FARMER PERCEPTIONS, USE AND PROFITABILITY OF BIOFIX® ON SOYBEAN *(GLYCINE MAX)* PRODUCTION IN WESTERN KENYA

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DECLARATION AND APPROVAL

DECLARATION

This thesis is my original work and has not been presented for award of a degree in any other University.

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APPROVAL

This thesis has been submitted for examination with our approval as Supervisors.

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DEDICATION

This thesis is dedicated to all smallholder farmers in Africa whose contribution to global food security is invaluable.

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ABSTRACT

Research on the use of *Rhizobia* inoculants to enhance BNF has been conducted in Africa since 1950's. It has demonstrated the benefit of the use of inoculation on legumes in relation to the use of nitrogenous fertilizers. However, the use of inoculants has not been widely applied by the smallholder farmers in Sub-Saharan Africa despite the challenges of acquisition of nitrogenous fertilizers and other environmental concerns. The aim of this study was to examine how farmers perceive BIOFIX® inoculant, factors that drive its use and its profitability among the smallholder farmers. It uses data collected from 210 soybean farmers in three regions of Western Kenya namely, Bungoma West in Bungoma County, Mumias in Kakamega County and Bondo in Siaya County. Regression techniques were used to assess factors influencing perception and drivers of BIOFIX® inoculant use and partial budget analysis techniques to examine the profitability. The results show that farmers who have used BIOFIX® view it more positively than those who do not use. Perception is significantly ($p < 0.01$) influenced by frequency of contacts with organizations that promote BNF and membership in soybean producer group. Other factors that influence perception of inoculants is farmer's age ($p < 0.10$), use of nitrogenous fertilizers on legumes ($p < 0.05$) and region from where the farmer comes from ($p < 0.05$). The study finds that farmer's decision to use inoculants is determined by knowledge of legume root nodules ($p < 0.01$), contact with organizations promoting BNF technologies ($p < 0.01$), membership in soybean promoting group ($p < 0.01$), location of the farmer and area under crop ($p < 0.10$). The intensity of BIOFIX® use is mainly influenced by area under crops, frequency of contacts with organizations promoting BNF technologies, group membership and the distance to collection centers, knowledge of the importance of roots nodules and location of the farmer. Partial budget analysis finds a 26% increase in soybean yields by farmers who inoculate their soybean (864 kg ha^{-1}) in comparison to those who do not inoculate (78 kg ha^{-1} less) with the difference in mean yields significant at $p<0.01$. Difference in gross margins achieved by users of inoculants (Ksh. 21,651 ha^{-1}) and non-users (13,641 ha^{-1}) is highly significant ($p<0.01$). The findings of this study imply that there is need to strengthen local institutions and for greater involvement of commercial sector (agro-dealers) and public extension to enhance promotion of inoculants use. Other channels of passing information and knowledge of BNF technologies need to be explored such as the use of radio, television and mobile phones. The findings also highlight the importance of markets as drivers of technologies adoption. This suggests that for soil fertility improvement technologies such as inoculants to be adopted, there is need to strengthen the output market.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AEZs	Agro-ecological Zones
BNF	Biological Nitrogen Fixation
BSFR	Biological Soil Fertility Replenishments
CIMMYT	International Center for Wheat and Maize Improvement
FAO	Food and Agricultural Organization
FGDs	Focus Group Discussions
Ha	Hectares
ISAR	Rwanda Institute of Agronomic Sciences
ISF	Integrated Soil Fertility
ISFM	Integrated Soil Fertility Management
K	Potassium
Kg	Kilogram
LM	Lower Midland
MIRCEN	Microbiological Resource Centre
MSc	Master of Science
MT	Metric Tones
N	Nitrogen
NBRM	Negative Binomial Regression Model
NEPAD	New Partnership for Africa's Development
NGO's	Non-Governmental Organizations
NM	Nutrient Management
P	Phosphorus
PRM	Poisson Regression Model
S	Sulphur
SSA	Sub-Saharan Africa

UM	Upper Midland
UNESCO	United Nations Education and Science Council
USAID	United State Agency for International Development
ZINB	Zero Inflated Negative Binomial
ZIP	Zero Inflated Poisson

CHAPTER I

1.0 INTRODUCTION

1.1 General

Poor soil fertility is a challenge to achievement of food security and rural wellbeing in Sub-Saharan Africa (Sanginga and Woomer 2009). Nutrient depletion, being a key factor in low soil fertility results when nutrients removed through crop off-take and other loses are not adequately replaced, which is widespread across Kenya and sub-Saharan Africa at large (Stoorvogel *et al*., 1993; Shepherd *et al*., 1996; Onwonga and Freyer 2006). Nitrogen is the most affected due to its high uptake, vulnerability to leaching, losses in gaseous form and through crop harvest. The use of inorganic fertilizers to alleviate the problem of low soil fertility is limited by high cost of inputs leading to very low usage per unit area. In addition, smallholders fail to use the recommended rates of inorganic fertilizers.

In response to the challenges highlighted above, a new paradigm has developed around Integrated Soil Fertility Management (ISFM). One goal of ISFM is to develop and promote soil fertility replenishment technologies that are suitable for different types of resource-poor farm households (Crowley and Carter 2000). One such technology is the use of *Rhizobia* inoculants that enhance Biological Nitrogen Fixation (BNF), which can be a cost effective alternative of alleviating low soil fertility problem (Giller 2001). Many soils contain *Rhizobia*, but are often present in small populations or are non-effective to many host legumes or partly-effective at symbiotic BNF. At the same time, native *Rhizobia* may pose a barrier to nodulation by inoculants (FAO, 1984; Thies *et al*., 1991). This necessitates the need for inoculation with an elite *Rhizobia* strain in high quality formulation. Inoculant production in Kenya was initiated as part of the Microbial Resources Centre Network (MIRCEN) that was established by the University of Nairobi in 1977 (Karanja *et al.*, 1998). The center developed an inoculant known as BIOFIX® that was later licensed and marketed by MEA Limited starting in 2010. BIOFIX® for soybean contains *Bradyrhizobium japonicum* strain USDA 110, a widely used industry standard and contains >10^9 *Rhizobia* per g^{-1} in an organic carrier material (Lupwayi *et al*., 2000). This is the only legume inoculant commercially available in East Africa and is steadily being promoted among farmer groups and agrodealer associations (Wafulah 2013). N2Africa Program is assisting in promoting the inoculant (Woomer 2013). Notwithstanding its potential, Kenya is still far from realizing wide-scale use of this innovation among its smallholder farmers.

