EX-ANTE EVALUATION OF THE ECONOMIC POTENTIAL OF HERBICIDE COATED MAIZE SEED IN THE CONTROL OF *STRIGA* WEED IN WESTERN KENYA

By

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Declaration

I hereby declare that this thesis is my original work and has not been presented for any degree at any other University.

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Dedication

To My family

Tom, Bob and Sollow

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LIST OF ACRONYMS

BMZ	The German Federal Ministry for Economic Cooperation and Development
CBS	Central Bureau of Statistics
CIMMYT	International Maize and Wheat Improvement Centre
CVM	Contingent Valuation Method
GDP	Gross Domestic Product
ICRISAT	International Crops Research Institute for Semi-arid Tropics
IITA	International Institute for Tropical Agriculture
KARI	Kenya Agricultural Research Institute
LDC	Less Developed Countries
MoALDM	Ministry of Agriculture, Livestock Development and Marketing
MoARD	Ministry of Agriculture and Rural Development
NRM	Natural Resource Management
PRGA	Participatory Research and Gender Analysis
ROK	Republic of Kenya
SSA	Sub Saharan Africa

ABSTRACT

This study was motivated by the need to find out whether the farmers could increase their maize production and profits through *Striga* control using herbicide-coated maize seed technology. The major objective was to determine adoption potential of the technology. The farmers' technology evaluation and preferences were identified and improvements on the technology suggested to improve adoption.

The data used was obtained from a survey of 123 smallholder farmers in 4 districts and through field trials in western Kenya. This included socioeconomic, maize production and contingent valuation data. Field trials were conducted both on-station and on-farm and data collected included both inputs and outputs data for the production of a herbicide resistant maize variety, coated with imazapyr and grown at two different fertilizer rates.

A survey of the farmers showed that *Striga* is a major problem in maize production. The various *Striga* control options that are available to them have not yet been effective in controlling *Striga*. The farmers who have participated in the trials involving the use of herbicide-coated seed technology are happy with the yields and the ability of this technology to control *Striga*. On average, the farmers are willing to pay Kshs. 150/kg, which is higher than the price of currently available commercial seed, and a premium above approximate value of herbicide coated seed. The demand is expected to be higher in the long rains season than in the short rain season. However, the only complaint was that the maize variety is late maturing. The high price of the currently available hybrid seed maize is also a problem to the farmers since financial constraints hinder them from buying hybrid seed each season.

Economic evaluation was done for both on-farm and on-station data. The results indicated that herbicide-coated seed technology is very effective in suppressing *Striga*, thereby increasing yields from about 1 to 3.5 ton/ha. The net benefits for the farmers increase by Kshs 23,790/ha for an added cost of Kshs 312/ha. Under the conditions of the trial, the technology is highly profitable. Production function analysis showed that the use of fertilizer significantly increased yields on-station but not on-farm due to the inherent high soil fertility in the selected farms. Marginal analysis showed that the use of herbicide resulted in very high rate of return while the use of fertilizer gave acceptable rate of return (of 50%) only when *Striga* was controlled. Use of herbicide is not sensitive to up to a 50% change in its price. However, the use of fertilizer is quite sensitive to its price changes, especially when *Striga* is not controlled.

The major conclusion which can be drawn from this study is that the herbicide coated seed technology should be made available to the farmers, as it is able to meet their immediate need of producing more maize. The study recommends that trials be carried out in more sites so that more farmers are made aware of the technology. Further research on the technology should incorporate the farmers' preference for early maturing seed variety. However, the problems that lead to limited use of hybrid seeds need to be addressed, especially through the provision of credit.

CHAPTER 1: INTRODUCTION

1.1 Background information

Sub-Saharan Africa (SSA) is one of the regions of the world where the number of poor people living on less than one dollar ($1) a day each has been increasing in the past decade (World Bank, 2000). The number of the poor is estimated to be nearly half of the population. Most of the poor in SSA reside in rural areas, and migration options are limited due to poor growth in industrial and service sector jobs (World Bank, 2000). A key component of the rural poverty complex is the declining per capita food production. The growth rate of per capita cereal production is less than the population growth rate. For instance, Kenya's growth rate in agricultural production declined from about 5 percent in the early 1980's to about 3 percent in the late 1980's (Kimenye, 1984; Okello, 1994). In the mid 1990's, Kenya's agriculture showed a negative growth (RoK, 1996), and for the 2000, agricultural growth rate was -2.4% (RoK, 2001). With a population growth rate of 2.8 percent per year (RoK, 2000), per capita food production and incomes have persistently declined, resulting in recurrent food insecurity, increased per capita expenditures on food and escalating rural poverty.

The biggest challenge facing Kenya today is how to reduce poverty and accelerate the rate of economic growth for national development. Commitment to address this challenge is shown by all the key stakeholders in the economy. One strategy to achieve this entails the inclusion of the poor rural smallholder farmers in decision-making in the design and implementation of technologies aimed at tackling the challenges of poverty. Effective participation of the farmers leads to the development and design of well-targeted safety net programmes.

Maize, the main staple food crop, accounts for 60% of calorie consumption in Kenya and its demand is growing at 0.7% annually due to the increase in human population (Pingali, 2001). The per capita maize consumption is high, averaging 103 kg/year but there has been a 1.3% per year decline in the growth rate of maize production (Pingali, 2001). This accelerating demand for maize must be met through increases in domestic supply. The problem of declining productivity is exacerbated by limited productive land. Growth in output will therefore have to come from intensified production on current maize land through the adoption of productivity-enhancing technologies.

The average maize yield in the industrialized countries is more than 8t/ha, while the yield in developing world is slightly less than 3t/ha, with Kenya having an average yield of 1.5 t/ha (Pingali, 2001). Biological, environmental and physical stresses faced by farmers have caused a gap between achievable and actual yields. Physical stresses include climatic conditions and soil-related factors, while biological factors are related to tropical insect pests, diseases and weeds (Pingali, 2001). One of the major constraints to increased production of maize in SSA is *Striga* weed. *Striga* species (witchweeds) negatively affect the livelihood of more than 100 million Africans and inflict a crop damage totaling approximately US$7 billion annually to the African economy (Berner *et al.,* 1995). In Kenya, *Striga hermonthica* infests approximately 160,000 ha in the Lake Victoria Basin where the farmers have identified this weed as the most important constraint to maize production (Hassan *et al.,* 1995). The recent estimates are 434,000 ha with yield losses valued at US$ 37-88 million per year to the farmers in western Kenya (Table 1). In western Kenya, intensive agriculture, constant monocropping of maize, and the decline in soil fertility and soil organic matter content have favoured the build up of S*triga* (Vogt *et al.,* 1991, Oswald *et al.,* 1998). The dominance of maize in the cropping system tends to exacerbate the *Striga* problem; with commercial hybrid maize more susceptible to *Striga* than sorghum, the alternative subsistence cereal crop (Ransom *et al.,* 1992).

Table 1. Estimated value of loss from *Striga* in Kenya

District	Pop[a] ('000)	Production[b] (Tons)	long rains[c] (ha)	short rains[d] (ha)	infested area[e] (%)	loss at 30%[f] (tons)	value of loss at 30% ('000$)	loss at 50%[f] (tons)	value of loss at 50% ('000$)
Bungoma	878	154,413	56,750	1,200	46	66,177	4,913	154,413	11,464
Migori	517	70,943	17,500	14,030	89	30,404	4,325	70,943	10,091
Nandi	582	155,250	61,200	500	40	66,536	4,258	155,250	9,936
Siaya	480	46,081	21,034	13,100	99	19,749	3,119	46,081	7,277
Nyamira	500	74,841	20,387	9,812	56	32,075	2,853	74,841	6,658
Gucha	464	82,990	13,500	12,950	44	35,567	2,504	82,990	5,842
Homabay	291	36,154	17,351	7,300	100	15,495	2,479	36,154	5,785
Kericho	472	83,250	29,500	2,000	41	35,679	2,352	83,250	5,488
Rachuonyo	308	30,539	10,250	6,716	100	13,088	2,094	30,539	4,886
Kakamega	605	54,036	28,000	2,020	56	23,158	2,090	54,036	4,876
Vihiga	499	33,966	13,200	9,000	65	14,557	1,514	33,966	3,532
Busia	371	21,324	12,450	5,776	97	9,139	1,423	21,324	3,320
Kisii	487	44,982	7,200	7,050	44	19,278	1,351	44,982	3,152
Suba	156	12,186	7,200	2,450	100	5,223	836	12,186	1,950
Nyando	297	11,633	7,025	700	99	4,986	790	11,633	1,843
Kisumu	500	8,934	5,832	2,262	99	3,829	605	8,934	1,411
Bondo	239	4,355	7,405	1,403	99	1,867	296	4,355	690
TOTALS	7,646	925,878	335,784	98,269	75	396,805	37,800	925,878	88,201

Sources: [a]CBS (2000), [b,c,d]MOA (2000),[e]Frost (1995), [f]Hassan *et al*., (1994)

A number of S*triga* control methods that have been experimented by International Maize and Wheat Improvement Center (CIMMYT), International Crops Research Institute for Semi-arid Tropics (ICRISAT), Kenya Agricultural Research Institute (KARI) and International Institute of Tropical Agriculture (IITA) include the use of organic and inorganic fertilizer, and the use of tolerant varieties and catch crops that suppress *Striga* (Frost, 1995). The current control measures being undertaken by farmers include hand weeding, fallowing, and use of organic and inorganic fertilizers. However, substantial crop yields continue to be lost to *Striga* weed owing to minimal success of the various recommended and conventional methods of *Striga* control. One of the most promising approaches to suppressing *Striga* parasitism tried so far is the application of herbicide in seed coating using herbicide resistant maize varieties. Research by CIMMYT agronomists has shown that seed dressing with *imazapyr* and *pyrithiobac* herbicides gives season-long

Striga control (Kanampiu *et al.,* 2001). The herbicide treated seed does not affect the sowing of herbicide sensitive intercrops like beans and cowpea (Kanampiu *et al.,* 2002), thus allowing the technology to be used in traditional small-scale farmers' intercropping systems.

This technological innovation of herbicide seed dressing as a *Striga* control method has not been released to the end-users by research stations. The market value of the finished product is therefore not available. A survey of the potential users and selected farmers who have used the technology as undertaken in this study, was meant to provide data for the assessment and recommendation of its acceptability and hence its release into open market for eventual adoption by end-users.

1.2 Problem statement

Most farmers in western Kenya recognize the impact of crop yields losses resulting from *Striga* infestation, given the limited success of the control methods currently used by farmers. Studies over a long time indicate that maize yield is reduced by 30-50% due to *Striga* under typical field infestations (Hassan *et al.,* 1994). In western Kenya, *Striga* is not only spreading into new areas, but it is also increasing in severity in areas already infested (Frost, 1995). This is a threat to the food security situation in the *Striga* infested areas of western Kenya where over 400,000 hectares are put to maize production annually (Table 1). Yield losses of up to 100% are not uncommon, yet substantial increases in productivity are needed to improve food security. Although efforts by the researchers have come up with various *Striga* control measures, farmers have not adopted some of them to any appreciable levels. The reasons for low adoption include the mismatch between technologies and farmers' socio-economic conditions, particularly the non-availability of economically feasible and effective technologies that are adapted to these conditions (Debrah and Sanogo, 1993; Debrah *et al.,* 1998).

