An evaluation of the effects of information and technology characteristics on technology choice and adoption:

The case of Striga and Stemborer control technologies in maize production in western Kenya

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DEDICATION

To GOD almighty, My ALL…

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List of Acronyms

CIMMYT	Centre Internacional de Mejoramiento de Maiz Y Trigo (International maize and wheat improvement centre)
FAO	Food and Agriculture Organization of the United Nations
ICIPE	International Centre of Insect Physiology and Ecology
IPAR	Institute of Policy Analysis and Research
IR Maize	Imazapyr herbicide resistant maize
KARI	Kenya Agricultural Research Institute
MoA	Ministry of Agriculture
NGO	Non governmental organization
NPPV	Not Push-pull village or neighbour
PCA	Principal Component Analysis
PPNB	Push-pull neighbouring village
PPT	Push-pull Technology
PPV	Push-pull Village
ROK	Republic Of Kenya

Abstract

Kenya's population is increasing, thus leading to increased demand for food, especially maize which is a staple food for most of the Kenyan population. Demand for maize in Sub Saharan Africa is projected to double to 52 million tons by 2020 (Pingali and Pandey). The increasing population has also caused the per capita farm holdings in Kenya rural areas to become smaller due to continuous sub-division. Besides the reduced farm holding, maize production is constrained by both biotic and abiotic factors. Two of the most important biotic constraints in maize production are Striga and stemborer infestations.

Maize yield loss due to stemborers has been estimated to range from 20-80% depending on the severity of the infestation by the pest and the growth stage of the crop (Khan et al, 1997a). Striga is a highly invasive parasitic weed and it infests more than 400,000ha of Kenyan farmland (Kanampiu, 2003). In western Kenya, 50-100 percent yield losses due to Striga have been reported in both on on-farm and on-station experiments (Hassan et al, 1994).

Since the opening of new land is not a viable option in contributing to increased maize production in Kenya, increasing maize production is dependent on two factors; the ability of the research and development agents to supply constraints mitigating technologies and the ability of the farmers to access and utilize such technologies. The purpose of this study is to evaluate the factors that influence the farmers' knowledge, choice and adoption of technologies for the control of Striga/stemborer in Vihiga and Suba Districts.

Data was collected from 476 randomly selected farm households through a cross-sectional household survey, using a pre-designed questionnaire, in 2006. Principal Component Analysis (PCA) was used to generate and classify two proxy indices that were used to represent the type of agricultural information as obtained by farmers from various sources. Multivariate regression was used to evaluate the factors that influence the agricultural information indices. Conjoint analysis was applied to assess the technology characteristics that the households consider important in influencing choice of Striga control technology. A bi-variate probit and Tobit analyses were used to assess the factors that influence awareness, adoption and use of the Push-Pull Technology (PPT).

Results show that the farmers accumulate two distinct types of agricultural knowledge (i.e. type I and type II) from 15 information sources, which significantly influence their decision to adopt a technology to control Striga or stemborer. Technology messages are better disseminated using a host of different communication channels. Different farmers' access agricultural information through different channels, depending on their education level, association with groups, relationships with neighbours, and opportunities to travel and visit research institutions, among others. The most popular information channels, based on those accessed by over 30% of the farmers in both districts, are farmer groups, contact farmers, pamphlets and brochures, agricultural shows, PPT farmer teachers and posters.

Farmers also identified seven important characteristics that influence their choice when adopting a technology to control Striga in their cereal crops, including: (i) change in costs per season, (ii) if a fallow period is required, (iii) yield increase attained, (iv) possibility of intercropping food legumes, (v) additional benefits like animal feed supplements or firewood obtained from the technology, (vi) requirements for crop rotation and (vii) the amount of labour required. Except for crop rotation, the influence of the other six characteristics was validated as being statistically significant in influencing the probability of a farmer choosing a Striga control technology for adoption. Farmers' assessment of technologies in terms of these characteristics should be integrated into the ex-ante diagnostic surveys so that the farmers' preferences are included in technology design.

The adoption decision for Push-pull technology (PPT) was modelled as a three-phase decision model: (i) factors influencing awareness of existence of PPT, (ii) factors influencing adoption of PPT, and (iii) factors influencing the intensity of use of PPT. The results show that 30% of the respondents knew of the existence of the PPT and this was significantly influenced by age, travel time to the nearest market, and being in a village used for PPT demonstration. Of those who were aware of the PPT's existence, 19% had decided to adopt the PPT and this was significantly influenced by whether they had access to farm labour, the area under maize, farmers' assessment of the severity of the Striga infestation, farm income and farming experience. The intensity of use (proportion of their maize farm put under PPT) was significantly influenced by farming experience, farm income and land tenure security index. The residual effects from the awareness and adoption phases were also significant in influencing the intensity of use of the PPT.

Push-pull technology is not yet widely known by the farmers. This study recommends that strategic information dissemination programmes, in collaboration with the Ministries of Agriculture and Livestock Development, NGO's and CBO's partner organizations, would increase the number of farmers reached and made aware of the existence of PPT and its benefits. This is critical in order to enhance its adoption and thus ensure food security in the Striga infested areas of western Kenya.

CHAPTER 1: INTRODUCTION

1.1 Background information

Maize has continued to be an important part of the food security equation in East Africa in general and Kenya in particular, where per capita consumption is 81kg/year (FAO Statistics, 1997-2002). Majority of farmers grow maize to meet their subsistence requirements. The production level per hectare of land is however very low, compared to the yield potential. Pingali and Pandey (2000) show that maize yields achieved by farmers across major agro-ecological zones in the developing countries are much lower than the zones' yield potential. For example, the highland/transitional zones of the developing world have a potential yield of 5.0 tons/ha but the achieved average maize yield levels are only 0.6 tons/ha. The mid-altitude/sub tropical regions have a potential of 7.0 tons/ha but only an average of 2.5 tons/ha are achieved by farmers. In the tropical lowlands, the dominant maize production ecology, 0.7 tons/ha are achieved while the potential is 4.5 tons/ha. The low yields of maize can be attributed to, among other things, abiotic and biotic production constraints. Stem borers and Striga weeds are important biotic constraints.

Maize yield loss due to stem borers has been estimated to range from 20-80 percent, depending on the severity of the infestation by the pest and the growth stage of the crop (Gebre-Amlak, 1985; Seshu-Reddy, 1991; Khan *et al*, 1997a). In a survey of the coastal drylands, semi-arid areas, transitional and high potential areas of Kenya, De Groote (2002) established that an average of 13.5 percent maize yield is lost due to stem borers across the agro-ecological zones.

On the other hand, Striga related maize yield losses are estimated at 5 percent yield loss per every Striga plant per m^2 (Parker and Riches, 1993). Striga is a highly invasive parasitic weed, which attacks maize and other cereals as host plants. Striga sprouts fasten directly to roots of maize seedlings, sucking away nutrients and thus leading to severe yield losses. Striga establishes preferentially in nutrient poor soils, which have been exhausted by continuous cropping (Esilaba, 2000). In Kenya, Striga infests over 400,000 ha of farmland and in Western Kenya 50-100 percent yield losses have been reported both in on-farm and on-station experiments (Hassan *et al*, 1994; Kanampiu, 2003.). In some cases, the infestation can be so severe that farmers decide to abandon their fields altogether (Ransom, 1996).

According to the FAO estimates, over 100 million farmers in Africa lose half of their cereal crop production to the parasitic weed, Striga (Berner *et al.*, 1995a; b). It has also been estimated that losses of $7-13 billion can be attributed to Striga infestation on cereals across Africa (Khan *et al*, 2001).

Given human population growth and projected income growth, demand for maize in the world is expected to grow at 2.7% by 2025 (Pinstrup-Andersen, 1994) and to double in Sub Saharan Africa (SSA) to 52 million tons by 2020 (Pingali and Pandey, 2000). This demand for maize in Sub Saharan African in general and Kenya in particular, can only be met through dramatic increases in supply, either through the opening of new land or adoption of new technologies (Pingali and Pandey, 2000). In the past, Africa has relied on cultivation of new land for production increases (Pinstrup-Andersen and Pandya-Lorch, 1997), which is getting increasingly unsustainable and impractical unless high financial and ecological costs are paid (Reardon et al, 1999). There is thus a strong pressure on African farmers to intensify agriculture to obtain high yield gains per hectare of land (Ibid) by using more labour and capital and adopting new agricultural technologies.

Rogers (1995) defines adoption as the act of the adopter accepting an innovation with approval and putting it into practice. An innovation is an idea, practice or object that is perceived as new by an individual or other unit of adoption (Rogers, 1995). Adoption is a product of choice. Choice consists of a mental process of thinking and judging the merits and demerits of multiple options and selecting one for action. Choice is guided by individual adopter's preferences. Preferences or tastes assume a real or imagined likes and differences between alternatives and the possibility of rank ordering of the alternatives.

Adoption is assessed in terms of whether or not an innovation is used by households (Semgalawe, 1998). In some cases, the analysis is expanded to include the extent or intensity of use based on various indicators such as land area under the technology or the components of technology used. The theory of diffusion of innovations posits five steps/stages in the technology adoption process: knowledge, persuasion, decision, adoption and confirmation (Rogers, 1995). The process of adoption is bound together by knowledge and information, and the potential adopters assess the risks and benefits associated with different choices they have.

Adoption process for innovations can be explained at 'individual' household level or at 'aggregate' level. The individual household level approach analyses the behaviour of single farm households towards adoption of technologies. The analysis often relates the degree of adoption to the factors affecting it. The aggregate adoption approach is based on the assessment of the proportion of households using the technology in a particular area.

Striga and stem borers are two major constraints to maize production in Kenya especially in Western Kenya. Several research efforts by different institutions have targeted Western

Kenya for intervention in the management of Striga and/or stem borer. These include the Ministry of Agriculture, research organizations (such as KARI, ICRAF, ICIPE) and several NGO's. In the process, technologies such as IR maize, improved fallow, soil fertility improvement and use of trap crops have been disseminated to the farmers for the control of Striga. Early planting, applications of bull-dock and bio-pesticides have targeted the management of stem borers. Push and Pull Technology (PPT), introduced in Western Kenya region in 1998/1999 through on farm trials, is one of the recent additions to the list of technologies to help control Striga and stem borer.

PPT as a technology to control the parasitic weed called *Striga hermonthica*, and the stem borers involves intercropping maize with desmodium/molasses grasses in alternate rows in a plot of land while napier grass is planted in 2-3 rows around the margins of that plot as a hedgerow crop (Khan *et al*, 1997a; 2001).

PPT maximizes on interaction of three components (desmodium, napier, stemborer) to achieve control of Striga and stem borer. Desmodium protects the maize by producing a smell that repels the stem borer moths from laying eggs on the maize plant (Khan, 1997a; Khan, 2001) and it enhances effectiveness of the natural enemies (parasitoids) of the stem borers (Gohole, 2003). Napier protects the maize by serving as an alternative host for the moths, being more preferred by the gravid female moths for laying eggs (Khan and Pickett, 2004). When the eggs are laid on the Napier grass, they hatch into larvae, which are veracious feeders. Later, the larvae attempt to burrow into the stem of the Napier grass in search of food while seeking protection from predators. As a defence mechanism against injury, Napier varieties produce a sticky substance that traps the borers, leading to their death (Khan and Pickett, 2004).

Desmodium has also been shown to suppress the germination of the Striga weed through allelopathy, smothering, nitrogen fixation and suicidal germination (Khan *et al.*, 2000; Khan *et al*, 2001). Additionally, desmodium is a very effective nitrogen-fixing legume with strong nodule development and therefore is well suited for nitrogen deficient soils (Whiteman, 1969). Suttie (1968) estimated that desmodium contributes approximately 160 kg/ha/year of nitrogen fertilizer in association with grasses in Kenya. Desmodium is also used as a leguminous fodder for cattle (Khan *et al*, 2000).

By controlling Striga and stem borer, PPT promises to contribute in closing the maize yield gap and thus satisfy a proportion of the increasing demand for maize among small-scale subsistence farmers currently constrained in maize production. In researcher-managed experiments in the year 2002/2003 in Suba District, PPT yielded 89.5kg on a 5*5 meters plot compared to 53.2 kg from a maize mono-crop (Midega *et al*, 2005), which is a 68.2 percent increase in yields. In other on-farm experiments in selected Districts, maize yield increases ranging from 27.5 percent in Trans Nzoia District to 12.9 percent in Suba District were realised (ICIPE, 2003). If adopted by farmers constrained by Striga and/or stem borer, PPT gives promise to the possibility of significantly reducing the maize yield gap in Kenya and similar regions of Africa.

Information is important for agricultural extension to bring about technical change. Agricultural information is central in formulating and disseminating agricultural information and knowledge and in teaching farmers how to be competent decision makers. The process of information exchange is woven in transmission processes and is a fundamental basis for technology adoption. Information seeking activities by a potential adopter reduces the uncertainty about an innovation to a tolerable level so that he/she is able to make a decision to adopt or not adopt an innovation.

While it is expected that farmers in Western Kenya seek for information on the available methods for control of Striga and stemborer control through various communication channels, there are no studies that have documented these efforts and the impact they have on farmers' decisions to adopt or not adopt technologies. Economic investigations of the process of social learning have made assumptions that relate to observed relationships between individuals, such as geographical or cultural proximity to unobserved flow of information. This study seeks to find out how farmers access information on Striga and stemborer, the kind of knowledge they generate from this sources and whether such knowledge influences the farmers decisions to control Striga and/or stemborer.

1.2 Statement of the problem

Maize yield in Western Kenya, at 0.6tons/ha, continues to be well below the region's potential of 5.0 tons/ha. This is despite an increasing human population and an exploding increase in demand for maize, which is projected to be double the current amounts by the year 2020 (Pingali and Pandey, 2000). The need to increase productivity is even critical because the household farm sizes in the region are consistently getting smaller as the fathers share out a fixed piece of land as an inheritance to their sons (Mango, 2002). Closing the maize yield gap is therefore likely to be dependent on two major factors: the ability of the research and development agents to supply constraint-mitigating technologies and the ability of the farmers to access and utilize the available technologies. PPT for the control of Striga and/or stem borer is one of such innovative technologies. ICIPE, KARI and MoA have developed this technology through collaborative efforts. However, adoption of Striga and stemborer control technologies remains low.

Technology choice, adoption and intensity of its use determine the welfare gains achieved from a technology. By controlling Striga and stemborer, PPT can contribute to closing the maize yield gap and thus satisfy a proportion of the increasing demand for maize among small-scale subsistence farmers. However, this contribution in reducing the maize yield gap can only be realized if farmers learn about PPT, accept it, adopt it and use it intensely in maize production. Studies documenting factors that influence the choice of technology, adoption decision and intensity of use of the chosen technologies in the control of Striga and stem borer are very few. There are no studies indicating the level of farmers' awareness of PPT in western Kenya. The factors that influence the adoption and the intensity of use of PPT have also not been documented. This study will therefore evaluate the factors that influence the awareness, adoption and intensity of use of the PPT by farmer in Vihiga and Suba districts. Lancaster 1966 (new consumer economics) proposed that consumption of goods is assumed to transform commodity space into characteristics space. Accordingly, consumers maximize utility through the consumption of characteristics. An agricultural technology can be likened to a good, with farmers as the consumer of the given technology. However, none of the currently available studies has attempted to decompose the Striga and/or stemborer control technologies into their various attributes/characteristics and assess the effect of each of these characteristics on farmers' adoption decision. The challenge is to determine the factors that influence the farmers' choice of a particular technology or a combination of technologies from an array of technologies available for the solution of particular problems facing them.

This study contributes to knowledge by developing and applying a methodology for evaluating the factors that influence the farmers' technology choice and adoption in Striga and/or stem borer control in western Kenya, specifically focusing on the Push-Pull Technology (PPT). The information generated through this study will be valuable to the research and development agencies when making decisions related to technologies for improving food security and humanity's welfare with regard to western Kenya in particular and Kenya in general.

1.3 Study objectives

The broad objective of the study was to evaluate the factors that influence the farmers' choice and adoption of Striga and stem borer control technologies in Vihiga and Suba Districts of western Kenya, including the impacts of information access.

The specific objectives were three.

i) Identification of the sources and influence of agricultural information on the farmers' choice of Striga and stemborer control technologies in Vihiga and Suba districts of western Kenya.

ii) Identification of how the farmers characterize the Striga control technologies and how these influence their adoption decision in Vihiga and Suba districts.

iii) Evaluation of the decision variables in the adoption and utilization of the PPT in Vihiga and Suba districts.

1.4 Hypotheses

The following hypotheses were tested:

i) Farmers' socio-economic characteristics do not influence the agricultural knowledge that they acquire through different sources of information

ii) Technology attributes do not influence the farmers' choice of a Striga and/or stem borer control technology from among the many technologies that are available in Western Kenya

iii) Agricultural knowledge and technology characteristics do not influence adoption and intensity of use of a new technology, such as the PPT

1.5 Scope of the study

The study was implemented in two Districts namely, Suba and Vihiga Districts in the year 2006. Although there are more than 15 Districts in the Western Kenya region where PPT has been disseminated by ICIPE through on-farm demonstrations, only Suba and Vihiga District were studied due to limitations of finances and time. In each of the Districts, two divisions were selected. One division was where PPT was disseminated and the other where PPT was not disseminated. The study limited itself to the agricultural information search and acquisition by the farmers, factors influencing the choice of the available technologies, and farmers' evaluation of technology characteristics and also the adoption and utilization of PPT.

1.7 Contribution of the study

The effort to analyse and document the channels that the farmers' use in accessing agricultural information will give practical information to designers of technology dissemination strategies aimed at the control of Striga and stemborers in Western Kenya. They will be able to compare the different channels and the coverage of farmers they reach. The study also gives insight into the factors that influence the process of agricultural information acquisition among farmers. This valuable information will help development workers choose the channels to use to reach many farmers that are constrained by Striga and stemborer, and offer them baskets of technologies to choose from in the control efforts.

The study also provides information on what characteristics farmers look for when they evaluate a technology for adoption. As an example, the Striga control technologies are decomposed. The utilities farmers associate with these characteristics provides an indication of how important each of the characteristics is to the farmers. This is valuable information for researchers and development workers who are tirelessly working hard to generate technologies that are sometimes adopted by very few farmers. With this information, agricultural researchers can take into account the farmers' needs and thus enhance higher adoption levels for their technologies.

This study also provides information on the adoption of PPT. PPT is a unique technology because it controls both Striga and stemborer. The developers of the technology wished to understand how acceptable the technology is, how farmers get to be aware of its existence and the factors that influence its adoption and intensity of use among the target farmers. Such information will contribute in designing of dissemination strategies for the PPT, as well as improving the technology for wider acceptance and adoption among farmers. Higher levels of the farmers adoption of the PPT would mean enhanced control of Striga and stemborer in maize production, increasing the maize yields and hence improving the food security status of farm households in Western Kenya.

Farm households in both Districts use maize as a staple cereal. Household subsistence needs for maize are usually met through own production. However, in the recent years, human population in these Districts has grown faster than other regions of Kenya. The population density is very high in Vihiga District with 886 persons per square kilometer being recorded (RoK, 2001). Land holdings per household have been diminishing rapidly over the years as fathers share out land to their sons as an inheritance. Mango (2002) reports an average household farm holding of 0.5ha in the District. With declining farm holdings and soil fertility levels, production of maize or any other crop, is challenged. Maize yield gap is stretched further by the existence of *Striga* and stem borer, among other biotic and a-biotic maize production constraints.

The socioeconomic situation of the farmers in these regions is also unique and different from that in the rest of Kenya, and it is worth evaluating how this impacts on technology choice and adoption. Farm holdings in Suba District are larger than those in Vihiga, with households having an average of 5.5 ha. Approximately 39% of the arable land is under cultivation. The major food crops are maize and sorghum; local animals are also kept under free range most of the year. There is limited horticultural farming along the shores of Lake Victoria, mainly using bucket irrigation. Suba District is estimated to have 20,000 households and a population density of 92 persons per square kilometer.

Farmers in Western Kenya have had many technologies disseminated to them by different actors in research and development. These include improved fallow, crop rotation, intercropping, use of fertilizer, manure and compost, Striga tolerant varieties (IR maize, KSTP94), and more recently Push-pull technology. It is expected that the farmers in these Districts have an advanced system of acquiring information about new technologies that address their production constraints. The farmers have many technologies to choose from, hence they should have an established system of comparing one technology to another. Because of their production constraints and food requirements, they are receptive to new technologies like PPT that may effectively reduce their maize yield gap. It is, therefore, anticipated that this area is a rich source of data that can be used to model farmers' technology choice decisions in order to understand factors that influence their decisions to control or not control Striga and stem borer.

1.8 Outline of thesis

In this dissertation, we report the findings in three results-based chapters. Each of the result chapter (Chapter 2-4) is a stand-alone chapter, with an introduction specific to the chapter, literature review specific to the chapter, the chapter study objectives, summary of the methodology followed, including model specification and data requirements, results obtained, discussions and conclusions and references.

Chapter One gives a general introduction to the study, outlining the background, the research problem, the overall study objectives and the contribution of this study to information.

Chapter Two focuses on farmers' search for information regarding the technologies that can control Striga and stemborers in Western Kenya. The chapter reviews available literature as a background on agricultural information. The chapter also gives a summary of steps followed in executing the fieldwork to generate data for the whole study. Channels that farmers use to obtain information on Striga and stemborer control are analysed. The principal component analysis is used to classify the agricultural information among farmers. Linear regression is then used to identify factors that influence accumulation of agricultural information. This was important in order to inform research and extension programmes on how to enhance effective diffusion and adoption of the technologies.

Chapter three focuses on the characteristics of technologies used in the control of Striga. The focus on Striga only for this chapter was necessitated by the fact that very few farmers in the study sample indicated that they controlled stemborer on their farms. Data on stemborer control was therefore not enough for analysis of the stemborer control technologies' characteristics. Farmers are regarded as consumers of Striga control technologies. In a focus group discussion, farmers were asked to identify the most important characteristics they consider in the control of Striga. Those characteristics are used to form profiles of hypothetical technologies with different combinations of the characteristics. These hypothetical technologies are presented to farmers to choose their most preferred technology. The choice data is subjected to analysis using the proportional hazards regression in a multinomial logit framework to identify the utility values that the farmers attach to each characteristic. Results are presented on which technology characteristics are important in the control of Striga among farmers in Suba and Vihiga Districts.

Chapter Four focuses on adoption and use of Push-Pull Technology (PPT). Data is collected on whether farm households know about PPT, whether they have decided to adopt PPT and how much of their maize farm is put under PPT. Using a bi-variate Probit model and the Tobit model, we identify factors that influence awareness, adoption and intensity of use of PPT. We show that information is important for the awareness and adoption decisions while technology characteristics are important for the adoption and intensity of use decisions.

Chapter five presents the summary of the key findings of the study and the major policy implications. It also focuses on the limitations of the study and recommendations for future research.

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CHAPTER 2: CLASSIFICATION AND INFLUENCE OF INFORMATION ON STRIGA AND STEMBORER CONTROL IN WESTERN KENYA

2.1 Introduction

This chapter focuses on how farmers in Vihiga and Suba Districts in Western Kenya access information on the control of Striga and stemborer. The chapter also attempts to classify the type of knowledge farmers generate depending on communication channels they access. The chapter also assess whether this knowledge influences farmers probability of adoption of improved technologies to control Striga or stemborer.

2.2 Sources of agricultural information

Sources of agricultural information can be categorised into three. These include (i) agricultural extension, (ii) social learning and (iii) other sources.

Agricultural extension

Information is inevitably important for agricultural extension to bring about technical change. One of the important sources of agricultural information is a formal sector programme of agricultural extension. The exchange of agricultural information is the rationale for the organization of the 'agricultural extension' departments in most agricultural systems in the world. Roling (1988) defined extension as a 'professional communication intervention' deployed by an institution to induce change in voluntary behaviours with a presumed public or collective utility. Nagel (1997) defined agricultural extension as the 'organised exchange of information and the purposive transfer of skills'. Leeuwis and Van den Ban (2004) view extension as a series of 'embedded communication interventions' that are meant, among others, to develop and/or induce innovations which supposedly help to resolve problematic situations. Definition of agricultural extension is embedded in information and information exchange. Agricultural extension is central in formulating and disseminating agricultural information and knowledge and in teaching farmers how to be competent decision makers. It is an out of school education for farmers.

Agricultural extension operates within a broader knowledge system that includes research and agricultural education. The Food and Agricultural Organization of the United Nations (FAO) and the WorldBank refer to this larger systems aa 'Agricultural Knowledge and Information Systesms in Research and Development (AKIS/RD)' while the Organization for Economic Co-operation and Development (OECD) countries refer to it simply as the 'Agricultural Knowledge System (AKS)'. Axinn (1988) categorised eight extension appproaches in delivery of agricultural information. They include:

- General agricultural approach
- Commodity specialised approach
- Training and visit (T&V) approach
- Agricultural extension participatory approach
- Project approach
- Farming systems development approach (FSDA)
- Cost sharing approach
- Educational institution approach.

Farmer field schools (FFS) have also been developed more recently as a group extension process based on adult non-formal education methods. The first field schools were established in Central Java in 1989 by crop protection officers who wanted to test and develop field training methods as part of their Integrated Pests Management (IPM) 'training of trainers' course (www.farmerfieldschool.net). FFS teach basic agro-ecology and management skills.

All these approaches in agricultural information sharing and knowledge building generally cluster into three main categories of extension: public extension, private extension and farmer-led extension.

i) Public extension

Public agricultural extension is the oldest approach in information exchange, mainly based in the Ministries of Agriculture (Rivera, *et al*, 2001). It serves to provide agricultural information among other related services to rural and urban farmers; farmers in subsistence production as well as those in cash crop production; and farmers in high potential and marginalized ecological zones. This wide mandate has been a challenge for the public extension system delivery of services. Besides, public agricultural extension has faced a challenge of funding over the years, especially after the structural adjustment programmes were implemented in developing countries. The public extension 'top-down' model of communication of agricultural information has been challenged as not being appropriate (Chambers *et al*., 1989; Frank and Chamala, 1992). Large numbers of farmers have not been reached by the publicly supported extension services (Malouf, *et al*.; 1991). The public extension is therefore reforming and re-organizing. The perception of agricultural information as a public good that is subject to market failures has provided the basis for continued provision of government/public extension services (Marsh and Pannell, 1999).

In response to the challenges of the public extension, other categories of extension and information dissemination that acknowledge that demand-driven approach is more responsive to farmers' needs have emerged, including privatized extension and farmer-led extension.

ii) Privatized Extension

Privatized extension is an important source of agricultural information for farmers. In this arrangement, 'agricultural information' is traded as a private good. Private extension implies a full transfer of ownership from public extension to a private entity; with the entity meeting all costs and receiving any profits (Rivera and Cary, 1997). Though this category of extension is fully developed in some developed countries like the Netherlands and New Zealand, developing countries are still experimenting with the concept, amid challenges. The biggest challenge is how to reach the poor and disadvantaged farmers whose value of information may be low and therefore may have low propensity to pay for it (Rivera and Cary, 1997).

iii) Farmer-led extension

Scarborough *et al.* (1997) define farmer-led extension as a multi-directional 'communication' process between and among farmers and extension. Robert Chambers places farmers first in this category, appreciating that they have sound local knowledge and good reasons for their behavior (Chambers, *et al*. 1989). It involves the sourcing, sharing and development of knowledge and skills in order to meet farming needs and develop innovative capacities among all actors. Farmers have a controlling interest and they play a key role in technology development and sharing of information about it. Variations of farmer-led extension include farmer-to-farmer extension, Farmer Field Schools and the problem census/problem solving approach. Non-governmental organizations and government collaborations on these approaches provide limited external assistance that enables farmers to manage, adapt and spread innovations and information about such innovations through their own efforts.

Farmer-led extension is participatory in nature, where the extension process of agricultural information is both iterative and interactive (Wilson, 1992). The key stakeholders in participatory approaches are involved in a cooperative and flexible process that facilitates the implementation of activities to achieve practical improvements. Many participatory techniques exist, including rapid rural appraisals (RRA), participatory rural appraisals (PRA), focus group discussions (FGD) and structured workshops (Carmen and Keith, 1994) and farmer field schools (Rivera, 2001).

Social learning

Another important source of agricultural information, besides the formal agricultural extension, is the social learning process. This is what farmers learn from friends, from neighbours and relatives. Social networks effects have been appreciated in development studies to be important for individual learning and knowledge building. Individuals in developing countries take into account the experiences of their social contacts when deciding whether to adopt new technologies, thus generating a process of social learning (Miguel and Kremer, 2003). Social networks may influence technology adoption through their function as (i) a source of informal finance (both credit and insurance), (ii) channels of information and thus vehicles for learning and (iii) means for resolving externalities and collective action problems through enforcement of social norms (Hogset, 2005). It has been shown that farmers within a group learn from each other with regard to how to grow new crop varieties (Foster and Rosenzweig, 1995; Conley and Udry, 2001).

Social networks and learning processes are deliberately exploited when the agricultural extension system service establishes partnerships with farmer groups and directs teaching and training efforts to group members collectively (Hogset, 2005). Such groups generate learning externalities, since knowledge disseminated through such groups eventually becomes available to the community at large as members observe the outcomes of group members' experimentation with new technologies.

Other sources

Other sources of agricultural information include structured education and training possibilities (ICRA, 1996). These could be short-term planned learning activities that are directly relevant to the farm or farming constraints and that require relatively short blocks of time from a few hours to a few days. The training could be executed through seminars, workshops or training sessions organized by development organizations, universities or government ministries.

Farmers' experimentation has also been recognized as a source of agricultural information and knowledge (Abdulai and Huffman, 2005). Farmers generate agricultural information through trial and error through years of 'own experimentation' as they tackle agricultural production constraints. This information may then be consolidated into indigenous knowledge as it is shared from farmer to farmer and through the generations. Flavier *et al.* (1995) define indigenous knowledge as the information base for a society, which facilitates communication and decision making.

2.3 Communication channels

Communication is the process by which participants create and share information with one another in order to reach mutual understanding (Rogers, 1995). Communication channels are the means by which messages get from one individual to another. In the transmission of agricultural information between research, extension and farmers, communication channels become very important. The nature of the information –exchange relationship between a pair of individuals determines the conditions under which a source will or will not transmit the innovation to the receiver and the effect of the transfer.

There are two major categories of communication channels: mass media channels and interpersonal channels. Mass media channels are often the most rapid and efficient means to inform an audience of potential adopters about the existence of an innovation, creating awareness and knowledge. Mass media channels are all those means of transmitting messages that involve a mass medium, such as radio, television, newspapers and so on. Mass media enable a source of one or a few individuals to reach an audience of many. On the other hand, interpersonal channels are more effective in persuading an individual to accept an innovation. This is especially more so if the interpersonal channel links two or more individuals who are similar in socio-economic status. Interpersonal channels involve a face-to-face exchange between two or more individuals (Rogers, 1995).

2.4 Agricultural Information and adoption of technologies

Communication is the process by which participants create and share information with one another in order to reach mutual understanding (Rogers, 1995). Information has been recognised as a factor of production alongside the classic factors i.e. land, labour, capital and management (Antholt, 1995; Sumberg, *et al.,* 2004). UNESCO recognises information as one of the main requirements for development. Information, when relevant, is proposed to have huge multiplier effects on the efficiency and effectiveness with which the other production resources are utilised (Plant, 2001). Information underpins all theories of innovation and technical change (Sumberg *et al.,* 2004), including agricultural change. As the information flows among members of a social system, then the process of diffusion is witnessed.

