes; attributes associated with the technology (Adesina and Zinnah., (1993); Misra *et al.,* (1993); and the farming objective (CIMMYT, 1988). On the other hand, other authors (e.g Bonabana, 2002; and Mauceri, 2004) categorized these factors under social, economic, managerial and institutional factors. In the farm and farmer category, the farmer's level of education, age, or family and farm size were considered. The second category depends on the type of technology (e.g., the kind of characteristics a farmer likes in an IPM technology). The third category assesses how different strategies used by the farmer, such as commercial versus subsistence farming, influence the adoption of technologies.

A review of empirical evidence on adoption of IPM CRSP technologies in Uganda

This section reviews the empirical findings of IPM CRSP studies on adoption. Specifically, four studies are reviewed: Bonabana-Wabbi *et al*., (2013), Bonabana-Wabbi and Taylor (2012), Moyo *et al.*, (2007) and Mugisha *et al*., (2004). Bonabana-Wabbi *et al*., (2013) study investigated adoption intensity of three hot pepper IPM technologies (irrigation, ridging and optimal pesticide use) while Bonabana-Wabbi and Taylor (2012) investigated the adoption (probability of adoption and adoption intensity- in terms of multiple adoption) of eight IPM technologies. The eight IPM technologies considered were: FERT (applying fertilizer on sorghum); ECAT (intercropping *celosia argentia* with sorghum); ROTN (crop rotation of sorghum with legumes such as cowpea and groundnuts); ICPV (improved cowpea variety Ebelat); TPCP (early planting of cowpea); ICCP (cowpea intercropping with cereal crops); CLSP (close spacing of groundnut seed at planting); and IGNV (using the improved groundnut variety, Igola-1). Moyo *et al.,*(2007) investigated adoption (probability of adoption) of improved peanut varieties while Mugisha *et al.,*'s (2004) study analysed adoption of groundnut technologies including growing improved and rosette resistant variety (Igola 1) with improved or traditional practices and growing the local varieties (Erudurudu and Etesot). The improved practices were early planting, spacing of 30cm X 10cm and 45cm X 15cm and 3 chemical sprays. Tables 1 to 6 (in Appendix A) below show the various factors determining the adoption of IPM technologies in Uganda.

Socio-economic Factors influencing the adoption of IPM technologies in Uganda

From Table 1 below, it can be seen that off-farm income significantly and positively increases the probability of adopting IPM technologies in cowpea, sorghum and groundnuts (Bonabana-Wabbi and Taylor, 2012). As expected, having off-farm income sources also positively influences adoption of multiple technologies (Table 4). This is because off-farm income helps in solving liquidity constraints in agricultural production which enhances adoption of technologies (Holden *et al*., 2001; Nkonya, 2002). Off-farm income provides revenue which can be used to finance crop activities. Given the problems of limited financing for the agricultural sector, one can easily obtain credit using off-farm sources and use it to finance agricultural production. Additionally, household income has been found to both positively and negative influence the adoption of IPM technologies. The possible explanation of the negative relationship between adoption and household income could be that as the income of a farmer increased he/she shifted away from agriculture or even kept in agriculture but invested in other agricultural enterprises such as the production of cash crops. Groundnuts is mainly regarded as a food crop and farmers may not necessarily invest in the use of IPM practices to produce it (Mugisha *et al*., 2004). On the other hand, an increase in per capita income positively influences the adoption of improved groundnut varieties (Moyo *et al.*, 2007) because the increased income would enable the farmer to buy the improved varieties which are high yielding. Increased income would also help in expanding production hence increased adoption.

Use of fertilizer on other crops was found to positively influence adoption of improved agricultural practices in cowpea and sorghum production (Bonabana-Wabbi and Taylor, 2012). Use of fertilizer positively influences adoption of intercropping because the farmer knows that fertilizer is a yield enhancing input hence he can maximize utility derived from the use of fertilizer in intercrops. Also, fertilizer application suppresses the growth of striga weed. However, use of fertilizer on other crops negatively influences the adoption of close spacing (Table 1). This is because with closer spacing, a farmer cannot intercrop groundnuts with other crops hence the low probability of taking up the practice. Additionally, the positive coefficient on the variable representing labor constraints in fertilizer use was unexpected as it indicates that high labor requirements involved in fertilizer use positively affect its adoption. On the other hand, this result may

simply acknowledge that higher labor use is required for fertilizer use on sorghum compared to not using fertilizer (Bonabana-Wabbi and Taylor, 2012).
Farming experience was found to negatively influence adoption of intercropping in cowpea. Perhaps accumulated farming experience decreases the likelihood of intercropping cowpea with cereal crops. It is possible that past experience with poor performance of cowpea intercrops discourages increased intercropping (Bonabana-Wabbi and Taylor, 2012).