Small-scale farmers are among the groups that form the bulk of the nation's poor and who need to be assisted to improve their well being. These farmers have scarce resources and face socio-economic and institutional constraints that necessitate different production decisions and practices. Technology adoption by agricultural producers is an essential prerequisite for economic prosperity in Less Developed Countries (Nkonya *et al.,* 1997). Research by CIMMYT on coating maize seed with a herbicide would offer an alternative method of controlling *Striga* and the success of such research efforts will depend on the farmers adopting the technology. An evaluation of the farmers' acceptability, willingness to pay and relative profitability of the technology will also determine the incentives that farmers might require for the adoption of the technology and also facilitate further improvements on the technology.

1.3 Justification of the study

Kenya's development policy recognizes agriculture as the pillar of the economy. Priority is focused on ensuring food security, increasing export earnings, and provision of employment income and livelihood for over 70% of the population. *Striga* infestation has led to a decline in agricultural and per capita food production in western Kenya as it negatively affects the production of staple food crops (maize, millet and sorghum). Emerging studies show that herbicide-coated maize seeds can effectively control *Striga* using herbicide resistant maize. Adoption of the technology would be achieved by ensuring that the technology is profitable and acceptable to the farmers. A survey of acceptability and adoption should therefore form part of the technology generation process (CIMMYT, 1993). Since most small-scale farmers have low incomes, an assessment of their willingness to pay will establish whether the technology is adequate to their needs and resources. The researchers require feedback from end-users of the technology that has been developed. The feedback is important in the design of the research strategy and in refining the final product so as to increase its likelihood of being adopted. The information generated will be useful for the private sector actors who will be involved in the delivery of the seeds since they would be guided in fixing prices in such a way that they will sell and make a profit. Policy makers, especially those in the Ministry of Agriculture, would be interested in the findings to guide them in deciding on how much of subsidy, if any, they should allocate to the supply of the seeds to make them affordable by farmers and consequently improve their welfare by lowering the losses from *Striga.*

1.4 Objectives of the study

The overall objective of this study was to identify factors that facilitate the adoption of a new technology, which will contribute to the overall productivity and food security among the people of western Kenya.

The specific objectives were to:

1. Determine whether the farmers would be willing to use the herbicide-coated maize seed technology for *Striga* control.
2. Determine the amount of money farmers would be willing to pay for herbicide-coated seed technology in *Striga* control.
3. Evaluate the profitability of herbicide-coated maize seed for S*triga* control in maize production.

1.5 Research questions

Given the study objectives, the main research question that this study sought to answer is whether the herbicide coated seed maize technology is profitable as a *Striga* control method in maize and whether the technology is acceptable to the farmers and at what cost.

CHAPTER 2: LITERATURE REVIEW

2.1 Background

Witchweeds (*Striga sp*) are root parasites, which cause significant damage to food crops in Asia and Africa. The most damaging species in sub-Saharan Africa, *Striga hermonthica*, affects maize, sorghum, rice, millet and sugarcane. *Striga* is difficult to control as it produces numerous tiny seeds, which can remain viable in the soil for up to 20 years. *Striga* attacks susceptible host crops shortly after germination. After attachment to the roots, it draws all of its water and nutrient and part of its carbohydrate requirements from the host. Additionally, it exerts a potent phytotoxic effect on the host, causing severe stunting and a characteristic "bewitched" (hence, the common name 'witchweed') and chlorotic whorl. This causes yield losses far in excess of those expected from a pure competitive association.

CIMMYT's weed control activities in Eastern and Central Africa involve a multi-pronged approach to alleviate the S*triga* problem. These approaches include agronomic approaches, host plant tolerance, and biotechnological methodologies. CIMMYT's project known as "Developing *Striga* control strategies for cropping systems in Kenya" (1995-2000) funded by The German Federal Ministry for Economic Cooperation and Development (BMZ) and the project known as "Development and diffusion of integrated S*triga* control practices for small-scale farmers in western Kenya" (1999-2001) funded by Participatory Research and Gender Analysis-Natural Resource Management (PRGA-NRM) are complementary and essentially integrated. Co-operating partners for the two projects were the University of Kassel (Germany), KARI, the MoALD, CARE-Kenya and the Kenyan farmers. Various *Striga* control methods were studied on-station and in farmer managed on-farm trials. The methods evaluated at on-station conditions included intercropping maize with S*triga* trap crops and fodder legumes, catch cropping, weeding, testing of commercial maize varieties and crop rotation. For the purpose of disseminating S*triga* control technologies and to compare and evaluate different methods, on-farm trials and demonstrations were initiated in Nyanza Province in the Lake Victoria basin by the MoARD and CARE-Kenya respectively. The project involved training of MoARD frontline extension workers and CARE community extension workers. The training comprised sessions on *Striga* biology, S*triga* control and prevention methods, and methods of participatory farmers' training.

The agronomic practices, though effective (CIMMYT, 2001), are rarely adopted because their effects are only seen in the medium to long-term (Odhiambo *et al.,* 1994), and they require an understanding of the biology of *Striga* parasitism, which farmers usually lack. They also require rotating land out of maize production. CIMMYT in collaboration with IITA, the Weizmann Institute of Science, the University of Sheffield and KARI has in recent years undertaken several biotechnological approaches to address the *Striga* problem. These include the identification of alternative sources of resistance to *Striga* among its wild relatives, teosinte and *tripsacum*, the evaluation of mutator-induced resistance in maize (Kim *et al.,* 1994), and the use of low-dose herbicide seed treatment on herbicide-resistant maize varieties.

2.2 Herbicide resistant maize to control Striga

The objective of *Striga* control is to stop production, diminish the seed reserve in the soil and prevent damage by the parasite to the host crop (Eplee, 1989). Efforts in formulating *Striga* control methods in developing countries is complicated by a diversity of climatic zones, intercropping farming practices, cost of materials, application methodology and the knowledge of the users.

Several methods of herbicides application have shown success in *Striga* control. The pre-plant incorporated herbicides are incorporated into the soil before planting and the seeds planted in a furrow or hole below the treated soil. Care must be taken to ensure that no treated soil is directly over the maize seeds. *Striga* plants attach to the roots of maize and inflict some yield reducing injury but there will be much less emergence thereby reducing seed production. Pre-emergence herbicides are applied to the soil surface after the maize has been planted but before emergence. The herbicide suppresses *Striga* if rainfall moves the herbicide into the soil before *Striga* emergence. The systemic herbicides are applied to the foliage of maize after which it translocates to the roots, where *Striga* has attached and accumulates to toxic level in the parasite. Its effectiveness is dependent on proper timing therefore must be applied during or soon after attachment. The systemic herbicides cannot be used in intercropping situations or where sensitive crops are in the environs of the treatment. Some herbicides will kill *Striga* when applied directly on the parasite. These treatments are effective if they are applied when *Striga* is young with minimum contact with the lower portion of the maize stalk. This method of application cannot be used with intercropping and a new flush of *Striga* may soon reappear.

The new approach to *Striga* control that CIMMYT has undertaken involves the use of low-dose herbicide seed treatments that kill *Striga.* This approach utilizes maize varieties developed from a natural mutant of maize which allows application of high herbicide levels, which can be localized on or near the crop seed (Kanampiu *et al*., 2002). These varieties are not Genetically Modified (GMOs)(Kanampiu, personal communication). *Imazapyr* and *pyrithiobac* (imidazolinones) are systemic herbicides that have been shown to be highly effective against *Striga.* When applied as a seed dressing on imidazolinone resistant (IR) maize, they are imbibed by germinating seed and absorbed into the growing maize seedling. *Striga* seeds, stimulated to germinate by maize roots, attach to the maize roots and are killed by systemic herbicide in the maize seedling before any damage is inflicted on the maize host plant. Very small quantities of herbicide (30-45 grams active ingredients/ha) applied using this method have been found to be highly effective in providing season-long control of *Striga.* In addition, this technology allows maize to exude germination stimulants into the rhizosphere, which induce germination of *Striga* seeds, thereby depleting the *Striga* seed banks. Herbicide sensitive intercrops like beans and cowpea are safely sown as closely as 15cm from treated maize (Kanampiu *et al*., 2002). Seed dressing with imazapyr and pyrithiobac combined with handpicking of the few *Striga* plants that escape the effect of herbicide may provide a stopgap until more long-lasting genetic resistance becomes available (Pingali, 2001, Kanampiu *et al*., 2002).

2.3 Distribution of Striga

Hassan *et al*. (1994), using agro-climatic zones for maize production as developed by the Kenya Maize Data Base Project (MDBP), explored the geographic distribution of *Striga* on maize in Kenya. According to that study, *Striga* is most common in the relatively warmer locations of western Kenya, mainly the moist mid-altitude zone (MAT) around lake Victoria. On average, 39% of the 118,000 ha planted to maize in the moist MAT are infested with *Striga,* which causes an average damage of 51%. *Striga* infestation is not yet severe in the transitional zone (TNZ) and is only confined to moist parts where 1% of the area is infested and it causes an average damage of 42%.

The moist MAT and TNZ zones are concentrated around lake Victoria to the Western border of Kenya, whereas the dry segments of the two zones fall towards the eastern side of the country, with the Rift Valley in between. *Striga* is not reported in the relatively cooler climate of the high tropics (HT) and the drier segments of the MAT and TNZ east of the Rift Valley, although moisture levels in those areas are considered sufficient for *Striga* to develop there. *Striga* infestation covers the 17 districts of Western and Nyanza provinces.

2.4 Farmers practices and control measures

Striga infestation is higher in the moist MAT zone, especially in areas of higher population density and intensive cultivation (Hassan *et al*., 1994). Hassan *et al.,* (1994) found that, on average maize was planted two weeks earlier in areas heavily infested with *Striga* compared to relatively *Striga* free areas, and this could be a farmers' strategy to control *Striga.* However, experimental data has shown that planting date does not affect *Striga* parasitism in maize and sorghum (Ransom *et al.,* 1991). More manure and less inorganic fertilizer is used in areas of high infestation, suggesting that the farmers expect organic fertilizer to limit the build up of *Striga.* Results from experiments conducted by Odhiambo *et al*., (1997) showed that organic fertilizer reduced the level of *Striga* emergence and generally increased the maize yields. However, the effect of organic fertilizer application is more pronounced when combined with hand weeding (Odhiambo *et al.,* 1997). The observation that *Striga* is often endemic on infertile soils raises the possibility that fertilizer might help in its control (Mumera *et al.*, 1993). The lake region local yellow maize variety, *Nyamula*, is believed to possess some tolerance to *Striga* (Frost, 1995), and most farmers in the MAT zone prefer *Nyamula.* However, the level of *Striga* tolerance in this maize variety is still far from what is needed. There are also some inherent dangers in relying on tolerant varieties, because they encourage *Striga* seed production and increased soil seed load (Eplee, 1989, Kim *et al.*, 1994). Although no complete resistance has been found, the need is so great and the potential benefits so large that a continued effort in searching for resistant varieties is necessary. Mixed cropping, especially between rows, was found in high *Striga* infestation areas, and this could be a farmer's strategy to control *Striga*. Hand pulling of *Striga* weeds was also common in the areas with high *Striga* levels. It is effective in *Striga* seed bank depletion especially where the population is scarce. To be effective, hand pulling should be done before the pods contain viable seeds and should thus be conducted throughout the season, as long as there are *Striga* plants emerging. Although this practice is labour intensive (Eplee, 1989), it can be a sound investment if diligently used. Other studies (Hassan *et al*., 1994) however, showed that other practices like crop rotation, intensity of cultivation, use of inorganic fertilizer and tillage methods did not show any statistical significance in reducing the severity of *Striga* damage.