1.2 Problem Statement

A challenge for agricultural researchers is to understand how and when the developed technologies are used by farmers and the constraints affecting their use. This has resulted in the search for information relating to the mechanisms underlying technology use (Doss, 2006). Research on inoculation of legumes with *rhizobia* have been conducted in Africa since the 1950's and the benefit of inoculation clearly demonstrated (Woomer *et al.* 1997; Giller 2001; Otieno *et al.* 200 and Bala *et al.*, 2011). However, despite this demonstrated benefit and the high cost of using artificial nitrogenous fertilizers, the technology has not been widely used in sub-Saharan Africa.

Woomer *et al.*, (1997) identified lack of information concerning inoculants availability and use as an important constraint to use of the technology, and this problem continues. Similar challenges regarding adoption of most Biological Soil Fertility Replenishments (BSFR) have been reported in other parts of Africa (Ajayi *et al.*, 2007). The use of *Rhizobia* inoculation has mostly been supported by programs under the government or non-governmental organizations and once these programs come to an end the scale of adoption declines (Bala *et al.*, 2011).

Despite the potential in the use of inoculants, diffusion of the technology among smallholder farmers in Kenya has generally been low. The low adoption of these technologies necessitates a thorough analysis of the barriers to using these promising, renewable and environmental friendly technologies. Generation of this information is essential in deriving recommendations for up-scaling the use of inoculant among smallholder farmers in Kenya and the region.

1.3 Objectives

The overall objective of the study was to examine farmer perceptions, use and profitability of BIOFIX® inoculant on soybean (*Glycine Max*) production among smallholders in Western Kenya.

1.3.1 Specific objectives

The study specifically sought:

i. To assess farmers' perception of the use of *Rhizobia* inoculants in soybean production.
ii. To examine the role of institutional factors on the use of inoculants by the smallholder soybean producers.
iii. To evaluate the profitability of inoculants on soybean production.

1.3.2 Research questions

The study aimed at addressing the following questions:

i. How do the smallholder farmers perceive the use of *Rhizobia* inoculants?

ii. What is effect of institutional factors on the use of inoculants?

iii. Is the use of inoculants economically feasible for the market oriented smallholder soybean farmer?

1.3.3 Hypothesis

The following hypotheses were tested:

i. There is no difference in perception of *Rhizobia* inoculants between the users and non-users of BIOFIX®.

ii. Institutional factors do not influence farmer's decision to use inoculants.

iii. The use of inoculants by the market oriented smallholder soybean farmer is not profitable.

1.4 Justification of the Study

Nitrogen is the nutrient that most often limit plant growth, yet it is the most abundant naturally in form of nitrogen gas in the air. This mineral is also the most mobile and is exposed to many loses in the soil through surface wash by rainwater, leaching and de-nitrification. For good crop production, farmers usually need to add nitrogen to their soils, either as organic amendments or as inorganic fertilizers.

Legumes are among the world's most important crops that can obtain most of their Nitrogen requirements from symbiotic Nitrogen fixation. The formation of an effective symbiosis requires the presence of strains of *Rhizobium* in the soil that can nodulate the host legume.

However, Marufu *et al.*, (1995) pointed out that, effective *Rhizobia* strains are often either not present in soils or are present in only very low numbers and need to be availed to farmers as seed inoculant. BNF has been used in farming systems to reduce the use of inorganic fertilizers which in turn reduces the cost of farming (Shamseldin and Werner, 2004; Shamseldin, 2007; Vinuesa *et al.*, 2003 and Otieno *et al.*, 2009). Studies have shown that legumes can fix more than 250 kg N/ha^{-1} through Biological Nitrogen Fixation (Otieno *et al.*, 2009). Inoculation with elite Rhizobia strain increases BNF where the crop is able to acquire nitrogen for its growth requirements resulting to increased yields. In countries that rely on importation of nitrogenous fertilizers (mostly in Sub-Saharan Africa), there is great need for cost effective alternatives such as BNF. Inoculation with an elite strain of *Rhizobia* has the advantage of little or no use of a nitrogenous fertilizer and higher yields in legume production (Saginga *et al.*, 1994). Therefore, BNF offers improved nitrogen management that optimizes economic returns to farmers and minimize environmental concerns associated with use of inorganic nitrogenous fertilizers. BIOFIX® inoculant is available to legume growing farmers in most parts of Kenya for use in various legumes such as soybeans, common beans, cowpeas and groundnuts; leguminous pasture crops such as lucerne and desmodium and leguminous trees such as sesbania, leucaena and caliandra.

This study sought to examine farmer's perception of inoculants, assess factors influencing the use of the technology and examine whether the technology is profitable or not. Researchers and extension service providers require feedback from end users of the technology that has been developed. The feedback is important in informing future research and in refining the dissemination and extension approach to increase use and adoption of the technology.

CHAPTER II

2.0 LITERATURE REVIEW

2.1 Background on inoculation

According to Bashan (1998), inoculation of plants with beneficial bacteria can be traced back for centuries. By the end of the 19^{th} century, the practice of mixing "naturally inoculated" soil with seeds became a recommended method of legume inoculation in the USA (Smith, 1992). For almost 100 years, *Rhizobium* inoculants have been produced around the world (Bashan, 1998). Some legumes, such as soybean *(Glycine max)* in Brazil, are not fertilized with nitrogen, but are only inoculated. Soybean inoculation has made a major agricultural impact in the USA, Brazil, and Argentina (Bashan, 1998). In countries such as Australia, North America, Eastern Europe, Egypt, Israel, South Africa, New Zealand, and, to a lesser extent, Southeast Asia have used inoculation on other legumes. However, the large majority of less developed countries in Asia, Africa, and Central and South America, inoculant technology has had little impact on crop productivity (Bala *et al.*, 2011).

Fertilizers, especially nitrogen and phosphates, are one of the most important inputs used in the global agricultural industry. The FAOSTAT, (2003) reported that between 1960 and 2000, the annual world use of nitrogen fertilizer increased from 13 to 89 million tons N, a seven-fold increase in 40 years. Even though the inoculant sector represents a relatively small industry, it is an important part of the increasingly competitive global agricultural production demands. Inoculants used as either substitute or complement to the use of commercial or non-commercial fertilizers have the potential to increase productivity and profitability of legume crops, enhance food production, support social progress in many under-developed countries, and moderate environmental effects of use of commercial inorganic fertilizers in agriculture.