The number of family members working off the farm has been found to positively influence the adoption of crop rotation for sorghum, close spacing and improved groundnut varieties (Table 1). In sorghum, the presence of striga weed makes the enterprise labor intensive in terms of weed control hence farmers adopt crop rotation which is labor saving when they do not have family labor. In groundnut production, non-availability of family labor enhances the adoption of improved varieties because such labor may be employed off-farm and are able and willing to buy the improved varieties which are high yielding. Additionally, the working labor may also be able to finance the farming operations through hiring labor for carrying labor intensive activities like spacing. On the other hand, the number of family members working on farm was found to negatively influence multiple adoption of cowpea technologies (Table 4).

As shown in Tables 1 and 4 below; gender of an IPM farmer was found to significantly and positively influence adoption of IPM technologies (both probability and intensity of adoption) (Moyo *et al.*, 2007; Bonabana-Wabbi and Taylor, 2012; Bonabana-Wabbi *et al.*, 2013). This is in line with the findings of Mamudu *et al.*, (2012) who also found that male headed households were more likely to adopt improved technologies. The positive influence of gender on adoption of IPM technologies may be due to men's access to information about the IPM technologies or the women's lack of information on IPM (Bonabana-Wabbi and Taylor, 2012). Additionally, males are the majority heads of the householdsand hence likely to influence allocation of household resources. On the other hand, gender negatively influenced adoption of crop rotation in sorghum when males make farm implement purchase decisions.

The findings in Table 1 also show that if a farmer grew an improved variety then he or she is likely to adopt close spacing in groundnut production. This is because once a farmer has realized the benefits of using improved agricultural technologies then such a farmer is likely to continue adopting other improved agricultural technologies.

As shown in Tables 1 and 4 education was found to positively and significantly influence both the probability of adoption of IPM technologies (Moyo *et al*., 2007; Mugisha *et al*., 2004) and multiple IPM adoption (Bonabana-Wabbi and Taylor, 2012) which is in line with Daku (2002) and Doss and Morris (2001). This is because education is thought to reduce the amount of complexity perceived about a technology thereby increasing a technology's adoption. Additionally, the more educated farmers are in better position to search for and process information as well as understand the technical aspects of a technology, especially spacing and insecticide use in the case of IPM. Thus, more educated persons are more likely to adopt IPM technologies compared to the less educated individuals who would not want to risk with new technologies until they have seen the benefits (Mugisha *et al*., 2004).

The proportion of total acreage in the improved variety was positively related to multiple cowpea technology adoption (Table 4). This implies that using the new variety appears to encourage use of the other IPM technologies. This is because farmers want to maximize their utility of using the improved variety hence they adopt other technologies that may foster maximization of the utility objective. However, on the other hand amount of land owned negatively influenced adoption of improved hot pepper technologies like ridging and irrigation (Bonabana-Wabbi *et al.*, 2013) which is also in line with (Yaron *et al.*, 1992; and Harper *et al.*, 1990). This is probably because the ridging technology involves making land improvements like making channels for water to flow and flood in the hot season as a control measure against a major hot pepper disease (bacterial wilt and root rot). Such land improvements are expensive to effect and putting them means foregoing the piece of land to other alternative uses. Therefore if a farmer has less land he/she may not adopt such land improvement technologies like ridging and irrigation because of the opportunity cost associated with foregoing the returns from other alternative crop enterprises. Alternatively, farmers are unlikely to land improvement technologies because of the disadvantages of asset specificity.

However, Mugisha *et al.,* (2004) found out total cultivatable land was positively related to adoption of groundnuts IPM technologies in Mayuge district (Table 1). The plausible explanation is that since land size is an indicator of wealth, farmers with larger land sizes are in better position to obtain information about new technologies and apply them. Household wealth in terms of capital (like the numbers of hoes) owned by the household was found by Moyo *et al*., (2007) to influence adoption of improved groundnut varieties. The availability of hoes can also be related to availability of implements for production.