2.5 Contingent Valuation Method

2.5.1 Theory

Contingent Valuation Method is a non-market valuation which derives money-based valuation of changes in quality or quantity of a good or service that is typically not yet priced in a market. The methods involved are based on the assumption that the individual is familiar with market systems and therefore can state reasonable estimates for certain goods and services. In developing countries, markets may be weak or non-existent for certain products and the concept of value in local currency amounts may be harder to determine. While subsistence use of farm produce may not involve cash transactions, it may still represent great value to the household in terms of nutrition and saved income.

The two main approaches to non-market valuation include the indirect or inferential approach and the direct approach. The indirect approach includes travel cost modeling (TCM) and hedonic price modeling (HPM), while the direct approach uses contingent valuation method (CVM) (Thobani, 1983).

Indirect approach to non-market valuation rely on observation of existing behavior, usually market behavior. This indirect method assumes that an environmental good or service has a market price associated with it. If consumers make an actual market choice and buy a commodity with non-market components (e.g. buy a house), the value of the non-market amenity is inferred from the market data for the good (e.g. the cost of the house reflects the quality of the surrounding environment). Since this type of valuation relates the value of the good to a market, it measures the use value but cannot be used to elicit non-use values (Thobani, 1983).

Contingent valuation method (CVM) does not look at behavior. Respondents are presented with a scenario, focusing on the description of the amenity to be valued, a hypothetical payment vehicle and a question to assess their willingness-to-pay (WTP), or alternatively their willingness-to-accept (WTA), for the outcome of the scenario. The individual's response to WTP or WTA question represents the theoretical welfare measure of their value for that amenity. CVM studies implicitly assume that people fully understand their preferences and are familiar with the concept of value through exposure to prices, trade and consumption of marketed goods. CVM incorporates the individual's perceptions and decision-making process into the valuation process (Thobani, 1983).

In the application of the CVM in this study, the bidding approach is employed to assess the farmers' willingness to pay for a new technology should a market exist for it. This approach can either be iterative bidding in which the valuation question is asked repeatedly or non-iterative bidding which asks the valuation question once. In a standard bidding game, a respondent will first be asked whether he/she would be willing to pay a specified amount, known as the "starting point" amount. If the response is affirmative, the amount is increased to successively higher levels until a maximum "willingness to pay" figure is reached. If the starting point amount elicits a negative response from the respondent, the amount is revised to lower amounts until a maximum "willingness to pay" figure is indicated by the respondent

CVM can be estimated econometrically. However, the econometric method for estimating CVM depends on the type of bidding approach adopted. For close-ended non-iterative approach, probit or logit procedures are more appropriate. If the bidding approach is iterative, or non-iterative but open ended, a least squares estimation is more appropriate for the analysis.

The reliability of CVM depends on three potential biases that are peculiar to contingent valuation: strategic bias, hypothetical bias, and starting-point bias (Debrah, *et al*., 1993). A carefully designed and executed contingent valuation questionnaire will be required in order to minimize these biases.

Strategic bias is present if respondents intentionally mislead the researcher for strategic reasons. For example, if the respondent believes that stating a high value would enhance his/her status, he/she might state a higher than true value. If he/she believes that the researcher will recommend provision of government assistance to those who bid low, lower values could be stated. Although such conditions are generally rare in CV studies and strategic bias is much less of an impediment to CV studies than many Economists have assumed, the possibility of strategic bias must be taken seriously (Mitchell *et al.,* 1989). According to Mitchell and Carson (1989) questionnaires that unnecessarily call attention to the hypothetical character of valuation exercise, either directly by using wording such as "pretend" or assume a "hypothetical situation" when eliciting for WTP amount, or indirectly by the use of highly abstract or implausible payment vehicle, run the risk of encouraging overbidding by respondents who want the good to be provided. This situation would be exacerbated by wording that emphasized the importance of the respondents' answers to policy makers. The questionnaire used in this study was therefore designed in a way that it would create a plausible payment obligation.

Hypothetical bias stems from the inability of respondents to accurately perceive the market being described and therefore give hypothetical responses to contingent questions. The researcher who wishes to conduct a valid CV study has to create a believable and meaningful set of questions, which will simulate a market for the good in question, with sufficient plausibility that the respondents' answers may be taken as an accurate representation of how they would behave if confronted with an actual market for the good (Mitchell et al., 1989). CV researchers have reasoned that the more realistic the situation that is, the hypothetical market and the mechanism for payment, the easier it will be for people to respond accurately. To reduce hypothetical bias, the product definition was provided to the respondents, which involved presentation of technical information in a form that is understandable to the respondents. This ensured that the respondents got a complete concept of what they were valuing in order to come up with realistic values.

Starting-point bias occurs when the starting bid amount is set too low or too high. The respondent's bid is influenced by the starting-point amount. Confronted with a dollar figure in a situation where the respondent is uncertain about an amenity's value, he may regard the proposed amount as conveying an approximate value of the amenity's true value and anchor his WTP amount on the proposed amount. To reduce the bias, the price of herbicide-coated seed was made to be as reflective as possible to the likely final price of the product. Since herbicide dressing is done together with the pesticides, only the price herbicide was added to the average price of hybrid seed.

2.5.2 Applications of CVM in Africa

CVM has been used in developed countries for the valuation of non-market goods, e.g. natural resources and recreational facilities (Debrah *et al.,* 1993). In developing countries, CVM has been applied to financing of social services, such as education, public health and water supply (Thobani, 1983). Under these circumstances, CVM is an analytical tool used to determine the appropriate rates to charge individuals for the social amenities previously provided by the Government (Boadu, 1993).

In Kenya, CVM has been used in a household survey by Echessah *et al* (1997) in Busia district, to assess people's willingness to contribute labor and money to control tsetse flies that transmit trypanosomiasis. In that study, a Heckman's two-step model was estimated to identify the factors affecting the probability that a respondent was willing to contribute labour or money and the factors affecting the amounts of labour or money he or she was willing to contribute, while a contingent valuation method was used to get information on the amount of money they would be willing to pay. The results of the study indicated that the households willing to contribute the most money were those whose heads were female and well educated, while those willing to contribute the most labour were those headed by men, had high cash income and had participated in an educational event.

Graham *et al.* (1997) while providing a background information and framework for valuation of small wildlife resources in Zimbabwe found CVM to be the most appropriate of the non-market valuation methods. According to his study, the variables that were likely to influence the values for small wildlife included income, household size, education, information and perception, age, gender, religion, ethnicity, market access and environmental conditions as well as the factors affecting household food security. Graham, however, notes that the conditions vary greatly, even across communal areas and villages. Therefore, a blanket approach to CVM is not applicable, and some modifications are needed to adapt it to suit the local conditions. Otherwise, factors such as income constraints or cultural traits may limit its success.

A study by Debrah and Sanogo (1993) to evaluate the profitability and adoption potential of 2,4-D for controlling S*triga* was done in Mali. The objective of the study was to elicit information about the maximum amount of money the farmers would be willing to pay for *Striga hermonthica* control and to examine the socio-economic factors that influence their willingness to pay. The results showed that the farmers were willing to pay between 3% and 18% of the total household income. Income was the principal-determining factor in the ability and willingness of farmers to pay for S*triga* control. *Striga* control using 2,4-D was found to be profitable in maize, millet and sorghum. In the break-even analysis, sorghum output price and yield would have to be roughly 15% higher than they were for the use of 2,4-D to be profitable.

Jabbar *et al* (1997) studied farmers' preferences in relation to market values of cattle breeds of west and central Africa. The study was undertaken in the derived savanna area of southwest Nigeria to determine the prospects for conservation through the use and possible improvement of the *muturu*[1]. A logit analysis of the relation between breed preferences and breeding practices confirmed a strong trend away from *muturu* relative to

[1] A west African shorthorn breed believed to be in decline throughout southwest Nigeria.

other breeds. An analysis of cattle market prices found small but significant price differences in relation to the cattle breeds. Provision of incentives was considered the best option for increased utilization of the *muturu* in other areas of west Africa, such as south east Nigeria, where the *muturu* is better suited to the farming systems and there is a large market for this breed.

Swallow *et al.,* (1994) in a study conducted in Ethiopia applied CVM to determine the maximum amount of money and/or labour that the households are willing to contribute towards a trypanosomiasis control programme. The study employed the open-ended method. They acknowledged that though the method results in data that is easy to analyze, it raises some concerns due to large numbers of non-responses and protest zero responses. The factors affecting willingness to contribute money or labour were tested with multiple linear regressions. Gender, cattle herd size and participation of the household in the guarding of technological inputs were found to be related to willingness to contribute money.

From the review of literature on CVM, it can be inferred that previous studies have tended to concentrate on the estimation of only WTP. This study is unique in that, in addition to estimation of WTP, it will also involve the farmers' evaluation of the technology, determine the amounts of herbicide coated seed that the farmers are willing to buy and suggest improvements on the final product that would enhance its adoption.

CHAPTER 3: METHODOLOGY

3.1 Conceptual framework

Biological, physical and socio-economic constraints faced by farmers are the main challenges that have led to the design and implementation of technologies aimed at tackling them. When new technologies are being developed, priorities are set on the basis of their potential benefits to farmers including consideration of profits and risks and the ease with which farmers may be able to adopt them including compatibility with farming system, the possibility that they can test the new technologies themselves, and the availability of institutional support (CIMMYT, 1993). Concerns with acceptability must form a part of the technology generation process from its early stages (Debrah *et al.,* 1998). When a program of research is being planned, it is essential to get a clear idea of what type of changes or technologies would be acceptable to farmers. Farmers should be involved in the evaluation of the technology being developed so as to understand the problems that may impede the spread of the technology (CYMMYT, 1993). This helps in refining the research objectives to meet the needs and conditions of the farmers, and hence increase the likelihood of eventual adoption and hence increased production. If the technology does not result into the desired increase in production, then it is taken back to the farmers for reevaluation, which should lead to further refinement. This can be summarized in the flow in figure 1.