2.2 Inoculant Production and use in East Africa

Bala *et al*., 2011 reports that in East Africa inoculant production has been done in Kenya, Tanzania, Uganda and Rwanda with varying intensity at different times. In Kenya, the Nairobi MIRCEN located at the University of Nairobi has a collection of more than 250 *Rhizobial* strains from local and foreign sources (Bala *et al*., 2011). It was founded in 1977 with funding from UNESCO. Using some of the *Rhizobial* strains in its collection, the centre has developed inoculants for various legumes including pulses, pasture legumes and trees. These include *Phaseolus vulgaris* (common bean), *Glycine max* (soybean), *Medicago sativa* (lucerne), *Arachis hypogaea* (groundnut), *Desmodium* spp. (desmodium), *Sesbania* spp. (sesbania), *Leucaena leucocephala* (leucaena), *Vigna unguiculata* (cowpea) and *Pisum sativum* (Garden pea).

The Nairobi MIRCEN has since 1981 produced an inoculant known as BIOFIX®, which is the main inoculant in East African market (Odame, 1997). The product was initially available in 100 g packets, with one packet sufficient to inoculate 10 kg of seeds needed per hectare of common beans or soybean. In partnership with MEA Limited, mini packs of 50 g, 20 g and 10 g have been introduced to cater for smallholder farmers, which are sufficient to inoculate about 5 kg, 2 kg and 1 kg soybeans (Karanja *et al.,* 1998). It is reported that the average sales of BIOFIX® was about 1,350 kg per year between 1992 and 1993 (Mugabe, 1994), the level at which production had stagnated throughout the 1990's (Karanja *et al*., 1998). The stagnation was attributed to low demand of the inoculants due to inadequate and inefficient marketing channels and outlets, as well as inadequate extension services covering inoculant use (Odame, 1997). Since 2008, MEA Ltd started commercial production of BIOFIX® inoculants after entering into a memorandum of understanding with the University of Nairobi to commercialize the product.

In the 1990's, the Food and Agricultural Organisation (FAO) supported a project to select better strains of *Rhizobia* in Tanzania (Mugabe, 1994). The Sokoine University of Agriculture developed at a commercial level an inoculant called *'Nitrosua'* for use in soybean production. In collaboration with the Ministry of Agriculture and Non-Governmental Organizations (NGOs), the University also established extension activities to disseminate the inoculants to local farmers. However, little has been documented on the use of the technology by farmers.

Bala *et al*., (2011) reports that at least two plants produce inoculants in Uganda, these are Madhavani Ltd – a sugar factory with inoculant research laboratory near Jinja and Biological Nitrogen Fixation at Makerere University. The Biological Nitrogen Fixation at Makerere University was established with the aid of the United States Agency for International Development (USAID) in 1990 with average annual production of about 1,500 kg of unsterile inoculants in 250 g packets. The adoption of the technology by farmers is still not clearly documented.

In Rwanda, FAO helped to set up an inoculant production facility at the Institut des Sciences Agronomique du Rwanda (ISAR) in 1984 and had reached an annual production level of 2.4 tonnes by 1990 (Cassien and Woomer, 1998). However, the factory was destroyed in 1994 genocide.

2.3 Role of soybeans in soil fertility improvement

Legumes provide a relatively low-cost method of fixing nitrogen in the soil through the process of biologically nitrogen fixation. This enhances soil fertility and boosts subsequent crop yields (Sanginga and Woomer 2009). Inclusion of soybean in the farming systems contribute to improvement in soil fertility. Chianu *et al.*, (2008) argues that the dual-purpose soybean varieties are particularly good in both nitrogen fixation and provision of mulch materials. Soybean can fix up to 200 kg N/ha if properly inoculated and adequately supplied with phosphorus leading to a substantial savings in fertilizer costs (Smith and Hume, 1987). Since soybean is effective in fixing atmospheric nitrogen, it makes little or no demand on soil nitrogen and actually spares the same for the subsequent crop in a rotation or the companion crop(s) in an intercrop. The biomass from soybean is also an important source of feed, green manure, and mulch. Soybean is also relatively drought resistant and makes efficient use of available soil water resources (Sanginga and Woomer 2009).

Soybeans are a major legume crop worldwide that has been grown for thousands of years originating in Asia (Hymowitz, 1990). Production of soybean in Kenya is estimated at 2,100 tons from 2,500 ha (FAO 2008). Kenya consumes about 400 000 MT of vegetable oils while local production from key sources (oil palms, sunflower and soybeans) only meets a third of this demand (Chianu *et al.*, 2008). Due to this demand and for other uses such as soybean cake for animal feeds manufacturing, Kenya can easily absorb up to 100 000 MT of soybean in raw form annually (Lokuruka, 2011). Western Province is the leading soybean producing province in Kenya, accounting for nearly 50% of total national smallholder production with main soybean producing districts including Butere/Mumias, Busia, Bungoma, Teso, Kakamega, Mount Elgon, Lugari, and Vihiga (Chianu *et al.*, 2008).

2.4 Review of empirical literature

2.4.1 Farmer perception of agricultural technologies

According to Nabifo (2003), farmer's perception of a technology is a key determinant in the decision to use. If farmers' perceptions are that the technology is not profitable, there will be low investment in the technology. Perception studies on soil fertility improvement technologies have focused on both perception based on soil fertility, whether farmers view it as a problem or not and based on specific attributes and benefits of a technology. In the studies that are based on farmer perceptions of soil fertility, farmers who view soil fertility as a problem have higher acceptance and adoption of a technology. Shepard *et al.,* (1997), reported that limitations for the adoption potential of hedgerow intercropping included inappropriate targeting, where the farmers' priority problem is not low soil fertility. Farmer participation was being enhanced by the provision of incentives such as fertilizers, improved crop material and limited monitoring of labour requirement, crop and economic performance.

In studies that focus on specific attributes and benefits of a technology, it has been shown that, the attributes are perceived differently by farmers depending on factors such as socio-economic and asset endowment. Sanchez (1999) reported that grass fallows in Rwanda are found in farms that are less than a hectare of land, thus dispelling the notion that extensive land sizes are required for the fallow technology. He indicates that short term improved woody fallows on the other hand are used by farmers for fuel wood, N-fixation, the prevention of weeds and energy sources for soil micro-organisms.

Farouque and Hiroyuki (2007) in a study aimed at determining farmers' perception of Integrated Soil Fertility (ISF) and Nutrient Management (NM) for sustainable crop production found that the landless, marginal and small farmers had a low level of awareness when compared to medium and large farm holders and thus affected their perception. The study found that a significant proportion (78%) had either a low or a very low level of perception while 22% had a medium to high level of perception. They indicate that individual farmers had a low perception of preparation of farm yard manure and the role of organic matter as well as the beneficial aspect of ISF and NM for sustainable crop production. Among the characteristics of farmers; education level, farming experience, farm size and communication exposure influenced farmers positively while family size and fertilizer use negatively influenced farmers' perception of ISF and NM.