Age of the household head was found to negatively influence the adoption of improved groundnut technologies (Moyo *et al.,* 2007). An increase in the age of the household by one year results in a decline in the probability of adoption of 0.13%. Although this finding is in line with Baidu-Forson (1999), it appears to be in contradiction with other studies which found that age was positively related to adoption of improved technologies (Beyene *et al*., 1998; Regassa *et al.,* 1998; Degu *et al*., 2000). Household size was also found to negatively relate to adoption. The probability of adoption was decreased by 6.7% for every increase in family size by one member. This was in line with the findings of Nnadi and Nnadi (2009) but contrary to the findings of Kato (2000) that increase in family size increased the adoption of an improved bean variety.

Institutional Factors influencing adoption of IPM technologies in Uganda.

From Table 5 below, it can be seen that access to credit (whether the farmer borrows to finance crop production) was negatively related to multiple adoption of sorghum IPM technologies while the same variable was positively related to adoption of both groundnut and hot pepper technologies (Tables 2 and 5). This mixed finding is brought about by the fact that IPM technologies in sorghum were not capital intensive (for example the use of celosia) whereas those for hot pepper were capital intensive (like ridging and irrigation). Therefore access to credit in hot pepper production would enhance adoption intensity because credit would ease the liquidity constraints needed to control against the pests and disease ravages. In groundnut production, access to credit enables the farmer to purchase inputs like draught power and improved seed to carry out production.

As expected, membership to a farmers' organization positively influences the adoption of IPM technologies (Tables 2 and 5). For example in groundnuts production, the probability of adopting IPM technologies increased by 46.5% if a farmer belonged to a farmer organization (Mugisha *et al.,* 2004). This is in line with Ntege-Nanyenya *et al.,* (1997) who established the same relationship. Social capital through group membership enhances group learning, information sharing and also fosters technology uptake.

Receipt of extension training and knowledge about other pest control measures positively and significantly influences IPM adoption (Tables 2 and 5). This is because extension training enhances farmers' knowledge on his or her production and equips the farmer with new techniques of managing agricultural production. The farmer can then easily adopt improved methods of farming. For example in a study by Mugisha *et al.,* (2004) extension was found to positively influence the adoption of improved groundnut technologies with the probability of adoption increasing by 40.5% if an extension agent visited the farmer. Extension visits enable the farmer to get information about new or improved technologies and the extension workers encourage them to adopt. Extension agents also establish relationships with these farmers who then act as contact farmers and thus can be selected to participate in training and demonstrations (Bisanda *et al.,* 1998). However, information from extension agents was found to have a negative impact on *celosia* use in sorghum. Perhaps this might be a result of limited knowledge on the side of the extension agent to fully advise the farmer. Such conflicting messages between the IPM researchers and extension agents disrupt the farmers' decision making process on whether to adopt IPM technologies or not. However, receiving pest control training increases the probability of *celosia* adoption.

Access to information sources has been found to influence adoption of IPM technologies both positively and negatively (Table 2). For example obtaining information from agricultural researchers enhances the adoption of improved cowpea varieties (Bonabana-Wabbi and Taylor, 2012) while receipt of market information the previous year influenced adoption of improved groundnut varieties (Moyo *et al*., 2007). On the other hand, receipt of information from informal information sources like neighbours negatively influences the adoption of close spacing in groundnuts production (Bonabana-Wabbi and Taylor, 2012). This thus shows the impact of neighbourhood effects on technology adoption. Perhaps being neighbour to a non-IPM farmer reduces the likelihood of adoption of IPM technology adoption.

Tenure security was also found to positively influence adoption of groundnut IPM technologies (Table 2). According to Moyo *et al.,* (2007), having a freehold tenure status positively influences adoption of improved groundnut varieties. This is because with freehold a farmer is stable and can carry out his/her production unchallenged and therefore is emphatic about receiving the full benefits of his production unlike when tenure is threatened. Additionally, with freehold tenure, a farmer can access financial resources which can help him or her obtain improved production technologies; that is, it is easier for micro-finance institutions to lend to a farmer who has a stable land tenure-ship and collateral than one without.