According to Rogers (1995), diffusion is a particular type of communication in which the message content that is exchanged is concerned with a new idea. The essence of the diffusion process is the information exchange, through which one individual communicates a new idea to one or several others. A communication channel is the means by which messages get from one individual to another.

Rogers (1995) defines diffusion as the process by which an innovation is communicated through certain channels over time among members of a social system. An innovation is an idea, practice or object that is perceived as new by an individual or other units of production. Thus diffusion process involves the spread of a new idea from a source to potential users/adopters. This process of information exchange is woven in transmission processes. Information for change is therefore a fundamental basis for technology adoption. Information seeking activities by a potential adopter reduce the uncertainty about an innovation to a tolerable level so that he or she is able to make a decision to adopt (or reject) the innovation. It is therefore important to expect that farmers do seek for information on the possible control methods for Striga and stemborer through various communication channels.

The innovation-decision process is the process through which an individual passes right from the first knowledge of an innovation to forming an attitude towards the innovation, and all the way to making a decision to adopt or reject the use of the new idea and the confirmation and implementation of this decision. Rogers (1995) conceptualised five main steps in the innovation-decision process:

- Knowledge – knowledge occurs when an individual learns of the innovation's existence and gains some understanding of how it functions

- Persuasion – persuasion occurs when an individual forms a favourable or unfavourable attitude towards the innovation
- Decision – decision occurs when an individual engages in activities that lead to choice to adopt or reject the innovation
- Implementation – implementation occurs when an individual puts an innovation into use
- Confirmation - occurs when an individual seeks enforcement of an innovation-decision that has already been made, but the individual may reverse this previous decision if exposed to conflicting messages about the innovation.

The innovation-decision process is an information seeking and information processing activity in which an individual obtains information in order to reduce uncertainty in the innovation (Rogers, 1995). The innovation-decision process is bound together by knowledge and information. At the knowledge stage, an individual mainly seeks information that reduces uncertainty about the cause-effect relationships involved in the innovation's capacity to solve an individual's problem. At the persuasion and decision stages, an individual seeks information in order to reduce uncertainty about innovation's consequences; the advantages and disadvantages in his/her own situation. Knowledge is generated through learning processes. As knowledge is used, results are shared and tested in application, understanding is multiplied among potential users and knowledge becomes tacit (Rogers, 1995).

2.5 Empirical studies on agricultural information

Although information about farmers' communication and information seeking behaviours is useful for understanding the needs of client groups and to target intervention programs (Ford and Babb, 1989), economic researchers seldom have direct data on information usage and technology adoption (Abdulahi and Huffman, 2005). Early adoption studies in development economics focused on individuals and plot/farm characteristics (e.g. Feder *et al.,* 1985; Evenson and Westphal, 1995). These studies did not have variables that separated the role of learning processes from the other determinants of technology adoption. It seems as if information was assumed to be homogenous among farmers; the farmers' ability to make sense of the information was also assumed homogenous or taken for granted (Just *et al.,* 2003).

Recently, economic development studies are making efforts to measure the quantitative importance of information, its sharing processes and impact on technology adoption decisions. Conley and Udry (2001) advance that when there are multiple adopters of a new technology in similar circumstances, as is often the case with an innovation in agriculture, then the process of learning about the new technology maybe *social.* Social learning process investigations are therefore the most common approach in testing the effect of information on diffusion and adoption of agricultural technologies. In social learning, analysis is carried out on whether or how individual technology adoption decisions depend upon the choice of other individuals in the same social networks. Examples include Foster and Rosenzweig (1995), Behrman, *et al.,* (2002), Miguel and Kremer (2004), Munshi (2004), Mwakubo *et al.,* (2004), Conley and Udry (2001, 2005), Bandiera and Rasul (2006), Hogset and Barrett (2007).

2.6 Gaps in information studies

Due to lack of direct data on information and learning effects, economic investigations of the process of social learning have typically made assumptions that relate observed relationships between individuals, such as geographic or cultural proximity, to unobserved flow of information (Bandiera and Rasul, 2006). An exception is the study by Conley and Udry (2001) who collected detailed and precise data on farmers communication pattern to define each individual's information neighbourhoods and the set of others from whom they might learn. They used these relationships to test if the farmers change their fertilizer input decisions to align with those of their neighbours who were successful in previous periods in pineapple farming in villages in Ghana. In studying adoption of maize storage technologies in Benin, Adegbola and Gardebroek (2007) studied the effect of information sources on technology adoption and modification decisions. Farmers were either informed by extension or by other farmers and their results show that there are differences in adoption and modification of technology depending on the source of information. Moser and Barrett (2003) looked at the dynamics of smallholder adoption of high-yielding low external input technologies in rice production in Madagascar. They show that learning effects, both from other farmers and extension agents, exert significant influence over adoption decision. Information and the channels of communication are therefore proven to be very important in the adoption of agricultural technologies. Available literature indicates that no studies have investigated the role of information in farmers' decision to adopt improved technology in the control of Striga and/or stemborer in Kenya. In this study on adoption of Striga control technologies in Western Kenya, we seek to find out how farmers obtain information on Striga and/or stemborer control within their environment with the following research questions: (i) What are their channels of information gathering? (ii) What kind of knowledge do they generate through interaction with these channels? (iii) Is learning about Striga and/or stemborer control the same for farmers accessing different channels of information? (iv) can this knowledge be measured directly or represented indirectly by a proxy measure? Would this knowledge influence a farmers' probability of adopting a control technology if they are constrained by Striga and/or stemborers?

2.7 Objectives of the chapter on agricultural information

This chapter investigates the relationship between the farmers' knowledge of Striga and stemborer control technologies and the farmers' decision to adopt a control technology on their farms through empirical analysis. The purpose of this chapter which was derived from the first objective of the study was to:

a) To identify the farmers' different sources of information on Striga and stemborer control technologies in Western Kenya
b) To identify the 'knowledge' developed from these information sources and identify factors that influence the knowledge acquired
c) To investigate how the 'knowledge' acquired influences farmers' decision to adopt Striga and/or stemborer control technologies in cereal farming in Western Kenya

To account for information differences, an index was generated to proxy for knowledge (henceforth referred to as knowledge index) of Striga/stemborer control among the farm households in Vihiga and Suba Districts of Kenya. Two propositions were tested: whether the knowledge index was statistically significantly influenced by the households' socio-economic characteristics and whether, an increase in the knowledge index of a household significantly improved the level of the households' probability of deciding to use a control technology against Striga or stemborer on the farm. These propositions were investigated by analysis of the data collected in a cross sectional survey of 476 households in six sub locations across Vihiga and Suba District.

2.8 The model

We assume that a farmer i wants to learn about optimum methods of Striga and/or stemborer control; let this optimum of knowledge on Striga and/or stemborer control be u_i. The farmer sources information from social networks (u_{si}), from formal extension links with government and non-governmental organizations (u_{ei}), from media sources (u_{mi}) and from own farming experience (u_{xi}). Therefore u_i is a function of ($u_{si}, u_{ei}, u_{mi}, u_{xi}$) and is a bundle of knowledge that each farmer accumulates, based on access to information sources and their internal competencies to learn and adapt. According to Shultz (1975), a major cause of differential access to information is heterogeneity in internal competencies of the decision makers or differences in ability to learn and adapt. The differences in ability to learn and adapt are in turn influenced by one's educational competencies, the strength of external linkages one has or ties to sources of pertinent information. This study does not concern itself with the process of 'how' the farmers obtain information from the social networks (u_{si}), from formal extension links with government and non-governmental organizations (u_{ei}), from media sources (u_{mi}) nor from own farming experience (u_{xi}), but rather on whether the farmers obtained information on Striga and/or stemborer control from these sources, which they consider useful and effective in helping them reach a decision to adopt an improved technology on the farms.

2.9 Data and methods

2.9.1 Household and farm characteristics, Striga and stemborer infestation and control

Through a cross sectional survey of 476 households in Vihiga and Suba Districts, data were collected on household composition and characteristics, farm characteristics, livestock ownership and income generation. Data were collected on whether Striga and stemborer were constraints to cereal production (coded as 1 if the household reported Striga as a constraint, 0 otherwise; and similarly the same procedure was done for stemborer). Farm households' perceptions of the intensity of the Striga and stemborer infestation in their farms were also recorded (0 for no infestation, 1 for minor infestation, 2 for moderate infestation and 3 for major infestation). Data were collected on whether the household had adopted any technology to control either Striga or stemborer on the farm (coded as 1 if a household used any Striga control technology, 0 otherwise; similarly for done for stem-borer).

2.9.2 Sources of information on Striga and stemborer control

From literature review and focus group discussions, it was established that farm households in Vihiga and Suba Districts obtained information about Striga and stemborers control through several dissemination pathways including farmer group meetings, on-farm demonstrations, contact farmers, radio, agriculture extension agencies from the government and non governmental organizations, pamphlets, brochures, posters, attendance in agricultural shows, visits to research and extension institutions, field days, chiefs' public (*baraza)* meetings, informal information exchange between neighbours and from 'Push-Pull Farmer Teachers'. Own experience in farming was also an important source of information. This also apply to other technologies that farmers adopt.

Thus the major sources of information on Striga and stemborer control that were considered in the information variable were: 1) Membership in farmer groups, 2) Participation in on-farm demonstrations, 3) Interaction with a contact farmer in the neighbourhood, 4) One-to-one interaction with community leaders, 5) Farmer visits to organizations of agricultural research or extension, 6) Radio programs, 7) Contact with agricultural extension agents from government or non-governmental organizations. 8) Reading of pamphlets and brochures on agricultural information, 9) Attending agricultural shows in the District, the province or national events, 10) Attending chiefs meetings (*Baraza's*) in the local area, 11) Attending agricultural field days in the local areas, 12) Interaction with neighbours and friends, 13) Reading posters on agricultural information, 14) Interaction with 'Push-Pull Farmer Teachers' in the local areas. Data were obtained on the following attributes: households' access to the

14 sources of information (coded as 1 if a household had linkages to a pathway, 0 otherwise); whether such a source was a source of knowledge on Striga or stemborer control for the household (coded as 1 if household learnt of Striga/stemborer through this pathway, 0 otherwise); and the household members' judgement of such a pathway as effective in disseminating information on control of Striga or stemborer to them (coded as 0 if not effective, 1 if effective and 2 if very effective). The effectiveness variable were rescaled to 0 if the pathway was considered ineffective and 1 if effective or very effective. A source can be defined as 'effective' if farmers feel that they got sufficient information to be able to make decisions of technology adoption on their farms. The effectiveness variables, together with the farming experience variable, were used in the principal component analysis to generate a 'knowledge index' for each household.

Farming experience is important in Striga and stemborer control and was recorded as the number of years a household had been farming and making farm decisions independently. A mean of the farming experience was obtained and the actual household variable was re-scaled to 1 if the farming experience was equal or greater than the mean, and 0 if the farming experience was less than the mean. This was done in order to obtain a binary variable for farm experience that could be used in the principal component analysis.

2.9.3 Generating knowledge index

It can be assumed that an interaction of the farm households with various sources of information on Striga and stemborer control leads to an accumulation of 'knowledge' on practices of management and control of Striga and stemborer control. The more a household interacted with many sources of information and judged them as effective, the higher the level of 'knowledge' that such a household accumulated on the control of Striga or stemborer. However, it is not easy to measure the level of 'knowledge' accumulated by the households directly. The study sought to make use of the Principal Components Analysis (PCA) approach to have an index that would proxy for a 'measure' for knowledge acquired through the various information sources accessed.

PCA involves a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called 'principal components' (Lawley and Maxwell, 1971). Factor analysis and PCA have been used in other studies to generate proxy indices that are then subjected to further analysis. Tucker and Napier (2002) used factor analysis to assess preferred sources and channels of soil and water conservation information among farmers in the US watershed. Amudavi (2005) used PCA to assess farmers' propensity to adopt integrated natural resource management practices in Vihiga, Baringo and Embu Districts of Kenya. Principal component analysis is useful for extracting a few components or factors that capture the common variability in the correlations between variables (in these case pathways most effectively (Stevens, 1996)). In this study, data from 15 pathways of dissemination of Striga and stemborer control information were reduced to 2 components[1].

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[1] As many factors as the numbers of original variables are extracted. However, only factors with Eigen values greater than 1 are retained. This means that unless a factor extracts at least as much as the equivalent of one original variable, it is dropped from further analysis (Kaiser, 1960).

In doing a principal components analysis (PCA) for agricultural information sources, the procedure begins with a set of K variables, a^*_{1i} to a^*_{Ki} representing the source of agricultural information for the *i*th household. Each variable, a^*_{1i}, is specified by its mean and standard deviation, $a_{1i} = (a^*_{1i} – a^*_1)/(s^*_1)$, where a^*_1 is the mean of a^*_{1i} across all N households and s^*_1 is the standard deviation. The selected variables are linked with latent components (factors) for each household *i* through the equation:

$$a_{1i} = v_{11} \text{ x } A_{1i} + v_{12} \text{ x } A_{2i} \ldots + v_{1K} \text{ x } A_{Ki} \;\; \ldots \; i = 1, \ldots, \text{N (Households)}$$

$k = 1, \ldots, \text{K}$ (agricultural information source)

$$a_{Ni} = v_{N1} \text{ x } A_{1i} + \ldots + v_{KK} \text{ x } A_{Ki}$$

(2.1)

where the A’s are the components and the v’s are the coefficients on each component for each variable and these are constant across all households. It is only the left hand-side that is observed, making the solution to the problem indeterminate. The PCA solves this problem by determining specific linear combinations of the variables with maximum variance accounted for in the first principal component A_{1i} (Lawley & Maxwell, 1971). The procedure is repeated for each successive component accounting for the maximum of variance remaining. Reversing equation (2.1) yields factor loading from the model; that is the estimates for each of the K principal components:

$$A_{1i} = f_{11} \text{ x } a_{1i} + f_{12} \text{ x } a_{2i} \ldots + f_{1K} \text{ x } a_{Ki} \;\; \ldots \; i = 1, \ldots, \text{N}$$

$$A_{Ki} = f_{K1} \text{ x } a_{1i} + f_{K2} \text{ x } a_{2i} \ldots + f_{NK} \text{ x } a_{Ni}$$

(2.2)

Where A_{1i} is the first principal component, a_{1i} the normalized variable**,** f_{1i} is the factor score coefficient (weight) by which the normalized variable is multiplied to obtain a factor score in the linear combination. Thus, the agricultural information proxy index for each household is based on the expression:

$A_{1i} = f_{11} \text{ x } (a^*_{1i} – a^*_1)/(s^*_1) +\ldots+ f_{1N} \text{ x } (a^*_{ni} – a^*_N)/(s^*_N)$

(2.3)

The first factor accounts for the maximum variance in the original set of survey items. With further extraction of uncorrelated components, the amount of variance explained by each subsequent factor decreases (Stevens, 1996).

Adopting the procedure of principal component analysis (PCA), data on the households' perception of effectiveness of a source of information were reduced to principal components that explained much of the variance in the original data set.

Bartletts test of sphericity tested the null hypothesis that the study sample was randomly drawn from a population in which the correlation matrix was an identity matrix. This hypothesis is rejected at 1% significance level as shown in table 2.1. KMO measure of sampling adequacy (MSA) tests whether the correlations between χ^2 and the other variables are unique, that is not related to the remaining variables outside each sample correlations. Kaiser describes MSA above 0.9 as marvellous, above 0.8 as meritorious, above 0.7 as middling, above 0.6 as mediocre and above 0.5 as miserable while below 0.5 as unacceptable. The study sample had a MSA value of 0.823, which can be described as meritorious and so principal components were extracted

Table 2.1 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.823
Bartlett's Test of Sphericity	Approx. Chi-Square	1129.198
	Df	105
	Sig.	.000

Using the procedure called ‘varimax rotation with Kaiser normalization’, the principal components were rotated to establish which information sources loaded heavily with which component. Two principal components, accounting for 34.6% of variation in the original data set, were extracted. Since principal components are orthogonal, the two components were seen to represent two distinct types of ‘knowledge’. The two principal components, considered proxy indices for knowledge, were then used as dependent variables in multivariate linear regression analysis. This was to test what socioeconomic factors influenced farmers’ level of knowledge. The two principal components were then used as independent variables in logistic regression to test the null hypothesis that an increase in the knowledge level improves the likelihood of a household’s decision to control Striga or stemborer using improved technology.

2.9.4 Modelling factors influencing ‘knowledge index’ on Striga and stemborer control

Linear regression. A multivariate linear regression is used to understand how marginal changes in one variable, holding the other explanatory variables constant, affects the expected value of the dependent variable and also indicates how important each explanatory variable is to this value. The household was our unit of analysis and the knowledge index the dependent variable. Two models were regressed to assess the influence of socio-economic characteristics, one for the ‘1st principal component’ and the other for the ‘2nd principal component’. The regression model estimated took the form:

$$y = \beta_0 + \sum_{1}^{10} \beta_i x_i + \varepsilon \text{ ……………………………………………Eq. 2.4}$$

where:

Table 2.2: Summary of the symbols, descriptions and measurement of the independent variables in equation 2.4

Variable Symbol	Variable description	Variable measurement
χ_1	Gender of the head of household	1=male, 0=female
χ_2	Age of the head of household	Continuous variable
χ_3	Education level of the head of household	- Head of household with no education (1 if yes, otherwise 0) - Head of household with primary school education (1 if yes, otherwise 0) - Head of household with secondary school education (1 if yes, otherwise 0) - Head of household with post-secondary school education (1 if yes, otherwise 0)
χ_4	Land tenure security index for the farm owned by the household	Continuous variable
χ_5	Total farm size owned by the household, measured in acres	Continuous variable
χ_6	Time to the nearest market, measured in hours	Continuous variable
χ_7	Total livestock units index	Continuous variable
χ_8	Level of stemborer infestation	- No stemborer infestation, (1 if yes, otherwise 0) - Minor stemborer infestation (1 if yes, otherwise 0) - Moderate stemborer infestation (1 if yes, otherwise 0) - Major stemborer infestation (1 if yes, otherwise 0)
χ_9	Level of <u>Striga</u> infestation in the farm	- No stemborer infestation, (1 if yes, otherwise 0) - Minor stemborer infestation (1 if yes, otherwise 0) - Moderate stemborer infestation (1 if yes, otherwise 0) - Major stemborer infestation (1 if yes, otherwise 0)
χ_{10}	Village location	- Location in a push-pull village (PPV) (1 if yes, otherwise 0) - Location in a village neighbouring a push-pull village (PPNB) (1 if yes, otherwise 0) - Location in non push-pull village (NPPV) (1 if yes, otherwise 0)

γ is the proxy for knowledge index (principal component I or II), which is a unitless measure; β_0 is the intercept and the β_i's were the parameters to be estimated as coefficients of the independent variables; ε the error term, which represented the variation, not accounted for by the model's independent variables. It is assumed to be uncorrelated with the same set of predictors and is normally distributed with a mean of '0' and a population variance of 1. The χ_i's are the independent variables as specified in table 2.2.

The β coefficients from a linear regression indicate the difference in response per unit difference in the predictor. The output also gives the beta-coefficients. These are what the regression coefficients would be if the model were fitted to standardized data, i.e., for each observation, we subtract the sample mean and then divide by the sample standard deviation. The t-statistic tests the hypothesis that a population regression coefficient $\beta = 0$; that is $H_0; \beta = 0$. The P-value for the independent variable tells us whether the independent variable is statistically significantly different from zero, hence indicative of predictive capability.

2.9.5 Effect of 'knowledge index' on a household's decision to control Striga or stem-borer

To investigate if Type-I and Type-II-knowledge influenced a household's likelihood to use a control technology against Striga or stemborer, logistic regression model was fitted to the data. Households were asked if they used any technology to control Striga and/or stemborer on their farms (coded as 1 if yes in either case, 0 otherwise). This binary variable was used as a dependent variable in the logistic model, while the Type-I and Type-II knowledge indices entered the model as explanatory variables, together with the selected independent variables. Two models were estimated, one for the farmers who reported using improved technologies to control Striga on their farms and the second for the farmers who reported using improved technologies to control stemborers.

Logistic regression

Our independent variables are both categorical and continuous and so logistic regression is chosen as an appropriate model for analysis. Logistic regression model examines the relationship between independent variables and the log odds of the binary outcome variable. In our model, the binary outcome is 1 (household is controlling Striga or stemborer on their farm) or 0 (household is not controlling Striga or stemborer on their farm). The model takes the form:

$$\ln(odds) = \ln\left(\hat{y}/(1-\hat{y})\right) = \beta_0 + \sum_{1}^{17}\beta_i x_i \text{ ………………………Eq. 2.5}$$

Where $\hat{y}$ is the predicted probability of a household controlling Striga or stemborer, and

$(1-\hat{y})$ is the predicted probability of a household not controlling Striga or stemborer. To predict the odds that a household controls Striga or stemborer in their farm, the model takes the form:

$$odds = e^{\beta_0 + \sum_{1}^{17}\beta_i x_i} \text{ ……………………………………………..Eq.2.6}$$

To convert the odds to probabilities, the following equation is used:

$$\hat{y} = odds/(1+odds) \text{ …………………………………………..Eq. 2.7}$$

Independent variables

The explanatory variables X_1 to X_{10} as presented from the multivariate regression in equation 3.1 above were included as explanatory variables in the logistic regression. Other variables included in this model are summarised in table 2.3.

Table 2.3 Summary of the symbols, descriptions and measurement of the independent variables in equation 2.5

Variable Symbol	Variable description	Variable measurement
χ_{11}	Size of the household (an indicator of demand for food for the household)	Continuous variable
χ_{12}	Number of male household members providing labour on the farm	Continuous variable
χ_{13}	Number of female household members providing labour on the farm	Continuous variable
χ_{14}	District of study	1=Vihiga, 0=Suba
χ_{15}	Number of times household members go to the market in a month	Continuous variable
χ_{16}	Principal component 1 representing knowledge type 1	Continuous variable
χ_{17}	Principal component 11 representing knowledge type 11	Continuous variable

Important tests in logistic regression included the omnibus test of model coefficients, the Hosmer/Lemeshow test, the Wald Test and the Nagelkerke R^2 test were run for the models. The application of these tests is given in Table 2.16. The Omnibus test of model coefficients, (χ_0^2) is the test of the null hypothesis that adding the predictor variables to the model has not significantly increased our ability to predict the decisions made to either control Striga or control stemborer. If the null hypothesis was rejected, we could conclude that the predictor variables used in the model increase the ability to predict the farmers' decisions. The Hosmer-Lemeshow ($\chi_{h.l}^2$) tests the null hypothesis that there is a linear relationship between the predictor variables and the log odds of the criterion variable. A non –significant χ^2 indicates that the data fits the model well. The Wald χ^2 tests the unique contribution of each predictor, in the context of the other predictors (i.e., holding them constant). The Nagelkerke R^2 is a measure of the variation in the model that is explained by the predictor variables. The Exp (β) coefficient is the odds ratio predicted by the model. The relationship between odds and probabilities:

Odds=prob/(1-prob) or Prob = odds (1+odds).

2.10 Study area

This study was designed and executed among the Striga/stemborer constrained farmers in Suba and Vihiga[2] Districts in Western Kenya. The two Districts were chosen on the basis of being among the Districts where Striga and stemborer are major cereal production constraints that are of economic importance in Kenya, and PPT had been introduced in both areas between 1998 and 2001. These Districts represent the arid and transitional agro ecological zones respectively where the production of cereals in general and maize in particular is constrained by Striga and stemborer. Farm households in both Districts use maize as a staple cereal. Household subsistence needs for maize are met through own production. However, in the recent years, human population in these Districts has grown much faster than in the other regions of Kenya. The population density is very high in Vihiga District, with about 900 - 1100 persons per square kilometer being recorded (RoK, 2001). Land holdings per household have been diminishing rapidly over the years as land continually undergoes sub-division to facilitate inheritance by maturing male members of families, leading to holding ownership of even less than 0.5ha in the District (Mango, 2002). With declining farm holdings and soil fertility levels, production of maize or any other crop is challenged. Maize yield gap is stretched further by the existence of Striga and stemborer infestation, among other biotic and abiotic maize production constraints.

Vihiga District lies at an altitude of between 1300 and 1550m above sea level and between longitudes $34^{o}3''$ and $30^{o}0''$ and latitudes $00^{o}0''$ and $0^{o}15''$ North in the highlands of Western Kenya (Republic of Kenya, 1997). At the time of the study, the District had six divisions: Luanda, Emuhaya, Vihiga, Tiriki West, Tiriki East and Sabatia. The villages for this study were drawn from Luanda and Tiriki west divisions. Vihiga District receives an annual rainfall

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[2] Soon after the execution of the study, Vihiga District was divided into three Districts i.e. Emuhaya District (Luanda and Emuhaya divisions), Vihiga District (Vihiga and Sabatia divisions) and Hamisi District (Tiriki west and Tiriki east divisions). In this study, Vihiga District will refer to the District before the sub-division.

of 1800-2000mm that is bimodally distributed with peaks in March/May and September/November.

The District has two main agro-ecological zones: the upper midland zone (UM1) and lower midland zone (LM1). The upper zone, covering 90% of the District, has fertile well drained dark red soils which support production of food and cash crops e.g. tea, coffee, maize, beans, finger millet, cassava and horticultural crops, such as tomatoes, onions, fruits, vegetables and avocadoes. The zone also supports livestock keeping, including cattle, goats, sheep, poultry and pigs. Both crop production and livestock keeping are hampered by small land holdings that average 0.6 hectares (Mango, 2002; Salasya, 2005; Amudavi, 2005). The lower zone has loamy soils derived from sediments and basement rocks, which support the growing of sugarcane, maize, coffee, beans, finger millet and sorghum. The District has a high population density of 800-1100 people per square kilometre and a growth rate of about 3%, which calls for intensive production systems. The District suffers from severe soil nutrient depletion due to considerable leaching and continuous cultivation over the years. Related to the low soil fertility problem is emergence of Striga as an important constraint in cereal production besides the stemborer problem, small land sizes and lack of farm inputs (Salasya, 2005).

Suba District is situated in the South Western part of Nyanza Province. It borders Homabay District to the east, Lake Victoria’s Nyanza gulf to the north, Migori District to the south and Republic of Uganda to the west. It covers a total area of 1810 square kilometres (sq-km), with 957 sq-km being land area while the rest is water surface (Homabay District Surveyor, 1997). About 530 sq-km of the land is arable. Ruma National Park, located here, covers 120sq-km while 157 sq-km is forest reserve. At the time of this study, the District was divided into 5 administrative divisions, including Gwassi, Lambwe, Central, Mbita and Mfangano. Our study villages were drawn from Lambwe and Central divisions. The District receives a bimodal rainfall of 600-700 mm per annum, with 60% reliability. The first bout of rains peaks in March/April while the second peak in November/December. The elevation of the District ranges from 1125-2275 m above sea level. The District comprises of four main agro-ecological zones, including upper midland zone 4 (UM4), lower midland zone 3 (LM3), lower midland zone 4 (LM4) and lower midland zone 5 (LM5). The District has a population of 176,097 with a 3% growth rate according to the national population estimates (RoK, 1999).

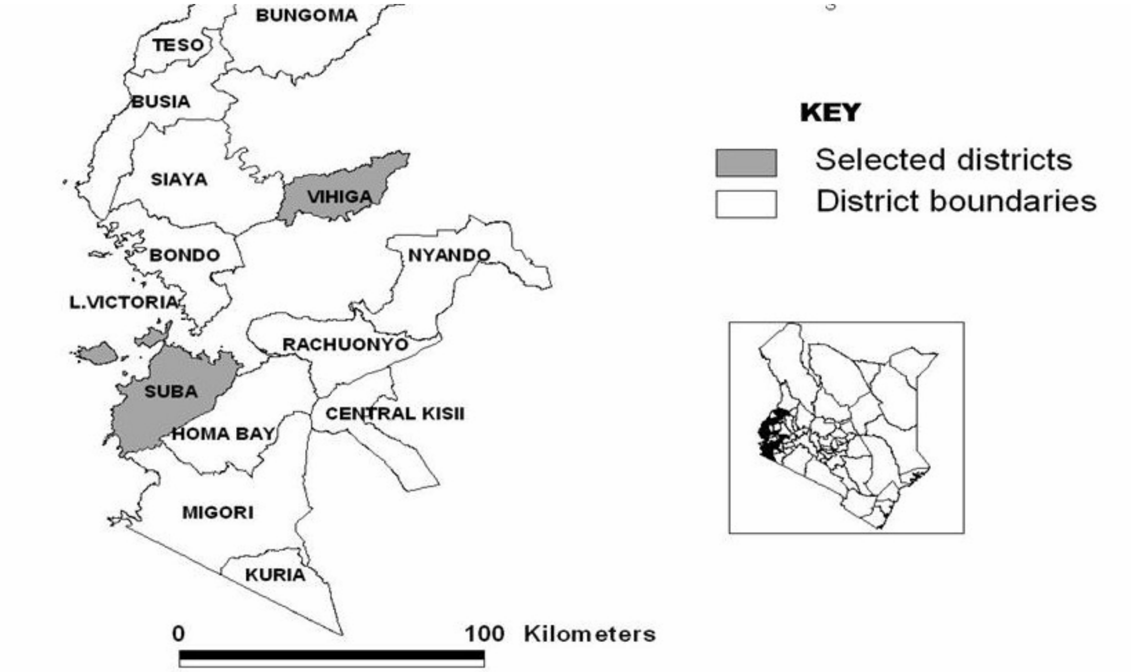


Fig 2.1 A map showing the position of Vihiga and Suba Districts in the western region of Kenya

Approximately 39% of the arable land in Suba District is under cultivation. The major food crops on the lower zones are maize and sorghum. Local breed livestock are kept under free-range conditions for most of the year. There is limited horticultural farming along the shores of Lake Victoria, mainly using bucket irrigation. The major food crops grown in the upper zones are maize, sorghum, beans and cassava. Cereal farming is constrained by Striga weed, stemborer and unreliable rainfall.

2.11 Sampling procedures

The households covered in the study were purposively drawn from 3 different villages in each District as shown in table 2.4. The first type of villages was characterised as the Push-pull villages (PPV) and these were drawn from divisions (and eventually locations and sub-locations) where ICIPE had established PPT on-farm trials. The provincial administration officers (chiefs and assistant chiefs) were contacted and requested to provide a complete census of the household names in the selected sub-locations. Each village in the selected sub-location contributed a number of households to the sample that was weighted according to its proportion to the total households in the sub-location. Households were listed with an assigned number each and using a computer based randomisation programme (www.randomizer.org). A total sample of eighty households was randomly selected for interviews from the Push-pull villages.

The second type of villages consisted of farmers neighbouring the Push-pull village (PPNB). These were selected to enable the study to assess the impact of diffusion effects from the PPV. These villages were randomly selected and a sample of 80 households obtained following the same steps as were followed in selecting the sample from the Push-pull villages. PPV and PPNB were selected from the same division.