Bruening *et al.,* (1992) in their study on farmers' perception about usefulness of informational and organizational sources found that those farmers who had more than a high school education perceived water pollution, manure mismanagement, and nutrient mismanagement as more serious environmental issues than those farmers who had not completed high school. Ahmed *et al.,* (2004) in their investigation into the perceived farm management and marketing educational needs of farm operations in Jordan found that higher perception ratings were observed for those who utilized more sources of information and preferred group extension. Buckles and Triomphe (1999) reported that farmers in northern Honduras adopted *mucuna* due to its attributes such as fertilizer effects (yield increment), moisture conservation, ease of land preparation, use as livestock feed, income generation from seed and ease in establishment.

Duncan (2004) when investigating knowledge and perceptions of Virginia secondary agriculture educators toward the agricultural technology program reported that the educators either agreed or strongly agreed that the agricultural training program will contribute to students' success in the agriculture industry and that the program offers a valuable educational experience for students. Adesina and Baidu-Forson (1995) showed that farmer perceptions of technology characteristics significantly affect adoption decisions of new agricultural technologies. They suggested further research to include farmer subjective perceptions of the characteristics of new agricultural technologies. However, Ajayi (2007) indicates that technical characteristics are important but not exclusive conditions for farmers' acceptability and adoption of good agricultural technologies. He further points out that there is relatively little information and systematic feedback regarding farmers' perception and knowledge of technologies.

2.4.2 Determinants of agricultural technology use by the smallholder farmers

According to Feder *et al.*, (1985), adoption is "the degree of use of a new technology in long run equilibrium when a farmer has full information about the new technology and its potential". The rate of adoption is defined as 'the percentage of farmers who have adopted a new technology or the area under a new technology' (Feder *et al.*, 1985).

In adoption literature, there are studies that have looked into acceptance of technologies or potential adoption and adoption of technologies. Potential adoption studies focuses on the evaluation and trial processes after the initial diffusion, awareness and interest stages of the adoption process (Everett, 2003). Potential adopters, according to Everett (2003), are socially integrated with a large degree of opinion leadership in their social systems.

Adoption literature shows that a host of socio-economic, institutional and technological factors, farmers' perception about technology attributes and their attitude towards risk (Feder *et al.*, 1985; Shakya and Flinn, 1985; Kebede *et al.*, 1990; Adesina and Zinnah, 1993) affects adoption of agricultural technologies. Lindner's (1987) survey of research on adoption at the farm level found that most studies were concerned with identifying those characteristics of the adopters or the innovations that influenced adoption decisions.

Studies conducted to identify factors affecting the use of agricultural technologies include 22 studies done from 1996 to 1998 by CIMMYT in collaboration with national research organizations in East Africa (Doss, 2006). These studies looked into adoption of improved varieties of wheat and maize as well as chemical fertilizers in Ethiopia, Kenya, Tanzania and Uganda. They provided useful information on who is using improved seed and fertilizer and shown that farmer characteristics such as age, gender, and wealth are key factors to adoption decisions.

A study by Mugwe *et al.,* (2008) showed that factors that significantly influenced early adoption of Integrated Soil Fertility Management technologies were farm management, ability to hire labour, age of household head and number of mature cattle kept by the household. Other studies that have been done on the use of technologies include: Ouma *et al.,* (2002) who reviewed the socio-economic and technical factors that affect adoption of improved maize and fertilizer use in Embu District, Kenya, and the role of credit in improved maize and fertilizer use adoption. Mutune, (2009) evaluated factors influencing the adoption of conservation tillage practices and their implication on profitability in maize-cowpea cropping systems in Makueni District, Kenya.

Adesina and Zinnah (1993) found that farmer's perception of the characteristics of modern rice varieties significantly affected adoption decisions in Sierra Leone. Adesina and Baidu-Forson (1995) had similar results in their study on modern sorghum and rice varietal characteristics, which showed that farmer perceptions of technology characteristics significantly affect adoption decisions of those new agricultural technologies. Mather *et al.,* (2003) examined the adoption of disease resistant bean varieties in Honduras. Hintze *et al.,* (2003) examined the factors, including varietal characteristics, affecting the low levels of adoption of improved maize varieties in Honduras. Ransom *et al.,* (2003) examined the adoption of maize varieties in the hills of Nepal.

Eelko *et al.,* (2009) investigated the differences between companies with regard to their knowledge, perceived potential value, implementation and satisfaction with e-commerce. The study involved 127 companies and found that there are higher scores for companies at the advanced level and significant negative interaction effects between adoption level and adoption intention. Due to the magnitude of these effects, the interaction effects tended to cancel out the additional effect of adoption intention for companies at the advanced level. Makokha *et al*., (1999); Oluoch-Kosura *et al*., (2001); Waithaka *et al*., (2007) and Wanyama *et al.,* (2010) also did similar studies on use of technologies.

As pointed out by Feder *et al.,* (1985), factors that influence whether farmers adopt technologies has been the focus of past adoption studies and have been crucial for the development of techniques for studying adoption. However, these studies fail to adequately answer the questions of factors such as institutions and markets affect the use and adoption of new technologies. This study seeks to address this gap in determination of technology use.

2.4.3 Assessment of profitability of soil improvement technologies

According to Negatu and Parikh (1999), farmer’s decisions are rational and therefore are made based on utility maximization. The financial gains associated with technology use should outweigh the costs of its use. According to Swinkels and Franzel (1997), key characteristic perceptions of potential adopters of a technology could be categorized into the feasibility, profitability, and acceptability. The feasibility evaluates the ease with which the farmer can manage various aspects of the technology such as application, the profitability evaluates the benefits in relation to the costs. The acceptability depends on the advantages in relation to the disadvantages. This refers to the use of the technology given limited resources, and the degree to which the technology matches with existing needs, socio-cultural beliefs and previously introduced ideas (compatibility), as key factors that are evaluated by potential adopters.

According to Graene and Casey (1998), profitability needs to be considered together with other factors such ease of use since they reported that promising new technologies are not adopted by farmers because they are not profitable.

Suri (2011) showed that technology profitability, farmers' training and differences among farmers and across farming systems, are the major determinants affecting maize technology adoption in Kenya. Studies conducted in northern Honduras on the other hand found that the relative profitability of a *Mucuna pruriens* system was not solely dependent on the higher maize yields, labour costs and lower production risk but also on the seasonally high prices that favoured the second season maize crop (Buckles and Triomphe 1999). Maize yields were reported to be twice as high and labour costs 17% lower, on average, owing to the weed suppression properties of *mucuna*. The yield losses associated with drought stress were also lower due to the moisture conservation characteristic of mulch in the *mucuna* system.