Technology related attributes/farmers' perceptions affecting technology adoption

From Tables 3 and 6, farmers' perceptions regarding the technologies were found to significantly influence both probability and multiple adoption of groundnuts, sorghum and cowpea technologies. Farmers' perceptions about the technologies have led to mixed results on adoption decisions. For example: while perceived yield losses due to insect incidences in the previous season positively influences adoption of early planting in cowpea production in the subsequent season, perceptions about disease incidences last year and farmers' perceptions of a yield loss last season negatively influenced adoption of sorghum technologies. This is because with early planting, a cowpea farmer sees a fifty-fifty chance of harvest because the farmer perceives that when he/she plants early, the cowpea crop might mature early before it is attacked by pests. With sorghum there is no such optimism for the farmer because when the crop is planted there is little chance that they will survive striga weed even with use of celosia. This is therefore the reason why farmers are likely to dis-adopt the sorghum technologies.

Farmers' knowledge about the incidence of insects positively and significantly influences early planting in cowpea production. High labour requirements for early planting and increased land requirements were positively related to multiple adoption of cowpea technologies. The findings can be explained in a way that when a sorghum farmer perceived a crop loss due to striga, he/she would disadopt sorghum technologies while the positive relationship associated with increased resource requirements in cowpea were tolerated probably because the increased resource requirements came along with increased cowpea yields. As shown in Table 3 below, higher land requirements with close spacing, encourages the use of close spacing, which seems counterintuitive. It may be that farmers only perceive that more land is required for close spacing than with conventional sowing since they are more precise in their sowing methods and thus have a better perception of the amount of land that they are actually planting. Or, they may be planting more land with this method than they did with conventional methods (Bonabana-Wabbi and Taylor, 2012).

In addition high labor demands for early planting induce farmers to plant early possibly to avoid peak labor demands later in the growing season. Intercropping cowpea with cereals is positively influenced by weed incidence implying that perhaps, as a weed control strategy, farmers who experience high weed incidences are induced to intercrop. Ridging (width of ridging) was found to negatively influence pesticide use intensity in hot pepper production implying that the adoption of IPM technologies is likely to reduce the negative impacts of pesticide use on the environment.

Conclusions

From the review of the empirical evidence, it can be seen that although technology related attributes/perceptions significantly influence adoption, it is mainly the socio-economic and institutional factors that are determining farmers' adoption decisions of IPM technologies. Among the socio-economic factors, income, farming experience, gender, education, amount of land owned, age among others have been found to significantly influence the adoption of IPM technologies in Uganda.

Income (off-farm, per-capita and household) was found to positively influence adoption; implying that increase in income is likely to increase the adoption of IPM technologies. This is mainly because income helps in solving farmers' liquidity constraints in agricultural production which helps the farmer to access improved technologies. Education was also found to positively influence the adoption of IPM technologies probably because education is thought to reduce the amount of complexity perceived in a technology thereby increasing a technology's adoption. On the other hand, farming experience and amount of land owned were found to negatively influence the adoption of IPM technologies. This finding may be due to a possibility that past experience with poor performance of a technology discourages its increased use. Amount of land owned was found to negatively influence the adoption of land improvement technologies like ridging and irrigation due to fear of the disadvantages associated with asset specificity.

Gender was found to positively and negatively influence the adoption of IPM technologies. Gender's positive influence on adoption may be due to men's access to information about the IPM technologies or the women's access lack of information on IPM. However, where males were involved in farm implement purchase decisions; it was found that adoption of improved technologies did not take place. This is certainly because of their influence in household decision making regarding resource allocation.

Credit access, belonging to a farmers' organization, access to information and tenure security among others were the institutional factors influencing the adoption of IPM technologies. Credit was found to both positively and negatively influence adoption. This ambivalence may be due to capital intensiveness of an enterprise. For example unlike in sorghum in hot pepper, land improvement technologies require capital investment hence the reason credit was found to positively influence adoption. Tenure security (free hold tenure) was also found to positively influence adoption implying that efficiently functioning land markets that enhance allocation and accessibility of land by smallholder farmers who are efficient producers will enhance adoption of improved technologies. Belonging to a farmers' organization was also positively associated with the adoption of improved IPM technologies implying the role of social capital in the agricultural sector. Extension was both positively and negatively related to adoption of IPM technologies. The negative adoption could be due to limited knowledge on the side of the extension agent to advise the farmer thereby calling for technical backstopping of the agents.

Receipt of market information the previous year influenced adoption of IPM; implying the role of information in production and marketing decisions for the smallholder farmers. Although obtaining information from the researchers positively influenced adoption decisions, the use of informal information networks like the neighbours negatively influenced adoption thereby implying the role of neighbourhood effects in technology adoption.