The third type of villages was the non-Push-pull villages (NPPV) and these were selected in divisions where Push-pull technology had not been disseminated yet, so that they were geographically far from PPV and PPNB. They were drawn from a different division from the

PPV and PPNB. A sample of 80 households was drawn from these villages using the same random procedure that had been employed in the other village types.

In total, 480 households were selected for interviews in Suba and Vihiga Districts. When the interviews were eventually carried out, 476 households were actually interviewed, representing a 99.2% response rate. Four of the selected household heads in Suba District were found to be too old and did not do farming anymore; their data were therefore not used in the analysis.

Table 2.4 Number of households interviewed across PPV, PPNB and NPPV in Suba and Vihiga Districts

Village type		**District of study**		
		Vihiga	**Suba**	**Total**
Villages where PPT is disseminated	n_1	80.00	80.00	160.00
	% within Village type	50.00	50.00	100.00
	% within District of study	33.33	33.90	33.61
Villages neighbouring those where PPT is disseminated.	n_2	80.00	77.00	157.00
	% within Village type	50.96	49.04	100.00
	% within District of study	33.33	32.63	32.98
Villages where PPT is not disseminated, far from PPV	n_3	80.00	79.00	159.00
	% within Village type	50.31	49.69	100.00
	% within District of study	33.33	33.47	33.40
	N	240.00	236.00	476.00
	% within Village	50.42	49.58	100.00
	% within District of study	100.00	100.00	100.00
	% of Total	50.42	49.58	100.00

2.12 Questionnaire

A structured questionnaire was developed and used to obtain information through a cross sectional survey. The questions, the wording and sequencing were fixed and identical, thus providing the assurance that variations in responses were not due to enumerator differences but due to differences (variation) between the respondents. The questionnaire contained seven sections providing the following major types of information:

- Household characteristics
- Characteristics of the households' farm holdings
- Household income
- Household's access and acquisition of agricultural information
- How household controls stemborer
- How household controls Striga
- Use of Push-pull Technology in Striga and stemborer by the household

The questionnaire was pre-tested in both Vihiga and Suba Districts to evaluate the validity of the questions in terms of clarity, sequence, relevance and missing items. 32 questionnaires were pre-tested in each district. After pre-testing, the questionnaire was revised and the enumerators employed and trained to carry out the household interviews.

2.13 Recruitment and training of the enumerators

Enumerators were hired from amongst the communities in the study areas. Key considerations in hiring the enumerators included level of education, persons with knowledge of the local language, familiarity with local farm conditions, customs and taboos. Persons with training on research methodologies in social sciences and experience in household interviews were especially preferred. University students or recent graduates were preferred for recruitment as enumerators on assumption that they are easier to train and are able to conceptualise new ideas more easily.

Four enumerators were recruited in each of the Districts. The hired enumerators were taken through three days of training, which focused on Striga and stemborer biology; and the Striga and stemborer control technologies that are available in literature and could be anticipated in the field. The objectives and purpose of this study were explained to the enumerators. The pre-selected villages and the list of the selected households were assigned to the enumerators, depending on the area where he/she resided in the sub-locations. On the third day, the enumerators carried out household interviews in a village not earmarked for the main interviews under supervision of the author and this was taken as part of the pre-testing exercise and a learning experience. On this day, the enumerators' interviewing skills were monitored and the quality of data recording noted and where necessary, the enumerators were advised on what needed improvement.

2.14 Structure of the interviews and data collection

Since the list of the farmers to be interviewed was generated randomly using lists obtained from the government provincial administration records, there was a need to have village elders guide the enumerators to the selected homesteads and introduce them to the potential respondents. In each sub-location, the assistant chief was contacted to introduce the research team, explain the objectives of the study and identify village elders to work with the enumerators. The village elders were given a list of the households selected in their areas of jurisdiction. They were able to alert the household members on the intended interviews days before the interviews were carried out. This reduced the chances of going to a homestead and missing the owners. In case a selected household could not be interviewed for one reason or another, the enumerators were instructed to send a short messaging services (SMS) to the author and replacements were drawn using the computer based randomisation programme. At the end of each day, the questionnaires were checked for completeness, errors, omissions and irrelevant responses. Any challenges encountered in the field were discussed in the evenings. In total, 240 households were interviewed in Vihiga District and 236 in Suba District. The exercise was carried out in October – November 2006.

2.15 Data entry and development of indices

Data from the questionnaires were checked and entered into the computer using Statistical Package for Social Sciences (SPSS, version 11.5). To aid in statistical analysis, some indices were generated from the data including the following:

Tropical livestock units: The concept of Tropical Livestock Units (TLU) provides a convenient method for quantifying a wide range of different livestock types and sizes in a standardised manner (FAO, 1991-2000). It would be difficult to compare the wealth of a farmer who has a cow with another who has 20 goats and a third who has 1,000 chickens. Live animals data is reported in TLU for comparison of different species. The LU is a standardized animal unit obtained by multiplying total number of animals with a conversion factor that take into account the feed requirements for each animal. I TLU is equivalent to 250kgs live weight. The FAO compendium of Agricultural-Environmental Indicators (1991-2000) has guidelines on conversion factors for different regions of the world. Table 2.5 gives the FAO conversion factors for Sub Saharan Africa, which are used in this study to compute the TLU for each household.

Table 2.5 Conversion factors for TLU equivalents from the FAO statistics for Sub Saharan Africa.

Animal type	Cattle	Sheep	Goats	Pigs	Horse	Camel	Chicken	Ducks /Turkey	Rabbits
Conversion factor	0.5	0.1	0.1	0.2	0.8	1.1	0.01	0.03	0.02

Land tenure index. The index of land tenure security was developed from household perceptions of the breadth and assurance of their rights to the land. As security of tenure is not directly observable, it is difficult to create an objective scale or index for it. Following the framework suggested by Place *et al.,* (1994), a hierarchical index was estimated to measure the breadth and assurance component of land rights for the households. Based on the suggested framework, the following assurance indices were used:

Dummy 1: use 1 if the land boundaries are informally marked by the community members or elders, 0 otherwise

Dummy 2: use 1 if the land boundaries are formally demarcated but no title deeds are held by the farmers, 0 otherwise

Dummy 3: use 1 if the household has a formal title deed to their land, 0 otherwise.

To obtain the assurance component, the dummies were summed up. A value of ‘1’ was added to the sum of dummies 1-3 when developing the assurance component to ensure that the product of the breadth and assurance indices is positive and above 0. The highest value expected was 4 for the assurance component.

The breadth index was constructed in the following way:

Dummy 1: Use 1 if the household farm on its own without having to share with extended family, 0 otherwise

Dummy 2: Use 1 if the household enjoyed unrestricted rights to farm any crops they desired, 0 otherwise

Dummy 3: Use 1 if the household enjoyed unrestricted right to bequeath land to children, 0 otherwise

Dummy 4: Use 1 if the household enjoyed unrestricted rights to sell the land, 0 otherwise.

The breadth component for the household was obtained by summing up the breadth dummies. To obtain the composite index for estimating land tenure security for a household i, the sum of the households’ breadth component and assurance component were multiplied, yielding scores ranging from 1 (least secure) to 16 (most secure).

Men Equivalent Units. Although the size of the household may be used as an indicator of labour available to a household, not all members of a household are in a physical state to provide labour. Some members are young children while some members are too old. To handle this challenge, Runge-Metzger (1988) devised a way of calculating the Men Equivalent Units (MEU) for each household, which is a better approximation of labour available for each household. We obtained the MEU by classifying the household members according to age brackets and multiplying with an index shown in table 2.6 sourced from Runge-Metzger (1988)

Table 2.6 Conversion factors for men equivalent units of labour adopted from a study by Runge-Metzger (1988)

Age Bracket	0-9	10-15	16-49	49-max
Conversion factor	0	0.7	1	0.7

2.16 Results

2.16.1 General household characteristics

The descriptive statistics of the households are summarised in Table 2.7. Over 80% of the households in Vihiga District and about 70% of the households in Suba District were male headed. Male headed households had a ‘husband’ either staying at the farm or working away from the farm. Female headed households were headed by women. Distribution of the education levels attained by heads of households was similar in both Districts with about 17.5%, 58%, 17% and 7.5% having attained no formal education, primary education, secondary education and post-secondary education respectively.

The size of the household was five on average for the two districts, with 1.6 and 1.6 male and female household members, in both districts, being available to provide farm labour for a complete season. Over 40% and 31% of the households in Vihiga and Suba respectively employ farm labour (male or female) to supplement the household labour.

Table 2.7 Descriptive statistics on farmer, household and farm characteristics in Vihiga and Suba Districts, Kenya

Characteristic (N=476).	Vihiga	Suba	Overall	Sig
1. Sex of head of household (%)				***
Male headed	82.1	69.5	75.8	
Female headed	17.9	30.5	24.2	
2. Education level of head of household (%)				
a. No education attained	17.2	17.9	17.5	
b. Primary education attained	58.2	58.3	58.2	
c. Secondary education attained	17.2	16.6	16.9	
d. Post-secondary education attained	7.5	7.2	7.4	
3. Farming experience years (%)				***
0 if below mean	43.3	63.2	53.1	
I if above mean	56.7	36.8	46.9	
4. Age of the head of household (mean in years)	53.66	49.84	51.78	***
	(0.929)	(0.921)	(0.659)	
5. Size of the household (mean in numbers)	5.69	4.04	5.17	***
	(0.157)	(0.131)	(0.105)	
6. Number of male household members providing labour (mean in numbers)	1.51	1.76	1.63	**
	(0.071)	(0.076)	(0.052)	
7. Number of female household members providing labour (mean in numbers)	1.45	1.78	1.612	***
	(0.053)	(0.068)	(0.044)	
8. Whether household employs male labour (%)				
No	59.6	63.7	61.6	
Yes	40.4	36.3	38.4	
9. Whether household employs female labour (%)				**
No	58.4	68.5	63.4	
Yes	41.6	31.5	36.4	
10. Means of reaching the nearest market (%)				**
a. Walking	91.7	90.5	91.1	
b. Bicycle	4.2	7.8	5.9	
c. Matatu	4.2	0.9	2.5	
d. Others	0.0	0.9	0.4	
11. Time to the nearest market				***
a. 0 – 30 minutes	73.3	35.1	54.6	
b. 30 min – 1 hour	20.4	32.5	26.3	
c. 1 hour – 2 hours	4.6	19.0	11.7	
d. > 2 hours	1.7	13.4	7.4	
12. Number of times to the market per month (%)				***
a. Daily	30.0	3.6	17.1	
b. Once a week	54.9	75.0	64.6	
c. Once every two weeks	8.0	9.8	8.9	
d. Once a month	4.6	8.9	6.7	
e. Not regular	2.5	2.7	2.6	
13. Total farm size in acres	1.56	5.99	3.75	***
	(0.101)	(0.395)	(0.226)	
14. Land tenure security	3.24	3.23	3.24	
	(0.0472)	(0.052)	(0.035)	
15. Total livestock units	1.08	3.367	2.214	***
	(0.061)	(0.209)	(0.12)	

NB: 1. Means of all interval/ratio variables were analysed using the F-test, while χ^2 tests was used for binary and categorical variables. 2. Numbers in parenthesis represent the standard errors of the means. 3. Statistically significant levels: *** p<0.01; **p<0.05; * p<0.10

Source: Authors work, 2006.

Slightly over 90% of the household members reached the nearest market by walking while the rest used either bicycles (commonly referred to as *bodaboda,* (5.9%), taxi's (locally known as *matatu, 2.5%*) and a small minority used personal cars (0.4%).

Over 73% of the households in Vihiga compared to 35% in Suba were located within 30 minutes of travel to the nearest market, using the various means of transport. Approximately 13.4% of households in Suba compared to 1.7% in Vihiga districts are located outside 2 hours of travel to the nearest market centre. This is an indication of a better infrastructural development in Vihiga District compared to Suba District. This explained perhaps why 30% of households in Vihiga had a member of the household going to the market daily compared to 3.6% in Suba District. About 75% of households in Suba compared to 55% in Vihiga have members going to the market once every week. This mostly coincided with a market day, which is usually once or twice in a week for each market centre. The markets are focal points of trading in farm produce, acquiring farm inputs and engaging in information exchange.

Average total farm holdings were larger (6 acres) in Suba compared to those in Vihiga (1.6 acres). The land tenure security index was similar in both Districts (3.2). Total livestock units were significantly higher (3.4) in Suba District compared to Vihiga District (1.1). The average age of the head of household head is 53.6 and 49.8 years in Vihiga and Suba Districts respectively.

In Suba District, the livestock play an important role as a source of draught power in land preparation unlike Vihiga District where farmers rely more on hand labour. Additionally, farm households in Suba had larger farms than their counterparts in Vihiga and so could support more animals.

2.16.2 Farmers' perceptions on Striga and stemborer infestation

Table 2.8 presents the analysis of the farmers' perceptions of Striga and stemborer infestations on the farms. The analysis revealed that 21.8% and 5.1% of households in Vihiga and Suba respectively, indicated that they did not have stemborer infestation in their farms, while 38.9% of households in both Districts indicated having minor stemborer infestation. About 24% and 17.5% considered stemborer infestation in their farms a major problem in Vihiga District and Suba District, respectively. Only 10% and 8% of households in Vihiga and Suba Districts respectively reported adopting any form of technology to control stemborer in their farms.

Table 2.8 Farmers perceptions of Striga and stem-borer infestation in the maize farms in Vihiga and Suba Districts

Characteristic	Vihiga	Suba	Overall	χ^2	Df
Rating of stem-borer infestation on maize farms (%)				51.037***	3
1. No problem	21.8	5.1	13.5		
2. Minor problem	38.9	38.9	38.9		
3. Moderate problem	15.1	38.5	26.6		
4. Major problem	24.3	17.5	20.9		
Whether household controls stem- borer (%)				0.544	1
No	89.9	92.0	91.0		
Yes	10.1	8.0	9.0		
Rating of Striga infestation on maize farms (%)				45.942***	3
1. No problem	26.4	10.3	18.4		
2. Minor problem	20.1	7.3	13.7		
3. Moderate problem	18.8	32.5	25.6		
4. Major problem	34.7	50.0	42.3		
Whether household controls Striga on their farm (%)				21.158***	1
No	35.6	59.0	48.3		
Yes	64.4	41.0	51.7		

NB: χ^2 test was used for binary and categorical variables; Statistically significant levels: *** p<0.01; **p<0.05; * p<0.10

Source: Authors work, 2006

In Vihiga District 26.4% of households and 10.3% in Suba District indicated they had no Striga infestation on their farms. More than 80% of households in Suba District compared to 53.5% in Vihiga District rated Striga infestation in their farms as moderate or major problem.

However, significantly more households (64.4%) in Vihiga reported using a technology to control Striga on their farms compared to Suba District (41.0%). Findings of Table 2.9 also provide a profile of farmers' sources of information on Striga and stemborer control.

Table 2.9 Farm households' information sourcing for Striga and stemborer control technologies

Source of information (n=number of farmers accessing that source)	Farmers accessing the information source as % of total sample (N=476)	% Of farmers gaining Striga/stemborer control information from a source (n specific to source)			
		Vihiga	Suba	Average	Chi square value
1. Farmer groups (n=104)	21.8	26.7	52.5	41.3	7.048***
2. On-farm demonstrations (n=109)	22.9	66.7	52.5	58.7	2.237
3. Community leaders (n=374)	78.6	21.0	15.2	17.4	2.089
4. Contact farmers (n=20)	4.2	3.3	7.2	5.3	2.639
5. Institutional visits (n=43)	9.0	12.9	7.6	10.3	1.849
6. Radio (n=249)	52.3	61.9	40.3	49.4	11.362***
7. Agricultural Extension (n=90)	18.9	52.0	60.0	55.6	0.576
8. Pamphlets/Brochures (n=111)	23.3	25.0	37.3	31.5	1.933
9. Agricultural shows (n=117)	24.6	34.7	51.5	44.4	3.246
10. Chief's baraza (n=231)	48.5	41.9	33.3	38.1	1.756
11. Field day (n=134)	28.2	73.7	61.0	66.4	2.348
12. Neighbours (n=356)	74.8	71.9	82.7	77.5	5.919**
13. Posters (n=26)	5.5	88.9	82.4	84.6	0.193
14. Push-pull farmer teachers (n=69)	14.5	60.0	79.5	71.0	3.128*

NB: Household use of an information source was identified as 1, 0 otherwise; statistically significant levels: *** p<0.01; **p<0.05; * p<0.10

Source: Authors work, 2006

Sources of information accessible to at least 48% of households in the two Districts were community leaders, radio, chiefs' public meeting (*baraza*) and neighbours. Access to posters, contact farmers and institutional visits was to less than 10% of the households in the two Districts.

Comparing the number of farmers, who learnt about Striga/stemborer control from accessing a source of information in the two Districts, revealed there were no significant differences between the two Districts except in learning from farmer groups, which was higher in Suba (52.5%) than Vihiga (26.7%). Similarly, learning from neighbours was higher in Suba (82.7%) than Vihiga (71.9%); learning from Push-pull farmer teachers was higher in Suba (79.5%) compared to Vihiga (60.0%) while learning from radio was higher in Vihiga (61.9%) than Suba (40.3%).

2.16.3 Farmers' perception of effectiveness of a source of Striga/stemborer control information

Effectiveness of a source in conveying Striga and stemborer control information was analysed from the farmers' perceptions. Analysis was done to test for differences across Districts and across the village types (Table 2.10). Analysis revealed that significantly more farmers located in the PPV indicated that on-farm demonstrations as sources of information were effective (7.5% in Vihiga, 9.1%% in Suba), followed by the number of farmers located in the PPNB (4.6% in Vihiga, 3.4% in Suba) while the households located in the NPPV had lower number of farmers (0.4% in both Districts) recording it as an effective source. This trend was similar for agricultural extension agents, pamphlets and brochures, field days, and push pull farmer teachers. This was also the case even when the source of information was generally available for all farmers like the radio. In Vihiga District, farmers who judged farmer groups as effective was significantly higher in the PPV (2.5%) followed by those in the PPNB (1.3%) while no farmer thought they were effective in the NPPV. There was no significant difference among the farmers in the three different villages in Suba on evaluation of farmer groups. Similar results were obtained in the case of radio and chiefs' public meetings (*baraza's).* The evaluation of community leaders was not significantly different among households in the three villages in Vihiga.

Table 2.10 **Farmers' perceptions of effectiveness of information sources across the sampling frame**

	Push-pull village (PPV)		Villages neighbouring Push-pull village (PPNB)		Villages far from Push-pull villages (NPPV)		Chi square value
Source of information	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	
1. Farmer group	%	%	%	%	%	%	
Vihiga (n=238)	31.1	2.5	31.9	1.3	33.2	0.0	6.1**
Suba (n=233)	30.0	3.9	27.0	5.6	30.0	3.4	1.8
2. On-farm demonstration							
Vihiga (n=240)	25.8	7.5	28.8	4.6	32.9	0.4	16.7***
Suba (n=232)	25.0	9.1	29.3	3.4	32.8	0.4	22.7***
3. Contact farmers							
Vihiga (n=240)	32.9	0.4	32.9	0.4	32.9	0.4	0.0
Suba (n=236)	33.9	0.0	32.6	0.0	33.1	0.4	1.9
4. Community leaders							
Vihiga (n=239)	29.3	4.2	30.1	2.9	29.3	4.2	0.7
Suba (n=236)	29.2	4.7	26.7	5.9	31.4	2.1	5.1*
5. Organizational visits							
Vihiga (n=240)	29.2	4.2	31.3	2.1	31.3	2.1	2.7
Suba (n=236)	20.7	4.2	31.8	0.8	32.2	1.3	7.8**
6. Radio							
Vihiga (n=240)	22.5	10.8	26.7	6.7	28.8	4.6	8.5**
Suba (n=236)	23.3	10.6	25.4	7.2	26.7	6.8	2.9
7. Agric extension agents							
Vihiga (n=240)	25.4	7.9	32.1	1.3	32.5	0.8	25.3***
Suba (n=236)	27.1	6.8	30.9	1.7	32.6	0.8	16.7***
8. Pamphlets/Brochures							
Vihiga (n=240)	30.4	2.9	32.5	0.8	32.5	0.8	4.8*
Suba (n=236)	28.0	5.9	30.5	2.1	32.6	0.8	11.8***
9. Agricultural Shows							
Vihiga (n=240)	32.1	1.3	30.0	3.3	31.7	1.7	2.9
Suba (n=236)	25.8	8.1	28.0	4.7	31.4	2.1	9.6***
10. Chief's Baraza							
Vihiga (n=240)	28.8	4.6	28.3	5.0	24.6	8.8	5.1*
Suba (n=236)	27.1	6.8	28.8	3.8	30.1	3.4	3.7
11. Field days							
Vihiga (n=240)	22.5	10.8	28.8	4.6	32.1	1.3	24.5***
Suba (n=236)	22.0	11.9	26.7	5.9	31.8	1.7	22.8***
12. Neighbours							
Vihiga (n=240)	20.4	12.9	19.2	14.2	19.6	13.8	0.2
Suba (n=236)	11.0	22.9	19.5	13.1	14.4	19.1	11.9***
13. Posters							
Vihiga (n=240)	33.3	0.0	30.8	2.5	32.5	0.8	7.2**
Suba (n=236)	30.1	3.8	31.4	1.3	32.2	1.3	4.9*
14. Farming experience							
Vihiga (n=238)	16.8	16.4	14.7	18.5	11.8	21.8	4.0
Suba (n=231)	22.9	11.7	21.2	10.4	19.0	14.7	2.3
15. PPT farmers teachers							
Vihiga (n=240)	28.8	4.6	32.5	0.8	33.3	0.0	16.8***
Suba (n=236)	25.4	8.5	29.2	3.4	33.5	0.0	23.9***

NB: Statistically significant levels: *** p<0.01; **p<0.05; * p<0.10; **Source, Authors work, 2006**

However significantly higher percentages of farmers in the PPVs and PPNB (4.7% and 5.9%) compared to NPPV (2.1%) in Vihiga evaluated community leaders as effective sources of information. Similarly, the evaluation of agricultural shows and neighbours were not significantly different among households in the three village types in Vihiga.

In Suba, significantly more households in the PPVs evaluated agricultural shows and neighbours as effective compared to less households in the PPNB and lesser in the NPPV.

2.16.4 Generating a knowledge index from access to information sources.

Table 2.11 presents the results of the Principal Component Analysis (PCA). Four principal components with an eigenvalue of >1 were identified through the principal components analysis procedure. These are the components that had variations from more than one initial variable. The first component explained 24.3% of the variance in the farmers' perception of effectiveness of sources of information.

Table 2.11 Principal component analysis of the sources of information about Striga and stemborer control used by farmers in Suba and Vihiga Districts, Kenya

	Principal component			
	1	2	3	4
1. Community leaders	**.691**	-.174	.182	-.055
2. Field days	**.674**	.391	.014	.006
3. Agricultural Show	**.670**	.064	-.036	.017
4. Chief's Baraza	**.644**	-.052	-.177	.266
5. Farmer groups	**.585**	.045	-.083	-.302
6. Radio	**.566**	.248	.257	-.033
7. On farm demonstrations	**.479**	**.442**	.189	-.097
8. Neighbors and friends	**.391**	.262	-.214	.075
9. Pamphlets and brochures	.133	**.658**	-.057	-.106
10. Agricultural extension agent	.076	**.645**	-.094	.008
11. Organizational visits	.051	**.588**	.309	.213
12. Posters	-.042	**.506**	-.075	-.004
13. Farmer teachers	.375	**.421**	.236	-.144
14. Contact farmers	-.003	-.076	**.862**	.017
15. Farming experience	-.007	-.014	.008	**.914**
Eigenvalue (7.39)	*3.64*	*1.55*	*1.11*	*1.09*
% of variance explained (49.25)	*24.28*	*10.34*	*7.39*	*7.23*

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
Source: Authors work, 2006.

The second component explained 10.3% of the variance in the data. The third and the fourth components accounted for 7.4% and 7.2% of the variance, respectively.

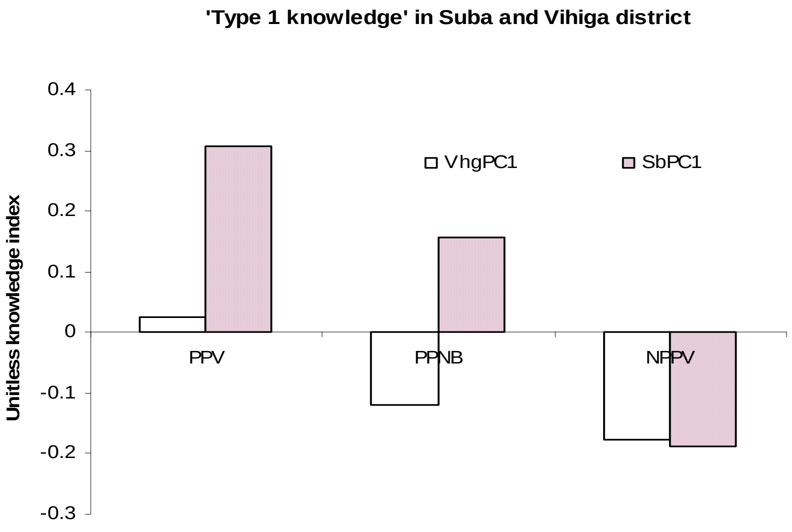
When the components were rotated using varimax rotation with Kaiser normalization procedure, eight of the information sources loaded heavily on the first component, six on the second principal components while one information source each loaded the third and fourth components respectively (Table 2.11). The first two components were therefore chosen for further interpretation. The first component had the following information sources loading heavily with it: community leaders, field days, agricultural shows, chiefs *barazas* (public meetings), farmer groups, radio, on-farm demonstrations and exchanges with neighbours. The loading factors for on-farm demonstrations were high on the first and second principal components, implying that on-farm demonstrations loaded heavily with the 1st and the 2nd component. We examined for similarities in the sources of Striga/stemborer control information that loaded heavily with the first principal component; the following characteristics stood out:

- Group seeking process
- Seeing and listening (except in on-farm demonstrations)
- High frequency (strong ties)
- Common knowledge sources

The second component had heavy loadings from the following information sources: pamphlets and brochures, extension agents, institutional visits, posters and Push-pull farmer teachers and also on-farm demonstrations. Examining these sources for similarities reveals that they characterize:

- Individual actively seeking sources
- Informational sources for reference

This seemed to indicate that there were two distinct 'types' of knowledge that the farmers accumulated from the diverse sources of information they had on Striga/stemborer control. We characterised them as Type-I knowledge (the knowledge obtained from sources loading heavily on principal component 1) and Type-II knowledge (the knowledge obtained from sources loading heavily on principal component 2). Fig 2.2 and 2.3 shows the values obtained for the type-I knowledge and type-II knowledge respectively. Farmers in the push pull villages had accumulated the knowledge type I in both Vihiga and Suba district. However, those in Suba had higher levels of knowledge type I compared those in Vihiga district. Farmers in villages neighbouring the push pull villages in Suba had accumulated positive values of type 1 knowledge while those in Vihiga district did not have positive values.

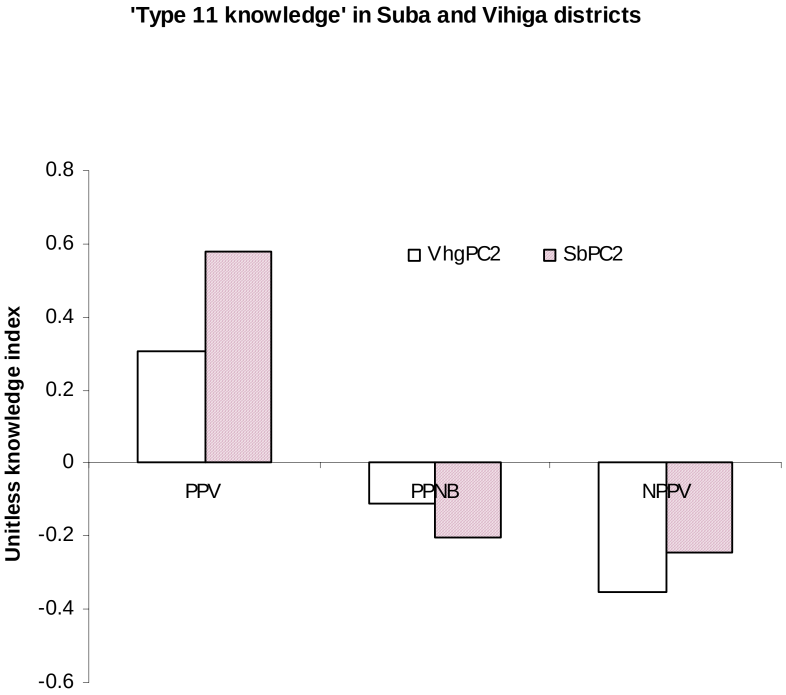


Legend: PPV= Push Pull Villages, PPNB=Push Pull Neighbours, NPPV=Far away villages

Source: Authors work, 2006

Fig 2.2 Average indices of the 'Type-I knowledge' by village location in Vihiga and Suba Districts

This is an indication there were diffusion effects in Suba from the Push Pull Villages to their neighbours and while there is very little diffusion in Vihiga district. Farmers in villages far away from the Push Pull Villages in both Suba and Vihiga districts had not accumulated type I knowledge. Farmers in the Push Pull Villages had accumulated positive values of type II knowledge in both Suba and Vihiga districts. However, the values were higher in Suba district compared to Vihiga district. Farmers in the villages neighbouring the push pull villages and those far away from the push pull villages did not have positive values of type II knowledge.



Legend: PPV= Push Pull Villages, PPNB=Push Pull Neighbours, NPPV=Far away villages

Source: Authors work, 2006

Fig 2.3 Average indices of 'Type-II knowledge' by village location in Vihiga and Suba Districts.

Based on the PCA results, we can summarise our knowledge indices as follows:

a) Type-I knowledge: acquired and accumulated by farmers that participate in group based activities like agricultural shows, chief's meetings (*baraza's)*, farmer groups, on-farm demonstrations.

b) Type-II knowledge: acquired and accumulated by farmers that seek information individually from pamphlets and brochures, posters, institutional visits and also on-farm demonstrations.

Comparison of the means of the ‘knowledge index’ reveals that there was a significantly high knowledge base (Type-I and Type-II) on Striga and stemborer control among farmers in the PPV villages in both Suba and Vihiga Districts. The PPNB households in Suba also had positive values for the Type-I knowledge mean suggesting diffusion effects from the PPV. A negative index value was obtained for the PPNB households in Vihiga District. The value was expected to be positive if knowledge was diffusing from the PPV to the neighbouring villages, but this outcome gave a contrary impression. This implies that the social networks are not effective in diffusing information from the PPV villages to the neighbouring villages. Type-II knowledge index was negative in both the PPNB and NPPV in both Districts suggesting that the individual farmer’s information networks were not diffusing information from the PPV villages beyond a short radius.

2.16.5 Factors influencing farmers ability to acquire knowledge on Striga and stemborer control

Table 2.12 gives a summary of the results obtained from the multivariate regression to evaluate factors influencing accumulation of the knowledge types by farm households. The model had a relatively low predictive power of 0.12 but this is acceptable for models based on qualitative variables. Woodridge, (2006) asserts that low predictive power in the model is an indication of difficulties in predicting human behaviour. Primary education, total livestock units, perception of minor or moderate infestation of stemborer, perception of minor, moderate and major Striga infestation, being located in PPV and PPNB villages, and ability to reach the market centres easily, were associated with a significant increase in the farm level knowledge. Households with small farm sizes were associated with an increase in farm level knowledge. The land tenure security index was not associated with an increase in the Type-I knowledge as had been anticipated, but rather with a decrease, that was also significant.