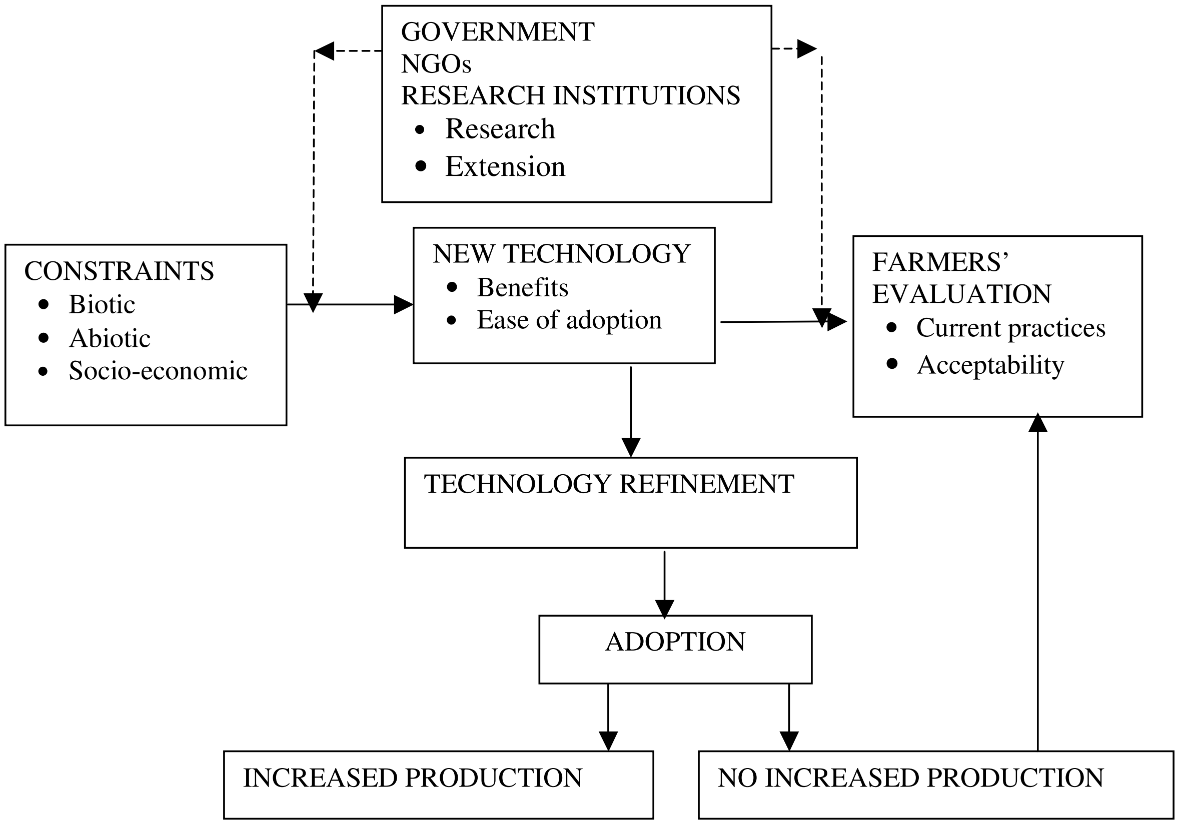

Figure 1. Conceptual framework

3.2 Study area and data sources

The study was conducted in the *Striga*-infested area of Western Kenya that forms a belt around Lake Victoria and touches 17 districts. In these districts, over 41% of the farms are infested. However, this study was conducted in 4 districts. Altitude in the sampled districts ranges from 1200 to 1600 meters above sea level and the landscape is undulating with slopes of 2% to 8%. Rainfall is bimodal, with an average of 1300 to 1800 mm per year, falls over the long rains season (March to July) and the short rains season (August to November). Main soil types are Ferralsols, Acrisols and Nitisols with a pH of 5 to 7 (Shepherd *et al* 1995). In the study area, maize dominates the cropping system, though often intercropped with beans, cowpeas and groundnuts. Only a few farmers grow cash crops, such as sugarcane, coffee or tea. The inhabitants of the study area mainly belong to the Luo and the Luhya ethnic communities.

The study made use of both primary and secondary data. Secondary data were collected from several sources, among them the publications from CIMMYT, Ministry of Agriculture and libraries. Primary data consisted of household survey and field trials data. Household survey data was collected using a semi-structured questionnaire. A reconnaissance survey was conducted in the study area to identify the types of farmers to be interviewed, while a pre-test of the questionnaire was done using 10 farmers in the same area.

3.3 Data collection

3.3.1 Experimental data

Experimental data were used to investigate the response of grain yield of maize to fertilizer and herbicide. On-station and on-farm trials were carried out at KARI-Kibos field station and farmers' fields in Kisumu District respectively during the 2002 long rain season. On-farm sites were selected on the basis of a history of high *Striga* infestation and are not representative on the basis of soil fertility. At Kibos research station, the plots were artificially infested with *Striga*. The response function and partial budget were estimated from the quantities of yield obtained and inputs used in the experiments.

The trials involved IR-maize hybrid variety, using 3 nitrogen levels (0, 30 and 60kg/ha, with the last two treatments also receiving 77 kg P_2O_5/ha) and 2 herbicide (imazapyr) levels (0 and 30gms active ingredients/ ha). Fertilizer was applied in the form of diammonium phosphate (DAP) (18:46:0) at planting, while top dressing was done with calcium ammonium nitrate (CAN) (26:0:0). Nitrogen application was split, with 30 kg/ha applied at planting, except in the zero treatment. The remainder was applied as top dress. The maize was planted on 8 rows of 5 m length at a spacing of 0.75 m by 0.50 m, with 3 seeds per hill, later thinned to 2. Hand weeding was done twice. The trial was arranged in a completely randomized block with 3 replications in Kibos and 2 replications in each of the 3 selected farms. All the plots were researcher managed. Grain yield was measured for the entire plots, and adjusted for 15% moisture content.

3.3.2 Household survey

The household survey covered four districts: Siaya, Vihiga, Rachuonyo and Homa Bay. These districts were selected because of their high *Striga* infestation, which ranges between 65% and 100% (Table 1). There were 2 sets of samples; a purposive random sample of the farmers who participated in the trials the previous season (2001) and a random sample of farmers in the study area. Random sampling was done using a table of random numbers.

A multi-stage random sampling procedure was used to select the non-trials participating sample. From each of the districts selected, 2 divisions were randomly selected. From the selected divisions, 2 locations were randomly selected. 2 sublocations were then randomly selected from these locations. Within each selected sub location, 3 farmers to be interviewed were selected at random, apart from 5 sublocations in which 4 farmers were sampled because of their high number of households. The sampling is summarized in the table 2.

The second set of sample was obtained from a list of names of trials participating farmers at Kibos field station where the trials are organized and coordinated. Out of the 78 farmers who had participated in the trials involving the herbicide-coated seeds in 2002, 22 were randomly selected. This gave a total of 123 sampled farmers who were interviewed and used in the analysis.

The data collected comprised of: socio-economic, crop production, and contingent valuation. This included farm and farmer characteristics (household size, age, sex, education level, extension, credit and occupation), maize production activities and knowledge and perception of *Striga* control practices.

Table 2. Sampling of non-trials participating farmers

Districts	Divisions	Locations	Sub locations	No. of Farms
Siaya	Boro	C. Alego	Kochieng 'A'	3
			Kochieng 'B'	3
		S.central Alego	Kadenge	3
			Obambo	3
	Yala	C. Gem	Gongo	3
			Kagilo	4
		Nyandiwa	Nyawara	3
			Siriwo	3
Vihiga	Luanda	C. Bunyore	Essunza	3
			Esiruro	3
		S. Bunyore	Esabalu	3
			Maseno	3
	Emuhaya	Wekhomo	Ebusundi	3
			Iboona	3
		N. Bunyore	Ebulonga	3
			Ebukhubi	3
Rachuonyo	Kasipul	N. Kamagak	Nyalenda	3
			Kawere kamagake	3
		Kowidi	Kanyango	3
			Kokal	4
	E. Karachuonyo	Kamser nyakongo	Kamser A	3
			Kamser B	3
		Rambira	Kamser seka	3
			Kagwa	3
Homabay	Asego	E. Kanyada	Kobwola-kogwang	3
			Kanyach-kachar	4
		Homa bay town	Arujo	4
			Asego	4
	Nyarongi	W. Kwabwai	Kasirime	3
			Kamdar-rachar	3
		W. Kanyidoto	N. Kabura	3
			S.Kabura	3
			Total	101

3.4 Analyzing the profitability of herbicide coated maize

3.4.1 Production function analysis

A general production function may be represented as;

$$Y = f(X_i) \qquad 3.1$$

Where Y = the output of maize per hectare (yield)

X_i = set of i inputs

Such a model is chosen and values for its parameters (coefficients) are estimated from appropriate data, preferably by some Maximum Likelihood Statistical procedure (or least squares regression). Modeling these physical relationships may be a major difficulty and therefore assumptions are made to enable estimation.

The model adopted for this study was of the quadratic form as in equation 3.2. This type of model exhibits both diminishing and negative returns phases. The model displays a unique maximum with symmetry of curvature around such a maximum. The ratio of marginal productivities of inputs (in a two input case) commonly referred to as the rate of technical substitution, declines at constant rate for this type of model. Further, the quadratic type of model can accommodate interactions among variables affecting maize yield i.e. herbicide (H) and nitrogen (N). Such interactions are included as cross-product terms, such as HN in the equation. For these reasons, the quadratic type of model was selected, as it is easier to explain the meaning of the linear, interaction and the power terms in the model. It can be noted that the square-root function can also be used. It was not used in the study because the linear terms in the square-root model are more complex and difficult to explain particularly in large equations.

The production function essentially gives the yield responses that will be obtained for various application rates of inputs. To work out the yields response, therefore, the quadratic production function, 3.2 was adopted:

$$Y = b_o + b_1H + b_2N + b_3N^2 + b_4HN \qquad 3.2$$

Where:

Y =	level of maize output (kg/ha)
b_o =	output obtained when inputs (H and N) are both zero (kg/ha)
b_1, b_2 and b_4 =	regression coefficients which measure the direct effects of the level of input on output.
b_3 =	rate of change in the slope of the response function.
H =	herbicide dummy. 0 where herbicide was not used and 1 where herbicide was used.
N =	fertilizer rate used (kg N/ha)
HN=	the interaction between the two variable inputs.

The production function was fitted to the data to determine yield responses to herbicide and fertilizer. There are other methods of reducing damage from *Striga*, but for the purpose of this study, herbicide coated seed and fertilizer was considered. The study utilized one type of fertilizer (N) and one type of seed (seed maize coated with imazapyr). Nitrogen was chosen because it has been shown to have various levels of activity in controlling *Striga* and improving yields. (Pietse *et al*., 1991; Agboli *et al*., 1991; Awad *et al*., 1991, Mumera *et al.,* 1993).

Ordinary least squares (OLS) regression method was used to estimate the model. OLS is a mathematical technique for estimating a regression line that summarizes and describes the functional relationship between a set of points. The technique is based on the principle of minimizing the sum of squared residuals.

To keep the estimation problem manageable, some simplifying assumptions are made in OLS estimation. These are assumptions about the regularity of the populations. For example, a fertilizer-yield experiment could be repeated many times at a certain fixed level of fertilizer x. Even though fertilizer application is fixed from experiment to experiment, not exactly the same yield would be observed each time. Instead there would be some statistical fluctuation of the Y values, clustered around a central value. If the probability of Y for a given x is given by p (Y/x) there will be many possible values of Y forming a population. There will be similar probability distribution for Y at any other experimental level of x. These peculiar populations will be difficult to analyse thus the simplifying assumptions of OLS;

1. The variance of the error term e should be a constant and equal to the variance of the Y i.e. $E(e_i) = var(e_i) = \sigma^2$. This is called constant variance assumption, i.e. homoscedastic. Changing the variance assumption leads to the problem of heteroscedasticity.

2. The covariance between e_1 and e_j should be equal to zero, i.e. $E(e_1 e_j) = cov(e_1 e_j) = 0$, for i not equal to j. This means that e_1 and e_j are independent i.e. the error terms are independent. If they are not independent, they serially correlated for time series data or autocorrelated for cross sectional data.

3. For a multiple regression equation, the explanatory variables should not be correlated with any other or with any linear combination of other explanatory

variables. When this assumption is violated, there is a problem of multicollinearity.

OLS estimation of the quadratic model is straightforward. In general form

$$Y= b_o+ b_1x^s+ b_2x^{2s} \qquad 3.3$$

It is nonlinear in x. It is however linear in the parameters b_0, b_1 and b_2. OLS is therefore applied quite easily after the transformation to get x^s and x^{2s} from the variable x.