In analyzing profitability of ISFM technologies, most researchers concentrate on controlled experiments with the controls depicting the farmer conditions. For instance, researcher managed trials in Kenya using *tithonia* biomass showed both increased maize yields and profitability. The yields and profits were even higher where *tithonia* was supplemented with phosphorus inorganic fertilizer, however, the use of the technology has remained low (ICRAF 1996; Place *et al.,* 1999 and Ajayi *et al.*, 2007). This shows that is useful to do further studies after the technologies have been released to the users and not just to rely on the researcher managed profitability evaluation. This study fills this gap in the literature.

CHAPTER III

3.0 METHODOLOGY

3.1 The Study Area

The study was conducted in Bungoma West, Bondo and Mumias sub-counties in western Kenya where the N2Africa Program (see www.n2africa.org) promotes BNF technologies among small-holders, including adoption of soybean best practices. The choice of districts was purposive based on the number of soybean groups working with N2Africa and agro-ecological zoning.

Bungoma West sub-county is situated in Bungoma County in Western Province along the Ugandan border. It receives rainfall ranging between 1400 mm to 2200 mm yr^{-1} depending on elevation. The predominant soils are Acrisols and Ferralsols (FAO 1977) used in smallholder maize-based farming. Mumias sub-county is also situated in Kakamega County in Western Province to the south of Bungoma County and receives about 1700 mm rainfall yr^{-1}. Its rural economy is dominated by sugarcane production and participation in outgrower schemes. The predominant soils are Acrisols, Luvisols and Gleysols (FAO 1977).

Bondo sub-county is situated in Siaya County in Nyanza Province along Lake Victoria, rainfall is lower ranging from 900-1,200 mm per annum. The predominant soils are mainly Cambisols and Vertisols (FAO 1997) and farmers cultivate maize, beans, cassava and other food crops.

3.2 Conceptual framework

Decision-making on the use of improved technologies by farmers is a complex process. Several authors (Feder *et al.,* 1985; Doss, 2006; Everett, 2003 and Eelko *et al.,* 2009) have proposed a theoretical model where in the technology-adoption process; an individual passes through the stages of knowledge, persuasion, decision, implementation (adoption) and confirmation (post-adoption assessment). Information is necessary at various stages to reduce uncertainty about the usefulness of the innovation. The decision stages result in adoption or rejection of the idea. Before farmers adopt a technology, they must know it, know about it and form a decision about it.

According to Everett (2003), the rate of use or adoption of a technology is determined by five characteristics. These are 1) the relative advantage of the technology over the existing ones; 2) compatibility with the existing values, past experiences, and needs of potential users; 3) complexity or ease of use of the technology 4) the degree to which an innovation may be experimented; and 5) how the results of an innovation are visible to others. The rate of diffusion is also considered very important in the adoption of technologies. Diffusion is seen as “the process by which an innovation is communicated through certain channels over time among members of a social system” (Everett, 2003). Most innovation and technology researchers consider adoption as a binary process, implying that technology has been adopted or not (Eelko, *et al.,* 2009).

Lindner’s (1987) classified adoption of technologies into two empirical study categories. The first is the cross-sectional studies in which the main question is why some producers adopt an innovation while others reject it. The second type of adoption studies is the temporal studies that are concerned with the determinants of the timing of adoption. These studies typically try to identify why some producers are early adopters while others are laggards.

The International Maize and Wheat Improvement Centre (CIMMYT, 1993), states that monitoring of technology acceptability with farmers may be conducted 2 years after the experimental trials while a formal adoption survey may be conducted 2 - 4 years following the technology release. The monitoring process identifies problems associated with the technology while formal adoption study identifies factors that are driving adoption, the rate and extent of adoption. A complexity in adoption studies is that the factors that are considered important at the early stages of adoption may become less significant in later stages. Since the inoculant (BIOFIX®) is a technology that is still being promoted by various players, the use of the technology was considered to be in the early stages of adoption and not at the full commercialised stages of adoption.

Empirical studies have revealed that in addition to farmers socioeconomic characteristics and institutional factors, farmers perceptions of the innovations are important in determining adoption of the technologies (Adekambi *et al.,* 2010). To assess the acceptability of a technology, it must be evaluated from farmers perspective. Based on the consumer demand theory, it is conceptualized that demand for a product (in this case BIOFIX®) is affected by the consumers perceptions of the product attributes. Focusing on farmer perceptions of technologies may provide a better understanding of technology adoption since they deal with the technologies and probably perceive technologies differently from researchers and extension agents (Farouque and Hiroyuki, 2007 and Nabifo, 2003).

Leagens (1979) argued that the decision to adopt an innovation or a new technology is a behavioral response arising from a set of alternatives and constraints facing the decision maker. These alternatives and constraints can be grouped into incentives and disincentives. Adoption proceeds when the incentives outweigh the disincentives. Economically, incentives are the returns while disincentives are the costs. If benefits are more than the costs, then farmers are motivated to take up technologies due to the expected high return on investment (Shideed *et. al*., 2005).

3.3 Empirical models

3.3.1 Farmers' perception on the use of inoculants in soybean production

In determining factors that influence perception of technologies, ordinal logistic regression, ordinal probit regression and factor analysis have been commonly used. Ordinal logistic and ordinal probit are mostly used when dependant variable is categorical and the continuous variable is either continuous or categorical (Coe, 2002). Both ordinal logistic and ordinal probit regression models give similar results and are embedded in the family of generalized linear models and are commonly used to analyze data that has ordered scores (ordinal response variables). Ordinal variables have a natural way of ordering among levels (such as low, medium, high). According to Sentas *et al.,* (2005), ordinal regression (either logistic or probit) is used to model the association between response variables and a set of explanatory variables. The explanatory variables can be either categorical or continuous.

Ordinal regression can be used where the researcher wish to study effect of explanatory variables on all levels of the ordered categorical outcome. Shrestha and Alavalapati (2006) used ordinal logistic regression to analyse local people's attitude towards Koshi Tappu Wildlife Reserve. They found that households living closer to the reserve and from larger households are more likely to reveal negative attitude towards conservation. They also found that educated respondents and farmers are likely to demonstrate a positive conservation attitude and households with poor socioeconomic status and greater dependence on the forest for firewood, fodder, and raw materials are likely to possess a more negative attitude towards conservation. Other studies that have used Ordinal logistic regression include Etter *et al.,* (2005), Rutto *et al.*, (2006), Minetos *et al.*, (2007), Rutherford *et al*., (2007) and Lohse *et al.*, (2008).