The model fitted on the Type-II-knowledge index had a predictive power of 0.15 which was also relatively low but acceptable for this type of model. Age of the head of household, education level of the head of household (primary, secondary and post secondary levels), land tenure security, total livestock units and being located in a PPV were associated with a significant increase in the Type-II knowledge of a household head.

Table 2.12 Socio-economic factors influencing farmers ability to acquire knowledge on Striga and stemborer control

Independent variables	**Type-I knowledge (Principal component I)**			**Type-II knowledge (Principal component II)**		
	B	**SE**	**Beta**	**B**	**SE**	**Beta**
Constant	0.08	0.36		**-1.42**	0.34	
1. Sex of the head of household (m=1, f=0)	-0.12	0.12	-0.05	-0.03	0.11	-0.01
2. Age of the head of household (years)	0.00	0.00	0.01	**0.01**	**0.00**	**0.11****
3. Education dummies (no education as reference)						
a. Head of household with primary education	**0.27**	**0.14**	**0.13****	**0.29**	**0.13**	**0.15****
b. Head of household with secondary education	0.21	0.18	0.08	**0.51**	**0.17**	**0.20*****
c. Head of household with post secondary education	0.05	0.22	0.01	**0.81**	**0.21**	**0.21*****
4. Land tenure security for land (unitless)	**-0.29**	**0.06**	**-0.22*****	**0.12**	**0.06**	**0.09****
5. Total farm size (in acres)	**-0.02**	**0.01**	**-0.10***	0.00	0.01	0.00
6. How much time it takes to reach the market (in hours)	**-0.08**	**0.04**	**-0.09***	0.04	0.04	0.04
7. Total livestock unit (Unitless)	**0.07**	**0.02**	**0.19*****	**0.03**	**0.02**	**0.09***
8. Stemborer infestation (no infestation as the reference)						
a. Minor stemborers infestation	**0.28**	**0.15**	**0.13***	-0.12	0.14	-0.06
b. Moderate stemborers infestation	**0.32**	**0.16**	**0.14****	-0.07	0.15	-0.03
c. Major stemborers infestation	0.28	0.17	0.11	0.03	0.16	0.01
9. Striga infestation (no infestation as the reference)						
a. Minor Striga infestation	-0.04	0.16	-0.01	0.14	0.15	0.05
b. Moderate Striga infestation	**0.25**	**0.14**	**0.11***	-0.03	0.13	-0.01
c. Major Striga infestation	**0.25**	**0.13**	**0.12***	-0.08	0.13	-0.04
10. Village location (Villages far from PPV as reference)						
a. Push-pull villages	**0.39**	**0.12**	**0.18*****	**0.73**	**0.11**	**0.36*****
b. Villages neighbouring Push-pull villages	**0.33**	**0.12**	**0.15*****	0.16	0.11	0.07
	F=4.50, p=0.00***, R^2=0.15, Adj R^2=0.12			F=5.55, p=0.00***, R^2=0.18, Adj R^2=0.15		

NB: Statistically significant levels: *** p<0.01; **p<0.05; * p<0.10

Source: Authors work, 2006

2.16.6 Evaluating whether knowledge acquired influence farmers' likelihood of controlling Striga /stemborer on the farm

Table 2.14 presents factors that influence a farmers' decision to control Striga and stemborer. Statistics from the model fitting data on the control of Striga are given in table 2.13 The logistic model fitting data on farmers' use of an improved technology to control Striga had a robust prediction rate of 70.2% and an R^2 of 30.5%.

Table 2.13 Test results for the model on household decision to control Striga in maize farming

Test	Statistic	Df	Sig	Decision
Omnibus test of model coefficients	91.427	20	0.000***	Reject the null hypothesis that adding the predictor variables did not increase ability of the model to predict household decision to control Striga
Hosmer / Lemeshow test	11.245	8	0.188	Not reject the null hypothesis that there is a linear relationship between the predictor variables and the log odds of the criterion variables; the model fits the data well.
Cox and Snell R^2	0.229			
Nagelkerke R^2	0.305			The model explains at least 30.5% variation in the Striga control decision
Overall prediction power of the model=70.2%				The model is good.

Table 2.14 shows the variable coefficients, Wald Test, odds ratio and the associated probabilities for each of the independent variables in the Striga control model. Size of the household, the District of study, total livestock units, referenced knowledge and being in a PPV had significant partial effects on the likelihood of a household using an improved technology to control Striga. The Type-I knowledge index did not have a significant effect in the farmer's likelihood to use an improved technology to control Striga

Table 2.14 Socio economic factors influencing a households decision to use improved technology on Striga or stemborer

Independent variable	**Households using improved technology to control Striga**				**Households using improved technology to control stemborers**			
	β	**Wald**	**Odds Ratio**	**Prob**	**β**	**Wald**	**Odds ratio**	**Prob**
1. Gender of head of household (1=male, 0 female)	0.24	0.55	1.27	0.56	0.02	0.00	1.02	0.51
2. Size of household in numbers	0.24	**7.94**	**1.27*****	**0.56**	0.06	0.23	1.06	0.52
3. Male household members providing labour on farm (in numbers)	-0.16	1.53	0.85	0.46	0.18	0.65	1.20	0.55
4. Female household members providing labour on farm (in numbers)	-0.04	0.08	0.96	0.49	0.13	0.26	1.14	0.53
5. District of study (1=Vihiga, 0=Suba)	0.97	**8.15**	**2.63*****	**0.72**	0.93	2.20	2.54	0.72
6. Land tenure security calculated as an index (unit less)	0.14	0.70	1.15	0.53	0.13	0.20	1.14	0.53
7. Total farm size (in acres)	0.00	0.00	1.00	0.50	-0.02	0.11	0.98	0.49
8. Total livestock units (unit less)	0.11	**3.64**	**1.11****	**0.53**	0.09	0.99	1.10	0.52
9. Time it takes to reach the nearest market in hours	-0.15	1.77	0.86	0.46	-0.06	0.10	0.94	0.48
10. Number of times household members go to the market in a month	-0.19	1.66	0.83	0.45	0.07	0.07	1.07	0.52
11. Type-I knowledge (principal component I), unit less index	-0.06	0.26	0.94	0.48	**0.53**	**9.57**	**1.69*****	**0.63**
12. Type-II knowledge (principal component II), unit less index	0.70	**13.57**	**2.02*****	**0.67**	**0.67**	**13.92**	**1.96*****	**0.66**
13 Education, categorical variable, with no-education as base								
a. Primary level education	-0.23	0.16	0.79	0.44	-0.73	0.33	0.48	0.32
b. Secondary level education	0.35	0.51	1.43	0.59	0.58	0.63	1.79	0.64
c. Post secondary Education	-0.20	0.13	0.82	0.45	-0.50	0.33	0.61	0.38
14. Perception of Striga infestation, categorical, no infestation as a base		1.90		0.00				
a. Minor Striga infestation	18.35	0.00		1.00				
b. Moderate Striga infestation	0.27	0.56	1.30	0.57				
c. Major Striga infestation	0.38	1.76	1.46	0.59				
15. Perceptions of stemborer infestation, categorical, no infestation as base								
a. Minor stemborer infestation					-19.42	0.00	0.00	0.00
b. Moderate stemborer infestation					-0.38	0.53	0.68	0.41
c. Major stemborer infestation					-0.18	0.11	0.84	0.46
16. Location of village, non pushpull village as the base		5.25		0.00		1.88		
a. Push-pull village (PPV)	0.76	**5.06**	**2.13****	**0.68**	0.74	1.32	2.11	0.68
b. Villages neighbouring the Push-pull villages (PPNB)	0.49	2.44	1.63	0.62	0.85	1.80	2.33	0.70
17. Constant	-2.33	**5.96**	**0.10****	**0.09**	**-5.40**	**8.41**	**0.00*****	**0.00**

NB: Statistically significant levels: *** p<0.01; **p<0.05; * p<0.10: Source, **Authors work, 2006**

Holding all other factors constant, a unit increase in Type-II knowledge increases a farmer's chance of using a Striga control technology by 7.54 times. The results show that the farmers in Vihiga are 3.56 times more likely to control Striga than the farmers in Suba. Being located in a village hosting Push-pull technology, a farmer was 8.4 times more likely to use an improved technology to control Striga than a farmer in distant villages.

The logistic model fitting data on farmers' use of an improved technology to control stemborers had robust prediction rate of 92.6% and an R^2 of 29.8% (Table 2:16).

Table 2.16 Test results for the model on household decision to control stemborer in maize farming

Test	Statistic	Df	Sig	Decision
Omnibus test of model coefficients	56.711	20	0.000***	Reject the null hypothesis that adding the predictor variables did not increase ability of the model to predict household decision to control stemborer
Hosmer / Lemeshow test	8.282	8	0.406	Not reject the null hypothesis that there is a linear relationship between the predictor variables and the log odds of the criterion variables; the model fits the data well.
Cox and Snell R^2	0.135			
Nagelkerke R^2	0.298			The model explains at least 28.9% variation in the stemborer control decision
Overall prediction power of the model=92.6%				The model can reliably predict the decision.

Table 2.16 shows the logistic regression coefficients, Wald Test, odds ratio and the associated probabilities for each of the independent variables in the stemborer control model. Only the Type-I and Type-II knowledge indices had significant partial effects on the farmer's likelihood to use an improved technology to control stemborers. Improving a farmer's Type-I and Type-II knowledge by one unit, holding all other factors constant improves his/her likelihood to use an improved technology to control stemborer by 5.4 times each. Socio economic characteristics were not significant in influencing the farmers' likelihood of controlling stemborer using an improved technology. Only 9% of farmers in the study sample control stemborer in their farms. This may have been too few for variations in household characteristics to be elicited in this analysis.

2.17 Discussion

Information is an important factor of production just like the classic land, labour capital and management (Antholt, 1995, Sumberg *et al.*, 2004). This study intended to identify and characterize the farmers' sources of information on Striga weed and stemborer pest control in Vihiga and Suba Districts of Western Kenya. Fifteen sources of information were associated with the different channels of communication in agricultural extension. These included channels used in the technology transfer model (e.g. mass media, contact with agricultural extension agents), social networks model (e.g. farmer groups, friends and neighbours), participatory model (on-farm demonstrations) and farmer experimentation (represented by farmers' years in farming). It is apparent that the different information sources are complementary channels for the farmers. All respondents in the study reported more than one source of information for their households.

The knowledge gained from interactions with different channels for each household was measured through a proxy index. This is consistent with other studies where indices have been used as plausible proxies for unobserved variables, e.g. in Tucker and Napier (2002) with respect to soil and water conservation information and Amudavi (2005) with respect to measuring indicators of wealth using households assets and incomes. Using the principal component analysis, based on the variance in the 15 sources of information considered in this study, two main and distinct principal component variables were extracted. Each variable was assumed to indicate a type of knowledge. These two components were labelled as Type-I knowledge (from the 1st component with over 24% of the variance) and Type-II knowledge (from the 2nd component with over 10% of the variance).

Type-I knowledge was closely related with group-oriented sources of information, including community leaders, field days, agricultural show events, barazas, neighbours/friends and on-farm demonstrations. On-farm demonstration had an approximately same level of loading on the Type-I and Type-II knowledge indices. The radio, although not group oriented in its processes, also loaded heavily on the Type-I knowledge. 83.2% of the sample households owned radios. Type-I knowledge was significantly influenced by primary level education attainment by the head of household, high levels of land tenure security, lower farm sizes, and shorter time periods to reach the market from the location of the household, higher wealth (indicated by high values of total livestock units) and a perception of high infestation of both stemborer and Striga. Holding all other factors constant, a one unit increase in Type-I knowledge causes a farmer to be 5.4 times more likely than an average farmer to adopt an improved technology to control stemborer. Type-I knowledge, however, did not have a significant influence on the farmers' likelihood to use an improved technology to control Striga. It appears that the farmers' experience with Striga required that they get convinced with new knowledge that is confirmed by materials from reputable sources.

Type-II knowledge on the other hand was related to sources of information that require individual action, including reading a pamphlet or brochure, discussions with extension agents, visits to research and extension organizations and discussions with farmer teachers. In Type-II knowledge, farmers seek out accurate information through active learning. This suggests that Type-II knowledge is associated with a higher level of personal interest for a farmer to seek more information from an authority in the field or a point of reference. This type of knowledge was significantly and positively influenced by higher education levels of the farmer, higher levels of wealth (as proxied by total livestock units), higher land tenure security and location within a research participating village. Type-II knowledge was found to be significant in influencing the farmers' likelihood to control both Striga and stemborer. Holding all other factors constant, increasing this type of knowledge by one unit increases a farmer's likelihood to control Striga by 7.5 times and to control stemborer by 5.4 times.

Type-II knowledge is significantly influenced by education level; a change from one level of education to the next causes a significant increase. However, about 17% of the farmers in the sample households were uneducated while about 58% were having primary school level education. This is a big challenge for the development agents while promoting Striga and stemborer control technologies in the study area. At the national level, this is also important and implies that over 70% of the rural households may not be able to take advantage of this Type-II knowledge due to human capital limitations. Given the high levels of illiteracy and low levels of education in the rural populations, it therefore remains a challenge for the scientists to simplify technology messages for the farmers.

Holding all other factors constant, farmers' participation in research activities (households located in the research participating villages) was one factor that contributed the most to farmers' accumulation of Type-II knowledge. However, only a very small percentage of the study sample farmers are able to directly participate in on-farm research activities. The farmer field school approach to information dissemination might therefore be a good alternative to ensure as many farmers as possible participate in on-farm field activities and benefit from the gains they make in acquiring Type-II knowledge.

Farmers' own experimentation (proxied by farming years) did not load heavily on either of the two types of knowledge. This might be an indication that indigenous systems of knowledge generation that have not succeeded in getting effective solutions against Striga and stemborer infestations in cereal farming in Western Kenya. It is regrettable that the farmers in Western Kenya attribute the Striga persistence to witchcraft practices (Author's communication with farmers during field surveys). With this kind of explanations, farmers may have given up trying to resolve the problems on their own. Research and development programmes are therefore the main sources of technologies against Striga. Information dissemination programmes for the farmers should be prioritised in the research and development programmes, particularly in the case of Striga control in Western Kenya.

Hogset and Barrett (2007) classified the active and passive social learning processes. In passive learning, since individuals are not purposefully seeking out information they obtain, it results merely in awareness of prevailing pattern of behaviour. In such processes of learning, farmers may not gain information that may influence them to adopt technologies. This type of learning may be what is involved in the Type-I knowledge where farmers gain information in farmer-group activities.

It was evident from this study that the farmers in the villages that hosted research activities accumulated significantly more knowledge on Striga and stemborer control than the neighbouring villages or those that are geographically located further from them. In the research-hosting villages, information may constantly be exchanged between researchers and perhaps the development agents as they monitor the research activities. This could also be due to infrastructural support that is given to the farmers in such villages to visit research institutions. They could also have printed material from the researchers. However, this knowledge was not diffusing fast enough as would be expected to the neighbouring villages, who had much lower levels of knowledge. The knowledge levels were even much lower in villages far away from the research villages. It seems to indicate that local information networks were not very effective in diffusing the knowledge from one village to the next.

Incentives need to be created to encourage farmers to actively seek information about Striga and stemborer control, especially beyond the areas where villages have participated in on-farm research work. Technology development, of especially knowledge intensive approaches, should be accompanied with intensive information sharing campaigns beyond the on-farm research areas. The information should be processed into very simple forms that even farmers without formal education can understand because a big percentage of rural farmers have no formal education or have only primary education.

2.18 Conclusions

This study demonstrates that information is an important factor in stemborer and Striga weed control in maize farming in Western Kenya. Farmers' access information from 14 sources namely farmers groups (21.8%), on farm demonstrations (22.9%), community leaders (78.6%), contact farmers (4.2%), institutional visits (9.0%), radio (52.3%), agricultural extension officers (18.9%), pamphlets and brochures (23.3%), agricultural shows (24.6%), chiefs barazas (48.5%), field days (28.2%), neighbours and friends (74.8%), posters (5.5%) and push pull farmer teachers (14.5%). All the farmers also depend on their experience ein farming as a source of information. From these sources, farmers generate two distinct types of knowledge; Type-I knowledge which is closely related with group activities in sourcing information and Type-II knowledge was closely related with individual activities in sourcing information.. Type-I knowledge did not significantly increase the farmers' likelihood to use an improved technology in the control of Striga, but it increased the farmers' likelihood to use an improved technology in stemborer control. Type-II knowledge positively and significantly influenced a farmer's likelihood of using improved technology in both Striga and stemborer. Only the two types of knowledge variables were found to be significant in influencing the farmers' likelihood to use improved technology in controlling stemborers. This suggests that information and the knowledge generated was the most important factor in determining whether farmers controlled stemborer in their cereal crops.

Among the factors that positively influence farmers' accumulation of Type-II knowledge are higher education levels and participation in on-farm research. Given that most farmers in rural areas had low education levels, with 17% having no education while 58% had only primary level education, this suggests that specific training programmes to provide non-formal education could be necessary. This is because it is hard to change education status of the farmers in the short run. Another strategy would be to simplify agricultural messages so that the more than 70% of the population in the rural areas of Kenya can also benefit from Type-II knowledge, which has significant impact on the control of Striga and stemborer.

Due to logistical constraints, only few farmers participated in on-farm research activities yet this was identified as one of the most important factor that influences Type-II knowledge. Farmers' ability to acquire both Type-I and Type-II agricultural knowledge should be enhanced for increased use of improved technologies against Striga and stemborers. Simplifying agricultural messages and engagement in more interactive learning settings, such as Farmer Field Schools, would help majority of rural farmers with low education status to accumulate Type-II knowledge, which is critical for control of Striga and stemborer, the most serious cereal production constraints. Farmer Field Schools would be a recommended avenue where more and more farmers participate in on-farm research activities since they provide more interactive learning opportunities.

This study has been able to identify the farmers' sources of information, and also identify the two types of knowledge that farmers generate through interaction with the sources. Its clear that the practical and group oriented approaches of information sharing approaches are important for farmers to access information. The government extension services should therefore have a policy where the more practical approaches like farmer field schools are adopted for use in all technology dissemination activities. This should also be supported with simple reference materials that farmers can read for themselves. This approach would ensure that farmers benefit from the type-I and type-II knowledge in all subjects.

2.19 References for chapter two

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CHAPTER 3: ANALYSIS OF THE CHARACTERISTICS OF STRIGA-CONTROL TECHNOLOGIES AND THEIR EFFECTS ON PROBABILITY OF TECHNOLOGY ADOPTION IN VIHIGA AND SUBA DISTRICTS

3.1 Introduction

This chapter focuses on the farmers' perceptions of technologies and their technology characteristics in the control of Striga[3]. The technology adoption decision for Striga control is presumed to be a multivariate determined decision since the farmers have the option of using various options, including improved fallow, fertility improvement through use of manure/fertilizers, Push-pull technology, IR-maize technology, fallowing of land, hand-pulling and crop rotation/intercropping. Non-use of any of the options to control Striga/stemborer is also an option in the choice set. All this technologies have been disseminated by various institutions in Western Kenya in the last 25 years. An important question then is, in choosing a technology from a basket of options, are technology characteristics important? What characteristics are they? Can farmers articulate such characteristics in the case of Striga control technologies? How important are the characteristics to the farmers? That is, do the characteristics influence the probability of a technology being adopted by farmers?

3.2 Chapter objectives on technology characteristics

The purpose of this chapter was to empirically test whether a technology's characteristics are important in influencing the adoption of technologies for the control of Striga among farmers in Suba and Vihiga Districts. This purpose was generated from the second objective of the study as presented in chapter 1 to:

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[3] The data collected showed that there were only 9 farmers that were controlling stemborer in the study sample. So it was decided to focus on the characteristics of Striga control technologies where enough data was available.

a) Establishing the farmers' knowledge of Striga control technologies and how they characterize them

b) Estimating the marginal utilities of the 'characteristics' that the farmers considered in Striga control technologies; and

c) Estimating how technology 'characteristics' influenced the probability of a farmer's technology choice from a set of options for adoption in control of Striga.

3.3 Striga control technologies

A review of the extent of damage caused by parasitic weeds in the Striga, genus was given in Chapter 1. Several conventional Striga control methods, based on the principles of reducing Striga seed banks in the soil and preventing production of new seeds and spread from infested to non-infested soils, have been tried with some limited and localized success (Berner *et al.*, 1995a; Oswald, 2005). There are agronomic, genetic, chemical and biological control methods that can be clustered into direct and indirect methods for the Striga control (Oswald, 2005).

Direct Striga control methods are intended to attack the parasite directly and have immediate effect on Striga densities in the field, but not always on crop yield of the same season. The direct methods comprise use of resistant host crop varieties, chemicals (herbicides and ethylene), biological control agents, catch cropping and seed dressing with selected herbicides (e.g. herbicide-resistant maize) and transplanting of host crops. Indirect methods are those that aim at the cropping system and soil fertility management and try to control the parasite by making its growth conditions less favourable. These methods often need several cropping seasons before an effect can be observed, but they control Striga in a more sustainable way and increase crop yields over time. The indirect methods include crop rotation, intercropping with Striga host and non-host crops and soil fertility management (see the review by Oswald, 2005).

This study examined, from the farmers' perspective, some of the technologies practised by farmers for controlling Striga in Suba and Vihiga Districts, which included:

Organic and inorganic fertilizers for soil fertility improvement. The use of nitrogen (N) as a method to suppress Striga has been demonstrated in the east and central African highlands (Gacheru and Rao, 2001; Esilaba *et al.,* 2000;). Nitrogen is sourced from either organic sources like farmyard manure or inorganic sources like mineral fertilisers. Mumera and Below (1993) found that although Striga infestation generally declined with increasing nitrogen-availability, the impact was partially dependent on the severity of infestation. Results of field trials with basal applications of N-fertilizers over many years in many countries have not been consistent in terms of either increased crop yield or reduced Striga numbers (Esilaba, 2006). The differences in results from various nitrogen studies may be due to differences among host plants, chemical interactions, micro-organisms, soil texture and moistures (Ibid). Other factors may include the source of the nitrogen and the time of its availability in relation to crop growth, including the transfer of ammonium nitrate (Mumera and Below, 1993). The use of nitrogen from farmyard manure is a familiar strategy with farmers in Western Kenya. Sometimes, farmyard manure is used in small amounts targeted to spots on the farm where Striga plants are observed. However, the efficacy of this method is not yet established.

***Hand pulling of* Striga *plants*:** Hand pulling is a widely practised Striga control method in Kenya (Odhiambo and Ransom, 1994). Due to the high labour costs involved, it is recommended that hand pulling should not begin until 2-3 weeks after Striga begins to flower so as to prevent seeding (Parker and Riches, 1993). Labour needed for such hand pulling is less than half that required when pulling of Striga is started earlier in the season. Hand pulling of Striga before seeds set in a maize crop is as effective as trap cropping in restoring the productivity of the land infested with Striga in Western Kenya (Odhiambo and Ransom, 1994). To be effective, hand pulling will usually need to be continued for 3-4 years and is most economical on the least infested fields (Ransom, 1996; Parker and Riches, 1993).

Rotation: trap and catch crops**:** Planting of non-susceptible or non-host crops on infested land or fallowing is theoretically the simplest solution (Esilaba, 2006). Rotation with non-host crops interrupts further production of Striga seeds and leads to decline in the seed population in the soil. The practical limitation of this technique is the more than three years required for rotation. The choice of rotational trap or catch crop is based primarily on its suitability to the local conditions and only secondarily on its potential as a trap crop (Parker and Riches, 1993). Catch crops are planted to stimulate a high percentage of the parasite seed to germinate but are destroyed or harvested before the parasite can reproduce. The main crop could then be planted during the main rains (Parker and Riches, 1993). Examples of catchcrops include cotton, cowpeas, soya beans, pigeon peas, chickpeas and groundnuts stimulate the germination of Striga. Trap crops should be cultivated for at least three consecutive years in order to reduce parasite seeds.

Intercropping/mixed cropping**:** There are conflicting reports on the effect of intercropping cereals (hosts) with legumes (non-hosts of cereal Striga) (Esilaba, 2006). However, intercropping is a very common practice among the small-scale farmers of Kenya (Salasya, 2005), especially in Vihiga District where the farm sizes are small. The crops mostly used in the intercrops are the food legumes including cowpeas, soya beans, pigeon peas, chickpeas and groundnuts. Intercropping maize with cowpeas between the rows of maize has been shown to significantly reduce Striga numbers compared to cowpea within the maize row (Odhiambo and Ransom, 1994). On-farm trials showed that intercropping of maize and beans in the same hole in Striga infested farmers' fields increased maize yields significantly in Western Kenya (Odhiambo and Ariga, 2004). The crops mostly used in the intercrops are the food legumes, including cowpeas, soya beans, pigeon peas, chickpeas and groundnuts.

***IR-maize seed technology**:* IR-maize seed technology is a relatively new technology. The technology was developed and tested by CIMMYT scientists with collaborators. The technology had not yet been fully released to the farmers at the time of our field survey, but some farmers who had been involved in on-farm trials and who grew IR-maize to control Striga were in our study sample. The technology involves combining low doses (*ca.*30 grams per hectare) of a systemic acetolactate synthase-inhibiting herbicide (such as imazapyr or pyrithiobac) as a seed coating (Kanampiu *et al.*,, 2003). The treatment leaves a field virtually clear of emerging Striga stalks up to harvest time and allows intercropping with legumes as long as the legume is intercropped between the maize rows at least 12 cm from the treated maize seed. Since the maize seed is treated, there is no need for added cost for spraying equipment and the possibility of off-target application. The herbicide is compatible with commonly used fungicides/insecticides for seed dressing and is applied with them.

Fallowing of land: The term 'fallow' as conventionally used refers to agricultural land lying idle as a means to 'rest tired soils' (Sanchez, 1999). This involves 'resting' the land that has been infested with Striga from all forms of seasonal cultivation. It is perhaps the oldest practice in the control of Striga in farms in Western Kenya. Through natural biomass accumulation, the land would replenish its fertility levels. Natural woody fallows are the backbone of shifting cultivation (Sanchez, 1999). This practice requires that the farmers have alternative pieces of land where they would plant their crops while waiting for the land under fallow to improve. This approach is now threatened by the declining household land holdings that have resulted in relatively small farm sizes in Western Kenya and their need to keep the farms under production in all seasons in order to meet the household food needs.

Improved fallow: This is a practice in which leguminous trees are planted and intercropped with food crops during the first season, but the trees are left to grow alone in the subsequent season in order to replenish soil fertility. A number of tree species have been identified as good candidates for managed fallows and have been shown to stimulate Striga germination, reducing the Striga seed banks in the soil (Sanchez, 1999). They include Sesbania Sesban (L) merr, Senna *spp.*, Crotalaria agatiflora Schweinf, Crotalaria grahamiana Wight & Arn, Calliandra calothyrsus Meis, Leuceana Leucocephala Lam de Wit and Desmodium Intortum Macbr. This concept was developed and promoted by the International Centre for Research in Agro Forestry (ICRAF, now renamed World Agro-forestry Centre). Once established, the trees need very little management and can produce much-needed fuel-wood, and fodder for some species, while significantly enhancing the nitrogen status of the soil (Rao and Gacheru, 1998). Multi-purpose trees grown on farms may have the potential to increase soil fertility and/or cause suicidal germination of Striga seeds and thereby help to reduce the level of Striga infestation. After two or more seasons, the trees can be uprooted and food crops planted again.

Push-pull technology (PPT): This is a technology that simultaneously controls Striga and stemborers and also improves soil fertility. It has been described in section 1.1 of this thesis.

Local varieties: In Suba District, some farmers plant a local variety of maize, *'Nyamula'* which they report that it is resistant to Striga infestation.

Doing nothing**:** Some farmers, though constrained by Striga in their cereal production, do not adopt any technology to control it. This has been a challenge for both scientists and development agents involved in Striga control research because it raises a number of questions. For example: (i) are the technologies fitting the needs of the farmers? (ii) What characteristics do farmers look for when they want to adopt a Striga control technology? (iii) How much 'weight' do they attach to such characteristics? (iv) Are some of these characteristics a 'turn off' or a 'turn on' for the farmers who may want to adopt a Striga control technology?

Although these questions beg for answers, the adoption of Striga control technologies has not been studied exhaustively in Western Kenya. A major question is why there is such a high number of farmers doing nothing about Striga on their farms, in spite of the available mitigating options and yet they are suffering high yield losses in cereals. Over 71.9% and 77.4% of households in our study sample from Vihiga and Suba respectively, do not control Striga on their farmers. Agricultural researchers face many challenges. For example, during the research process through which the technologies are developed, little or no funds are set aside for dissemination and adoption studies (Oswald 2005). There is an underlying assumption that the structures within the farming communities and the good examples and success of those farmers who participate in project activities should be enough incentive to attract other farmers (Oswald, 2005). In one study, Ngare (2004) tried to establish whether the farmers would be willing to use the herbicide-coated IR-maize technology to control Striga. However, since the technology had not yet been released to the farmers, factors influencing adoption could not be included in the study. In contributing to knowledge on how farmers evaluate Striga control technologies for adoption, this study looks at the role of technology characteristics.

The adoption decision making for a Striga control technology is presumed to be a multivariate determined decision making process since the farmers have the possibility of using various options, including improved fallows, fertility improvement through use of manure/fertilizers, Push-pull technology, IR-maize technology, fallowing of land, hand-pulling and crop rotation/intercropping. Non-use of any of the options to control Striga/stemborer is also an option in the choice set. An important question then is: what factors do the farmers consider in making decisions to adopt a new technology or farm practice?

3.4 Technology characteristics

Rogers (1995) correctly observed that there is a lot of effort spent in studying ‘people’ differences in innovativeness and in determining the characteristics of different adopter categories. In most adoption studies, diffusion researchers compare farmers who had adopted or rejected a certain technology at a point in time (Batz *et al.*, 1999) and technologies are considered as ‘whole’ entities. Little effort has generally been devoted to analysing innovation differences and particularly how the properties of innovations affect their rate of adoption. In marketing studies, the view of goods as ‘whole’ entities has been challenged in the Lancaster theory of consumer demand. Lancaster (1966, 1991) proposes that goods *per se* do not give utility to consumers; rather the consumer maximises utility through the consumption of the goods characteristics (Karugia, 1997; Tano *et al.*, 2003; Makokha *et al.*, 2007). This implies that the overall utility for a good is linearly related to its attributes (Sy *et al.*, 1993) and can be decomposed into separate utilities based on constituent characteristics or benefits (Louviere, 1994; Tano *et al.*, 2003). Consumption is assumed to transform the commodity space into characteristics/attributes space where the characteristics enter the utility function as arguments and are maximised subject to consumers' preference for them and subject to restrictions (Tano *et al.,* 2003).

In agricultural technology adoption studies, there is a growing appreciation of the important role of technology characteristics in influencing farmers' choices, and empirical studies have sought to evaluate their impacts (Irungu, 2006; Ouma *et al.*, 2007; Makokha *et al., 2007*). Similarly, it can be assumed that Striga control technologies do not confer utility to farmers as whole entities, but that utility is maximised from the 'characteristics' of the technologies.