Farmers' perceptions about a previous pest attack and crop yield loss have led to adoption and disadoption of IPM (early planting and celosia) respectively; implying that most farmers are risk averse and are only likely to continue use of the technology when there is a fifty-fifty chance of output increase. It is important to note that risk factors influence the degree of adoption if the producer decided to adopt. Diffusion of technology – related information and measures that expedite this diffusion can have a positive effect on adoption by reducing the uncertainty associated with the improved technology.

Policy implications

This study calls for market based reforms that will be geared towards elimination of imperfections in credit, labour and agricultural information systems for the smallholder farmers. Efficiently functioning credit markets shall help enhance farmers' accessibility to credit thereby enabling the farmer to access land improvement technologies and also satisfy annual cash income constraints. Efficient labour markets will help in supporting rational allocation of time by peasant household betweens on-farm and off-farm work and among family labour and hired labour decisions. Given the importance of market information in technology adoption, efficiently functioning agricultural information systems will help in lowering transaction costs like high search costs that may arise due to imperfect information. Provision of market information shall also help in removing the high marketing margins that may result due to monopoly by some economic agents.

The study findings suggest the need for increased awareness of farmers through enhancing the extension delivery systems and research and outreach programmes given the importance of access to extension services and receipt of extension training on technology adoption. Additionally, there is also need to enhance the extension agents' training through technical backstopping so that their awareness about the availability of new and emerging technologies is enhanced. Also, given the negative effect of informal information access on adoption; it is imperative that farmer training is localised so that farmer and village leaders are trained as these can advise their fellow farmers given their availability in the farmers' local environment. The trained farmers can then help in playing the role of an extension agent when a farmer is in need of farming information.

Land reforms that enhance tenure security and facilitate exchange of land amongst farming households will help foster technology adoption. The finding that IPM technologies reduce pesticide use intensity has implications for environmental and technology transfer policies designed to reduce environmental pollution.

Areas for further research

It is important to note that the empirical studies on IPM adoption determinants in Uganda have heavily relied on cross-sectional rather than panel data which means that the underlying dynamics were rarely explored at an empirical level. The value of panel data is that it helps uncover the subtle dynamics of learning, strategic behaviour and coordination among producers faced with decisions about whether to adopt and how to most effectively deploy new technologies (Foster and Rosenzweig, 1995; Conley and Udry 2002).

Another area for which empirical evidence lacks is the sequential adoption of IPM technologies. For example; this is likely in tomato production whereby if a farmer adopts MT 56 (a variety), he or she is likely to adopt staking as a complementary technology.

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Appendix A.

Table 1: Socio-economic Factors influencing IPM technology adoption studies in Uganda

Study	**Sample**	**Nature of adoption**	**Dependent variable Definition**	**Variable name**	**Type of variable**	**Coefficient**	**Marginal probability**	**Technology**	**Crop**	**Comments**
Bonabana and Taylor (2012)	All farmers N=212 Males (108) Females (104)	Probability of adoption	Decision to adopt or not to adopt an IPM technology	If farmer has off farm income sources	Binary	1.061**	0.1081	Improved cow pea variety	Cowpea	The analysis for the decision to adopt or not to adopt IPM technologies was done using a Logit Model. The improved cow pea variety was Ebelat
				If farmer has off-farm income sources	Binary	0.614*	0.0417	Early planting	Cowpea	Early planting of cowpea
				Use of fertilizer on other crops	Binary	0.908**	0.1633	Intercropping	Cowpea	Cowpea intercropping with cereal crops
				Length of farming experience	Continuous	-0.021*	-0.0029	Intercropping	Cowpea	
				Use of fertilizer on other crops	Binary	3.164**	0.0246	Fertilizer	sorghum	Applying fertilizer on sorghum
				Lack labor to apply fertilizer	Binary	2.081*	0.0077	Fertilizer	Sorghum	
				Gender	Binary	1.97*	0.1442	Celosia	Sorghum	
				No. of family members working off the farm	Continuous	0.542*	-0.0377	Crop rotation	Sorghum	Crop rotation of sorghum with legumes such as cowpea and groundnuts
				Whether males make farm implement purchase	Binary	-1.367**	-0.0185	Crop rotation	Sorghum	

				decisions						
				No. of family members working on the farm	Continuous	0.140**	0.0309	Improved groundnuts variety	Groundnuts	Using the improved groundnut variety, Igola-1
				Use of fertilizer on other crops	Binary	-1.236*	-0.1692	Close spacing	Groundnuts	Close spacing of groundnut seed at planting
				Number of family members working off the farm	Continuous	0.636*	0.0913	Close spacing	Groundnuts	
				If farmer has off-farm income sources	Binary	0.890**	0.1984	Close spacing	Groundnuts	
				If a farmer grew an improved variety	Binary	1.081**	0.1717	Close spacing	Groundnuts	