Factor analysis has also been widely used in perception surveys (Guthiga, 2008). Factor analysis reduces data set from a group of interrelated variables into smaller sets of uncorrelated factors and achieves parsimony by explaining the maximum amount of common variance in a correlation matrix using the smallest number of explanatory concepts. Factor analysis can be utilized to examine underlying patterns or relationships for a large number of variables and to determine whether the information they contain can be condensed or summarized into a smaller set of factors or components.

The approach used for the empirical estimation of factors affecting perception in this study is ordinal logistic regression model. An advantage of ordinal logistic regression to factor analysis is that it requires fewer assumptions in regard to the relationship between the explanatory variable and the dependent variable (Minotos *et al.*, 2007). Ordinal logistic regression was chosen over the probit model because it is computationally simpler and has been widely applied in similar studies.

Ordinal logistic regression model makes it possible to compare perceptions of the product attributes for the two categories (users and non-users of the product). In this study, the dependent variables (ratings) are assumed to range from the lowest (1) to the highest (5). The five point Likert scale ratings was used on four parameters a) increase in yields of soybean b) cost c) profitability and d) ease of use, a composite score was taken for the four parameters to represent perception by each farmer. The perception parameter was treated as dependent variable while the explanatory variables (predictors) as *log of age, gender, household size,* *education level, distance to the local market, distance to soybean collection center, log of household income, area under crops, membership in soybean producer group, number of contact with organizations promoting BNF, access to credit, whether farmer applies nitrogenous fertilizer to legumes, perception of root nodules and region*.

The parameters for the ordered logit regression model were defined as follows:

θ_1 = prob (score of 1)/ prob (score greater than 1)

θ_2 = prob (score of 1 or 2)/ prob (score greater than 2)

θ_3 = prob (score of 1, 2 or 3)/ prob (score greater than 3)

θ_4 = prob (score of 1, 2, 3 or 4)/ prob (score greater than 4)

Where θ is the probability of event (1, 2, 3, 4) occurring.

The last category does not have an odds associated with it since the probability of scoring up to and including the last score is one.

All the odds are of the form:

θj = prob (score $\leq$j)/ prob (score $>$j)

θj = prob (score $\leq$j)/1- prob (score $>$j)

The ordinal logistic model for a single independent variable is:

$$ln(\theta j) = \alpha j - \beta x \quad (1)$$

- Where *j* is the scale rating of 1 to the number of categories minus 1.
- αj terms are the threshold values with α as the intercept while β is the logit coefficient.

3.3.2 Factors affecting the use of inoculants

Different models have been proposed in econometrics for estimating adoption processes. The most common include the Linear probability, Tobit, Probit and Logit regression (Liao, 1994; Maddala, 2001; Green, 2003; Gujarati, 2004; Okello *et al.,* 2012). The application of regression methods depends largely on the measurement scale of the outcome variables and the validity of the model assumptions. The outcome variables include continuous scale, binary measure or ordered category.

Some of the shortcomings of linear probability model include heteroscedasticity of disturbance terms, non-normality of their distribution and estimated probabilities may not always lie between the logical limits of 0 and 1 (Gujarat, 2004). Linear probability model cannot therefore be used to consistently estimate discrete choice in adoption models (Green, 2003). Logistic regression analysis works well for binary or dichotomous outcome while ordinal regression is more applicable for categorical data (Woodridge, 2002). The Tobit model gives a quantitative measure of the extent of adoption (Oluoch-Kosura *et al.*, 2001).

Logit and Probit regression are statistical techniques in which the probability of a dichotomous outcome (use or non-use in this case) is related to a set of explanatory variables that are hypothesized to influence the outcome (Odendo *et al*., 2009; Okello *et al.,* 2012). Logit and Probit regression models give the effect of the various factors on the use as well as the predicted probabilities of the use (likelihood of usage). The Probit and Logit models are often used in adoption studies that aim at identifying factors underlying adoption. Probit and Logit models provide identical substantive conclusions and are quite similar except at their tails, the logistic distribution has slightly fatter tails (Liao, 1994; Gujarati, 2004; Okello *et al.,* 2012). The logit model was chosen over the probit model because it is computationally simpler and has been widely applied in similar studies (Sirak & Rice, 1994; Okello *et al.*, 2012). Sirak & Rice (1994) also argue that the Logit regression model is more powerful, convenient and flexible and is often chosen if the predictor variables are a mix of continuous and categorical variables which is the case in this study. The model is specified as follows (Gujarati, 2004):

The logistic function:

$$f(Z) = \frac{e^{Z}}{e^{Z}+1} \tag{2}$$

Where: $f(Z)$ = the probability of a particular outcome to happen.

Z = the measure of the total contribution of all the independent variables used in the model and is known as the Logit.

e = the exponent

When Z is presented as the natural logarithm of the odds ratio, the model equation can be summarized as:

$$[ln[P(X)]/[P(1-P(X)] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \tag{3}$$

Where β_0 is the intercept and $\beta_1, \beta_2 \ldots \beta_n$, are the regression coefficients; X_1, X_2, X_n are the independent variables (explanatory variables) and ε is the error term. The intercept is the value of Z when the values of all independent variables are zero. The marginal effects of the regression coefficients describe the size of the contribution of that factor to the outcome. A positive coefficient means that the explanatory variable increases the probability of the outcome, while a negative regression coefficient means that the variable decreases the probability of that outcome; a large regression coefficient means that the factor strongly influences the probability of that outcome, while a near-zero regression coefficient means that that factor has little influence on the probability of that outcome. The dependent variable is the natural log of the probability of using a particular technology or technological component (P), divided by the probability of not using it (1-P).

Mutune (2009) used Logit model to evaluate factors influencing the adoption of conservation tillage practices and their implication on profitability in maize-cowpea cropping systems in Makueni District, Kenya. The study used primary data collected from 177 farmers. Eelko *et al.,* (2009) used Logit model to investigate the differences between companies with regard to their knowledge, perceived potential value, implementation and satisfaction with e-commerce. The study involved 127 companies, it found that there are higher scores for companies at the advanced level and significant negative interaction effects between adoption level and adoption intention. Due to the magnitude of these effects, the interaction effects tended to cancel out the additional effect of adoption intention for companies at the advanced level. Other studies that have used Logit regression include Adesina and Zinnah (1993), Mugwe *et al.,* (2008), Farid *et al.,* (2010), Kirui *et al.,* (2010) and Okello *et al.,* (2012).