Drawing on Lancaster's theory perspective (1966, 1991), the thesis of this study is that the farmers in Suba and Vihiga Districts do not view Striga control technologies as 'whole entities', but as 'bundles of characteristics'. This suggests that the farmers maximize their utility from the technology's 'bundle of characteristics'. Consequently, the utility maximised from the technology characteristics has significant influence on the farmers' probability of technology choice for adoption.

3.5 Empirical studies on technology characteristics

Most empirical adoption studies concentrate on the effects of farmers' characteristics on adoption decisions (Batz *et al.*, 1999). They examine farmers who have adopted or rejected a certain technology at a point in time, but report little about the influences of technology characteristics on adoption and diffusion of technologies (Ibid). This is despite the fact that both 'innovation diffusion' and 'economic constraint' paradigms assume that technology characteristics determine adoption and diffusion (Adesina and Zinnah, 1993). Knowledge of technology characteristics, which have influenced adoption and diffusion in the past, would inform what characteristics any new technologies should possess to become quickly and widely adopted (Batz *et al.,* 1999).

Technology characteristics are the attributes, components or parts that embody a technology. These characteristics may differ from technology to technology. In reference to the same technology, different definitions and characteristics are possible, depending on the discipline defining them. For example, the characteristics that the farmers see as embodying a technology may be different from what the researchers developing such a technology may define. Tano *et al.* (2003) assessed farmers' preferences for cattle traits in West Africa and identified feeding ease, weight gain, disease resistance, reproductive performance, size, milk yield, temperament, fitness to traction and fertility as the characteristics that the farmers considered before deciding the type of animal to adopt. In Burkina Faso, Adesina and Baidu-Forson, (1995) also found that the farmers identified yield, quality of local porridge, adaptability to poor soils, tolerance to Striga and tolerance to drought as important characteristics considered in the adoption of new sorghum varieties. These are different from the agronomic characteristics that the researchers would define as important in the consideration of such innovations.

There is consensus that the definition of such technology 'characteristics' is subjective from farmer to farmer (Ashby and Sperling, 1992). Nevertheless, these subjective definitions of technology characteristics influence choice and adoption behaviour (Nowak, 1992). Ultimately, farmers' decisions for technology choice will determine adoption and the intensity of use of a particular technology. Farmers' preferences for technology characteristics are to some degree the outcome of their livelihood strategies and are conditioned by their working environment (Wale *et al.,* 2005). Even though the choice set may be the same within a particular region, some farmers tend to give a high priority to certain characteristics of a technology, such as yield quantity, yield stability and produce marketability (Ibid). Subject to the influence of these factors, farmers will prefer technology attributes that address their concerns.

Farmers' perceived attributes of an innovation are an important explanation of the choice and the rate of adoption of a technology. Hence the probability of uptake of a technology in a farmer's field is a function of the extent to which it embodies the important attributes preferred by the farmer (Wale, 2005). Rogers (1995) showed that 49-87% of the variance in the rate of adoption of innovations was explained by the innovation characteristics. These characteristics are clustered in five broad categories that include:

1. *Relative advantage*: This is the degree to which a technology is perceived as being better than the idea it supercedes. The degree of relative advantage is often expressed as economic profitability where cost is an important consideration, social prestige or other benefits. The relative advantage of an innovation as perceived by members of a social system is positively related to the rate of adoption.

2. *Compatibility:* This is the degree to which a technology is perceived as consistent with the existing values, past experiences and needs of potential adopters. An idea that is more compatible is less uncertain to the potential adopter and fits more closely with the individual's life situations. A technology can be compatible or incompatible with a) socio-cultural values and beliefs, b) previously introduced ideas, or c) client needs for the technology. Compatibility of technology as perceived by members of a social system is positively related to its rate of adoption.

3. *Complexity:* Complexity is the degree to which a technology is perceived as relatively difficult to understand and use. Some technologies are clear in their meaning to potential adopters whereas others are not. Although research evidence is not conclusive, the

complexity of a technology, as perceived by members of a social system, is negatively related to its rate of adoption.

4. *Trialability:* This is the degree to which a technology may be experimented with on a limited basis. New ideas that can be tried in small portions are generally adopted more rapidly than innovations that are not divisible. Some technologies are more difficult to divide for trial than others. The personal trying-out of a technology is a way to give meaning to a technology, to find out how it works under one's own conditions, and to dispel uncertainty about the new technology. The trialability of a technology as perceived by members of a social system is positively related to its rate of adoption.

5. *Observability:* Is the degree to which the results of a technology are visible to potential users. The results of some ideas are easily observed and communicated to others, whereas some innovations are difficult to observe or to describe to others. The observability of a technology as perceived by members of a social system is positively related to its rate of adoption.

Assessing the utility of farmers' preference for characteristics using the conventional methodologies in econometrics is a challenge. Econometric researchers have looked upon the marketing approaches where conjoint analysis approach has been found useful in studying product characteristics (Irungu *et al.*, 2006; Tano *et al.*, 2003).

3.6 Conjoint analysis theory

Conjoint analysis was first developed for, and primarily applied in, marketing studies of consumer goods in developed economies (Tano *et al.*, 2003) to identify product/service characteristics that are most important to the consumers. Over time, the methodology has been applied in areas of ecological studies (Sayadi *et al.*, 2002), livestock studies (Irungu, 2006; Tano *et al.*, 2003;), acceptance of biotechnology in agricultural products (O'Connor *et al.*, 2006), and agricultural technologies (Baidu-Forson *et al.,* 1997) in both developed and developing regions.

Conjoint analysis is defined as any 'decompositional' method that estimates the structure of a consumer's preference, given his/her overall evaluation of a set of alternatives that are pre-specified in terms of levels of different attributes (Green and Srinivasan, 1990). The purpose of conjoint analysis is to analyse choice in a multi-attribute context. Consumers typically do not have the option of buying the product that is best in every attribute, particularly when one of those attributes is price (Kuhfeld, 2004). Consumers are forced to make trade-offs as they decide which products to purchase. Conjoint analysis is used to study these tradeoffs. The purpose of conjoint analysis is to estimate utility scores, called partworths, for these characteristics (Tano *et al.,* 2003). Utility scores are measures of how important each characteristic is to the respondents overall preference of a product. Conjoint procedure is used to estimate utility scores for each individual respondent and for the whole sample.

There are many different conjoint methods (SPSS 14 Manual). They come in a variety of forms including:

1. Adaptive Conjoint Analysis (ACA)
2. Traditional Full Profile Conjoint Valuation Analysis (CVA)
3. Choice Based Conjoint (CBC) Analysis.

3.6.1 Adaptive conjoint analysis' (ACA)

ACA's main advantage is its ability to measure more attributes than is advisable with traditional full profile conjoint analysis. In ACA, respondents do not evaluate all attributes at the same time, which helps solve the problem of information overload that plagues many full profile studies. ACA must be computer administered. The interview adapts to respondents previous answers, which cannot be done via paper and pencil. In the first part of the interview, respondents rank (or rate) attribute levels and then assign a weight (importance) to each attribute. Products/services are evaluated in a systematic feature-by-feature manner rather than judging products as a whole or in a competitive context. Using the information from the self-explicated section, ACA then presents trade-off questions. Two products are shown and respondents indicate which is preferred, using relative rating scales. The product combinations are tailored to each respondent to ensure that each is relevant and meaningfully challenging. Each of the products is displayed in partial profile i.e. only a subset (usually two or three) of the attributes is shown for any given question. Because of the self-explicated introductory section, the adaptive nature of the questionnaire and the ratings based on conjoint trade-offs, ACA is able to stabilize estimates of respondents' preferences for more attributes using a small sample size than the other conjoint methods. ACA does well for modelling high involvement choices where respondents focus on each of a number of products attributes before making a carefully considered decision.

3.6.2 Traditional full profile conjoint valuation analysis (CVA)

CVA has been the mainstay of conjoint research for decades. It is useful in measuring up to 6 attributes. The number varies from project to project depending on the length of the attribute level text, the respondents' familiarity with the category and whether the attributes are shown as prototypes or pictures. CVA is designed for paper and pencil studies. CVA calculates a set of partworth for each individual using traditional full profile card sort (either ratings or ranked) or pairwise ratings. Up to 30 attributes with 15 levels can be measured, though this is cumbersome in a real study. Through the use of compound attributes, in a limited way, CVA can measure interactions between attributes such as brand and price. Compound attributes are created by including all combinations of levels from two or more attributes, e.g. two attributes each with two levels can be combined into a single four level attribute.

CVA can design pairwise conjoint questionnaires (like ACA) or single concept (card-sort) designs. Showing one product at a time encourages respondents to evaluate products individually, rather than in direct comparison with a competitive set of products. It focuses more on probing the acceptability of an offering rather than differences between competitive products. If the comparative task is desired, CVA's pairwise approach maybe used. Another alternative is to conduct a card-sort exercise. Though respondents view one product per card, in the process of evaluating the deck, they usually compare them side-by-side and in the sets. Because the respondents view the products in full profile (all attributes at once), respondents tend to use simplification strategies if faced with too much information to process. Respondents may key on two or three salient attributes and largely ignore the others.

3.6.3 Choice based conjoint (CBC) analysis

CBC interviews closely mimic the purchase process for products in competitive contexts. Instead of rating or ranking products, respondents are shown a set of products in full profile and asked to indicate which one they would purchase. Respondents can decline to purchase in a CBC interview by choosing none. Choice tasks are more immediate and concrete than abstract rating or ranking tasks. Since choice based questions show sets of products in full profile, they encourage even more respondent simplification that the traditional full profile questions. Attributes that are important get greater emphasis (importance) and less important factors receive less emphasis relative to CVA/ACA. CBC results have traditionally been analysed at the aggregate or group level.

3.6.4 An orthogonal array

SPSS conjoint analysis uses the full profile approach, where respondents rank, order or score a set of profiles or cards according to preferences. Each profile describes a complete product or service and consists of different combinations of factor levels for all attributes factors (attributes) of interest. If more than a few factors are involved and each factor has more than two levels, the total number of profiles resulting from all possible combinations of the levels becomes too much for respondents to rank or score in a meaningful way. To solve this problem, the full profile approach uses what is termed as a ‘factional factorial design’, which presents a suitable fraction of all possible combinations of the factor levels. The resulting set, called an **orthogonal array** is designed to capture the main effects for each factor level.

An orthogonal array ensures that the respondents’ preferences are sufficiently investigated while not overloading them with too much information about each choice (Tano *et al.,* 2003). The orthogonal design results in profiles that are independent from one another: the process recognises main effects only and assumes non-significant interaction effects among the factors (Tano *et al.,* 2003). A main effect means there is a consistent difference between levels of a factor. The main effects design assumes that individuals process information in a strictly additive way, such that there is no interaction between factors (Tano et al., 2003).

3.7 Steps in conjoint analysis

There are four main steps in conjoint analysis. They include:

3.7.1 Generating the orthogonal design

3.7.2 Generating the experimental stimuli

Each set of factor levels in an orthogonal design represents a different version of the product under study. It should be presented to the respondents in the form of an individual product profile. This helps the respondents to focus on only the one product under evaluation. The stimuli should be standardised by making sure that the profiles are all similar in physical appearance except for the different combination of features.

3.7.3 Collecting the data

There is a great deal of between subject variations in preferences; hence much of conjoint analysis focuses on the single subject. To generalize the results, a random sample of subjects from the target population is selected so that group results can be examined. The sample size should be large enough to ensure reliability of the data. The profiles generated from the product/technology features can be presented to respondents in one of the following three ways: verbal descriptions, paragraph descriptions or pictorial representations (Tano, 2003). Verbal descriptions use cards in which each trait level is described in a brief line item fashion, while paragraph descriptions give a more detailed description of each level. Pictorial representations use some graphical images to present the levels of traits. Verbal and paragraph descriptions are convenient, straightforward and inexpensive. However, in areas of low literacy levels and rural populations that use different languages, data collection using the verbal and paragraph descriptions may become complex and inaccurate. Pictorial representations, on the other hand, are preferred since visual materials help respondents to process the information, thereby facilitating the interpretation and rating of the profile (Holbrook and Moore, 1981). The main disadvantage is the additional time that is needed to conduct field interviews in order to ensure that the respondents are interpreting the pictures in as similar manner as possible.

3.7.4 Data analysis

Due to observational deficiencies on the part of the researcher, arising from unobserved attributes and measurement errors, the analysis of respondents' choice of profile can be cast in a random utility framework (Maddala, 1983;). The framework models the probability that a respondent will choose a particular technology from the choice set as a function of differences in utilities among alternatives as well as the characteristics of the respondents (Ben-Akiva and Lerman, 1985). Since respondents are rational, it is assumed that they choose the technology that maximises their utility (Greene, 1997). On this basis, the observed choice of profile is assumed to be the option that confers the highest utility to the respondents. The choice data is then analysed through discrete choice modelling such as the use of logit and probit models.

The Mixed Logit Model: Multinomial logit models are used to model relationships between polytomous (more than 2) response variables and a set of regressors (So and Kuhfeld, 2004). The term 'multinomial logit model' includes in a broad sense a variety of models. The polytomous response model can be classified into two distinct types, depending on whether the response variable has an ordered or unordered structure. In an ordered model, the response Y of an individual unit is restricted to one of m ordered values, e.g. the severity of a medical condition may be none, mild or severe. The cumulative logit model is used when the response of an individual unit is restricted to one of a finite number of ordinal values. The cumulative logit model assumes that the ordinal nature of the observed response is due to methodological limitations in collecting the data that result in lamping together values of an otherwise continuous response variable (Mckelvey and Zavoina, 1975 in So and Kuhfeld, 2004).

In an unordered model, the polytomous response variable does not have an ordered structure. Two classes of models, the generalised logit model or the conditional logit model, can be used with nominal response data. The generalised logit model consists of a combination of several binary logits estimated simultaneously. In a conditional logit model, a choice among alternatives is treated as a function of characteristics of the alternatives, whereas, in a generalised logit model, the choice is a function of the characteristics of the individual making the choice. In an example, people are asked to choose between travel by auto, plane or public transit (bus or train). The variables ‘autotime’, ‘plantime’ and ‘trantime’ (alternative specific characteristic) represent the total travel time required to get to a destination by using auto, plane or transit respectively. The variable ‘age’ (individual characteristic) represents the age of the individual being surveyed and the variable ‘chosen’ contains the individual’s choice of travel mode. You use a generalised logit model to investigate the relationship between the choice of transportation and age; and you use a conditional logit to investigate how travel time affects the choice.

Modelling discrete choice data: Consider an individual choosing among m alternatives in a choice set. Let II_{jk} denote the probability that individual j chooses alternative k; let x_j represent the characteristics of individual j and let z_{jk} be the characteristics of the k^{th} alternative for individual j. For the mixed logit model that includes both characteristics of the individual and the alternatives, the choice probabilities are:

$$II_{jk} = \frac{\exp(\beta_k^{'} x_j + \theta^{'} z_{jk})}{\sum_{i=1}^{m} \exp(\beta_i^{'} x_j + \theta^{'} z_{jl})} \quad \text{………………………… Eq 3.1}$$

Where $\beta_1 \ldots \beta_{m-1}$ and $\beta_m \equiv 0$ are the alternative specific coefficients and θ is the set of global coefficients.

Fitting discrete choice model: The CATMOD procedure in SAS/STAT software directly fits the generalized logit model. SAS/STAT software does not yet have a procedure that is specially designed to fit the conditional or mixed logit models (So and Kuhfeld, 2004). However, with some preliminary data processing, the PHREG procedure is used to fit these models. The PHREG procedure fits the 'Cox Proportional Hazards Model' to survival data. The partial likelihood estimate of Breslow model has the same form as the likelihood estimate in a conditional logit model. The Breslow likelihood estimate is requested by specifying 'ties=breslow' option.

This mixed logit model has been used in several studies to evaluate preferences, e.g. in the area of marketing (Seetharaman and Chintagunta, 2003) and animal health service provision (Irungu, et al, 2006). So and Kuhfeld (2004) demonstrate how to estimate the Proportional Hazard model in choice-based studies under a multinomial logit framework. In many situations, a **mixed model** that includes both the characteristics of the alternatives and the individual is needed for investigating consumer choice. Both the generalised logit and the conditional logit models are used in the analysis of discrete choice data. The mixed model was chosen for use in this study in the analysis of factors that influence farmers' preferences in the choice of Striga control technologies in Vihiga and Suba Districts so that it can asses the characteristics of the farmers and the technologies.

3.7.5 Independence from irrelevant alternatives

In a model with cross-effects, the utility of an alternative depends on both its (alternative's) attributes and those of the other alternatives. The Independence from Irrelevant Alternatives (IIA) property states that utility only depends on attributes' own characteristics. The ratio of the choice probabilities for any two alternatives for a particular observation is not influenced systematically by any other alternatives. Cross effects add other alternatives' attributes to the model, so they can be used to test for violations of IIA (So and Kuhfeld, 2004). One of the consequences of Multinomial logit formulations is the property of independence from irrelevant alternatives. Under the assumption of the IIA, all cross effects are assumed to be equal; so that if a product gains in utility, it draws a share from all other products in proportion to their current shares. Departures from IIA exist when certain sub-sets of products are in more direct competition and tend to draw a disproportionate amount of share from each other than from other members in the category. Fitting a model that contains all cross-alternative effects and examining the significance of these effects can test IIA.

The PROC PHREG procedure in the SAS/STAT software allows one to specify a Wald test, which is based on the asymptotic normality of the parameter estimators. The test statement, with label IIA, specifies the null hypothesis that cross-alternative effects are 0. This test will be used to test for IIA among the technology profiles developed for Striga control technologies.

3.8 Data collection

3.8.1 Identification of important Striga control technology characteristics

A group of 20 farmers who are constrained by Striga in their cereal production in both Suba and Vihiga Districts were invited to a focus group discussion. Farmers identified all the technologies used for control of Striga or stemborers in their villages. During this meeting, they were requested to share with the research team the 'factors or characteristics' they considered important if they were to adopt a Striga control technology from the various options available. To clarify what the research team meant by 'factors/characteristics', an example of buying a shoe was given. When buying a shoe, farmers were asked what they would consider as important and some of the factors that came out of the discussion included shoe size, the colour, the type, the price and the money available. With such an introduction and background, the farmers were asked about the factors they would consider when choosing a technology to control Striga on their farms. To put the discussion into context, an average farm size of 0.25 ha was used as a basis for discussion. Out of the focus group discussions, a consensus emerged on seven key characteristics:

1. *Cost of the technology*. Farmers considered if the technology was cheap or expensive. 'Cheap' was defined to mean a cost that was less than Ksh. 1,000 while 'expensive' was considered to be a cost of more than Ksh. 1,000 per season.

2. *Yield improvement*. Farmers considered how much more maize they would obtain from the same plot by controlling Striga. Would adopting the technology lead to a 'small' increase in maize yield or a 'big' increase in maize yield? A 'small' yield increase was defined as an increase of less than half a bag (less than 45 kg) and a 'big' yield increase was defined as more than half a bag (more than 45 kgs). This would be the yield over and above what the farmers would obtain from the 0.25 ha without control of Striga.

3. *Additional benefits from the technology*. Farmers considered whether a Striga control technology had other benefits besides controlling Striga. These benefits included soil fertility improvement, source of animal feed and/or firewood. For the exercise, this characteristic was defined on two categories, namely soil improvement and firewood, or soil improvement and animal fodders.

4. *Change in family labour*. Farmers considered whether current labour supply on the farm would suffice to handle the technology or there would be need for additional labour. Farmers defined 'no labour change' as a situation where the technology labour requirement would be adequately handled by their 'current farm labour supply' without change, and 'change in labour' as the situation where the technology required that they add

farm labour by at least ‘one person equivalent’. The ‘one person equivalent’ meant that either the farm household members worked more per season or had to hire one more person.

5. *Fallow period*. Farmers considered whether they would be able to farm their crops continuously if they adopted a particular technology or if they were required to fallow their land for some seasons in order to succeed with the technology.

6. *Crop rotation*. Farmers considered whether they would require having a crop rotation regime with the technology or not.

7. *Intercropping food legumes*. Farmers considered whether it would be possible to intercrop food legumes with cereals if they adopted a particular technology or if they would have to give up their food legumes.

The seven ‘farmer-defined technology characteristics’ were therefore considered to be the most important characteristics in maximizing farmers’ utility of a Striga control technology. A farmer’s utility from a Striga control technology was therefore considered to be a function of the utility of the seven characteristics, including: cost of the technology, maize yield improvement due to technology, other benefits of the technology (e.g. soil fertility improvement, firewood or source of animal fodder), changes in household labour due to the technology, if household can farm cereals continuously or needs to fallow the land with the technology, if the technology requires crop rotation or not and whether farmer can intercrop maize with legumes or not with the technology. The farmers utility function for the technology choice was then validated through cross-sectional survey data analysis using mixed logit model as described in section 3.8.4.

3.8.2 Stimuli development for Striga control technologies

The seven Striga control characteristics identified in the focus group discussions were each defined at two levels as shown in Table 3.1. These factors and their levels were used as the basic data in generating an orthogonal array of profiles for Striga control technologies using SPSS version 11.5.

Table 3.1 Variables considered important in evaluating Striga control technologies by farmers in Suba and Vihiga Districts.

Variable Name	Variable label	Variable levels
Cost	Cost of having the technology on the farm per season	1 = technology costs less than Ksh. 1000 per season 2 = technology costs at least Ksh. 1000 or more per season
Yield	Increase in maize yield from use of technology	1 = less than 45kg (half a bag) per 0.25ha 2 = at least 45kg (half bag) per o.25ha
Other benefits	What other benefits the technology gives the farming system e.g. livestock feed or soil fertility improvement	1. Firewood and soil improvements 2. Cattle feed (Napier grass/desmodium) and soil improvement
Labour	Change in labour for the household due to use of technology	1. No change in labour requirement per season 2. At least one more person labour equivalent needed in a season
Fallowing	Whether the household can crop continuously with use of the technology or have to fallow their land for at least a season	1. No fallow period 2. Fallow at least one seasons
Crop rotation	Whether the technology requires the farmer to rotate their crops	1. Crop rotation 2. No crop rotation
Legumes	Whether the household can grow food legumes together with their cereal when using the technology	1 = Yes, can grow food legumes (e.g. beans) with maize 2 = No, can't grow food legumes (e.g. beans) with maize

Source: Focus group discussions by author and farmers in Vihiga and Suba districts, 2007

The generated orthogonal array resulted in 8-Striga-technology profiles and 4 holdout cards, useful for validating the conjoint model. The 12 profiles of hypothetical Striga control technologies are shown on table 3.2. For example profile 1 represents a technology that costs less than Ksh 1,000, the yield increase it gives in maize is less than half a bag, it gives firewood and soil fertility as extra benefits, it does not require change in labour nor a fallow period, one needs to do crop rotations and can intercrop food legumes. Each of the twelve profiles was further developed into a pictorial re-presentation of hypothetical Striga control technology (see example in Appendix 4a). The 12 profiles were designed into pictorial presentations to facilitate communication since the farmers in the study area were of low literacy levels and they speak different local languages. The pictorial presentations were expected to make it easier for the farmers to visualise the characteristics of the profiles. All the farmers who indicated that they had Striga constraints during the household survey, 204 in Suba District and 164 in Vihiga District, were interviewed for the conjoint survey.

3.8.3 Choice data from the Striga constrained farmers

The twelve pictorial profiles were presented to farmers by trained enumerators. It was explained that each profile represented a hypothetical technology. Once the farmers understood what the profiles entailed, they were asked to choose a profile that best represented their most preferred factors and levels of combinations of the seven characteristics, considering their own (farmers') circumstances. When a farmer chose the most preferred profile option, it was noted in a pre-designed form. Data was obtained for the 1st and 2nd most preferred profile for the 368 farmers.

Table 3.2 **Profiles of 'artificial' Striga control technologies based on the characteristics identified by the farmers.**

	Cost	Yield	Benefits	Labour	Fallow period	Cropping	Legumes
1	Less than Ksh.1000	Less than half a bag	Firewood / soil fertility	No change	No fallow	Crop rotations	Can intercrop legumes
2	More than Ksh.1000	More than half a bag	Cattle feed/soil fertility	No change	No fallow	Continuous cropping	Can intercrop legumes
3	More than Ksh.1000	More than half a bag	Firewood/ soil fertility	One person equivalent	Fallow period	Crop rotations	Can intercrop legumes
4	More than Ksh.1000	Less than half a bag	Firewood/ soil fertility	One person equivalent	No fallow	Crop rotations	Can't intercrop legumes
5	More than Ksh.1000	Less than half a bag	Firewood/ soil fertility	No change	Fallow period	Crop rotations	Can't intercrop legumes
6	More than Ksh.1000	Less than half a bag	Firewood/ soil fertility	No change	Fallow period	Continuous cropping	Can't intercrop legumes
7	Less than Ksh.1000	Less than half a bag	Firewood/ soil fertility	No change	Fallow period	Crop rotations	Can't intercrop legumes
8	More than Ksh.1000	More than half a bag	Cattle feed/ soil fertility	No change	No fallow	Continuous cropping	Can't intercrop legumes
9	Less than Ksh.1000	More than half a bag	Firewood/ soil fertility	One person equivalent	No fallow	Continuous cropping	Can't intercrop legumes
10	Less than Ksh.1000	Less than half a bag	Cattle feed/ Soil fertility	One person equivalent	Fallow period	Continuous cropping	Can intercrop legumes
11	More than Ksh.1000	Less than half a bag	Cattle feed/ Soil fertility	One person equivalent	No fallow	Crop rotations	Can't intercrop legumes
12	Less than Ksh.1000	More than half a bag	Cattle feed/ Soil fertility	No change	Fallow period	Crop rotations	Can't intercrop legumes

Source: Generated by the author, 2007

3.8.4 Data analysis

Marginal utilities of the attributes

Discrete choice modelling was used to investigate the farmers' stated preferences from the choice data. In choosing the 2 most preferred profiles, farmers' preferences for characteristics were considered exhaustively expressed. The choice data was analysed using the mixed logit model using the proportional hazards procedure of SAS. Equation 3.1 was fitted in SAS to give the marginal utilities for each of the seven characteristics. The farmers' choice of first and second profile data was used as the dependent variable. The profile choice variable was used as the artificial time variable as well as the censoring variable.

The choice variable was coded with a value of 1 for the first choice, 2 for the second choice and 3 for all the censored technology profiles. However, both the chosen (c=1, c=2) and the un-chosen (censored) (c=3) alternatives appear in the input data set since both are needed to construct the likelihood function. The un-chosen alternatives (c=3) enter into the denominator of the likelihood function and the c=1 and c=2 observations enter into both the numerator and the denominator of the likelihood function.

Effect coding was used for the categorical independent variables. The usual (0,1) dummy system was replaced by a (1, -1) system for two traits levels where (–1) is used for the variables that are normally excluded in order to avoid the dummy trap during the estimation. The use of effect coding generates estimates that measure the marginal change in the dependent variable as a result of a unit change in the independent variable (Tano, 2003; Makokha, 2007). Data on technology attributes in a profile (presence or absence) was used as the independent variables. The study District variable was used as an independent variable to assess if there were differences in preferences between respondents from Suba and Vihiga

Districts. A Wald test was used to test for Independence from Irrelevant Alternatives (IIA) among the technology profiles.

Probability of choice of the 12 technology profiles

The probability that an individual farmer will choose one of the 12 alternative profiles c_i, from the choice set C was estimated using:

$$P\left({}^{c_i}\!\diagup_{C} \right) = \frac{\exp(u(c_i))}{\sum_{j=1}^{12} U(c_j))} = \frac{\exp(x_i \beta)}{\sum_{j=1}^{12} \exp(x_j \beta)} \quad \text{……………………… Eqn 3.2}$$

where:

x_i is a vector of alternative attributes

β is a vector of unknown parameters

$U(c_i) = x_i \beta$ is the marginal utility for alternative profile c_i, which is a linear function of the 7 attributes.

The probability that an individual will choose one of the 12 profile alternatives presented to them is the exponential of the utility of the alternative divided by the sum of all the exponentiated utilities (Maddala, 1983 as quoted in Kuhfeld, 2004). Equation 3.2 is used to evaluate the probability of the choice of technology profiles in Suba and Vihiga Districts of western Kenya.

Review of existing technologies

Using literature and secondary sources, we reviewed the characteristics of the existing technologies that have been disseminated to farmers in western Kenya. We also attempted to map these existing technologies in terms of the seven characteristics that the farmers had identified. Using the utility values obtained from the results of the mixed logit analysis, we estimated the indicative probabilities of adoption for the existing technologies in relation to the seven characteristics that the farmers had identified.

3.9 Results

3.9.1 Striga as a constraint among farmers in Western Kenya

Table 3.3 shows the farmers perceptions of Striga's level on infestation in their farms across the districts. It also shows the percentage of farmers controlling Striga on their farms. Of the 368 Striga-constrained farmers, 55.2% were in Suba District while 44.8% were in Vihiga District. These farmers were revisited for the conjoint survey that focused on the technologies used for Striga control and their characteristics.

Table 3.3 Perception of Striga intensity and control on farms in Suba and Vihiga Districts

Aspect of Striga (n=368)	Vihiga (% Farmers)	Suba (% Farmers	Total (% Farmers)	Chi-square value
a) Perception of Striga infestation on farm				
No problem	0.3	0	0.3	0.448
Minor problem	12.5	4.3	16.8	0.000***
Moderate problem	10.9	20.7	31.5	0.007***
Major problem	21.2	30.2	51.4	0.173
Total	44.9	55.2	100	
b) Farmers controlling Striga				
No	16.6	32.7	49.3	0.000***
Yes	28.1	22.6	50.7	
Total	44.7	55.3	100.0	

*****=significance at 1% level, ** = significance at 5% level and *= significance at 10% level,**

Source: Authors work, 2007

Of all the farmers having Striga on their farms, a significantly higher percentage in Vihiga (12.5%) compared to Suba (4.3%) perceived it as a minor problem. About 10.9% and 21.2% of households in Vihiga perceived Striga infestation to be a moderate and major problem respectively. In Suba 20.7% and 30.2% of households perceived it as a moderate and a major problem respectively. Over 50% of households in Suba perceived Striga infestation to be a moderate or major problem compared to 32.1% households in Vihiga. However, only 50.7% (28.1% in Vihiga and 22.6% in Suba) of the farmers were found to have controlled Striga using a deliberate approach or technology on the farm.

Table 3.4 shows the percentage of the households that said that they use an improved technology to control Striga on their farms. It also shows the technologies that had been adopted by the farmers since 1960 for control of Striga in Vihiga and Suba districts.

Table 3.4: Percentage of farmers using an improved technology to control Striga

Control Method	Vihiga (n=164)	Suba (n=203)	Overall	Chi square value
1. Application of manure	29.7	17.2	22.8	0.005***
2. Land fallowing	0.0	1.0	0.5	0.201
3. Uprooting before flowering	27.3	13.3	19.6	0.001***
4. Crop rotation	0.6	4.4	2.7	0.025***
5. Double weeding	0.0	2.0	1.1	0.070*
5. Push-pull technology	3.6	3.0	3.3	0.715

*****=significance at 1% level, ** = significance at 5% level and *= significance at 10% level**

Source; Authors work, 2007.