Study	**Sample**	**Nature of adoption**	**Dependent variable Definition**	**Variable name**	**Type of variable**	**Estimate (standard error)**	**Marginal Effect (p-Value)**	**Technology**	**Crop**	**Comments**
Moyo *et al.*, (2007)	All sample N= 2,059	Probability of adoption	Use of hybrid or improved seed	Male headed household head	Binary	0.3107*** (0.0949)	0.0873 (0.0011)	Improved variety	Groundnuts	Analysis was done using a probit model
				Age of household head	Continuous	-0.0001** (0.0000)	-0.0000 (0.0154)			
				Completed secondary level education	Binary	0.2864*** (0.0821)	0.0916 (0.0005)			
				Income	Continuous	0.1217*** (0.0330)	0.0365 (0.0002)			
				No. of hoes owned (proxy for capital)	Continuous	0.2661*** (0.0704)	0.0799 (0.0002)			

Study	Sample	Nature of adoption	Dependent variable Definition	Variable name	Type of variable	Estimate (robust standard error)	Probability of adoption (robust standard error)	Technology	Crop	Comments
Mugisha *et al.*, (2005)	All sample N=76	Probability of adoption	Decision to adopt (1 if a farmer adopted IPM, 0= otherwise)	Education in years	Continuous	0.098 (0.054)*	0.039 (0.021)	IPM technologies	Groundnuts	
				Household size	Continuous	-0.168 (0.065)*	-0.067 (0.026)			
				Natural log of cultivable area	Continuous	0.518 (0.2097)*	0.206 (0.084)			
				Natural log f household income	Continuous	-0.388 (0.185)**	-0.155 (0.077)			

Note: Marginal effect refers to the marginal measured effect of the variable on the probability of adoption. p-Value is a test that the coefficient, which is distributed chi-square, is zero. *, ** and *** = significant at 10%, 5% and 1% respectively

Table 2: Institutional Factors influencing the adoption of IPM technologies in Uganda

Study	Sample	Nature of adoption	Dependent variable Definition	Variable name	Type of variable	Coefficient	Marginal probability	Technology	Crop	Comments
Bonabana and Taylor (2012)	All farmers N=212 Males (108) Females (104)	Probability of adoption	Decision to adopt or not to adopt an IPM technology	Whether information about IPM was obtained from researchers	Binary	12.161**	-0.1534	Improved cow pea variety	Cowpea	A binary variable had a yes (1) or no (0) response
				[redacted]						
				Frequency that farmer has had contacts with extension staff	Dummy	-1.76*	-0.1284	Celosia	Sorghum	This dummy variable had a responses like [0=None, 1=Few, 2=Many]
				[redacted]						
				Belonging to a farmer organization		0.792**	0.1902	Close spacing	Groundnuts	
				Whether farmer accesses information from neighbors and friends	Binary	-0.732*	-0.1558	Close spacing	Groundnuts	
Study	**Sample**	**Nature of adoption**	**Dependent variable Definition**	**Variable name**	**Type of variable**	**Estimate (standard error)**	**Marginal Effect (p-Value)**	**Technology**	**Crop**	**Comments**
Moyo *et al.*, (2007)	All sample N= 2,059	Probability of adoption	Use of hybrid or improved seed	Received extension advice	Binary	0.1464 (0.0304)	0.0440*** (<0.0001)		Groundnuts	Analysis was done using a probit model
				Market information received, 1998	Binary	0.1918 (0.0667)	0.0588*** (0.0040)			
				Freehold tenure status	Binary	0.2824 (0.0645)	0.0845*** (<0.0001)			
Study	**Sample**	**Nature of**	**Dependent**	**Variable name**	**Type of**	**Estimate**	**Probability**	**Technology**	**Crop**	**Comments**

		adoption	**variable Definition**		**variable**	**(robust standard error)**	**of adoption (robust standard error)**			
Mugisha *et al.*, (2005)	All sample N=76	Probability of adoption	Decision to adopt (1 if a farmer adopted IPM, 0= otherwise)	Access to credit	Binary	0.855** (0.404)	0.331** (0.146)	IPM technologies	Groundnuts	
				Association Membership	Binary	1.277*** (0.469)	0.465*** (0.132)			
				Extension visits	Binary	1.077*** (0.433)	0.405*** (0.149)			