3.4.2 Partial budget and marginal analysis

The profitability of *Striga* control using herbicide-coated seeds was worked out from a partial budget. Partial budget is used to arrive at the expected change in net benefits from individual treatments. This takes into account only those changes in costs and returns that result directly from the changes in treatments. Farm costs or returns that are unaffected by the changes are excluded from the calculation. The partial budget considered: -

1. The yields from each treatment
1. The cost of imazapyr
2. The cost of purchasing and application of fertilizer.

The budget components were expressed on per hectare basis. The price of maize used in the calculations was the average of the after-harvest prices received by the interviewed farmers at the end of 2001 long rains season, estimated at Kshs.9/kg. Fertilizer price and the cost of application was also obtained from the surveyed farmers, and this gave Khs.30/kg DAP, Kshs.26/kg CAN, and Kshs. 312/ha for labor for each application. The price of imazapyr, Kshs. 312/30g, was provided by the producer BASF in South Africa.

The purpose of marginal analysis is to reveal just how the net benefits from an investment increase as the amount invested increases. Marginal analysis involved comparing the costs that vary with the net benefits. Marginal rate of return (MRR) is the marginal benefit expressed as a percentage of the marginal cost. The MRR indicates what expected gains on the average in return for investment when changing from one treatment or technology to another.

3.4.3 Sensitivity analysis

It is in the nature of ex-ante studies that the data used are usually uncertain. The value of the output and the costs of the inputs are most likely to fluctuate in a liberalized economy. Thus it is worth looking at the sensitivity of the profits to fluctuating values of inputs and outputs. This analysis involves changing the parameters of a decision problem and studying how this affects the outcome. If the profits are sensitive, the use of the inputs is fairly risky. In this study, sensitivity analysis was carried out with respect to increases in price of imazapyr and fertilizer and a drop in the price of maize. Sensitivity analysis was done by varying the cost of herbicide-coated seed and fertilizer and the value of maize up and down within a range of 25 and 50% and their effect on rate of return observed.

3.5 Farmers' evaluation

3.5.1 Acceptability

To assess the acceptability of a technology, it must be analyzed from the farmer's perspective, which means much more than its biophysical performance and profitability. The adoption potential of herbicide-coated seed would be determined by the way farmers perceive the *Striga* control method and the rationale of their current practices. The farmers were asked questions on:

1) Practices: this investigated the type of seeds used by the farmers, whether improved or unimproved and the reasons for their choices. This determined the traits preferred by the farmers that can be incorporated in the final product.

Farmers were asked to state whether or not they would use herbicide-coated seed if it became available in the market and the quantities they would buy in each season.

2) Perception: information was sought on the farmers' reactions, opinion and expectation regarding the herbicide-coated seed; the information required here included the benefits and complaints the farmers could attribute towards the technology.

3.5.2 Willingness to pay (WTP)

This study made use of close-ended iterative approach to elicit the farmers' willingness to pay for using herbicide-coated maize seed for *Striga* control. The starting point amount consisted of the average cost of maize seed from the Kenya Seed Company as received by the farmers in the study area (Kshs 130/kg) and the cost of imazapyr (at 4US$ for 30g)[2]. This amount is approximated as follows:

25 kg/ha of seed maize and 30g/ha of imazapyr are required whose costs are Kshs. 130/kg of seed maize and Kshs. 12.48 for imazapyr for coating 1 kg of maize which adds up to Kshs 142.48/kg of imazapyr coated seed. To make responses from the farmers easier, the total cost was approximated at Kshs.150/kg for herbicide-coated seed. Since farmers prefer to buy seeds in different quantities, the starting point amount was Kshs 300 for the 2 kg bag, Kshs 1500 for the 10 kg bag, etc. This amount was adjusted upwards or downwards by Kshs 25/kg depending on the responses given until a maximum level of willingness to pay (WTP) was reached. The farmer was also required to state the quantity that he/she would be willing to buy at the prices for which he/she would have given a 'yes' response for both long rain and short rain seasons.

[2] The price is obtained from BASF, the producer in South Africa

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Profitability

4.1.1 Production function analysis

The purpose of production function analysis was to determine the effect of fertilizer and imazapyr on maize yield. The estimates of the parameters of the quadratic production function are presented in Table 3 below.

Table 3. Estimates of the Quadratic Production Function

Variable	Description	On-station	On-farm
	Constant	42	943
		(202)	(561)*
H	Herbicide dummy	1298.9	2763
		(272)***	(756)***
N	Fertilizer rate	37.5	11.9
		(13)**	(37)
N^2	Quadratic response to fertilizer	-0.54	-0.02
		(0.2)**	(0.60)
HN	Herbicide and fertilizer interaction	0.40	-0.40
		(0.20)	(0.70)
	F	27.30	6.40
	R^2	89%	45%
	Adjusted R^2	86%	38%
	Standard Error of the Estimates	365	1435
	Durbin-Watson statistic	2.005	1.731
	N	18	36

* Significant at 10% level
** Significant at 5% level
*** Significant at 1% level
Standard errors are in brackets

The production function model specification explained 89% and 45% of the variation in yield of maize at on-station and on-farm experimental sites respectively. This is given by the R^2 statistic, which is a measure of the goodness-of-fit of a given model specification. The adjusted R^2 was 86% and 38% for on station and on farm experiments respectively. The F-statistic was 27 and 6 for on-station and on farm experiments respectively and was significant at 1% level at both sites. This implies the existence of a linear relationship between the dependent variable and all the regressors specified in the model; and this indicates that all regressors jointly have some explanatory power on the model. The correlation coefficients for the data in this study are in appendix 3. They are within the acceptable limits. The regression results can therefore be accepted as unbiased estimate of the biotechnical condition. Durbin Watson test was used for data in this study and Durbin Watson values close to 2 were obtained indicating absence of first order serial correlation. The Breuch Pagan test was used to test for heteroskedasticity. The computed χ^2 value for the model in on farm and on station experiments were 7.83 and 4.56 respectively, while the tabulated chi-square value, at 4 degrees of freedom and 1% significant level is 13.2767. Since the calculated χ^2 in both cases were less than the tabulated χ^2 value, it means that the errors are homoscedastic.

The coefficient of H (herbicide) is positive, showing that there is a positive response of maize yield to herbicide application. Herbicide application as seed coating increased maize yields in both the on-station and the on-farm experimental sites. The coefficient of 2763 means that application of herbicide as seed coating increased the average maize yields by about 2.7 tons/ha at the on-farm experiment. This incremental yield was significant at 1% level. In the on-station experiment, application of herbicide increased the average maize yields by about 1.3 tons/ha. The yield increase was significant at 1% level.

The coefficient of N (nitrogen) was found to be positive. This gives the expected, that is there is a positive response of maize yield to applied fertilizers. This yield increase was significant at 5% level at the on-station experiments where 1 kg of nitrogen increased maize yield by about 37kg/ha. It is expected that maize yield responds to nitrogen application according to the law of diminishing marginal returns. This is shown by a negative sign for the coefficient of N^2. This quadratic response was significant at 5% level at the on-station experiment .The herbicide and fertilizer interaction (HN) did not give significant increases in yields at both sites. Although herbicide was significantly increasing maize yields, the non-response to HN interaction could be as a result of insignificant response to fertilizer.

Although fertilizer is known to increase maize yield, nitrogen failed the statistical test of significance at the on-farm experiments. In this case, the soils are likely to be well endowed with the nutrient so that the application of the same does not result in any significant yield increase. This hypothesis is strengthened by the fact that, after the suppression of *Striga*, the on-farm yields increased from 0.9 to 3.6 tons/ha without the use of fertilizer, thus indicating a high soil fertility level. Chege (1993) and Makokha (1995) also obtained similar results where the Nitrogen coefficients were always statistically insignificant. They both concluded that the nutrient was not limiting in the respective soils where the experiments were conducted.

4.1.2 Partial budget and marginal analysis

After the agronomic analysis of technological applications, it is important to do an economic analysis because the farmers are concerned with the benefits and costs of particular technologies. Partial budget was applied as a method of organizing experimental data and information about the costs and benefits of various alternative treatments. The partial budget in Table 4 gives the total variable costs and the net benefits of each treatment in the on-farm and on-station experiments.

Table 4. Partial budget for various rates of fertilizer and herbicide applications in maize production

		Without herbicide			With herbicide		
Fertilizer rates (kgN/ha)		0	30	60	0	30	60
Average yield (kg/ha)	On-farm	985	1200	1644	3663	3761	3575
	On-station	137	495	459	1246	2507	2236
Gross field benefits	On-farm	8865	10800	14796	32967	33849	32175
	On-station	1233	4455	4131	11214	22563	20124
Cost of herbicide (Kshs/ha)		0	0	0	312	312	312
Cost of fertilizer (Kshs/ha)		0	5010	8000	0	5010	8000
Cost of labor to apply fertilizer (Kshs/ha)		0	312.5	625	0	312.5	625
Total variable costs (Kshs/ha)		0.0	5322.5	8625	312	5634.5	8937
Net benefits	On-farm	8865	5477.5	6171	32655	28214.5	23238
	On-station	1233	-867.5	-4494	10902	16928.5	11187

The results show that the application of herbicide results into higher net benefits in both on-farm and on-station experimental sites, even where no fertilizer is used. In the on-farm experiments, the use of herbicide without fertilizer increased net benefits from Kshs. 8,865 to Kshs 32,655 per hectare, while in the station experiment, the net benefits increased from Kshs. 1,233 to Kshs. 10,902 per hectare. The use of herbicide alone is the most profitable treatment in on-farm experiment, since fertilizer usage lowered the net benefits. At the on-station experiment, it was more profitable to use herbicide in combination with 30 kgN/ha since it increased the net benefits from Kshs. 10,902 to Kshs. 16,929 per hectare. The use of fertilizer alone did not increase net benefits. In the on-station experiments, fertilizer use resulted into losses.

Marginal analysis involves comparing the variable costs with the net benefits. Marginal returns to a technology indicate expected gains, on the average, in terms of the return to investment when moving from one treatment or technology to another. For the farmers to adopt a new technology, it is generally assumed that the marginal return should be above 50% (CIMMYT, 1988).

Table 5. Marginal analysis for various rates of fertilizer and herbicide applications in maize production

Herbicide rate		Without herbicide			With herbicide		
Fertilizer rates (kgN/ha)		0	30	60	0	30	60
[a]Herbicide	On-farm				76.25	72.88	54.70
	On-station				30.99	57.04	50.26
[b]Fertilizer	On-farm		-0.64	0.21		-0.83	-1.51
	On-station		-0.39	-1.10		1.13	-1.74
[c]Combined herbicide and fertilizer	On-farm					3.43	-1.51
	On-station					2.79	-1.74

Key:

[a] compares with and without herbicide
[b] Compares higher to lower fertilizer rates
[c] Compares combined treatment with no treatment

For the majority of situations, the minimum rate of return acceptable to farmers will be between 50 and 100%. For technologies representing an adjustment in current farmer practice (such as the planting of herbicide coated seed), then a minimum rate of return as low as 50% may be acceptable (CIMMYT, 1993). In estimating a minimum acceptable rate of return, something must be added to the cost of capital to repay the farmers for the time and effort spent in learning to manage a new technology.

Herbicide treatment led to rate of returns that are higher than minimum acceptable to farmers, both on-station and on-farm. This also included cases where herbicide is used in combination with fertilizers. For instance, in the on-farm experiment, the use of herbicide alone increased net benefits by Kshs. 23,790/ha at an increased cost of Kshs. 312/ha. This gives a marginal return of 76.25 per hectare, implying that for every shilling invested in herbicide, the farmer recovers the cost, and on top of that receives an additional Kshs. 76.25, which is a very high rate of return of 7625%.