Results in table 3.4 show that the most common technologies used by the farmers are soil fertility improvement approach using the organic manure (using farm yard manure and few farmers also try compost manure) and uprooting of Striga plants before flowering. A significantly higher percentage of farmers (26.8%) in Vihiga District used organic manure to control Striga compared to Suba (18.8%). About 27.3% of the sample farmers in Vihiga and 13.3% in Suba reported uprooting Striga plants before they flowered. Three percent of the farmers in Suba District and 3.6% in Vihiga District were using PPT while 0.6% of the farmers in Vihiga District and 4.4% in Suba District used crop rotation. Fallowing of land was very uncommon and was used by only 1.6% of farmers in both Districts. Although improved fallow was one of the technologies that have been tried and disseminated in the areas where the samples were drawn in Vihiga District (Kiptot *et al.,* 2007), no farmer was found to be using it on their farms at the time of our survey. Some farmers had had experience with IR-maize the season prior to our survey, but none of them were using it during our survey. This was because the IR-maize seed was not yet officially released into the market at the time of the survey. Soil fertility improvement using inorganic fertilizers was also not being used for Striga control among the sample farmers. Intercropping/mixed cropping was almost always practised in the farming systems in Western Kenya, but the farmers interviewed in the survey did not quote it as one of the control strategies against Striga.

Table 3.5: Choice of Striga control technology characteristics (1st and 2nd choice data)

The PHREG (proportional hazards regression) Procedure, ties Handling=BRESLOW
Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Without Covariates	With Covariates
-2 LOG L	2057.503	1777.522
AIC	2057.503	1803.522
SBC	2057.503	1855.858

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > Chi Sq
Likelihood Ratio	279.9806	14	<.0001
Score	298.4715	14	<.0001
Wald	230.4478	14	<.0001

	DF	Parameter Estimate	Standard Error	Chi-Square	Pr > Chi Sq
Cost of technology	**1**	**-0.00104**	**0.0.00025**	**16.7248**	**0.0001**
Maize yield gain	**1**	**0.22805**	**0.06865**	**11.0362**	**0.0009**
Other benefits	**1**	**0.16281**	**0.07208**	**6.1023**	**0.0239**
No change in hhold labour	**1**	**0.22400**	**0.06606**	**11.4992**	**0.0007**
Fallow periods required	**1**	**-0.14867**	**0.06462**	**5.2938**	**0.0214**
Crop rotation required	1	-0.03498	0.07420	0.2223	0.6373
Can intercrop food legumes	**1**	**0.76624**	**0.06449**	**141.1767**	**<0.0001**
<u>Interaction variables</u>					
District*cost	**1**	**-0.00086**	**0.000255**	**11.421**	**0.0048**
District*yield	**1**	**-0.19441**	**0.06865**	**8.0200**	**0.0046**
District*benefits	**1**	**0.15291**	**0.07208**	**4.5010**	**0.0339**
District*labour	**1**	**0.11362**	**0.06606**	**2.9588**	**0.0854**
District*fallow period	1	0.07835	0.06462	1.4703	0.2253
District*rotation	1	-0.09691	0.07420	1.7060	0.1915
District*legumes	**1**	**0.13368**	**0.06449**	**4.2972**	**0.0382**

Source: Authors work, 2007

3.9.2 Marginal utilities for the seven defined technology characteristics

Table 3.5 shows the results of proportional hazards regression model used to estimate the utility values farmers attach to Striga control technologies.

Table 3.5 shows the maximum likelihood parameter estimates of the marginal utilities that the farmers associate with each of the seven characteristics of Striga control technologies. Except for crop rotation, all the other six farmer -defined characteristics (Cost of the technology, Maize yield gain, other benefits accruing from the technology, change in household labour, requirement for fallow periods, requirement for crop rotation, intercropping food legumes) had very small p-values and were thus statistically significant in influencing the farmers' choice of technology profiles. Four characteristics (cost of technology, maize yield gain, change in household labour and ability to intercrop food legumes) were significant at 1% level. Other benefits associated with a technology and requirement of a fallow period were significant at 2% level.

The 'cost of technology' parameter estimate as negative and significant, indicating that a high cost of a technology leads to a significant decrease in the farmer's marginal utility for a technology compared to a low cost of a technology, holding all other factors constant. The parameter estimate for 'maize yield gain' was positive and significant. This implies that farmer's marginal utility for a technology significantly increases if the technology leads to a higher increase in cereal yield compared to a smaller increase in yield, holding all other factors constant. The parameter estimate for 'fallow period required' was negative and significant. A fallow period required in implementing a technology leads to a decrease in farmers' marginal utility of a technology compared to a technology that does not require a fallow period, holding all other factors constant. The parameter estimate for 'crop rotation' was not significant. Whether a technology required crop rotation or continuous cropping on the same plot did not seem to influence a farmer's marginal utility for the technology. The parameter estimate for possibility of intercropping food legumes was positive and significant while it was also the largest parameter. This indicates that intercropping food legumes in the crops adopted for control of Striga significantly enhanced farmers' marginal utility for such a technology, compared to the inability to intercrop food legumes controlling for other factors and it was the most important factor for the farmers. The parameter estimate to 'no change in household labour' was positive and significant. This indicates that technologies that did not require an increase in labour significantly enhanced a farmer's marginal utility for such a technology compared to 'one person equivalent' labour increase. The parameter estimate for 'presence of other benefits' was also positive and significant; this indicates that technologies that offered farmers 'other benefits' (for example cattle feed, firewood or soil fertility enhancement) significantly enhanced a farmers marginal utility compared to technologies that did not, holding all other factors constant.

The null hypothesis that all the profile attributes (characteristics) do not influence the choice of the profile was rejected at 1% significance level. The seven characteristics that the farmers identified were found to be statistically significant in explaining farmers' choice of technology profiles. There was a significant variation in the importance of technology profiles between the Districts of study (Suba was coded as 1 and Vihiga as –1) for the variables cost, yield, other benefits, labour and food legume intercrops. Farmers in Suba had significantly higher marginal utilities for technologies with higher cereals yield and low cost input compared to farmers in Vihiga. Vihiga farmers had significantly higher utilities for technology profiles with 'other benefits', low labour requirements and where food legumes could be intercropped. The importance of fallow requirement and crop rotation did not vary significantly between Suba and Vihiga farmers implying that the farmers in both Districts had similar utilities for technologies that required fallow periods and crop rotation regimes.

3.9.3 Assessment of profile utility

From the utility values obtained for the seven characteristics that the farmers identified as important, we calculated the utility associated with each of the twelve profiles that were presented for choice among the farmers. The constituent characteristics of the 12 profiles are described in table 3.2. Profile utilities were calculated from the utilities of the combination of characteristics that a technology embodied. Table 3.6 gives a summary of the results.

Table 3.6 **Utilities for the 12 profiles presented to the farmers and probability of choice of each profile.**

Profile	Profile utilities ($x_i\beta$)	Exponential value of the sum of all profile utilities ($\exp(x_i\beta)$)	Probability of choice $(\mathrm{Exp}(x_i\beta))/\sum_{j=1}^{12}(\exp(x_j\beta))$
Profile 1	0.731	2.078	0.103
Profile 2	1.157	3.180	0.157
Profile 3	1.035	2.814	0.139
Profile 4	0.189	1.208	0.060
Profile 5	-0.184	0.832	0.041
Profile 6	-0.149	0.862	0.043
Profile 7	-0.184	0.832	0.041
Profile 8	0.391	1.478	0.073
Profile 9	0.452	1.572	0.078
Profile 10	1.004	2.730	0.135
Profile 11	0.352	1.422	0.070
Profile 12	0.207	1.230	0.061

Source: Authors work, 2007

Three clusters of technology profiles were identified from this analysis: A cluster with less than 5% probability of being selected by farmers consisting of profiles 5, 6 and 7; These were profiles that required a fallow period and did not have the possibility of intercropping food legumes. Cluster with 5-10% probability of being selected by farmers including 4, 8, 9, 11 and 12; The cluster with the most preferred profiles comprised of 1, 2, 3 and 10 with 10.3%, 15.7%, 13.9% and 13.5% probability of being selected by farmers, respectively. Profile 2 had the highest probability (about 15.7%) of being chosen by farmers for control of Striga in Vihiga and Suba districts, Kenya. The four most preferred profiles had the possibility of intercropping food legumes in their assortment of technology characteristics and three of them did not need a fallow period.

3.9.4 Characteristics of current Striga control technologies

The results of this study show that six of the seven farmer-defined characteristics are statistically significant in influencing the farmers' marginal utility for a Striga control technology and consequently have the propensity to increase the probability of adoption of a technology containing such attributes. An important question therefore is whether the farmer-defined characteristics are sufficiently embedded in the technologies that have been so far released / availed to the farmers for the control of Striga in Western Kenya through various research and development programs. Through literature review, the characteristics of the available technologies were identified and matched to the characteristics identified by the farmers in this study. Based on the marginal utility estimates for each characteristic, an attempt to calculate the probability of adoption of the existing technologies using Equation 3.2.

Table 3.7 shows a summary of the technologies and practices that were identified through literature review, the levels of the seven characteristics that they embody, and the estimated probability of choice for adoption. From these estimates, IR-maize technology had an 11%

probability of choice for adoption, organic and inorganic fertilisers had 9% probability, improved fallows had 4% probability, hand pulling had 7% probability, crop rotation and legume intercrop have 9% probability each.

Table 3.7 Estimated probabilities of adoption for existing Striga control technologies and practices in Western Kenya.

Technology/ practice	References	Cost	Yield	Other benefits	Change in labour	Fallow period required	Crop rotation required	Food legumes intercrop	Probability of adoption
IR maize	Kanampiu *et al.,* 2002, Kanampiu *et al.,* 2003	Usd5/ha (low) each season	Doubles or more	No	No	No	No	Yes (12 cm away from maize crop)	0.11
Push pull technology considered expensive (with beans)	Khan *et al.,* 1999; 2000, 2002, 2008	High (first season) low (subsequent season)	Doubles or more	Yes	Yes (first season) no (subsequent season)	No	No	No	0.067 (0.13)
Push pull technology considered cheap (with beans)	Khan *et al.,* 1999; 2000, 2002, 2008	High (first season) low (subsequent season)	Doubles or more	Yes	Yes (first season) no (subsequent seasons)	No	No	Yes	0.145 (0.29)
Organic fertilisers	Esilaba, 2006, Ransom & Odhiambo, 1994	High	Low	No	No	No	No	Yes	0.09
Inorganic fertilisers	Esilaba, 2006; Mumera & Below, 1993	High	Low	No	No	No	No	Yes	0.09
Improved fallow	Kiptot *et al.,* 2007; Sanchez, 1999	High	High (farmers may consider the season and think its low)	Yes	No	Yes	No	No	0.04
Hand pulling	Esilaba, 2006, Ransom, 2000, Esilaba, 1997.	Very high	Little change	No	Yes	No	No	Yes	0.07
Crop rotation	Ransom J.K. 2000	Low	Low	No	No	No	Yes	Yes	0.09
Legumes intercrop	Oswald *et al.,* 2002; Carsky *et al.,* 1994; Odhiambo and Ransom, 1993	Low	Low or high, depending on location, type of legumes	Yes (nitrogen fixation)	No	No	No	Yes	0.09

Source: Literature review and analysis by author, 2007

In the case of PPT, four scenarios were considered; (i) If the farmers view PPT as a high cost technology, without food legumes, the probability of choice for adoption was 6.7%, (ii) If the farmers view PPT as a high cost technology but with beans integrated in the technology, the probability of choice rose to 13%, (iii) If the farmers perceived PPT as cheap (with a view of high cost only in the first season and lost costs in the subsequent seasons), then the probability of choice rose to 14.5% without legumes and (iv) If the farmers perceived PPT as cheap (with a view of cost past the first season), then the probability of adoption rose to 29% if food legumes were integrated.

3.10 Discussions

This study empirically demonstrates that the farmers in both Suba and Vihiga Districts of Western Kenya do not view Striga control technologies as 'whole' entities, but as 'bundles of characteristics'. In a focus group discussion, the farmers were able to identify seven characteristics and two levels for each characteristic that were important to them. The seven 'characteristics' are the basis on which farmers' utility for a Striga control technology is maximised. Since farmers are consumers of agricultural technologies, these findings are consistent with the Lancaster theory of consumer demand (Lancaster, 1966; 1991), that consumers do not consider 'goods' as whole entities but rather as a bundle of 'constituent characteristics'. Our results are also in tandem with the findings by Tano *et al.* (2003 and Ouma *et al.* (2007) where farmers articulated the characteristics they look for in cattle traits in West and East Africa respectively. Irungu *et al.* (2005) also showed that farmers can articulate the characteristics they look for among the animal health providers in Eastern Kenya, while Makokha *et al.* (2007) showed that farmers can articulate the characteristics they look for among dairy animals in Western Kenya.

Despite some difference in socio economic conditions between Vihiga and Suba districts, the farmers identified similar characteristics that they consider in evaluation of a Striga control technology. The seven characteristics identified as important attributes for Striga control technologies were the cost requirements of a technology, the change in yield, additional benefits accrued from the technology, little change in labour requirements, requirements for fallow periods, crop rotation requirements and the ability to intercrop food legumes. These characteristics demonstrate that the economic viability, system compatibility as well as the soundness of the technology or practice are important considerations for farmers. These issues are briefly discussed hereafter.

Farm resources and their cost

Farm resources are the basic ingredients in the process of technology adoption and use in smallholder farms. Farmers' allocation of land and labour influences what can or cannot be accommodated at the farm each season. It is therefore a rational concern when the farmers start by considering land allocation (fallowing), labour requirement and capital (cost) involved if they were to adopt a Striga control technology. Land is especially of key concern in Western Kenya where per household farm holdings have been declining rapidly over the last two decades as fathers shared out land to their maturing sons according to culture (Mango, 2002). It is evident from this study that the farmers prefer Striga control technologies that neither require high capital investments nor long fallow periods. A possibility of farm labour not increasing with adoption of a technology gave a significant and positive parameter estimate. Labour, as a farm resource, is more divisible and mobile compared to land (Kamau, 2007). Consequently, labour can be shifted from one farm activity to another when the farmers view it as profitable to do so. A small increase in labour requirement is therefore not expected to dampen the farmers' preferences for a Striga control technology.

Multiple benefits

Direct benefits (yield increase) and indirect benefits (for example, soil fertility improvement, source of firewood or source of cattle feed) are important characteristics in the consideration of Striga control technologies by farmers (Khan *et al.*, 2008). Yield increase is an important parameter used by technology developers to assess how superior a particular technology, such as Striga control technology, is. Higher yield increase associated with a technology leads to a significant increase in the farmers' utility for the technology. Soils in Western Kenya are of low fertility, while the farmers use very low external inputs to enhance fertility (Salasya, *et al.*, 1998). Due to small per capita farm holdings of less than 1.0 ha (Salasya, *et al.*, 1998; 2005; Mango, 2002), land areas allocated to grow animal feeds are very small. Some households do not even have such an allocation on their farms and this constrains the number and type of livestock households can keep. Indirect benefits, like soil fertility improvement and source of cattle feed, would be expected to give premium to preference of a technology, especially in Vihiga District where soils are heavily cultivated and exhausted (Odendo, *et al*, 2006). This was demonstrated to be the case in this study, where the parameter estimated for 'additional' benefit was found to be statistically significant. Multiple benefits provided by a potential Striga control technology thus influences the farmers' propensity to adopt positively.

Compatibility with cropping systems and livelihoods

Fallowing periods, crop rotation or possibility of intercropping of food legumes, were identified as important technology characteristics in both Suba and Vihiga Districts. They all have an impact on the cropping systems and household source of food, especially the food legumes. Due to the farm size constraint and the need to provide most of the household food from subsistence farming, households do not prefer technologies that do not allow them to continuously crop their land or technologies that may limit them in intercropping cereals with food legumes. This is despite the challenge of soil fertility decline that is associated with such a production objective.

Fifty one percent of farm households in Western Kenya are resource poor and practice subsistence agriculture. Rural Western Kenya is rated as one of the poorest regions in Kenya, with over 75% of expenditure by adult equivalent going into buying food (Government of Kenya, 2003).

Since most households in Western Kenya provide their household proteins (mainly from food legumes), vegetables and carbohydrates from subsistence farming, continuous cropping and intercropping of all types of crops is an important strategy for achieving this. However, soil fertility is low in Western Kenya and the use of external soil improving inputs is low (Salasya *et al.*, 1998;). Promotion of crop rotation may therefore be viewed as an affordable strategy at improving soil fertility. Besides crop rotation being affordable, it is an easy approach and checks the build up of Striga seed banks in the soils. Farmers would be expected to prefer Striga control technologies that accommodate legume intercropping, continuous cropping and crop rotation.

The results of the evaluation have shown that legume intercropping characteristics was the most important characteristic for farmers in Western Kenya, with the highest marginal utility value that was significant at 1% level. The marginal utility associated with the possibility of intercropping food legumes was 3.4 times that associated with higher yields and 4.7 times that associated with other benefits. Crop rotation was not statistically a significant factor, although farmers identified it as important.

The adoption rates of Striga control technologies have been low in Western Kenya (Gbehounou and Adango, 2003). This phenomenon has been puzzling to researchers and development partners alike who, based on biophysical parameters, have developed effective technologies against Striga. This study gives an insight into the farmers' assessment process when considering a technology for adoption. It highlights some pertinent issues, e.g. the possibility of intercropping food legumes, that may not be related to the technology directly, but which determine whether a farmer will consider such a technology as an option for adoption. A case in point is the improved fallow technology. It has been demonstrated to be effective in controlling Striga, leading to better maize yields and enhancing nitrogen (N) in the soil (Sanchez, 1999). This is an ideal technology option for a region that has high Striga infestation; where farmers use low farm inputs yet need to improve maize yields. However, it has a low adoption probability of only 4% based on the estimates of this study. Kiptot *et al.* (2007) showed in an empirical adoption study in Vihiga District that their study sample consisted of 38% of farmers who had tried to use the improved fallow technology and rejected it, 53% as those who did not even attempt to try the technology even though they had been exposed to all trainings on the technology, including being provided with seed, and about 8% as those who had adopted the technology at the time of their study. This low adoption rate is most likely due to the long periods of fallow which are considered very expensive for the poor farmers who have small farm sizes, and need to provide for their households food needs from subsistence sources by cropping their land season after season. The gains from the grain yield increase obtained after three seasons of fallow cannot possibly offset the cost of three seasons without food from the same plot. Their findings confirm that our probability of adoption estimates can be relied upon to make informed inferences.

The findings of our study also give an insight into farmers' preferences for PPT. It has been developed and found effective in controlling both Striga and stemborer. It has multiple benefits of providing cattle feed and leads to a high cereal yield increase. Its initial establishment costs maybe high, but in subsequent seasons, the costs get relatively low (Khan *et al.,* 2008). However, the initial design of PPT does not accommodate intercropping with legumes. As such, the probability of choice for adoption is found to be 6.7% if the farmers view it as an expensive technology, but this is raised to 13% when the farmers view it as a cheap technology in the long-term. However, if the PPT could accommodate intercropping with food legumes, the probability of adoption would more than double to 14.5% even if the farmers viewed it as expensive and triple to 29% probability of adoption if they perceive it as cheap in the long term. Hence, there is a need to consider integrating legumes into the PPT, while also having a comprehensive farmer education on the reduced costs for the technology beyond the first season of establishment when the costs relatively are high. A collaborative agenda with development partners who maybe willing to finance a portion of the initial establishment costs may push the adoption probability beyond 29%.

The findings of this study present lessons for development agents and policy makers. After the Structural Adjustment Programmes (SAPs), government subsidies to various sectors of the economy were abolished. Farmers in Western Kenya are poor, low input users and their per capita farm sizes are declining annually as household populations increase. They depend on subsistence sources for a significant amount of their household food needs; they prefer continuous tilling (mining) of the land. Technologies that require fallowing of land are adopted by very low numbers of farmers. The policy dilemma is whether the soils of Western Kenya will be replenished in a sustainable way if the farmers have to continue farming to meet their household food security needs. There may be need to consider subsidies for soil fertility improvement.

3.11 Conclusions

The influence of technology characteristics as perceived by farmers in Suba and Vihiga districts in western Kenya in the choice of Striga control technologies has been demonstrated in this study. Farmers were able to articulate the characteristics they consider important in a new technology/practice for Striga control. Seven characteristics, including cost of technology, maize yield gain, other benefits associated with a technology, change in household labour, fallow periods required, crop rotation required and the possibility of intercropping food legumes, were identified. Other than requirement for crop protection, all the other six characteristics were found to be statistically significant in influencing the probability of choice of a technology. Requirements for fallow periods and high cost of the technology significantly reduced the probability of choice of a technology while maize yield gain, other benefits associated with a technology, no change in household labour and the possibility of intercropping food legumes significantly increased the probability of choice of a technology.

Understanding the farmers' perspective on technology characteristics should be an integral part of research development programmes. Dissemination of technologies should not be left to the extension agents after technology development phase, but the assessments of the farmer needs should be an integral part of the process. Often times, the extension agents were not funded directly and they worked in isolation from the researchers. The linkages between research, dissemination strategies and farmer involvement should be strengthened to make the adoption process a researchable component attended to alongside the development of technologies. In designing technology development projects, actors should always budget for socio-economic studies and dissemination component along side all the other bio-physical activities.

Understanding the farmers' needs and tailoring technologies to fit those needs (e.g. the need to intercrop food legumes and have no fallow periods) increases a technology's probability of choice tremendously. In this study, we have demonstrated that the Push-pull technology (PPT) without allowing the integration of food legumes has an adoption probability of 13% but by re-designing the technology to integrate food legumes would more than double the adoption probability (29%). By investing in research to understand the farmers' perceptions, the returns in terms of higher adoption probabilities for new technologies could be enhanced. As a policy, assessment of technology characteristics from the farmers' perspective should be an integral part of diagnostic surveys. Marketing research approaches like conjoint analysis that have been developed to test hypothetical products before they are manufactured and released to the markets can be used to test the acceptance of technologies before they are developed for dissemination.

3.12 References for Chapter Three

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CHAPTER 4: EVALUATION OF THE ADOPTION OF THE PUSH-PULL TECHNOLOGY FOR STEMBORER AND STRIGA CONTROL IN VIHIGA AND SUBA DISTRICTS, KENYA

4.1 Introduction

Maize is an important part of the food security equation in Kenya, where the per capita consumption is 81kg/year according to the FAO statistics (FAO statistics, 1997-2002). Maize is a staple food for many Kenyan households (Nzuma, 2007). It is produced by over 90% of the rural households (Nyangito, 1997). However, the production level per hectare of land is very low, compared to the yield potential (Pingali and Pandey, 2000) with maize yield in Western Kenya being at 0.6 tons/ha, which is way below the regions potential of 5.0 tons/ha. The low production levels can be attributed to, among other things, a-biotic and biotic production constraints. Stemborer and Striga are important biotic production constraints in maize (Khan *et al*.2001; 2002).

Maize yield loss due to stemborers has been estimated to range from 20-80 percent depending on the severity of the infestation by the pest and the growth stage of the crop at which infestation occurs (Gebre-Amlak, 1985; Seshu-Reddy, 1991; Khan *et al.*, 1997a.). Striga related maize yield losses are estimated at five percent per every Striga per m^2 (Parker and Riches, 1993). Maize yield losses of 30-50% have been reported under typical field infestations by Striga (Parker, 1991; Vissoh, 2004). In Western Kenya, 100% yield losses have been reported in both on-farm and on-station experiments (Hassan *et al., 1994).* In some cases, the infestation can be so severe that farmers are forced to abandon their fields altogether (Ransom, 1996).

For many years, managing Striga and stemborer have been priority topics for research and development agents working in Western Kenya. Among the technologies developed for the control of Striga and stemborer is the Push-pull Technology (PPT), a technology that was first introduced to farmers in Western Kenya region during the 1994/1999 period (Khan *et al.*, 1997a; Khan *et al.*, 2001). PPT is a unique technology in that it has been demonstrated to be effective in controlling both Striga and stemborers.

The PPT system is based on a stimulo-deterrent diversionary strategy (Miller and Cowles, 1990), where insect pests are repelled from a harvestable crop and are simultaneously attracted to a ‘trap’ crop (Hassanali et al., 2008; Cook et al., 2007). It involves intercropping maize with fodder legumes in the genus Desmodium (e.g. Desmodium uncinatum) and planting Napier grass (Pennisetum purpureum) as a trap crop around the crop field. Volatile chemicals naturally emitted by desmodium repel the stemborer moths away from the maize field (push) while those released by the Napier grass attract them (pull) (Khan et al., 2000; 2001). Because stemborer moths prefer Napier grass to maize for oviposition (Khan et al., 2006; Van den Berg, 2006; Khan et al., 2007), majority of the eggs laid are consequently trapped by the Napier grass thus leaving the maize crop protected. Most of the resultant stemborer larvae, however, do not survive due to poor nutrient composition of Napier grass, production of sticky sap that entangles and kills the larvae, and abundant natural enemies associated with the grass (Khan and Pickett, 2004; Khan et al., 2007b). The desmodium also inhibits Striga proliferation through its effects of nitrogen fixation and addition of soil organic matter, ground smothering, and chemical allelopathy. Some of the allelochemicals produced by desmodium roots stimulate Striga seed germination while others inhibit development of Striga and subsequent attachment to maize roots (Khan et al., 2002; Tsanuo et al., 2003).

Because desmodium is a perennial crop, there is a continual depletion of Striga seed bank in the soil, even during periods when there is no cereal crop in the field.

By controlling Striga and stemborers, PPT can contribute toward closing the maize yield gap in Western Kenya and in similar regions of Africa. In controlled experiments in Suba district, Midega (2005) showed a maize yield increase of 68% with Push Pull technology. However, the contribution can only be realised if farmers knew about PPT, accepted it, adopted it and used it intensively in maize production. PPT has been disseminated in Suba and Vihiga Districts since 1994/5. Initially, this was done through on-farm trials where demonstration plots were laid in farmers' fields to serve as an example to the community and also a source of data for validation of the technology.

In the year 2003/2004, groups of farmers were selected and trained as PPT farmer teachers in all Districts in Western and Nyanza provinces of Kenya. The role of the farmer teachers was to offer their farms as demonstration plots and also be trainers to other farmers that were interested in adopting the PPT. The farmer field school approach was adopted as a system of dissemination of the PPT among the farmers since 2006. PPT technical information was also incorporated into agricultural radio programmes, developed into pamphlets and posters as well as displayed during the major agricultural show events in Kitale, Kisumu and Kakamega. Suba and Vihiga Districts are among the Districts where dissemination of the PPT has been done since 1998 and 2000 respectively.

The purpose of this chapter, based on the third study objective as given in Chapter 1, is to:

i. Establish the households' awareness levels for PPT in Suba and Vihiga Districts and identify the factors influencing the awareness

ii. Identify the factors influencing the farmers' decision to adopt PPT to control Striga or stemborer

iii. Identify the factors influencing the intensity of use (proportion of the maize farm under PPT) among the adopting farmers.

4.2 Literature review: Adoption of technologies

Feder *et. al.,* (1985) define individual adoption, i.e. adoption at the level of the individual farm (firm), as the degree of use of a new technology in the long-run equilibrium when the farmer (entrepreneur) has full information about the new technology and its potential. Rogers (1995) defines adoption as the act of the potential adopter accepting an innovation unreservedly and putting it into practice. An innovation is an idea, practice or object that is perceived as new by an individual or other unit of adoption (Rogers, 1995). Adoption is a product of choice. Choice consists of a mental process of thinking and judging the merits and demerits of multiple options and selecting one for action. Choice is guided by individual adopters' preferences. Preferences or tastes assume a real or imagined likes and differences between alternatives and the possibility of rank ordering of the alternatives.

Adoption of innovations can be explained at 'individual' or at 'aggregate' household levels. The individual household level approach analyses the behaviour of single farm households towards adoption of technologies. The analysis often relates the degree of adoption to the factors affecting it. The aggregate adoption approach is based on the assessment of the proportion of households using the technology in a particular area. The degree of the use of a new technology may provide a quantitative measure of the extent of adoption when the new technology is divisible, i.e. when this can be divided to measurable units (Dimara and Skuras, 2003). For no-divisible innovations, the extent of individual adoption is necessarily dichotomous (yes or no).

Adoption may be assessed in terms of whether or not an innovation is used by households (Semgalawe, 1998). Observing 'adoption' is restricted to recording the final decision of whether or not one has adopted. A dichotomous adoption decision is estimated in terms of adoption or non-adoption. Effects of various factors on the probability to adopt are examined in these static adoption studies (Dimara and Skuras, 2003).

Adoption can also be viewed as a dynamic, multi-stage procedure of organizational change. Factors influencing each stage are examined. Some studies view adoption as a two-stage decision process. In this case, the analysis is expanded to include the extent or intensity of use based on various indicators, such as land area under the technology or the components of technology used (Semgalawe, 1998).

Two assumptions are articulated in adoption studies, as highlighted by Feder *et al.,* (1985). There is the assumption of 'full information' where potential adopters in a study are assumed to be fully informed about the new technology and its potential. There is also the assumption of 'long term equilibrium'. This is a time when the technology has been with the farmers for a very long time and the number of new adopters is no longer increasing since all the farmers that would adopt the technology have adopted it. It is assumed that adoption studies are carried out after the long run equilibrium has been attained. The equilibrium may be attained at different periods for different technologies. If the two assumptions were to hold, it would be assumed that the farmers who do not adopt a new technology have clearly rejected the new technology. Probit or Logit specification for non-divisible technologies (models that can take a 0,1 variable as a dependent variable) and Tobit or other appropriate specifications for divisible technologies (that use dependent variables of continuous data) are used to model the adoption response (Dimara and Skuras, 2003). The two assumptions, i.e. full information and long-term equilibrium, do not always hold among the sampled farm households (Ibid).

Saha *et al.* (1994) showed that producers' choices are significantly affected by their exposure to information, especially for emerging technologies. Lack of information is a barrier to adoption of technologies (Lohr and Salomonsson, 2000). In addition, the long run equilibrium may never be attained, given the constant flow of overlapping innovations (Dimara and Skuras, 2003). Most adoption studies are carried out in a reasonably short period before long-term equilibrium is attained because of the introduction of overlapping technologies or innovations.

Households may not adopt technologies due to a violation of the full information assumption. Farmers may not be informed at all or may not possess sufficient information to allow them enter into a technology evaluation process. Before the long-term equilibrium is attained, some farmers that are 'aware' of the new technology may not exercise their option of adopting a new technology. These may be farmers that possess strong risk aversion behavior or farmers who expect low future adoption costs or higher profits and thus postpone the option of exercising adoption (Dimara and Skuras, 2003). This has significant implications for model specification in adoption studies. Specification of univariate models (logit and probit models for non-divisible technologies or tobit models for divisible technologies) assumes that all non-adopters possess the same chance of becoming adopters. However, it is known that some non-adopters do not have a chance of becoming adopters at all (Dimara and Skuras, 2003).