Note: *, ** and *** = significant at 10%, 5% and 1% respectively

Table 3: Technology-related factors/farmers' Perceptions influencing the adoption of IPM technologies

Study	Sample	Nature of adoption	Dependent variable Definition	Variable name	Type of variable	Coefficient	Marginal probability	Technology	Crop	Comments
Bonabana and Taylor (2012)	All farmers N=212 Males (108) Females (104)	Probability of adoption	Decision to adopt or not to adopt an IPM technology	Yield losses due to insect incidences last season	Discreet	2.250*	0.2986	Early planting	Cowpea	The decision to adopt or not to adopt was analyzed using a logit model. A discreet variable had responses like [1=0 No, 1=Yes, 2= Don't know)]
				Knowledge about the incidence of insects	Discreet	0.632*	0.0432	Early planting	Cowpea	
				Perceptions of about labor requirements for early planting	Binary	0.983**	0.0788	Early planting	Cowpea	Labor requirements were perceived as being high (1) or low
				Perceptions about fertilizer labor requirements	Binary	2.081*	0.0077	Fertilizer	Sorghum	Fertilizer requirements were perceived as being high (1) or low
				Perceptions about disease incidences last year	discreet	-1.328*	-0.0968	Celosia	Sorghum	Celosia was found to suppress striga weed when intercropped with sorghum (intercropping *celosia argentia* with sorghum
				Perceptions about weed incidences last season	discreet	-1.955*	-0.0377	Crop rotation	Sorghum	Crop rotation of sorghum with legumes such as cowpea and groundnuts
				Perceptions about labor requirements	Binary	-1.09*	-0.0126	Crop rotation	Sorghum	Crop rotation of sorghum with legumes such as cowpea and

				for crop rotation						groundnuts
[redacted]										
				Perceptions about labor requirements for close spacing	Binary	0.768**	0.1433	Improved groundnuts variety	Groundnuts	The improved groundnut variety was Igola-1
				Perceptions about land requirements for close spacing	Binary	0.676*	0.1081	Improved groundnuts variety	Groundnuts	The improved groundnut variety was Igola-1

Note: *, ** and *** = significant at 10%, 5% and 1% respectively

Table 4: Socio-economic Factors influencing IPM technology adoption studies in Uganda (intensity of adoption)

Study	Sample	Nature of adoption	Dependent variable Definition	Variable name	Type of variable	Estimate (Odds Ratio)[a]	Marginal probability	Technology	Crop	Comments
Bonabana and Taylor (2012)	All farmers N=212 Males (108) Females (104)	Intensity of adoption	Multi-category variable with an index "1", "2" and so forth representing adoption of one, two, or more technologies.	Gender	Binary	0.579(1.784)*	0.1275		Sorghum	A cumulative logit was used. The study examined farmers' adoption decisions when the technologies can be complementary.
				[redacted]						
				Proportion of total farm acreage under improved cowpea variety	Continuous	0.632(1.881)**	0.0001		Cow pea	
				Number of family members working on farm	Continuous	-0.110(.8958)**	0.0000		Cow pea	
				[redacted]						
				Total yield of improved	Continuous	0.243(1.275)**	0.0548		Ground nuts	