With untreated seed, increasing the rate of fertilizer application mostly resulted in negative marginal returns, except at 60kgN/ha whose marginal return of 21% is below the acceptable minimum. Only one fertilizer level gave an acceptable marginal return and this was with herbicide coated maize seed. 30kgN/ha combined with the herbicide on-station has a marginal return of 113%. This shows that in order to get good profits from fertilizer use, *Striga* must first be controlled.

4.1.3 Sensitivity analysis

Table 6. Sensitivity of imazapyr, fertilizer and maize to changes in their prices

Increase in imazapyr price		25%						50%					
		No herbicide			With herbicide			No herbicide			With herbicide		
kgN/ha		0	30	60	0	30	60	0	30	60	0	30	60
H	On-farm				60.8	58.1	43.6				50.5	48.25	36.1
	On-station				24.59	45.4	40				20.3	37.69	33.2
N	On-farm		-0.6	0.2		-0.8	-1.5		-0.6	0.21		-0.83	-1.5
	On-station		-0.39	-1.1		1.13	-1.7		-0.4	-1.1		1.13	-1.7
HN	On-farm					3.37	-1.5					3.31	-1.5
	On-station					2.73	-1.7					2.68	-1.7
Increase in fertilizer price		25%						50%					
		No herbicide			With herbicide			No herbicide			With herbicide		
kgN/ha		0	30	60	0	30	60	0	30	60	0	30	60
H	On-farm				76.25	72.9	54.7				76.3	72.88	54.7
	On-station				30.99	57	50.3				31	57.04	50.3
N	On-farm		-0.7	0		-0.9	-1.4		-0.8	-0.17		-0.89	-1.3
	On-station		-0.51	-1.08		0.73	-1.6		-0.6	-1.07		0.45	-1.5
HN	On-farm					2.63	-1.4					2.07	-1.3
	On-station					2.1	-1.6					1.62	-1.5
Drop in maize price		25%						50%					
		No herbicide			With herbicide			No herbicide			With herbicide		
kgN/ha		0	30	60	0	30	60	0	30	60	0	30	60
H	On-farm				56.94	54.41	40.8				37.6	35.94	26.9
	On-station				22.99	42.53	37.4				15	28.02	24.6
N	On-farm		-0.73	-0.09		-0.88	-1.4		-0.8	-0.4		-0.92	-1.3
	On-station		-0.55	-1.07		0.6	-1.6		-0.7	-1.05		0.07	-1.4
HN	On-farm					2.33	-1.4					1.22	-1.3
	On-station					1.84	-1.6					0.89	-1.4

Sensitivity analysis shows that the use of imazapyr is not sensitive to up to a 50% increase in its price since the marginal return remains above the minimum acceptable level. In the combined analysis, the 30kgN/ha in combination with herbicide was the only option that was acceptable or had positive rate of return at both sites. A higher fertilizer rate led to negative marginal returns.

The results of sensitivity analysis also indicate that a 25% increase in fertilizer price would make its use unprofitable in the presence of *Striga* infestation when no herbicide is used. However, using the lower fertilizer rate in combination with herbicide results into rates of return that are acceptable only on-station. A 50% increase in fertilizer price led to unacceptable rate of return at both sites, even when used in combination with herbicide.

Finally, sensitivity analysis shows that a 50% drop in the estimated price of commercial maize results into acceptable rate of return for herbicide usage at both sites. However, the use of fertilizer alone becomes fairly risky even at 25% drop in the price of commercial maize as it resulted into negative rates of return at both sites. A combination of herbicide and 30kgN/ha is acceptable on-station when the price of commercial maize is reduced by 25%. However, when the commercial maize price drops by 50%, even a fertilizer-herbicide combination is unacceptable at both sites.

4.2 Farmers practices, perceptions and willingness to pay

4.2.1 Choice of seeds

Seed use can depend on many factors, including the prices at which seed is available from alternative sources, farmers' incomes, tastes and preferences and the type of the crop (Rohrbach *et al.,* 1997). Generally, most farmers use local maize varieties as shown in table 7.

Table. 7. Maize seed varieties used for long rains and short rains season

(N=123)

	Long rains	Short rains
Variety	% of the total	% of the total
[a]Local white	38.2	26.8
[b]Local yellow	34.1	41.5
[c]Hybrid	26.9	10.6
Unknown	0	0.8
None	0.8	20.3

[a]Rachar, maragoli, jowi, anyore
[b]Nyamula, kipendi
[c]PH1, H511,H513, H614, H632

72.3% plant the local varieties (both white and yellow) during the long rains season and 68.3% during the short rains season. On the other hand, only 26.9% of the interviewed farmers were using hybrid seed maize varieties during the long rains season and this further dropped to 10.6% during the short rains season. Most farmers believe that the hybrid maize varieties are higher yielding than their local varieties, and the reasons most frequently cited by the farmers for not growing hybrid varieties were susceptibility to drought, *Striga*, low soil fertility and lack of money to purchase seed. Money problems make the use of hybrid maize seed risky with erratic rains (especially short rains), while fertilizer is too expensive. The local varieties are mostly white, yellow or a combination of both colors. The local white variety is the most preferred during the long rains season. This variety is believed to give a higher yield and fetches a higher market price than the yellow variety. However, during the short rains season, there are more farmers who grow the local yellow variety because it is early maturing and is believed to have some tolerance to *Striga*, low fertility and drought.

Farmers will save seed each year from their own harvest for a number of years following an initial purchase of certified seed. However they frequently renew their stock of hybrid seed, but tend to retain seed of local varieties for much longer periods. About 32.5% buy seed during the long rains season and only about 12.2% do so during the short rains. The types of seed purchased are usually the hybrid varieties, although some few farmers buy the local variety seed. About 61% of the farmers use seed types that have been recycled more than 3 times, mostly for the local varieties, although some farmers do recycle hybrids.

Farmers cite several reasons for choosing different varieties. This variety preference has led to switching varieties between seasons.

Table 8. Important variety attributes

N = 123

Choice	Long rain	Short rains
	% of respondents mentioning	% of respondents mentioning
High yields	52.8	32.5
Early maturity	41.8	40.7
Cheap	2.5	3.3
Available	9.9	7.3
Striga tolerance	4.1	5.7
Low fertility tolerance	3.3	2.4
Drought tolerance	10.6	13.8
Good taste	18.9	10.6

Essentially, yield is the key issue in adopting a seed variety. Other factors are important, e.g. maturity period, good taste, resistance to disease and drought tolerance. According to the interviewed farmers, the most preferred attributes are "early maturity" and "high yielding". "High yielding" is the most preferred attribute during the long rains season while in the short rains season, “early maturity” is considered to be the best trait. “Drought tolerance” is also considered to be important, especially during the short rains because the rains during the short rains season are sometimes erratic. “Good taste” is important because a proportion of maize is consumed when roasted or boiled. A few farmers chose *Striga* tolerance because *Striga* infestation affects all maize varieties and even the local yellow variety is not completely tolerant to *Striga*. Low fertility tolerance was also not very important because the farmers understand that yields can be improved with soil fertility improvement technologies. The cost of seed and its availability, though important, may not have taken a top priority, probably because most farmers use their own recycled seed.

4.2.2 Soil fertility

According to this study, about 31.7% of the farmers feel that the soils in their farms are poor. About 20.3% of the farmers think that soil fertility is not a problem while the rest think of it as a minor (18.7%), medium (30.1%) and severe (30.9%) problem. The soils are mostly loamy (53.3%), while the rest are sandy (23.8%) and clay (23%) types. To make the soils more productive, farmers use different types of fertilizer, which they also believe it has some effect on the level of *Striga* infestation.

Table 9. Types of fertilizer used and the farmers’ perception on their effect on *Striga*.

Fertilizer type	% of farmers using	Effect on *Striga* (% of all farmers)			
		Reduce	Increase	No effect	Don’t know
Manure	50.4	64.4	6.8	15.1	13.7
DAP	23.6	20	8.9	22.2	48.9
CAN	7.3	10	0	16.7	73.3
Urea	0	0	0	0	100

The above table shows that, most commonly used types of fertilizers are DAP, CAN and manure. Manure is the most widely used among the interviewed farmers, and most of the farmers (including those who do not use it) feel that it is able to reduce *Striga* infestation in maize and increase yields even in the presence of *Striga*. Many farmers do not know the effect of inorganic fertilizer on *Striga*, either because of non-use or because they have never been keen to observe. Only a few farmers top dress maize using CAN.

4.2.3 *Striga* control

Striga affects a large portion of acreage under maize in the study area. According to the interviewed farmers, only 32% of their maize area is *Striga* free, while 21% of the maize area has low, 12% has medium and 33% has high *Striga* infestation. The farmers have different views about the *Striga* problem. About 5.7% of the farmers feel that *Striga* is not a problem, just because they do not have it in their farms. All the rest have *Striga* in their farms and they rank the problem as minor (13.8%), medium (25.2%) and severe (55.3%). *Striga* infestation leads to severe yield losses, which the farmers approximate at about 50% in both seasons.

The farmers know a number of *Striga* control methods, although not all the farmers use these known methods. These methods are summarized in the table 9 below. Only 2 of the farmers who had not participated in the trials involving herbicide-coated maize knew about them.

Table 10. The *Striga* control methods known and used by the farmers

N = 123

Method	Known	Used
	% of all farmers	% of all farmers
Organic fertilizer	59.3	41.5
Inorganic fertilizer	27.6	12.2
Fallowing	19.5	11.4
Hand pulling	81.3	74
Normal weeding	67.5	67.5
Crop rotation	40.7	30.9
IR-maize	19.5	0
Others	37.4	37.4

The other methods used by the farmers include intercropping, use of *tithonia* biomass and plant residues. The farmers admitted that although they used these *Striga* control methods, none of them has managed to eradicate the *Striga* problem. Probably that is why about 8.9% of the farmers do not use any *Striga* control method. The main reason why the farmers use a particular *Striga* control method was to reduce *Striga* in their maize fields (65.9%). The other reasons include lack of alternative methods (21.1%), cheap (2.4%) and not harmful to other crops (1.6%).

4.3 Farmers' evaluation of the performance of the herbicide-coated maize

4.3.1 Yields

About 81.8% of the 22 farmers who have participated in the trials involving herbicide coated maize seeds felt that yields from the maize were good. Where the yields were not good, farmers attributed this to the rains that were insufficient during that particular season; otherwise the maize was expected to do better. The biggest concern was that the maize was taking a longer time to mature than the local varieties.

About 83.7% of the non-participating farmers also believe that hybrid maize varieties, though late maturing, give higher yields than their local varieties. However, they were concerned about the inability of the hybrid variety to withstand low rainfall and low fertility, which highly affect yields. This evaluation is similar to the one obtained by Fumo *et al*., (1994), where the farmers in Mozambique cited late maturity as the most common disadvantage of the improved varieties.

Yields are considered a very important attribute while selecting the types of maize variety to grow. On average, maize yields for the interviewed farmers are about 698 kg/ha for the long rains and 723 kg/ha for the short rains. From the trials conducted during the study, the results presented in 4.1.2 showed that *Striga* control using herbicide seed coating more than doubled maize yields. This is quite attractive for farmers who need to produce more maize to feed their families.

4.3.2 Ability to control *Striga*

From the trials conducted in this study, application of herbicide totally controlled *Striga* during the first 10 weeks of planting. In the plots having untreated seed, *Striga* emergence was as early as the 6^{th} week after planting. A few *Striga* plants (about 0.1 plants /m^2) were observed during the 12^{th} week of planting herbicide-coated seed, which is incomparable to about 31 plants/m^2 observed for the same period where no herbicide was used. This is shown in figure 2.