Saha *et al.* (1994) suggested that adoption studies that employ probit or logit to analyse survey data in identifying socio-economic characteristics of adopters and non-adopters may suffer from sample selection bias. The question of 'whether or not to adopt' is relevant only to a non-random sub-sample of respondents who are aware of a new technology. This implies that a separate sample selection equation, explaining the outcomes 'aware' versus 'not aware' needs to be estimated in addition to the adoption equation. Awareness about a new technology is partly a function of unobserved respondent attributes, which may be influential in the adoption decision. Saha *et al.* (1994) therefore recommend that, to address these issues, the sample selection and adoption equations should be jointly estimated, thus allowing for correlation between the equation errors.

In studying the adoption of PPT technology in Suba and Vihiga Districts, we therefore took into consideration the issues raised in Saha *et al.* (1994) and estimated a bi-variate probit model that analyses three major issues: whether the farmers were aware of PPT; whether farmers have reached a decision on 'whether or not to adopt PPT'; and the farmers' decision on 'the proportion of maize farm' to put under PPT.

4.3 Methodology

4.3.1 Theoretical framework

A learning period precedes any technology adoption decision. Rogers (1995) conceptualised five main steps in the innovation-decision process, including:

- Knowledge – knowledge occurs when an individual learns of the innovation's existence and gains some understanding of how it functions.
- Persuasion – persuasion occurs when an individual forms a favourable or unfavourable attitude towards the innovation.

- Decision – decision occurs when an individual engages in activities that lead to choice to adopt or reject the innovation.
- Implementation – implementation occurs when an individual puts an innovation into use.
- Confirmation – this occurs when an individual seeks re-enforcement of an innovation-decision that has already been made, but the individual may reverse this previous decision if exposed to conflicting messages about the innovation.

The innovation-decision process is an information seeking and information processing activity in which an individual obtains information in order to decrease uncertainty in the innovation (Rogers, 1995). The innovation-decision process is bound together by knowledge and information. At the knowledge stage, an individual mainly seeks information that reduces uncertainty about the cause-effect relationships involved in the innovations' capacity to solve an individual's problem. At the persuasion stage and the decision stage, an individual seeks information in order to reduce uncertainty about innovation's consequences; the advantages and disadvantages in his/her own situation. Knowledge is generated through learning processes. As knowledge is used, results are shared and tested in application, understanding is multiplied among potential users and knowledge becomes tacit (Rogers, 1995).

The farmer's optimal information level is a function of information costs, interaction with dissemination channels as well as such individual characteristics as age, farming experience and/or location of ones household relative to the market centers. Market centers are assumed to be the loci of information flow in the rural settings.

Conditional on having information on the cause and effects of PPT and its ability to solve the Striga and stemborer problem in maize, the farmer decides whether or not to adopt the technology. Consequently, the farmer's subjective assessment of the PPT plays a crucial role in this decision. Adoption decision is made only if the perceived benefits of the technology outweigh its costs. The farmer also, and this needs not be temporally distinct from the adoption decision, decides how much of his maize farm will be put under the PPT. Theoretically, these three decisions can be formalized as follows, borrowing from the model as applied by Saha *et al,* (1994):

i. Awareness of PPT

We posit that the farmers' optimal information level on PPT is the outcome of an underlying utility maximization problem:

$$i^* \equiv i(\mathbf{d}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq 4.1}$$

where i^* denotes the optimal information level and **d** is a vector containing the farmers relevant socio economic characteristics. A potential adopter forms an understanding about PPT only if the acquired information level crosses a given threshold; that is if:

$$i^*(\mathbf{d}) > i^0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq 4.2}$$

where i^0 is the threshold information level. Eq. 4.2 can also be expressed as:

$$Y^{H^*} \equiv i^*(\mathbf{d}) - i^0 > 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq 4.2a}$$

For purposes of estimation, equation 4.2a can be expressed as:

$$Y^{H*} \equiv X^H.\beta^H + \varepsilon^H > 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq.4.2b, so that}$$

$$Y^H = X^H.\beta^H + \varepsilon^H \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \text{ Eq. 4.3}$$

Where Y^{H*} is the cumulative knowledge on PPT, X^H is a vector of regressors containing the socio-economic characteristics of the farmer, which determine his/her acquired information level, and β^H is a vector of parameters to be estimated; ε^H is an error term. The $i^*(d)$, i^0

and consequently Y^{H*} are not observable. What is observed is the farmer's response to the question of whether he or she knows about the PPT. Therefore Y^{H} denote an indicator variable, which equals 1 if the farmer has heard about the PPT, i.e. $Y^{H*} > 0$, and zero otherwise.

In the second phase, the farmer's subjective perception regarding the PPT and the adoption of the PPT is conditional upon the acquired information being greater than the threshold level, $Y^{H*} > 0$

ii. **Adoption of PPT**

At the second level, the farmer decides to adopt the PPT if the perceived benefits, net of costs, are positive. However, the benefits or costs are not observable since it is the farmer's subjective perception about PPT. Observable elements may be the socio-economic characteristics, e.g. age, income or available land, that are captured in the vector of regressors X^{A} in the equation:

$Y^{A} \equiv X^{A}.\beta + \varepsilon^{A} > 0$ ……………………… Eq. 4.4

Since Y^{A*} is not observable, it is denoted by Y^{A}, a binary variable indicator which is equal to 1 when $Y^{A*} > 0$ if the farmer answers yes to the question of whether he has adopted the PPT, otherwise; $Y^{A} = 0$

iii. **Intensity of use of PPT**

A farmer's decision on how much of his/her maize farm to put under the PPT is a function of his/her socio-economic characteristics as well as the subjective assessments on the technology formed at the information stage (Eq. 4.3) and the adoption stage (Eq. 4.4). These subjective assessments are not observable, but the socio-economic characteristics are observed. The intensity decision can be captured by the equation:

$Y^P \equiv X^P.\beta^P + \varepsilon^P$ …………………….Eq 4.5

where Y^P is the adoption intensity expressed in terms of the percentage of maize farm that is under the PPT, X^P is a vector of regressors and ε^p denotes an error term. Unlike Y^H or Y^A, the dependent variable in Eq. 4.5 is continuous and observable.

A farmer's decision to put a proportion of his or her maize farm under PPT is conditional on having decided to adopt the PPT, which in turn is conditional upon having heard about the PPT. In terms of the estimation of the equations, this means that Y^P are observed only if $Y^A = 1$ and $y^H = 1$; while Y^A is observed only if $y^H = 1$. We assume that the disturbance terms of equations 4.3, 4.4 and 4.5 are distributed as trivariate normal, i.e. as:

$\{\varepsilon^P, \varepsilon^A, \varepsilon^H\} \sim TVN(0,0,0,\sigma^2,1,1,\psi^H,\psi^A,\rho)$

where:

$\psi^H = corr(\varepsilon^H, \varepsilon^P)$, $\psi^A = corr(\varepsilon^A, \varepsilon^P)$ and $\rho = corr(\varepsilon^A, \varepsilon^H)$. Under these assumptions, the conditional probability of adoption is given by:

$prob(Y^A = 1/Y^H = 1) = E\left[Y^A/(i^* - i^0) > 0\right] = \Phi(X^A\beta^A) + \rho\lambda(\alpha)$ ………… Eq. 4.6

where:

$$\alpha = -X^H\beta^H, \lambda = \frac{\phi(\alpha)}{1-\phi(\alpha)}$$

and Φ and ϕ denote the cumulative distribution function (CDF) and probability density function (PDF) of a univariate normal distribution, respectively. Equation 4.6 suggests that probit or logit estimation of Y^A on X^A would lead to inconsistent estimates of β^A. The inconsistency would stem from an omitted variable since the $\rho\lambda(\alpha)$ term in the right hand side of equation 4.6 would be ignored.

Maximum likelihood estimates of parameters β^H , β^A and ρ are obtained by maximizing the following log-likelihood function, which rests on the definition of conditional probability:

$$\left.\begin{array}{l} \ln L = \sum\limits_{Y^A=1, Y^H=1} \ln \Phi_2\left[X^H \beta^H, X^A \beta^A, \rho\right] \\ + \sum\limits_{Y^H=1, Y^A=0} \ln \Phi_2\left[X^H \beta^H, -X^A \beta^A, -\rho\right] \\ + \sum \ln \Phi\left[-X^H \beta^H\right] \end{array}\right\} \text{……………………………Eq. 4.7}$$

Parameter values obtained by estimating equations 4.3 and 4.4 separately are used as starting values in maximizing 4.7. The maximum likelihood estimates of parameters $\overset{\wedge}{\beta}^H, \overset{\wedge}{\beta}^A$ and ρ are then used in forming the regressors in the augmented ‘how much land under PPT’ equation. The augmented equation, based on the bi-variate probit model with sample selection, is:

$$Y^P = X^P \beta^P + \lambda^{\wedge H} \theta^H + \lambda^{\wedge A} \theta^A + \eta \text{ ………………………..Eq. 4.8}$$

where

η is the error term,

$$\lambda^{\wedge H} \equiv \phi(W^H).\Phi\left[(W^A - \rho^\wedge Y^H)/(1-\rho^{\wedge 2})^{1/2}\right]/\Phi_2 ,$$

$$\lambda^{\wedge A} \equiv \phi(W^A).\Phi\left[(W^H - \rho^\wedge Y^A)/(1-\rho^{\wedge 2})^{1/2}\right]/\Phi_2 ,$$

$W^H \equiv -X^H \beta^{\wedge H}$ and

$W^A \equiv -X^A \beta^{\wedge A}$.

Quantity Φ_2 is a bi-variate normal CDF (cumulative density function) given by $\Phi(W^H, W^A, \hat{\rho})$ and whose pdf (probability density function) is denoted by ϕ_2. If the sample selection problem is not addressed, regressors $\lambda^{\wedge H}$ and $\lambda^{\wedge A}$ in Eq. 4.8 are ignored and the estimation would suffer from omitted variable bias.

4.3.2 Data collection on the adoption of PPT

In order to run the three-stage model on awareness, adoption and intensity of use of PPT, data was needed for each farmer on whether he/she knew of PPT (binary), whether he/she had adopted PPT (binary) and the proportion of the maize farm that was under PPT at the time of the interview. Data were collected in two Districts, Suba and Vihiga. A total of 368 farmers were interviewed. Through prior sampling, each of these farmers had indicated experiencing Striga as a problem on his/her maize farm. Each farmer was asked if he/she knew or had ever heard about the PPT. If yes, the farmer was asked if he/she had adopted it in his/her own farms or not. If adopted, the farmer was then asked how much of his/her maize farm was under the PPT and how much was not under the PPT. Irrespective of the answers above, data were gathered on farmer's socio-economic characteristics, including the age of the household head, size of the household, proportion of household members providing labour on the farm (calculated as 'men equivalent units'), education level of the members in the households, location of the households in relation to the PPV (villages hosting on-farm research activities on PPT), NPPV (villages neighbouring the PPV) or NBPP (villages geographically far from PPV and where on-farm research activities are not carried out), gender of the household head and farm size. An index was also generated for the farmers' land tenure security.

Time taken to travel from the household's home to the nearest market (based on the type of transport used) was estimated in hours. This variable was preferred to physical distance because even though some households lived very far from market centres, they were able to reach the market centres easily if they used bicycle taxis (*boda boda*) or car taxis *(matatu*). Schedules of agricultural meetings would be most likely announced in market centres and farmers are expected to exchange agricultural information when they meet at market centres for whatever purposes. Farmers in the rural areas are known to visit the market centres often for socializing and 'information gathering'. Hence the ease of reaching the market centres may enhance one's frequency at the market.

Dummies representing the households' perceptions on the level of Striga and stemborer infestation on their farms were used. The farmers' total livestock units (TLU) were calculated. Data analysis was facilitated through the Limdep computer programme version 7. In modelling, various factors were hypothesised to be key in influencing the farm households' decision at each of the three phases of the PPT adoption decision process, as presented hereafter.

4.3.3 Farmers 'knowledge of PPT' phase

In influencing the knowledge of PPT awareness phase, the following factors were considered influential:

- *Location of the household in the PPV*: It was expected that the households located in the villages where the PPT on-farm trials were being conducted (PPV) would have a better chance of knowing about PPT, than those households located in villages distant from the on-farm trials (NPPV). The villages neighbouring the PPV were identified as PPNB in this study. Using the PPV dummy variable as a base, the transition to PPNB and then to NPPV was expected to have a negative coefficient.

- *Age of the head of household*: Older farmers may have experienced the problem of Striga/stemborer for a long time given the history of these pests in maize production. The older farmer had tried different options with different levels of success and had accumulated capacity in searching for information on new technologies. They were therefore more likely to know about the PPT than their less experienced counterparts. A positive sign on the age coefficient was thus expected.
- *Time to the nearest market*: Time taken to travel to the nearest market centre was estimated in hours for each household. Time taken to travel to the market centre would be an indicator of the ease with which a household reaches a market and thus an indictor of a higher probability of knowing about the PPT. A negative sign was thus expected on the coefficient of this variable.
- *Gender of the head of household*: Since men are the ones who most probably go to the market centres for 'information', it was anticipated that male-headed households had an advantage over female-headed households in knowing more about the PPT. Since male-headed households were coded 0, it was anticipated that the variable would have a coefficient with a negative sign.

4.3.4 Farmers 'decision to adopt PPT' phase

Together with the factors used in the knowledge phase, the following factors were considered important in influencing the farmers' decision to adopt PPT:

- *Land tenure security*: Farmers who were assured of land tenure for their farms were expected to invest in relevant Striga and stemborer control technologies. This is more so in the case of perennial technologies like the PPT whose benefits accumulate over time. It would be expected that the farmers who had high land tenure indices would more likely adopt the PPT compared to the farmers with low land tenure indices. A positive sign on the coefficient of this variable was therefore expected.

- *Total livestock units (TLU):* A high TLU implies that a household faces a high demand for livestock feed. One of the extra benefits of the PPT is the provision of cattle feed from the Napier grass and the desmodium herbage. This provision would make the PPT more attractive to the farmers who own livestock since they can meet their needs for livestock feed besides controlling Striga and stemborer in their maize farms. A positive sign was thus expected on the coefficient of the TLU variable.

- *Perceived level of* Striga *infestation*: When the farmers perceive that the Striga infestation level on their farms is severe, they may have a higher propensity to look for solutions to mitigate it and when they come across an effective technology like the PPT, they are more likely to adopt it on their farms. Using the 'no-Striga' dummy as a base variable, a positive sign was therefore expected on the coefficients of moderate and severe infestation dummy variables.

- *Perceived level of stemborer infestation*: Like in the case of Striga, when the farmers perceive that the stemborer infestation level on their farms is severe, they may have a higher propensity to look for solutions to mitigate it. When they come across a technology like PPT that is effective in managing stemborer, they are more likely to adopt it. Using the 'no-stemborer' dummy as a base variable, a positive sign was expected on the coefficients of moderate and severe infestation dummy variables.

- *Area under maize*: if farmers are growing maize on their farms, they are more likely to adopt PPT than the farmers who do not grow maize. At the same time, farmers with small portions of land under maize have a higher propensity to take greater care of their maize. They therefore are more likely to adopt the PPT when compared to farmers with large portions of land under maize. A large farm, on the other hand, may allow the farmer to put a portion under PPT while growing food legumes in other portions of the farm. A positive sign was therefore expected on the coefficient of this variable for small areas under maize, but a negative value was expected larger areas under maize. Therefore to investigate the effect of the area under maize on the probability of the expansion of the maize area under the PPT, we also included the squared value of the area under maize to take care of the possibility of a non-linear relationship.

- *Total household income*: This was a sum of all incomes accessible to a household in 6 months from employment, remittances, business income, crop and livestock produce. Some money is required to buy Napier grass cuttings, desmodium seeds, maize seed and fertilizers, in order to implement PPT. Households with relatively higher incomes would most probably afford this investment expense compared to the households with lower incomes. If households can afford the inputs, then most likely they will make a decision to adopt the PPT. A positive sign was therefore expected on the coefficient of the household income variable.
- *Total men equivalent units (MEU):* This is a measure of the proportion of the household members who can contribute to the household labour needs on the farm and off the farm. Households with higher MEU were most likely to be favoured in terms of labour required for investment in the PPT. They were therefore more likely to make a decision to adopt the PPT than the households who had lower MEU and thus were labour constrained. A positive sign was therefore expected on the coefficient of this variable.

The farmers' utility values for technology characteristics were also used to identify if the characteristics that the farmers identified were relevant for the adoption of the PPT. The utility values incorporated into the model were those associated with fallow periods, cost of technology and the yield increase.

4.3.5 'Intensity of use of PPT' phase

All the factors that were put in the awareness and adoption stages were assessed for their influence on the proportion of maize acreage that was put under PPT by farmers in Suba and Vihiga District. They included:

- Household income level
- Total household labour (Men Equivalent Units, MEU
- Total livestock units (TLU)
- Area under maize:
- The bias factors: The bias factors obtained in the bi-variate probit model for the awareness and adoption steps were analysed for their influence on the 'intensity of use of PPT' decision.

4.4 Results

4.4.1 Descriptive statistics

Table 4.1 gives a summary of descriptive statistics of the households sampled for this analysis. Some of the variables returned negative T-statistics indicating that means of our study sample maybe less that the standardised means of the populations in Vihiga and Suba. Some variables returned positive T-statistics indicating that the means of the study sample was higher than the population means in the Vihiga and Suba population. Farmers in Vihiga District with an average age of 54 years were significantly older than the farmers in Suba District who averaged 49 years in the study sample. The household sizes were also significantly higher in Vihiga District at 5.7 persons per household on average compared to 4.8 persons per household in Suba District. The persons capable of providing labour in the households, calculated as men equivalent units (MEU), were also significantly higher in

Vihiga (4.0) compared to Suba (3.4). The land tenure security index for the farm was similar in both Districts.

The average time taken to travel to the nearest market centre was significantly shorter in Vihiga District than in Suba District. This maybe an indication of there being more market centres in a given area in Vihiga District compared to Suba District. It could also be an indication of variations in infrastructure such that even farmers in more remote areas far from market centres were able to use either bicycle or car taxi's (locally known as *matatus*) and reach the markets more easily in Vihiga District.

The area allocated to maize farming by each household, either as a mono-crop or an intercrop, was significantly larger in Suba (1.98 acres) compared to Vihiga's (0.79 acres). The farm holdings per household were also significantly larger in Suba (5.09 acres) compared to Vihiga (1.30 acres). On average, the total maize area under the PPT was an average of 0.05 acre in Suba District and 0.2 acre in Vihiga District. The amount of money the households were able to generate in a season (six months) from crop and livestock sales, remittances, wage incomes and salaries averaged Ksh. 22,000 and Ksh. 26,000 in Vihiga and Suba Districts respectively and the difference was significant.

Table 4.2 presents the percentages of the households' awareness adoption of the PPT across the sample villages. Of the 368 households that were interviewed for this study, only 112 households were aware of the existence of PPT, approximately 30.4% of the sample. The number of those that were aware of the existence of PPT was significantly higher in Vihiga District than in Suba District. In the study sample, the households that had adopted PPT in both Districts were 21 households, approximately 19% of those that were aware of PPT existence. 15 of the adopting households were in the located in villages that hosted the PPT demonstration plots (PPV) and 4 in the villages neighbouring the push pull villages.

Table 4.1 **A summary of the descriptive statistics on household characteristics used in modeling the PPT awareness and adoption decision in Suba and Vihiga Districts (N= 368 households).**

		District		**T-test for equals means in both Districts**	
Variable	**Explanation**	**Vihiga means (se*)**	**Suba (means (se)**	**T-values**	**P-values**
Hhhag	Age of head of households	54.45 (1.09)	49.66 (1.01)	3.21	0.001
Hhsz	Total number of persons in a household	5.66(0.18)	4.67 (0.14)	4.41	0.000
Tothhmeu	Men Equivalent Units (members who can provide labour) in household	4.07 (0.15)	3.36(0.11)	3.92	0.000
Landtsp1	Land tenure security index	3.21(0.06)	3.19(0.06)	0.214	0.831
Timmkt	Time to the nearest market centre	0.67 (0.09)	1.3 (0.08)	-5.13	0.000
Tlu	Total livestock units	1.03(0.07)	3.28 (0.22)	-8.84	0.000
Fmexp	Farming experience in years	21.92(1.12)	14.64 (0.84)	5.29	0.000
Fmszp1	Farm size in acres where homestead is built	1.30 (0.12)	5.09 (0.42)	-8.04	0.000
Armz1	Area under maize	0.79 (0.06)	1.98 (0.12)	-8.11	0.000
Totinc	Total household income for a season (six months, in Ksh.)	22624.21 (2331.87)	26754.76 (2475.62)	-1.19	0.2331
Hhhsx	Sex of head of household, coded 0=male, 1=female	0.218(0.032)	0.30 (0.032)	-1.785	0.075
Ppknow	Whether household knows about PPT (expressed in percentage) (N=368)	0.39 (0.037)	0.26 (0.031)	2.01	0.045
Ppadopt	Whether household has adopted PPT (expressed in percentage) (n=112)	0.203 (0.058)	0.226(0.069)	-0.256	0.79
Pptall	Area under PPT in acres (n=21)	0.195 (0.009)	0.0499(0.018)	-1.56	0.12

Standard errors in brackets. Source: Authors work, 2008

None of the adopters came from the villages far away from the PPV. This is despite the fact 3.5% of households in the far away villages were aware of the existence of the PPT.

Table 4.2 **Percentage of households aware of the existence of Push Pull Technology (PPT) and its adoption across the sample villages**

		PPV	PPNB	NPPV	Chi Square Value
Whether household knows about Push Pull Technology (n=368)	**No**	14.1	24.7	30.7	
	Yes	17.9	9.0	3.5	0.000***
Whether household has adopted PPT On their maize farm (n=112)	**No**	42.1	25.4	14.0	
	Yes	15.00	3.3	0.0	0.114
	Total				

Source: Authors work, 2008.

4.4.2 Factors influencing awareness of PPT

A Bi-variate probit model was estimated using the maximum likelihood approach to identify the factors that influenced the awareness and adoption of the PPT. The dummy for the PPV village was used as a base for this variable. It was expected that the households located in the villages where PPT on-farm trials/demonstrations were conducted (PPV) would have an advantage in knowing about the PPT, while those households located in neighbouring villages may or may not know about the PPT due to lags in the diffusion of information. The distant villages from the on-farm trials (NPPV) were not expected to know about the PPT.

As results show in table 4.3, four factors were found to be significant in influencing the probability of awareness of the PPT. This included the age of the head of the household, gender of the head of household, time to the nearest market and the dummy for the villages neighbouring the PPV.

Age of the head of the household returned a negative parameter estimate that was significant at 1% level. Older farmers may be expected to have experienced the problem of Striga/stemborer for so many years that their interest in searching for information on how to control it was higher than that of the younger farmers. However, it seemed that younger farmers in the study sample were aware of the PPT compared to the older farmers. Age significantly reduced the probability of awareness of PPT. This maybe because the older farmer do not search for new solutions for control of Striga and stemborer, maybe after trying too many different technologies, while younger farmers are optimistic about new technologies for controlling Striga and stemborer.

Gender of the head of the household was found to cause a difference in the probability of the awareness of the PPT. The gender variable returned a negative and significant parameter estimate. This implies that male-headed households (coded as 0 in data set) had significantly higher probability of being aware of PPT than female-headed households. This could be due to the fact that male members of households travel more widely than female members of households and are therefore more likely to know about the existence of the PPT.

The location of the household in the different villages was found to be significant in influencing whether a household knew about the PPT. The villages neighbouring the push pull villages gave a positive and significant parameter estimate, indicating there was positive information from the PPV to the neighbouring villages. The parameter estimate for the far away villages was not significant.

Time taken to travel to the nearest market centre in hours was also significant, giving a negative and significant parameter estimate. It was found that the households that reached the market centres easily (within shorter time periods) had a higher probability of being aware of the PPT than the households that took longer time periods. Such households that needed longer periods to reach the markets maybe come to the market less frequently and may miss out on information. A bi-variate probit model was maximised to assess the factors that influenced the farmers' decision to adopt the PPT, subject to awareness.

Table 4.3: **Maximum likelihood estimates of a bi-variate probit model assessing the factors that influence the awareness and adoption of the Push Pull Technology in Suba and Vihiga districts**

AWARENESS OF PPT (n=368)

Variable	Coefficient	Standard error	P-value
Age of head of household	-0.175	0.187	0.00
Gender of head of household	-0.167	0.567	0.003
Education level of head o household	0.293	0.117	0.98
Time to nearest market centre	-0.211	0.151	0.00
Dummy for village neighbouring PPV	0.328	0.822	0.00
Dummy for village far from PPV	-0.73	0.174	0.67

ADOPTION OF PPT (n=112)

Variable	Coefficient	Standard error	p-value
Household members providing labour in the farm	-1.24	0.162	0.00
Area under maize	0.788	0.235	0.00
Farmers assessment – moderate Striga infestation	0.488	0.436	0.26
Farmers assessment – major Striga infestation	-0.287	0.603	0.00
Total income	-0.823	0.239	0.00
Square of total income	0.7914	0.162	0.00
Index for land tenure security	0.499	0.228	1.00
Farming experience	0.185	0.248	0.00

Source: **Authors work, 2008**

4.4.3 Factors influencing the adoption of the PPT

On the second part of Table 4.3, six variables are shown to be significant in influencing the adoption of PPT. They include number of household members providing labour on the farm, area under maize, farmers assessment of Striga infestation as ‘major’, total household income in a season (from crops, livestock, employment, remittances and/or business), the squared value of income and the households farming experience.

The parameter estimate for the area under maize was positive and significant. This indicates that farmers that were already growing maize had high probabilities of adopting the PPT.

They were already constrained by Striga and stemborer in their maize production and its expected that they should have high probabilities of adopting the PPT, so this positive sign was expected.

Total income, an indicator of the households' capacity to invest in technologies, gave a negative and significant coefficient, but the squared income variable gave a positive and significant coefficient. This may implies a non linear relationship between income and the probability of adoption of PPT. Farmers need to have a certain minimum level of income in order to be able to adopt the PPT ranging from USD235 – 393 per hectare of PPT according to Khan et al, 2007. In implementing PPT, money is needed to buy Napier grass cuttings, desmodium seeds, maize seeds and fertilisers/manure. The squared income variable implies that there is a point of inflection in income levels, above which an increase in income corresponds to higher probabilities of PPT adoption. This is the income level at which farmers are able to afford the initial implementation costs.

Total 'men equivalent units' (MEU): this is a measure of the proportion of household members who can contribute to the household labour needs on the farm and off the farm. This variable gave a negative and a significant coefficient variable. This may imply that for households that are labour surplus, they use labour intensive approaches to control Striga, e.g. uprooting, and may therefore have lower probabilities of adopting PPT.

Farming experience also returned a positive and significant coefficient. Farmers with a higher farming experience were more likely to adopt PPT if aware of its existence.

The parameter for farmers' perception that Striga infestation was a 'major' problem was significant but negative. This was unexpected since it would be expected that those farmers who have very serious infestation would be more willing to adopt the PPT, than those who view Striga infestation as not a problem or a moderate problem. However, this maybe an indication that this category of farmers have given up trying to control Striga on their farms and they need to see the technology working on other farms for them to be convinced that it works, before they can adopt the PPT.

4.4.4 Factors' influencing the Intensity of use of the PPT once the technology is adopted

Table 4.4 presents the results of the Tobit analysis of factors that influence the proportion of maize farm that is put under PPT.

Table 4.4 Maximum likelihood estimates of a Tobit model assessing the factors that influence the proportion of maize farm that is put under Push Pull Technology (Intensity of use) (n=112)

Variable	Coefficient	Standard error	P-Value
Constant	-0.834	12.98	0.95
Gender of the head of the household	-1.196	0.702	0.97
Education of head of the household	0.753	12.98	0.95
Time to the nearest market	-0.140	0.193	0.4676
Dummy for village neighboring the PPV	-0.655	0.915	0.473
Dummy for village far from PPV	-1.383	12.98	0.92
Number of persons providing labour in the household	0.166	0.197	0.400
Area under maize crop	-0.192	0.229	0.401
Farmers assessment: Moderate Striga infestation	0.797	0.753	0.289
Farmers assessment: severe Striga infestation	0.116	0.854	0.175
Households total income in a season	**-0.463**	**0.237**	**0.051**
Squared value of household income	**0.383**	**0.153**	**0.013**
Index for land tenure security for the farm	**0.777**	**0.447**	**0.082**
Farming experience	**-0.747**	**0.322**	**0.021**
Bias from the 'PPT awareness phase ($\hat{\lambda}^{h}$)	**-1.485**	**0.307**	**0.000**
Bias from the 'PPT adoption' phase ($\hat{\lambda}^{A}$)	**1.804**	**0.373**	**0.000**

Source: Authors work 2009

Four factors were found to be significant in influencing the intensity of use of the PPT including the income, security of land tenure, farming experience and a bias factor emanating from the awareness and adoption steps of the analysis**.** Income returned a negative and significant coefficient, but the squared value returned a positive and significant coefficient. This was similar to the adoption decision, indicating a non linear relationship between income and intensity of used of PPT. A certain minimum level of income is needed for a farmer to have high probabilities of increasing the proportions of the maize farm under PPT. Below this optimal level of income, the farmer is not likely to expand their maize area under PPT. The area under PPT was always found to be less than the total land under maize on the farm, so there was still room on the maize farms for expansion of the area under PPT.

An index for high levels of security in land tenure returned a positive and significant parameter estimate. Farmers that are assured of their rights of access to land and its use have higher probabilities of putting larger portions of their maize farm under PPT. This was expected.

The amount of the labour available in the household, based on the men equivalent units was not found to be significant. This could be because the labour requirement would not be increased under PPT as some of the farm activities are not done (like second weeding and land preparation; see Khan et al, 2007 for a description of the labour requirements in the PPT over time).

The bias factors for awareness and adoption phases were significant. The conditional specification of the Tobit equation was found to be appropriate as the coefficient estimates associated with the awareness and adoption equations were significant. The process of awareness and adoption was an important predecessor of the intensity of use decision. This implies that the PPT intensity of use equation would have been biased is it were estimated without recognizing that the dependent variable in this equation is only observed if the households is aware of the existence of the PPT and has made a decision to adopt it.

4.5 Discussion

This study has presented and demonstrated the application of a three-stage adoption model involving ‘awareness of PPT’; ‘decision to adopt PPT’ and ‘decision on the proportion of the maize farm to put under PPT’ (intensity of use of PPT). PPT can be considered a divisible technology since small plots of maize can be progressively put under the technology. The study demonstrates that information/awareness of a technology is one of the key factors in influencing adoption decision, for example in the case of PPT. If farmers did not know about the technology, it would be incorrect to conclude that they had rejected it if they were found not practicing the technology by the time of a survey. In actual fact, farmers will not have had a chance to exercise their adoption decision, if they were found to have incomplete or no information about a technology.

In the case of Vihiga and Suba study sample of 368 farm households, only 112 (approximately 30%) had heard of the PPT by the time of our survey. Of those who knew about the PPT, only 21 farmers had made a decision to adopt. In this sample, only 91 households can be concluded to have rejected the PPT due to different reasons (including labour constraints or lack of enough income to invest in PPT), while 256 of them had not had a chance to assess the PPT and make a decision to adopt or not to adopt.