				groundnut variety (IGOLA)						
				If a farmers has off-farm income sources	Binary	0.826(2.284)**	0.2010		Ground nuts	
Study	**Sample**	**Nature of adoption**	**Dependent variable Definition**	**Variable name**	**Type of variable**	**Coefficient (t-value)**	**P>|t|**	**Technolog y**	**Crop**	**Comments**
Bonabana *et al.*, (2013)	All farmers N=112 Males (73) Females (39)	Intensity of adoption	Proportion of the hot pepper acreage sprayed by the pesticides in a season.	Width of the ridge	Continuous	-16.62928 (-3.30)	0.001***	Pesticide Use	Hot pepper	Adoption intensity was analysed using a Tobit model.
				Gender of the farmer	Binary	1714.452 (3.37)	0.001***	Pesticide Use	Hot pepper	
Bonabana *et al.*, (2013)	All farmers N=112 Males (73) Females (39)	Intensity of adoption	The proportion of the hot pepper acreage under ridging in a season	Years completed in school	Continuous	0.0141 (2.57)	0.012**	Ridging	Hot pepper	
				Land owned in acres	Continuous	-0.0046 (-4.27)	0.000*	Ridging	Hot pepper	
			Proportion of the hot pepper acreage irrigated in a season	Land owned in acres	Continuous	-0.0742015 (-2.89)	0.005***	Irrigation	Hot pepper	

Note: *, ** and *** = significant at 10%, 5% and 1% respectively

Table 5: Institutional Factors influencing the adoption of IPM technologies in Uganda (intensity of adoption)

Study	Sample	Nature of adoption	Dependent variable Definition	Variable name	Type of variable	Estimate (Odds Ratio)[a]	Marginal probability	Technology	Crop	Comments
Bonabana and Taylor (2012)	All farmers N=212 Males (108) Females (104)	Intensity of adoption	Multi-category variable with an index "1", "2" and so forth representing adoption of one, two, or more technologies.	Whether the farmer borrows to finance crop production	Binary	-0.798(0.45)*	0.1681		Sorghum	A cumulative logit was used. The study examined farmers' adoption decisions when the technologies can be complementary
				Belonging to a farmer organization	Binary	0.595(1.813)***	0.1471		Sorghum	
				Receipt of training in pest control	Binary	0.809(2.246)*	0.1995		Sorghum	
				Belonging to a farmer organization	Binary	0.775(2.171)**	0.1883		Groundnuts	
Study	**Sample**	**Nature of adoption**	**Dependent variable Definition**	**Variable name**	**Type of variable**	**Coefficient (t-value)**	**P>|t|**	**Technology**	**Crop**	**Comments**
Bonabana *et al.*, (2013)	All farmers N=112 Males (73) Females (39)	Intensity of adoption	Proportion of the hot pepper acreage sprayed by the pesticides in a season.	Access to Credit	Binary	1823.704 (2.28)	0.025**	Pesticide use	Hot pepper	
				Receipt of Training in Pesticide Use	Binary	47.24001 (1.96)	0.053*	Pesticide use	Hot pepper	
			The proportion of the hot pepper	Access to Credit	Binary	0.1554 (1.95)	0.053***	Ridging	Hot pepper	
				Knowledge of other methods	Binary	0.1063 (2.07)	0.041**	Ridging	Hot pepper	

			acreage under ridging in a season	of Pests/disease control						
			Proportion of the hot pepper acreage irrigated in a season	Access to Credit	Binary	1.715167 (1.72)	0.088*	Irrigation		

Note: *, ** and *** = significant at 10%, 5% and 1% respectively

Table 6: technology related factors/farmers' Perceptions influencing the adoption of IPM technologies (intensity of adoption)

Study	Sample	Nature of adoption	Dependent variable Definition	Variable name	Type of variable	Estimate (Odds Ratio)[a]	Marginal probability	Technology	Crop	Comments
Bonabana and Taylor (2012)	All farmers N=212 Males (108) Females (104)	Intensity of adoption	Multi-category variable with an index "1", "2" and so forth representing adoption of one, two, or more technologies.	Whether the crop was harmed by weeds last season	Discreet	-1.277(.279)***	-0.2419		Sorghum	
				[redacted]						
				If the technology requires high labor to carry out early planting	Binary	0.618(1.855)*	0.0005		Cow pea	
				If the technology requires much land to carry out early planting	Binary	2.009(7.4559)*	0.0001		Cow pea	
Study	**Sample**	**Nature of adoption**	**Dependent variable Definition**	**Variable name**	**Type of variable**	**Coefficient (t-value)**	**P>|t|**	**Technology**	**Crop**	**Comments**
Bonabana *et al.*, (2013)	All farmers N=112 Males	Intensity of adoption	Proportion of the hot pepper acreage	Width of ridging	continuous	-16.62928 (-3.30)	0.001***	Pesticide use	Hot pepper	

	(73) Females (39)		sprayed by the pesticides in a season.							

Note: *, ** and *** = significant at 10%, 5% and 1% respectively