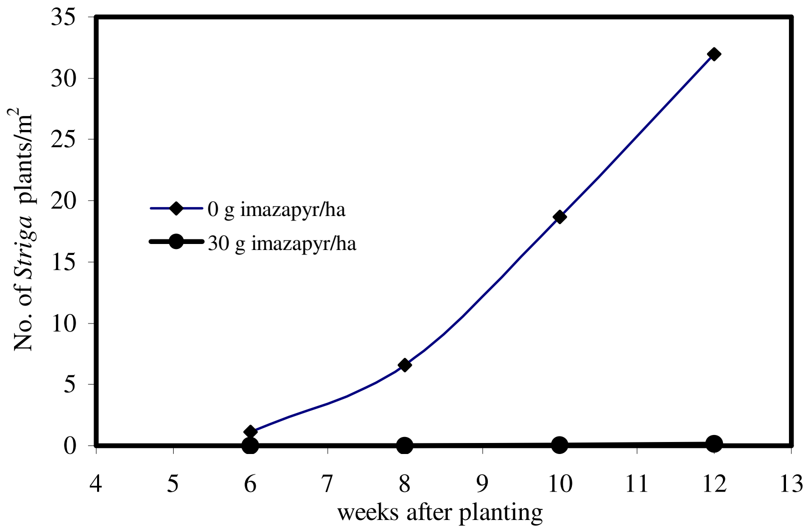

Figure 2. The average effect of imazapyr on *Striga* emergence at on-station and on-farm experiments during long rains, 2002

From experimental results in this study, herbicide treatment is capable of delaying *Striga* emergence until late in the season and when they do appear they are very few. Delayed infestation leads to a significant decline in parasite emergence and an overall increase in maize yields (Berner *et al.,* 1994). According to Berner *et al.,* (1994), there is a critical window of infection prior to 4 weeks plant age, beyond which parasite emergence decreases. *Striga* emergence at 12 weeks plant age in the treated seed protects the maize through the critical infection period, thereby increasing yields.

About 95.5% of the trials participating farmers termed as good the ability of herbicide coated maize seed to control *Striga*. The non-participating farmers felt that they spend a lot of extra resources controlling *Striga*, yet more yields continue to be lost. On average, *Striga* control costs them Kshs 1,269/ha and Kshs 935/ha for long rain and short rain seasons respectively. This is usually due to the cost of labor for hand pulling and destroying of the *Striga* plants.

4.3.3 Intercropping

Intercropping maize is a common practice in western Kenya. About 61.8% of the interviewed farmers intercrop maize with other crops during the long rains, while the figure for the short rains season is about 43.1%. Maize is often intercropped with beans, cowpeas, groundnuts, sorghum, millet, green grams, cotton and sweet potatoes. The intercrops ranged from one to four in a maize plot. Intercropping is done either by having straight rows between those of maize, broadcasting or by dibbling. Unlike the IR maize, which is resistant to imazapyr, these intercrops are sensitive. This implies that a lot of care must be taken if other plants are intercropped with herbicide-coated maize. Although the trials did not involve intercropping with herbicide-coated maize, research has shown that it can be done as close as 15 cm from the treated seed (Kanampiu, 2002), making possible for farmers to continue intercropping.

Most of the interviewed farmers (75.6%) felt that it was good if the herbicide would not interfere with the intercrops, which supplemented maize in their diets. The farmers who randomly broadcast the legume intercrops into maize expressed willingness to adjust their intercropping style to provide enough distance for the intercrop from the treated seed.

4.3.4 Cost of Hybrid Maize

One of the major reasons cited for low utilization of hybrid seed by the farmers is its price. High cost of seed maize was cited as a problem by 73.2% of the respondents. Money has to be found at the beginning of the season, yet credit facilities are rarely available for agriculture. Only 1.6% of the respondents had ever received credit, and none of it was meant for maize production. Generally, the price of local varieties is lower than that of hybrids. On average, the farmers buy the hybrid seeds for Kshs. 130

per kg while the local varieties are available at Kshs. 29 per kg. However, very few respondents cited low price as one of the most important attributes when they were asked to state what influences their choice of favorite seed type (table 8). This may be due to the fact that most farmers do not buy seeds but prefer recycling from previous harvest. The issue of cost of the seed therefore does not arise during the decision making process.

Yield or quality advantages of the new technology were unclear or uncertain, especially to the trials non-participating farmers. This study found that that the farmers would be willing to buy the treated seed at a higher price than the local varieties only if it is effective in controlling *Striga* and gives them higher yields with lower risks.

4.3.5 Recycling of seed

When buying the seed to plant, the decision by farmers to change varieties already adopted is termed variety replacement, whereas the decision to obtain fresh seed stocks of the same variety is termed seed renewal (Rohrbach *et al.*, 1997). If the farmer decides to retain seed from previous harvest then it is termed seed recycling. Recycling of seed is a popular practice among the interviewed farmers, with 66% of the interviewed farmers practicing it during the long rains and 67.6% practicing it during the short rains. Farmers reported that maize yields of hybrid varieties declined with years of recycling. With the local varieties, several farmers suggested that careful seed selection helps sustain yields.

About 40% of the respondents have no problem renewing the herbicide-coated seed each season if it performs well. However, another 40% would like to recycle when they cannot buy new seed. The herbicide-coated seed would not be effective in controlling *Striga* if recycled since it is the herbicide that destroys *Striga*. This means that the farmers would have to renew their seed every season if they were to adopt the growing of the herbicide-coated maize seed.

4.3.6 Willingness to pay

Farmers were found to be generally interested in herbicide treated seed as a new method of *Striga* control. At least 93.7% of the respondents expressed interest in buying the treated seed. The reasons given by the few who were found to be not willing to buy the treated seed were lack of cash (3.3%), no *Striga* problem (3.3%) and "had stopped planting maize in the *Striga* infested plot" (0.8%). The maximum price the farmers were willing to pay was ranging between Kshs. 50/kg and Kshs. 500/kg both in the long rains and short rains seasons.

The mean price that the farmers are willing to pay is Kshs. 150.20 per kilogram. This price is above the current price of locally produced seed, which is around Kshs. 130 per kilogram. Willingness to pay a higher price for the technology is likely to be due to the fact that *Striga* is considered a major problem causing severe yield losses and expensive to control. At the same time, the control methods currently used by the farmers are not very effective thus discouraging investment in maize productivity enhancing technologies. The fact that herbicide coated seeds will increase yield and control *Striga* reduces risks thus encourage investment in the technology.

At this mean price, the farmers would buy on average 3.28kg and 1.29 kg of treated seed maize each in the long rains and short rains season respectively. This would constitute 45% and 24.2% of the total seed required in the long rains and short rains seasons respectively. This implies that the farmers would not plant their entire maize plots to herbicide-coated seed when it becomes available. Most probably, the treated seed would be planted only where there is heavy infestation and the remaining portion put to other favorite varieties, especially the local seed. If this happens, it implies that the farmers need to continue using the other available *Striga* control methods for the portions of their plots not planted with herbicide treated seed in order to eradicate *Striga*. May be they will adopt when the benefits become more clear.

Among the trials non-participating farmers, Rachuonyo District respondents offered the highest price of Kshs 172 per kilogram, while Vihiga District respondents offered the lowest price of Kshs. 126.04 per kilogram of treated seed. Siaya and Homabay districts' farmers would be willing to pay Kshs 130 and 137.50 per kilogram of herbicide coated seeds respectively. The farmers who have participated in the field trials offered a price of Kshs. 203.40 per kilogram of treated seed, while those who have not would be willing to pay Kshs 138.60 per kilogram of treated seed. This shows that although the farmers are willing to take up the technology, adoption of the technology would not be uniform across the *Striga* infested districts. Trials participating farmers have an idea of the performance of the technology and this may have enhanced their willingness to pay. This means that exposing more farmers to the trials involving the technology may enhance its adoption, as the farmers would become surer of their investment.

About 99% of the interviewed farmers grow maize during the long rains season, but this reduces to 80% during the short rain season. Area under maize also reduces during the short rain season for those who farm for 2 seasons. The farmers are willing to buy more treated seed during the long rains season than in the short rains season at each price level as shown in the Figure 3 below. This may be due to the general factors that make the farmers grow less maize during the short rain season e.g. unreliable rainfall. The demand for the technology is therefore going to be lower in the short rains season. If this happens, it implies that *Striga* multiplication will continue in the short rains when the technology is not in use. The farmers should be encouraged to use the technology even in the short seasons for effective *Striga* control.

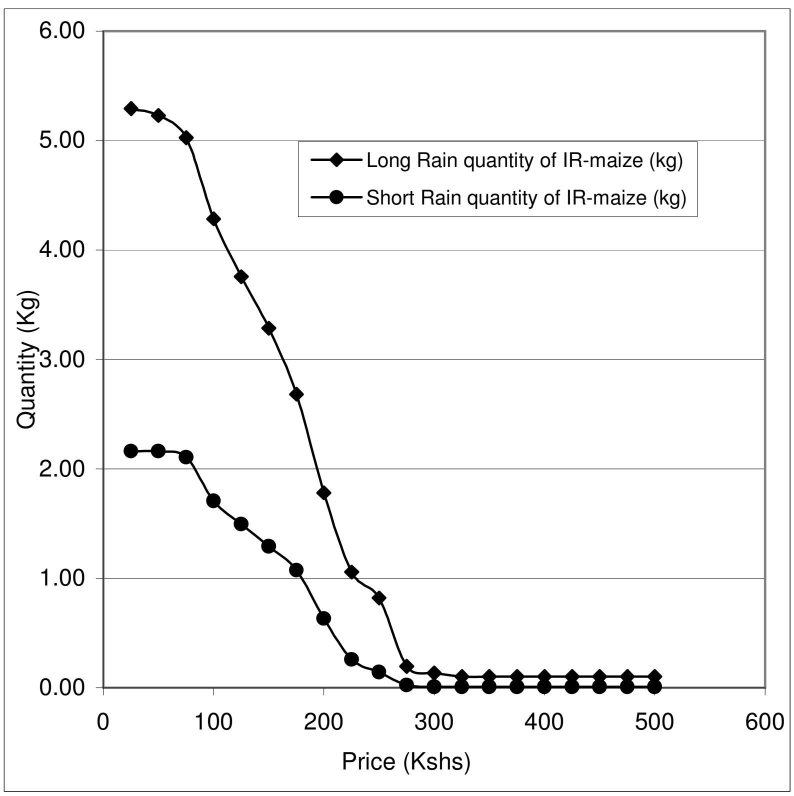

Figure 3. Mean demand for IR-maize

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary and conclusions

The broad objective of this study was to undertake an economic analysis of herbicide-coated seed in controlling *Striga* in smallholder maize production. To achieve this objective, maize yield response functions for fertilizer and herbicide application were estimated for experimental data using the quadratic specification of the production function. A calculation of partial budget and marginal analysis from the experimental data were then used to determine the profitability of herbicide and fertilizer use in maize on smallholder farms in western Kenya. A further survey of potential users of the technology using the contingent valuation method was used to determine whether there would be a demand for the herbicide treated seed.

The results of this study show that, farmers in the study area prefer the local varieties to the hybrids because these local varieties are cheaper, early maturing and more tolerant to drought, low soil fertility and *Striga*. Most of the seed is recycled. Farmers like seed varieties that are high yielding and early maturing. The local varieties that are commonly used are early maturing, but their yields are lower than for hybrids.