3.3.3 Intensity of inoculants use on production of soybeans

The number of packets the farmer has used in year 2011 measures intensity of use of BIOFIX® in this study. The dependent variable is therefore a count variable, which can only take on non-negative integer values (Woodridge, 2002). Regression models that are used to model dependent variables that describe count data include the Poisson Regression Model (PRM), the Negative Binomial Regression Model (NBRM), the Zero Inflated Poisson (ZIP) and the Zero Inflated Negative Binomial (ZINB) (Greene, 2008 and Wooldridge, 2002).

According to Okello *et al.,* (2012), the PRM and NBRM regression models have been commonly used in studies where response variables have nonnegative integer with no excess zero counts than would be expected. ZIP and ZINB are more used to account for cases with frequent zero counts (Lambert, 1992; Hall, 2000; Huiming *et al.,* 2012; Kirui *et al.,* 2010 and Okello *et al.,* 2012). In this study, there were frequent cases of zero counts since there were farmers who had not used BIOFIX® in year 2011. This necessitated the choice of ZIP over PRM and NBRM. ZINP is used to model count data (with frequent zero counts) that has problems of over-dispersion or under-dispersion (Greene, 1994 and Wooldridge, 2002). Test for over-dispersion and under-dispersion given by the significance of the alpha coefficient found absence of these problems in the estimated ZIP therefore the use of ZINP could not be justified. ZIP is obtained by mixing two distribution functions; one at zero and second with the Poisson distribution. The ZIP regression is expressed as follows (Lambert, 1992):

$$\text{Prob}\,(Y_i = y_i) = \begin{cases} \omega_i + (1-\omega_i)e^{-\mu_i}, & yi = 0 \\ (1-\omega_i)\dfrac{\mu_i^{y_i}}{y_i!}e^{-\mu_i}, & yi > 0 \end{cases} \qquad (4)$$

Where the counts of BIOFIX® y_i has any non-negative integer value; ω_i = is the probability of extra zero counts in the use of BIOFIX®; μ_i = is the expected Poisson count for the ith individual. $0 \leq \omega_i < 1$ and $\mu_i > 0$, with mean $E(Y_i) = (1-\omega_i)\mu_i$ and variance $Var(Y_i) = (1-\omega_i)\mu_i(1+\omega_i\mu_i)$. ZIP regression reduces to Poisson regression when $\omega_i = 0$.

Studies that have used ZIP include Sileshi (2008); Tamer *et al.*, (2008) and Harper (2011).

The implicit functional form of the model estimate to examine the intensity of BIOFIX® use is as follows:

Number of packets = f (log of age, relationship to household head, household size, education level, distance to the local market, distance to soybean collection center, log of household income, area under crops, membership in soybean producer group, number of contact with *organizations promoting BNF, access to credit, whether farmer applies nitrogenous fertilizer to legumes, perception of root nodules, region dummies) + e*

3.3.4 Determining the level of BIOFIX® inoculant use on production of soybeans

In order to estimate the effects of various factors on the extent of BIOFIX® use, a Tobit regression model is used. Tobit model was originally developed by James Tobin, the Nobel laureate economist (Gujarati, 2004). It has been applied in several empirical studies of adoption (Shakya and Flinn, 1985; Adesina and Zinnah, 1993). It was hypothesized that the acreage of soybean planted using BIOFIX® is influenced by several factors related to farmer's characteristics, farm characteristics, institutional parameters and regional dummies. The empirical model of the effects of a set of explanatory variables on the use of BIOFIX® is specified using the following relationship:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \qquad (5)$$

Where, Y is the acreage under inoculated soybean in 2011

β_0 is the intercept and β_1, $\beta_2 \ldots \beta_n$, are the regression coefficients of independent variables (X_1, X_2, X_n respectively) and ε is the error term.

Adesina and Baidu-Forson (1995) used Tobit model to study modern sorghum and rice varietal characteristics and showed that farmer perceptions of technology characteristics significantly affect adoption decisions of those new agricultural technologies. Other studies that have used Tobit Model include Makokha *et al.,* (1999); Oluoch-Kosura *et al.,* (2001); Waithaka *et al.,* (2007) and Wanyama *et al.,* (2010).

3.3.5 Defining institutional variables

i. Membership in farmer producer group

A producer group is an enterprise voluntarily owned and controlled by the people that use it (individual farmers). It is established and managed in order to meet the mutual needs of its owner members. These groups are established for solving specific farmer support problems such as securing access to loans, advisory services and marketing. Studies by Ntege-Nanyeenya *et al.,* (1997) and Chi Truong *et al.*, (2011) have shown that membership to farmer groups can significantly affect adoption of technologies.

ii. Contact with organizations promoting BNF technologies

The availability of extension services from both the public and private sector was assumed to have implications on the use of BIOFIX®. Studies on the influence of organizations and programs on adoption of agricultural technologies have shown varying results with both positive and lack of influence on different technologies. For instance, a study by Jagger and Pender (2003) in Uganda shown that the presence of agricultural programs and organizations in a community provided little evidence that they directly affect adoption of land management technologies. However, the same study showed a positive association on the adoption of pesticides.

Study by Ajayi (2007) showed extension as the major source of information for the majority of respondents, with farmers' field day and small plot adoption technique as the most preferred methods of extension contact. Farmers must have information about new technologies before they can consider adopting them. Since extension services are one important means by which farmers gain information on new technologies, the main parameter assessed was number of contact with extension service providers that promote BNF.

iii. Access to credit

Lack of credit may constrain farmers from using technologies that require initial capital. The lack of access to credit is often seen as an indication of market failures that require the public and private sector to address. Measures of credit use do not distinguish between farmers who chose not to use available credit and farmers who did not have access to credit (Doss, 2006).

Economically, farmers will borrow only if it is profitable to do so, where profitability depends on the price of credit and the potential returns of investment. Likewise, lending organizations will extend credit most readily where they think it is profitable to do so. Conceptually, the distinction between supply and demand for credit is important to determine whether credit market failures or successes are important constraints to technology adoption. Parameters determined were whether the farmer has ever received credit in the past and has membership in a group that can borrow credit whether in terms of finances or inputs and specifically inoculants.

iv. Product market

It is conceptualized that a readily available market for the final product (soybeans) by farmers could influence the uptake of inoculants. In the study area, farmers working with the project have a ready buyer for their soybean produce. Farmers are required to take their produce to a group collection centre and contact the buyer for collection. The group members are given priority than non-group members though the collection centres do not reject to collect from non-members. According to past studies and reports by Singh (2000), De Sousa (2005), Mwenda (2005), Kunkel *et al.*, (2009) and NEPAD (2009), farming under a market contract is increasingly becoming an important aspect of agricultural production and marketing that influences uptake of technologies. Kunkel *et al.,* (2009) defines a agricultural marketing contract as a contract by which a producer (sometimes called a “grower”) agrees to sell or deliver all of a designated crop raised in a manner set forth in the agreement to a contractor and is paid according to a formula established in the contract.