This study finds that the information flow about the PPT is incomplete. Most of the households that were aware about the PPT were located in the villages (PPV) where on-farm demonstrations had been carried out. Of the 30.4% households in our study sample that knew about PPT, 17.9% were in PPV, while 9.0% were in the villages that neighbours the PPVs (PPNB) and only 3.5% were in the far-away villages (NPPV). Of the households in the NPPV, none had exceeded the threshold awareness/information point needed to result in a decision to adopt the PPT. Since a total of 70% of the households in the study sample were not aware of the PPT, it appears that the local system of information dissemination has not been effective in spreading information from the focal PPV areas to the other areas about the PPT. Even within the PPV, there were a significant number of households, 17.9%, which were not aware of the existence of the technology. This calls for deliberately organized campaigns for the farmers to be made aware of the PPT if the desired adoption levels will be realized. This could be done through integrated extension programmes of demonstration like farmer field schools, pamphlets, posters, announcements through the provincial administration and church leaders.

Other than the location of a household in the different villages, the factors that were found to be important in influencing the farmers' awareness of PPT included the age of the farmer, gender of the head of household, and time taken to travel to the nearest market center.

The farmers' decision to adopt the PPT was found to be influenced by the perception of the Striga being moderate to severe, the household income, the total area of the farm that they had put under maize and household labour availability. If the adoption decisions were modelled without taking into consideration the awareness stage, this would also lead to a bias in the analytical results.

The proportion of maize farm put under the PPT was influenced significantly by three main factors: the household income levels, the level of land tenure security and the farming experience of the head of household.

The coefficients associated with the bias factors for the awareness equation and the adoption equations were also significant. This confirms that it was appropriate to consider the three-step model for analysis of adoption and use of the PPT. A household can only consider how much of their farm to put under PPT if they are aware of the technology's existence, are convinced that it can solve their problems and have made a decision to adopt and implement it on the farms. In modelling the intensity of use of a divisible technology, it is therefore important to consider whether a household is aware of it or not. This is in line with the recommendations that Atanu *et al. (1994)* made in their study of adoption decision for bST (bovine somatotropin), a yield enhancing growth hormone, among dairy producers in Texas.

4.6 Conclusions and policy implications

Adoption studies are useful in explaining the farmers' utilization of new technologies. For emerging technologies like PPT, the 'awareness stage' is demonstrated to be key in determining the subsequent stages of adoption. Ignoring the 'awareness stage' in any adoption study leads to a very significant bias in assessing the farmers' adoption decision-making process.

In modelling the PPT adoption decision among the farmers in Vihiga and Suba Districts, it has been demonstrated that the process can be divided into three distinct phases: the awareness stage, the adoption stage and the 'intensity of use' stage. Each of these phases is significantly influenced by different factors. Each phase is also shown to be significant in influencing the process in the subsequent phase, i.e. awareness influences adoption; while awareness and adoption influence the ‘intensity of use’ phase.

The study shows that the flow of information on PPT is still incomplete in Vihiga and Suba Districts, where the technology was first introduced during the 1994/1999 period, and where the farmers’ systems of information sharing do not seem to be very effective, even within the villages where the on-farm demonstrations were first done. This maybe because PPT in a knowledge intensive technology. Simple information sharing techniques among farmers are not sufficient in passing all the information required for farmers to make decisions to adopt the PPT. Therefore, there is need to have a deliberate and systematic awareness campaign that pushes the PPT information to all small-scale farmers who are Striga constrained in all areas. On farm demonstrations seem to be very effective in giving the information farmers needs as well as the printed materials like posters and pamphlets. Visiting research institutions where the PPT plots have been established could also give the farmers an opportunity to satisfy their information needs on the PPT.

Since ICIPE is mandated to carry out research and develop technologies, it may be practical to outsource the promotion and dissemination of PPT to a strategic partner in development work. Such a partner should have a wide network of operation within the rural areas and would be mandated with a specific task of promoting PPT and be sufficiently facilitated to carry out the task with technical backstopping from ICIPE. Such an effort is critical towards ensuring food security in Western Kenya and thus should be adequately supported and funded. Both desmodium and napier grass are also grown by farmers with other objectives; keepers of livestock, especially ruminants, are known to grow them for supplementing feeding. In this regard, the Ministry of Livestock Development (MoLD) that already has an established infrastructure throughout the country would be a good partner in promoting Push Pull Technology. As they promote dairy animals, the push pull technology can be a source of feeds so that they play a synergistic role in technology dissemination.

The objectives of this chapter have been met as the factors influencing awares of PPT in Suba and Vihiga have been demonstrated, the factors influencing farmers decision to adopt PPT have been evaluated as well as the factors influencing the intensity of use of the PPT.

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CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Background

Kenya's population is increasing leading to increased demand for food, especially maize which is a staple food for most of the Kenyan population. Demand for maize in Sub Saharan Africa is projected to double to 52 million tons by 2020 (Pingali and Pandey). The increasing population has also caused the per capital farm holdings in Kenya rural areas to become smaller due to continuous sub-division. Besides the reduced farm holding, maize production is constrained by biotic and abiotic factors. Two of the most important biotic constraints in maize production is Striga and stemborer infestation.

Maize yield loss due to stemborers has been estimated to range from 20-80% depending on the severity of the infestation by the pest and the growth stage of the crop (Khan et al, 1997a). De Groote (2002) established that an average of 13.5% of maize yield is lost due to stemborer across the agro ecological zones of Kenya. Striga related maize yield losses are estimated at 5% loss per every Striga plant per m^2 (Parker and Riches, 1993). Striga is a highly invasive parasitic weed and it infests more than 400,000ha of Kenyan farmland (Kanampiu, 2003). In western Kenya, 50-100 percent yield losses due to Striga have been reported both on on-farm and on-station experiments (Hassan et al, 1994).

Since opening of new land is not a viable option in contributing to increased maize production in Kenya, increasing maize production is dependent on two factors; the ability of the research and development agents to supply constraints mitigating technologies and the ability of the farmers to access and utilize such technologies. Research and development agents have developed technologies to control Striga and stemborer that include IR maize, improved fallow, Push Pull Technology, soil fertility improvement strategies using the organic and inorganic fertilizers, trap crops, hand pulling, resistant varieties as well as chemical use. These technologies are available for use by farmers in areas constrained by both Striga and stemborer. However, the levels of adoption of technologies for control of Striga and stemborer are still low.

This study therefore focuses on the second factor; the ability of farmers to access and utilize the available technologies. The study was designed to assess the factors that influence the farmers’ choice and adoption of Striga and stemborer control technologies in Vihiga and Suba districts of western Kenya. The study is divided into three parts; the first part focuses on the sources of agricultural information and assesses the factors that influence acquisition of agricultural information. The second part assesses how farmers evaluate technologies in terms of characteristics/attributes in order to consider them for adoption in control of Striga technologies. The third part evaluates if farmers know about the existence of the Push Pull Technology, a technology that was released by ICIPE, KARI and the Ministry of Agriculture, to simultaneously control Striga and stemborers in cereal farming. In this third part, the study also assessed the factors that influence the farmers, decision to adopt the push pull technology as well as those that influence the intensity of use of the PPT in the maize farms among the adopting farms.

Data were collected from 476 households in Suba and Vihiga Districts. Maize production in these two districts is constrained by Striga and stemborer districts. There has been a host of technologies to control Striga and stemborer disseminated in these districts over the years. It was expected that farmers in these two districts have developed advanced systems of acquiring information about and comparing Striga and stemborer control technologies, .

These two districts were therefore ideal for any study designed for assessing the farmers' evaluation strategies and the choice of technology in control of Striga and/or stemborer.

5.2 Summary of major findings

Chapter has an outline of the background to this study. The problem statement was defined, study gaps were identified and the objectives of this study were spelt out. The scope of this study was laid out and the chapter introduces the outline of this thesis.

Chapter 2 focuses on classification and influence of information on Striga and stemborer control in Western Kenya. Literature on the theoretical basis for agricultural information and diffusion of technologies was reviewed. The theory laid down in Rogers (1995) on the diffusion of innovations was especially found to be an important basis for the analysis undertaken in this study. Empirical studies that had attempted to actualise Rogers' theory in practical situations were identified, especially those that dealt with agricultural technologies. It was established that the farmers in Suba and Vihiga districts obtained information about agriculture technologies from fifteen different channels/sources/pathways. These included the mass media (radio, pamphlets, posters), extension agents, research organizations, farmer teachers, agricultural shows (technology transfer model), on-farm demonstrations, field days (participatory research), neighbours, friends, community meetings (community leaders) and farmers groups (social networks) as well as their own experience over time in farming. The different sources of agricultural information were complementary. Each farm household reported more than one channel as the source of accessing agricultural information. The most frequently reported channel were the community leaders and neighbours, while the least frequent sources were posters and contact farmers. Farmers reported having learnt about Striga and stemborer control methods from some of the channels and not from others. They were able to ‘subjectively’ rate a source as either effective or not effective in providing information about Striga and stemborer control.

Data based on the farmers’ contact with a source, whether they had learnt about Striga or stemborer from the source and their assessment of the effectiveness of such a source were analysed using the principal component analysis (PCA) approach. This resulted in two distinct and significant components that accounted for 24% and 10% of the variation in the data respectively. Component I was assumed to denote a distinct type of knowledge (Type-I) that was sourced from specific channels. The varimax rotation method showed that Type-I knowledge was associated with group-based sources of information, which included community leaders, field days, agricultural show events, neighbours and friends and on-farm demonstrations. Component II on the other hand denoted a distinct type of knowledge (Type-II), which was associated more with ‘individually sourced’ channels like reading posters, reading pamphlets, visits to research institutions, discussions with extension agents and farmer teachers.

Type-I knowledge was significantly influenced by the attainment of primary level education by the household head, shorter periods from the farm to the nearest market centres, a higher wealth status, as well as the perception of Striga and stemborer infestation as being a severe problem. Type-II knowledge was also significantly influenced by higher levels of education (secondary and post secondary levels) having been attained by head of household, high wealth status, high land tenure security and location of a household in villages hosting of-farm research (PPV) activities on Push-Pull Technology.

Type I and Type II knowledge were the only factors that significantly influenced the farm households' probability of using an improved technology to control stemborer. A household's probability of using an improved technology to control Striga was influenced by the household's wealth status, location of household in a PPV and labour availability as indicated by the household size.

Chapter 3, looked at the analysis of the characteristics of Striga –control technologies and their effects on probability of technology adoption in Vihiga and Suba districts. Literature was reviewed on applications of the conjoint approach, which was originally developed as a tool in marketing studies, on its application to agricultural technology studies. Conjoint analysis was chosen as a basis for the assessment of technology characteristics in Striga control technologies, because it can be based on qualitative assessment of technologies. Farmers were invited to share with the research team the characteristics they consider in assessing a Striga control technology. It was demonstrated that the farmers in Vihiga and Suba districts did not view Striga control technologies as whole entities, but as constituents of 'definable characteristics'. The seven characteristics that the farmers identified during focus group discussions included:

i. Cost of the technology
ii. Yield improvement attained when the technology is adopted
iii. Additional benefits to the livelihood system from the technology
iv. Change in labour that family will experience when the technology is adopted
v. Whether technology requires the farm to be left fallow
vi. Whether the technology requires a crop rotation regime and
vii. Whether the technology allows one to intercrop food legumes.

The seven characteristics were then generated into an orthogonal set of artificial technologies, using the conjoint analysis approach. A set of 12 profiles, consisting of 8-Striga control technology profiles and four holdout cards was then presented to farmers who ranked the profiles sequentially, on the basis of which best matched their needs in Striga control. The choice data was then analysed using the mixed logit in the multinomial framework in SAS. Except for crop rotation, the other six technology characteristics were found to be significant in influencing a farmers' choice of technology profile. The technology profiles that had the possibility of intercropping food legumes had the highest probability of being chosen for adoption by the farmers both in Suba and Vihiga Districts. They had higher than 10% probability of being chosen for adoption.

Existing Striga control technologies were reviewed in literature and matched with the farmers 'seven' characteristics. Using the utilities values obtained for each characteristic, the probabilities of adoption for existing technologies were estimated. Results from this showed that IR-maize technology had 11% probability of adoption, Push Pull Technology with no food legumes but considered expensive had 6.7% probability of adoption, Push pull technology with food legumes intercrop but considered expensive had 13% probability of adoption, Push Pull technology with no food legumes but considered cheap had 14.5% probability of adoption, while Push Pull technology that integrated food legumes and was considered cheap had a 29% probability of adoption; organic and inorganic fertilizers had 9% probability of adoption, improved fallow had 4% probability of adoption, uprooting of Striga plants had 7% probability, crop rotation systems had 9% probability while food legume intercrops had 9% probability of adoption.

Chapter 4 focused on the evaluation of the adoption of the push-pull technology for stemborer and Striga control in Vihiga and Suba districts. Literature was reviewed for different approaches that have been applied in the study of technology adoption. Theoretical framework based on the work by Rogers (1995) was reviewed. He identifies 5-main steps in the innovation-decision process to include knowledge, persuasion, decision, implementation and confirmation. Farmers who do not know about the existence of a technology cannot be said to be non-adopters in the analysis. The adoption of the Push Pull technology was therefore model as a three-part decision process. Factors influencing each part were identified. The first part was the awareness of the existence of push pull technology that was demonstrated to be significantly enhanced by younger age of the head of household, male household head, short time used to reach the nearest market centres and being located in a village hosting on-farm push pull demonstrations or trials. From the sample of 368 households, 30% were aware that Push Pull Technology existed.

The second part was the adoption decision whose probability was enhance by members of the household providing labour on the farm each season, area under the maize crop, farmers' perception that the level of Striga infestation was severe, total income the family has access to each season as well as the number of years farmers had experience in farming. Of the 30% households that were aware that Push Pull Technology existed, only 19% (6% of the whole sample) had adopted the technology on their farms. PPT is yet to be accepted for mass adoption as there is still a big proportion of the population that are not aware of its existence.

The third part of the analysis is the decision on 'how much' of the maize farm that households put under Push Pull technology. This area was influenced mainly by households' total income in a season, security of the land tenure of the maize farm, farming experience and a bias factor from the awareness and adoption stages of the analysis. This confirmed that the awareness and adoption stages were crucial in the analysis of the intensity of use decision. A decision to adopt a technology was only relevant to a sub-sample of households that were aware that the technology existed. A farmer's decision on the proportion of maize farm to put under PPT was only relevant to a sub sample of farmers who had already been aware of the existence of the PPT and had also made the adoption decision.

5.3 Conclusions

Farmers use different channels to access information on technologies that solve their constraints in farming. Farmers accumulate different types of knowledge depending on the channels that are available to them. This knowledge positively influences the farmers' likelihood of using improved technologies. Different channels of information should be used when designing dissemination strategies for any improved technology. Education is an important factor that influences farmers' accumulation of knowledge. However, in the rural communities, about 70% of the farmers have only up to primary level education. Simplifying technology messages for the rural communities is therefore very important and should be considered in all dissemination efforts. Interactive activities like on-farm research lead to high accumulation of knowledge. However, on-farm activities are expensive to implement, and only very few farmers benefit from them. It would be important to embrace strategies like farmer field schools that encourage participation of farmers. Farmer field schools can be used as avenues where new technologies are introduced and farmers get an opportunity to learn about it in an interactive way.

Farmers do not view agricultural technologies as whole entities. They view technologies as bundles of characteristics. Some of the technology characteristics can be subjective socio-economic considerations. These characteristics are the basis on which farmers make decisions to accept or reject technologies. The farmers' view of technology characteristics are therefore important and should be understood clearly and taken into account in the formulation of technology development activities. Understanding the farmers' views and needs and tailoring technologies to fit those needs increases the probability of adoption tremendously.

Adoption of divisible technologies should be modelled as a three-phase process, acknowledging the important stages of awareness, adoption and intensity of use. Adoption decisions are only relevant to a sub sample of farmers who are aware that a technology exists and that it can be used to solve their constraints. A sub-sample of farmers that are not aware that a technology that can solve their problems exists is judged unfairly when classified as non-adopters. The ways of encouraging adoption of technologies between these two groups of farmers are different. For those not aware, it would involve establishing why they have no access to information and availing to them avenues of information exchange. For the second group, it may involve understanding what factors are constraining them from adopting technologies and maybe subsidy interventions may help them overcome their constraints.

The objectives of the study to evaluate the factors that influence farmers' choice and adoption of Striga and stemborer control technologies in Vihiga and Suba districts of western Kenya were achieved in the study.

5.4 Policy implications

This study has demonstrated that farmers who have secondary and post secondary education accumulate a distinct type of knowledge that we call type II (associated with seeking information individually from written and reference sources) that contributes to technology choice decision when compared to farmers with less or no education. This knowledge is an important factor in influencing the farmers' probability of using an improved technology to control Striga and stemborer in Vihiga and Suba Districts. However, 17% of the heads of farm households in the study sample had no formal education while 58% had attained only primary level education. This implies that 75% of the households in our sample, and probably in the Vihiga and Suba general populations, were perhaps limited in their choice decisions by not having Type-II knowledge. This may be an indication that Vihiga and Suba farmers are not able to assimilate the technology information as currently disseminated. This is a major challenge for the technology developers and extension agents. To reach the rural farming households with technology information, there is an urgent need to have effective and efficient strategies to simplify the information being disseminated and also reach as many people as possible. Dissemination of technologies is either inadequately funded or not funded at all when technology development programmes are funded. There is an assumption that the local social systems of information exchange will lead to all farmers getting the information about a technology. In this study, it was found that approximately 70% of households in the study sample were not aware of PPT, even though the technology had been in the study Districts for over ten years. The policy of project funding should be reviewed to integrate the project dissemination funds.

Although funding is important for information and technology dissemination, it may not be sufficient. Since an organization like ICIPE has a major research mandate, the development of dissemination strategies within its programs maybe difficult and in contradiction with its institutional mandate. In recent years, commercial institutions have been outsourcing services from strategic partners who have relative advantage in carrying them out, while they focus on core business. In the same thinking, research organizations could have a policy to outsource services for the dissemination of technology from strategic partners (e.g. NGO's, CBO's and extension agencies) who have relative advantage in dissemination of technologies and have a wide network in reaching rural areas. With technical backstopping from research organizations and funding from donor partners, such a venture would result in the technologies being adopted by a larger number of farmers while the research organizations are able to concentrate in core research business.

Farmers' assessment of technologies is not similar to the biophysical science way of assessment. While impact on the target pest or weed and improvement on the yield of the target crop are key measures of the success of a technology from a biophysical perspective, the farmers' concerns are socio-economic in nature. Factors like whether the technology affects the possibility of growing other crops (food legumes in this case) and whether a part of the farm needs to be left fallow for a period have been demonstrated to be key factors in whether a household adopts a Striga control technology. An assessment of technology characteristics from the farmers' perspectives should therefore be an important part of diagnostic studies that are done ex-ante. Marketing research strategies, like conjoint analysis, have been developed that test artificial products before they are manufactured and released to the market. These methods can be adopted to assess farmers' acceptance of technologies before technologies are fully developed for dissemination. This will lead to identification and incorporation of the farmers' needs in a technology in the early stages of its development. This will not only save costs and time but it will also improve the probabilities of adoption and utilization once the technology is released to the farmers.

Intercropping of food legumes was the most important characteristic that farmers identified. Adopting of food legumes for control of Striga had a 9% probability of adoption. However, integrating the food legumes in the Push Pull Technology gives a probability of adoption of 29%. This is a there an opportunity that should be exploited in the control of Striga in Vihiga and Suba district and similar areas. Two possible ways of doing this would be:

- By identifying the ‘gene’ responsible for Striga control in desmodium and introducing it to food legumes so that food legumes can be used in the push pull intercrop instead of desmodium
- By integrating food legumes into the current design of the Push Pull Technology and also get ways of replenishing phosphorous in the soil as it is mined by the desmodium and the other food legumes.

Adoption studies, especially of emerging technologies, should always include the ‘awareness’ phase in modelling. As shown in this study, farmers consider adopting a technology only when they are aware of it. A population sample that is not aware of the availability of a technology cannot be said to have rejected the technology, until they have had the chance to review the technology. The factors that influence why they do not have a technology in their farms are different from the factors that would be at play if they knew about the existence of a technology. There are methods that have been developed to analyse this step, together with the adoption and intensity of use stages in the decision process. Training of socio-economists to collect data and estimate such models should be encouraged and funded.

5.4 Contribution to knowledge

This study has been innovative in generating empirical data on farmers’ information seeking behaviour and knowledge development. Although information about farmers’ communication and information seeking behaviour has been recognised as useful for understanding the needs of client groups and to target intervention programmes, there are very few economic programmes have generated empirical data on information usage and technology adoption. None of such information has been available in the area of Striga and stemborer technologies especially. Further, the study has demonstrated that farmers generate different levels of understanding and specific accumulation of knowledge depending on the information sources they are exposed to and their own competencies. These competencies are mainly influenced by their education level, while its clear that the education levels in the rural areas are low, with over 70% of the household heads having none or primary level education. This is the first time this assessment is done for Striga and stemborer constrained farmers in Kenya. This study lays a strong case for simplification of technology innovation and using a diversity of channels to communicate to farmers on new innovations.

This study also examined the way the farmers assess and choose technologies in the control of Striga. It has demonstrated that the farmers view Striga technologies as bundles of characteristics in much the same way as consumers assess products and services as bundles of characteristics. In adoption studies, assessment of technologies as ‘whole’ entities may lead to biases and incomplete evaluation of the factors that influence adoption decision. This study shows that there are gains to be made from assessing technologies from the farmers’ perspective as important characteristics, which may not be directly linked with the bio-physical aspects of the technology, can only be identified by the farmers and are integrated into technology development. The study has also confirmed that there are gains in adopting methodologies or approaches from marketing studies for assessment of adoption decisions. This is the first time Striga control technologies have been decomposed into their attributed for assessment of the utility farmers accumulate from the constituent characteristics. Once farmers’ preferences and needs for specific characteristics are identified, then the technologies can be re-designed to fit farmers’ needs like the case of beans integration into the Push Pull Technology design.

This study also confirms the importance of consideration of the information gathering/awareness phases in a technology adoption decision. Farmers who do not know of the existence of a technology cannot be said to be non-adopters, as they have not yet exercised their adoption decision. The factors influencing the fact that some farmers do not know that a technology exists are different from those influencing other farmers that already know about the existence of a technology and are making a decision to or not to adopt. Different approaches would have to be designed to disseminate the technology to the two groups of farmers. The factors influencing awareness and adoption decision are different from those influencing how much of the technology to use. This is the first study that assessed the adoption of the push pull technology in western Kenya using the three stage approach (awareness, adoption and intensity of use). It has demonstrated the importance of including all the stages in modelling an adoption decision for one to get complete understanding of the process of awareness, choice and adoption of technology.

5.5 Limitations of the study

This study is based on the assessment of the farmers' technology choice decisions in only two districts of Kenya i.e. Suba and Vihiga Districts. However, the PPT technology has been disseminated to farmers in over seventeen districts in Kenya over the last ten years. The technology has also been disseminated to selected districts in Eastern Uganda and Northern Tanzania. This study has also been based on a cross sectional data set collected in one season. These issues should be considered in future adoption studies in order to take into consideration diversity of the recipient farming communities. A wider study, involving more districts in the East African Region and based on a panel data collected over several seasons would give a fuller understanding of the trends of how farmers are adopting and utilizing PPT.

This study did not assess the factors that influence continuity of use or dis-adoption decision in regard to a given technology. The data set was limited for this kind of assessment. A study incorporating the continuity of use or dis-adoption decision would add value to this study.

Farmers identified 15 channels through which they access information on agricultural technologies. However, there are no studies that have focused on dissemination strategies for the PPT, specifically focusing on which of the dissemination channels would be best for which farmers and in which geographical locations.

This study has focused on the adoption and utilization of the PPT and the factors influencing each stage of the adoption process. However, the study did not get to assess the impact of the PPT on the farmers' livelihood and the ecosystems, specifically focusing on what impacts the PPT has had on (i) the maize surplus in the regions where it is adopted (ii) the household food security (iii) the dairy sub-sector since one of the key benefits is the production of livestock feed (Napier grass and desmodium) (iv) the soil fertility since desmodium, the key component of the PPT, is a nitrogen-fixing legume and (v) the development of desmodium seed market.

The findings of this study also show that intercropping of food legumes is one of the most important factors that the farmers consider before adopting the PPT. However, it did not assess the most important food legumes in different regions/districts that can be a basis of designing recommendations on how the food legumes can be integrated into the PPT cropping systems and the farming practices for different legumes. Such studies would be key in contributing to the success of the utilization of the PPT in controlling Striga and stemborer in Kenya and the other similarly affected regions. A biotechnology study exploring the gene in desmodium that is responsible for the control of Striga, its identification and transfer to food legumes would also be recommended. Such a finding would ensure higher probabilities of adoption of the PPT leading to control of Striga and stemborer, leading to higher maize and legumes yields in Suba and Vihiga districts, and similar districts, of Western Kenya.

6.0 APPENDICES

Appendix 3A Farmers perceptions of effectiveness of information sources across the study Districts

	Vihiga		Suba				
Source of information	**N (%)**	**Y (%)**	**N (%)**	**Y (%)**	**χ^2**	**Df**	**Difference**
Farmer group: PPV (n=159)	46.5	3.8	44.0	5.7	0.705	1.0	0.401
PPNB (n=155)	49.0	1.9	40.6	8.4	7.411	1.0	0.006***
NPPV (n=157)	50.3	0.0	44.6	5.1	8.538	1.0	0.003***
On-farm demonstration: PPV (n=159)	39.0	11.3	36.5	13.2	0.358	1.0	0.550
PPNB (n=155)	44.2	7.1	43.6	5.1	0.379	1.0	0.538
NPPV (n=157)	50.3	0.6	48.4	0.6	0.001	1.0	0.978
Contact farmers: PPV (n=159)	49.4	0.6	50.0	0.0	1.006	1.0	0.316
PPNB (n=155)	50.4	0.6	49.0	0.0	0.969	1.0	0.325
NPPV (n=157)	49.7	0.6	49.1	0.6	0.000	1.0	0.993
Community leaders: PPV (n=159)	43.8	6.3	43.1	6.9	0.055	1.0	0.815
PPNB (n=155)	46.2	4.5	40.4	9.0	2.908	1.0	0.088*
NPPV (n=157)	44.1	6.3	46.5	3.1	1.772	1.0	0.183
Organizational visits: PPV (n=159)	43.8	6.3	43.8	6.3	0.000	1.0	1.000
PPNB (n=155)	47.8	3.2	47.8	1.3	1.229	1.0	0.268
NPPV (n=157)	47.2	3.1	47.8	1.9	1.900	1.0	0.479
Radio: PPV (n=159)	33.8	16.3	34.4	15.6	0.029	1.0	0.865
PPNB (n=155)	40.8	10.2	38.2	10.8	0.102	1.0	0.749
NPPV (n=157)	43.4	6.9	39.6	10.1	1.192	1.0	0.275
Agric extension agents: PPV (n=159)	38.1	11.9	40.0	10.0	0.329	1.0	0.566
PPNB (n=155)	49.0	1.9	46.5	2.5	0.192	1.0	0.661
NPPV (n=157)	49.1	1.3	48.4	1.3	0.000	1.0	0.990
Pamphlets/ Brochures: PPV (n=159)	45.6	4.4	41.3	8.8	2.686	1.0	0.100*
PPNB (n=155)	49.7	1.3	45.9	3.2	1.469	1.0	0.226
NPPV (n=157)	49.1	1.3	48.4	1.3	0.000	1.0	0.990
Agricultural Shows: PPV (n=159)	48.1	1.9	38.1	11.9	13.491	1.0	0.000***
PPNB (n=155)	45.9	5.1	42.0	7.0	0.677	1.0	0.410
NPPV (n=157)	47.8	2.5	46.5	3.1	0.131	1.0	0.717
Chief's Baraza: PPV (n=159)	43.1	6.9	40.0	10.0	1.114	1.0	0.291
PPNB (n=155)	43.3	7.6	43.3	5.7	0.371	1.0	0.542
NPPV (n=157)	37.1	13.2	44.7	5.0	6.920	1.0	0.008***
Field days: PPV (n=159)	33.8	16.3	32.5	17.5	0.112	1.0	0.738
PPNB (n=155)	43.9	7.0	40.1	8.9	0.576	1.0	0.448
NPPV (n=157)	48.4	1.9	47.2	2.5	0.163	1.0	0.687
Neighbours: PPV (n=159)	30.6	19.4	16.3	33.8	13.277	1.0	0.000***
PPNB (n=155)	29.3	21.7	29.3	19.7	0.081	1.0	0.776
NPPV (n=157)	29.6	20.8	21.4	28.3	3.926	1.0	0.048**
Posters: PPV (n=159)	50.0	0.0	44.4	5.6	9.536	1.0	0.002***
PPNB (n=155)	47.1	3.8	47.1	1.9	0.943	1.0	0.332
NPPV (n=157)	49.1	1.3	47.8	1.9	0.220	1.0	0.639
Farming experience: PPV (n=159)	25.2	24.5	33.3	17.0	3.993	1.0	0.046**
PPNB (n=155)	23.0	28.9	32.2	15.0	7.991	1.0	0.005***
NPPV (n=157)	17.7	32.9	27.8	21.5	7.299	1.0	0.007***
PPT farmers teachers: PPV (n=159)	43.1	6.9	37.5	12.5	3.241	1.0	0.072*
PPNB (n=155)	49.7	1.3	43.9	5.1	4.095	1.0	0.043**
NPPV (n=157)	50.3	0.0	49.7	0.0			

Appendix 4A An example of Striga control Technology Profile

	
NO OTHER BENEFITS	
	NO BEANS

An example of a Striga control profile representing an example of the 12 combinations of characteristics presented to the farmers for ranking of the preferred combination, starting with the most preferred to least preferred for each farmer. In a focus group discussion, farmers identified all the technologies used for control of Striga or stemborers in their villages. They also identified the technology characteristics they consider while assessing such technologies for adoption. This information was incorporated into a structured questionnaire used during a cross sectional survey of 476 households. Each household was asked to list three technology characteristics they considered important in adopting the technologies they were using on their farms to control Striga and/or stemborers. Frequency tables 4.1 give a summary of the characteristics that farmers listed important as 1st, 2nd and 3rd considerations in Striga control technologies respectively. These technology characteristics were then chosen to develop the profiles for the conjoint survey. Orthogonal array of conjoint profiles were generated in SPSS version 11.5

Appendix 4b: Technology characteristics considered important before adopting a Striga control method by farmers in Suba and Vihiga Districts (Total Sample size, N=476)

	1st ccc* (n=161)	**2nd ccc (n=117)**	**3rd ccc (39)**	**Freq of a ccc as 1, 2 and 3rd.**
1. Cost of the technology	15.76	5.25	0.42	21.43
2. Technology inputs available locally	6.72	4.83		11.55
3. Ease of management	4.20	2.52	2.10	8.82
4. Its effective against Striga/higher yields	3.57	4.62	1.05	9.24
5. Attains affect on Striga within a short time	0.63	1.47	0.63	2.73
6. Its not labour intensive	2.31	4.41	1.89	8.61
7. Technology common with farmers in the area	0.21	0.42		0.63
8. Technology with many benefits	0.21	0.63	0.63	1.47
9. Length of fallow periods required	0.21		0.21	0.42
10. Possible side effects (human and livestock)		0.42	1.26	1.68
Percentage of total sample	33.82	24.58	8.19	

*ccc=technology characteristics