Striga was found to be a major problem to most of the farmers in the study area. The farmers use a number of control measures, but none is effective in managing the *Striga* problem. From the farmers' evaluation and trials conducted during the study, herbicide coated seed was found to be effective in controlling *Striga* in maize and resulted in good yields. Farmers like intercropping maize and a slight modification in intercropping the herbicide-coated maize seed is possible. This means that the herbicide seed technology would be acceptable to the farmers. The biggest concern is the price of herbicide-coated maize, which made some farmers want to know if herbicide coated maize can be recycled to minimize costs.

The mean price that the farmers are willing to pay per kilogram of the herbicide-coated maize seed is Kshs. 150/kg, which is above the average price of hybrid seed that farmers are currently using. Farmers are willing to buy more treated seed during the long rains season. Integrating the farmers' preference for early maturity and drought tolerance into the hybrid seed would, therefore, improve adoption during the short rains season.

The study found herbicide-coated maize to be highly profitable. Production function analysis showed that herbicide treatment resulted in a much larger increase in the yields than the use of fertilizer, which was only significant on-station. The use of fertilizer, even on-station, would not be profitable at current prices when *Striga* is not controlled. Increasing fertilizer levels even after suppressing *Striga* does not always improve the yields. This means that optimal fertilizer rates for the different sites need to be determined first before they can be used with imazapyr in an integrated *Striga* control management so as to improve both yields and net returns.

5.2 Recommendations

The findings from this study show that herbicide coated seed technology has the potential to reduce losses from *Striga* if it is adopted by the farmers. Effort directed at involving other stakeholders, especially extension agents, in taking trials to more places and to reach more people so as to improve adoption will be beneficial. The farmers need to be convinced that the technology would be profitable at the prevailing maize prices, since the farmers consider hybrid seed to be expensive. Capital to purchase inputs was found to be limiting and credit facilities should be made available to improve purchasing power for the farmers so that they can buy improved seed and discourage recycling. Organizations working with farmers should assist them to establish community based hybrid seed production units to make them available at lower price. Further work should be done on the hybrid seed to reduce maturity period and improve resistance to drought and low fertility in order to improve adoption.

The study had its limitations especially time and funds. This lead to coverage of only 4 out of the 17 districts known to be affected by *Striga*. The trials were also entirely researcher managed with the farmers only providing the plots. The results of this study suggest that the next round of trials should be farmer managed to estimate the economic efficiency of the technology under the farmers' conditions. More variables should be included in the analysis so that effect of other physical and environmental factors can be captured. A wider geographical spread of trials on representative soils should be carried out for more accurate economic assessment of the use of fertilizer. Since the level and severity of *Striga* infection vary in the districts, future studies should cover more districts.

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CHAPTER 7: APPENDIX

7. 1. Questionnaire

EX-ANTE EVALUATION OF THE ECONOMIC POTENTIAL OF HERBICIDE COATED MAIZE SEED IN THE CONTROL OF *STRIGA* IN WESTERN KENYA

Questionnaire for interviewing farmers

General information

Enumerator's name..

Questionnaire serial number...

Date of interview...

Name of the household head: first ....last

.........................sex……….

Name of the respondent: first.......................................last ....sex………

Period during which the respondent has operated the farm………………………….

District……………………………

Division…………………………..

Location…………………………..

Sub location………………………

Village..……………………..

GPS of the homestead:

Latitude………………………

Longitude…………………

A) **Household profile**

	First name	Last name	sex	Age	Occupation		Parenthood	Marital status	Education level	
			Male…….1 Female….2	(Years)	Primary Farming………1 Business………2 Farm worker…..3 Civil servant…4 casual worker…5 retired…………6 student.............7 Others(specify)	Secondary (same)	Relation of the member to the household head Head…………1 Spouse………..2 Son/daughter…..3 Parent…………4 Grandchild……5 Son/daughter-in-law…6 Relative……….7 Servant……….8 Others (specify)	What is the marital status of the household member Married monogamous…1 Married polygamous…2 Divorced………3 Separated………4 Widowed……….5 Single…………6	Highest level of education achieved by the household members Primary ….1 Secondary**…2** Post-secondary…3	No. of years

B) General farming activities

Total land owned (acres)				
	Owned	Rented in	Rented out	Communal
Cropland				
Open pasture				
Timber yard				
Wasteland				

Cropping pattern for 2001 long rain (LR) and short rain (SR) season

Field	Soils		Surface area (acres)	Crop grown	variety	% infested by Striga, by category of intensity				Total Production			
	Fertility V.poor……1 Poor………2 Average…..3 Good…….4 V.good…..5	Type Sandy.....1 Loamy…2 Clay…...3				none	low	medium	high	Long rain		Short rains	
										actual	Without Striga	actual	Without Striga

C) Maize production

C/1 What maize varieties did you grow last year (2001) and what was the seed source?

Variety	Quantity (kg)		Cost (Kshs/kg)		Source of the seed Bought seed….1 1st recycled…..2 2nd recycled….3 3rd recycled….4 >3rd recycled…5		Reasons for choosing the seeds Higher yields…..1 Cheap…………..2 Early maturity…3 Available………4 Good taste……..5 Others (specify)
	LR	SR	LR	SR	LR	SR	

C/2 What fertilizer did you use last year (2001) and what are your views on their ability to control *Striga*?

Fertilizer type	Quantity used		Cost		Views on it's potential to limit Striga Reduces *Striga*……1 Increases *Striga*……2 No effect…………...3 Don't Know………..4
	LR	SR	LR	SR	

C/3What other maize production inputs did you use last year and what was their cost?

Non-recurrent expenditures				
Input type	Long rains		Short rains	
	quantity	Price	quantity	Price
Bush clearing Family labour				
Hired labour				
ploughing Hire of tractor/ox-plough				
Family labour				
Hired labour				
Planting Family labour				
Hired labour				
1st Weeding Family labour				
Hired labour				
2nd Weeding Family labour				
Hired labour				
Topdressing Family labour				
Hired labour				
Harvesting Family labour				
Hired labour				
Post-harvest processing Family labour				
Hired labour				
Pest control				

C/3 Sales
C/3.1 Did you sell maize last year? Yes/no..................
C/3.2 if yes, where did you sell it? 1................................2....................................
C/3.3 What was the selling price of maize last year?
Before the harvest of long rains (Kshs)……………
After the harvest of long rains (Kshs)......................
Before the harvest of short rains (Kshs).............
After the harvest of short rains (Kshs)................
C/4 What major maize production problems do you experience? How do you perceive them?

Problem	How do you perceive the problem			
	No problem	Minor problem	Medium problem	Severe problem
(1) High costs of inputs				
(2) Unavailability of inputs in good time				
(3) Varieties are low yielding				
(4) Poor soils				
(5) Insufficient rainfall				
(6) *Striga* infestation				
(7) Pests and diseases				
(8) Other problems (specify)				

D) Institutional support
D/1Extension services over the last two years

Source of extension	Total No. of contacts		No. of times Striga was discussed	
	2000	2001	2000	2001
M.O.A				
Farmer group meetings				
Field days				
Others (specify)				

D/2 Credit over the last two years

Year	Source	Total amount	Amount spent on maize inputs
2000			
2001			

E) *Striga* related problems and Farmers evaluation

E/1 What method(s) do you know and which methods do you use for controlling *Striga*?............................

Methods	Known	Used
(1) inorganic fertilizer		
(2) organic fertilizer		
(3) Fallowing		
(4) Hand pulling		
(5) Crop rotation		
(6) Herbicide coated seeds		
(7) Others (specify)		

E/2. Why did you choose to use the method(s)

(1) Cheap
(2) Available
(3) They do not harm other crops
(4) They reduce damage from *Striga*
(5) Others

(specify)……………………………………………………………………

E/3 Estimated costs of controlling *Striga.*

LR			SR		
activity	units	costs	activity	units	costs

E/4. Suppose there is a new maize hybrid variety that is able to control *Striga*. This maize seed is coated with a chemical that kills the *Striga,* which means higher maize yields and lower costs of controlling *Striga*. However, this seed is not effective if recycled since it is the chemical and not the seed that destroys *Striga.* The seed is special in that the chemical cannot destroy it, but the chemical will destroy other ordinary maize seeds. However, this seed is not yet available in the market.

E/4.1 Have you ever heard of it? Yes/no..............................
E/4.2 If yes, how did you come to hear of it?.......................

1) Through a neighbour
2) Through a friend
3) Through extension agents
4) Through participating in the trials
5) Other sources (specify)………………………………………………… …………………………………………………………………………….

E/4.3 Would you be interested to buy the herbicide-coated seeds if they became available in the shops? Yes/no..........................

E/4.4 if no, give reasons for your answer.

....………………………………………………
………………………………………………………………………………
………………………………………………………………………………
……………..…………………
…………………

E/5 Evaluation of costs and benefits of herbicide coated seeds

	How do you perceive it				
Attribute	Good	Medium	Bad	Don't know	Comments
Increased maize yields					
Lower cost of *Striga* control					
Intercropping					
Cost of hybrid maize					
Recycling					

E/6 Comparing the herbicide coated seeds and the other *Striga* control methods, what are your views?

(1) Very good
(2) Good
(3) Average
(4) Not good
(5) Don't know
(7) Other comments……………………………………………………………

E/7. If the herbicide-coated seeds were available in the shops, how much would you be willing to pay for them and what quantities would you buy?

Starting point amounts Kshs (1) Kshs 300 for 2Kg bag……..

(2) Kshs750 for 5Kg bag…........

(3) Kshs 1500 for a 10Kg bag….......

Price (Kshs)	Willingness to pay and amount	
	Long rains	Short rains
	Yes/no………Amount………..	Yes/no………Amount………..
	Yes/no……… Amount………..	Yes/no………Amount………..
	Yes/no……. Amount………..	Yes/no………Amount………..
	Yes/no……. Amount………..	Yes/no……. Amount………..
	Yes/no……. Amount………..	Yes/no……. Amount………..
	Yes/no……. Amount………..	Yes/no……. Amount………..
	Yes/no……. Amount………..	Yes/no……. Amount………..
	Yes/no……. Amount………..	Yes/no……. Amount………..
	Yes/no……. Amount………..	Yes/no……. Amount………..
	Yes/no……. Amount………..	Yes/no……. Amount………..
	Yes/no……. Amount………..	Yes/no……. Amount………..
	Yes/no……. Amount………..	Yes/no……. Amount………..

Thank you

7. 2. Summary of trials results

	N	H	Yield		Striga counts			
			Mean	stdDev	Week 6	Week 8	Week 10	Week 12
Farmer	0	0	985	764	1.78	7.12	21.01	44.11
	30	0	1200	980	1.66	6.56	21.44	35.18
	60	0	1644	1416	1.7	7.51	21.17	38.29
	0	30	3663	1459	0	0.01	0.13	0.35
	30	30	3761	1415	0	0	0	0.14
	60	30	3575	2249	0	0.01	0.01	0.11
Station	0	0	137	147	0	6.07	13.61	17.68
	30	0	495	235	0	4.31	12.53	17.51
	60	0	459	217	0	6.58	14.53	17.05
	0	30	1246	287	0	0	0	0
	30	30	2507	434	0	0	0	0
	60	30	2236	554	0	0	0	0

7.3. Testing for multicollinearity (production function model) Partial correlation coefficients

1. On farm site

	Herbicide	Fertilizer
Herbicide	1	
Fertilizer	-0.0577	1

2. On station site

	Herbicide	Fertilizer
Herbicide	1	
Fertilizer	-0.4915	1