In contract marketing, quantity, quality requirements and prices are stipulated and are known in advance. The farmers are guaranteed the market (stabilizing the market, which is usually volatile). In addition, farmers can benefit from contract packages, which include appropriate seed varieties, fertilizers, agro-chemicals and extension support. Limitation to contracting is that both farmers and contracting companies are vulnerable to price fluctuations (volatile nature of agricultural produce). In some instances these are beyond the control of both and this disrupts contracts if there are no variation clauses. Sometimes parallel markets offer higher prices than those agreed in contracts and derailment of contracts causes disruptions to farmers' production programmes. Considering the volatile nature of agricultural marketing, contracts can be beneficial to both parties. This study considered distance to the soybean collection centre as a parameter to measure accessibility to market other than the local open-air market.

3.3.6 Hypothesis test on the effect of the Institutional factors on the use of BIOFIX®

The logit model as described in section 3.3.2 was used for analyzing the effect of institutional variables on the use of BIOFIX®. WALD test for joint significance was used to test the joint significance of the institutional variables on the use of BIOFIX®. The following hypothesis was tested:

Null Hypothesis:

$$H_0: \beta_{Group} = \beta_{Bcredit} = \beta_{Excont} = \beta_{DistSCC} = 0 \quad (6)$$

Alternative Hypothesis:

$H_1: \beta_i \neq 0$

for i = $\beta_{Group}, \beta_{Bcredit}, \beta_{Excont}, \beta_{DistSCC}$ (7)

Where:

β_i = Logit coefficient of the ith variable

Group = Membership in soybean producer group

Bcredit= Access to formal credit (financial and/ or inputs) in the last five years

Excont= Number of contact with organizations promoting BNF technologies

DistSCC= Soybean market (proxied by distance to the nearest soybean collection centre)

3.3.7 Testing variables for Multicollinearity

Multicollinearity refers to the presence of linear relationships among the explanatory variables (Gujarat, 2004). It causes the estimates of the coefficients to become indeterminate and the standard errors too large. In the study, measuring the degree of multicollinearity involved two methods as suggested by Gujarat, (2004). He states that there is no one unique method of detecting it or measuring its strength. Therefore, the following methods were used:

- Having high R^2 but few significant *t* ratios. Gujarat, (2004) suggests that, If R^2 is high, say, in excess of 0.8, the *F* test in most cases will reject the hypothesis that the partial slope coefficients are simultaneously equal to zero, but the individual *t* tests will show that none or very few of the partial slope coefficients are statistically different from zero.
- High pair-wise correlations among regressors.

3.3.8 Testing variables for Goodness of fit

The goodness of fit determines the accuracy with which the model approximates the observed data. Pearson is widely used in statistics to measure the degree of the relationship between the linear related variables. Deviance is a likelihood-ratio test used under full maximum likelihood. The deviance can be regarded as a measure of lack of fit between model and data. Generally, when the deviance is large, it is an indication that the data is not fitting well. Hosmer & Lemeshow (2000) and McCullagh & Nelder (1992).

3.4 Profitability of BIOFIX® inoculant on soybean production

3.4.1 Gross margin analysis

Gross margin of an enterprise is defined as the enterprise's financial output minus its variable costs (Olorusanya and Akinyemi, 2004). Gross margin is the difference between the total income and the total variable costs of an enterprise, which measures what the enterprise is adding to the overall farm profit. The gross margin concept can be used to make management decisions on the appropriateness of the farmer's enterprise investment. If gross margin is done for different enterprises, there is an opportunity for evaluation of economic worthiness of each enterprise and hence one can decide to change, reduce the cost of production where applicable, get a better market or drop that enterprise from the overall farm operations (Mohammed *et al*., 2011).

The use of gross margin became widespread from 1960's, when it was first popularized amongst farm management advisers for analysis and planning purposes (Barnard and Nix, 1993). Gross margin is used as the best estimator of short-run profit. The gross margin of a particular farm enterprise can then be compared with enterprises in similar farms in the area.

In order to enable the gross margins to be computed, simple financial records of outputs and input expenses of the enterprises are needed.

Idris (1992), in an economic study to access the profitability of enterprises either singly or in combination with other tools, showed the net return derivable from an enterprise after all the values of input used in such enterprises have been deducted. More studies have used gross margin for economic analysis of various enterprises. In Malawi, Zeller *et al.,* (1997) used gross margin analysis to understand its implications on technology adoption and agricultural productivity. Okon and Enete (2009) used gross margin analysis to estimate the cost and return to urban vegetable production in Nigeria. The study found that urban agriculture was profitable in the study area. Malaiyandi *et al.,* (2010) used gross margin analysis in enterprise budget survey in various crops and livestock enterprises in Uganda. Odoemenem (2011) used gross margin analysis to do economic analyses of rice in Cross River State Nigeria.

In this study gross margin was used to analyze the profitability of soybean enterprise based on two scenarios: A comparison was made by assessing gross margin by farmers who use inoculant on soybean production and those who do not. A t- test was done to statistically test whether the gross margins derived from the use of inoculant have any significant difference with non-use.

Gross margin was calculated as follows:

$$GM_i = TR_i - TVC_i,\ i = 1, \dots n \qquad (8)$$

Where: GM_i = Gross margin for the ith farmer in Kenya Shillings per hectare

TR_i = Total revenue from the sale of soybeans by the ith farmer in Kenya Shillings per hectare, calculated as shown in Equation 9 and TVC_i is the Total variable costs incurred by the ith farmer in Kenya Shillings per hectare calculated as shown in Equation 10 and n = Number of farmers interviewed in each group (users and non-users of BIOFIX®).

$$TR_i = P_i(Q_i); i = 1, \dots n \quad (9)$$

Where P_i = Price of soybeans Kg^{-1} as sold by the i^{th} farmer

Q_i = Output of soybean in kgs $hectare^{-1}$ achieved by the i^{th} farmer

$$TVC_i = X_{ij} P_{ij} \quad (10)$$

X_{ij} = The j^{th} input of used by i^{th} farmer per hectare in production of soybeans. The inputs include labour in workday's $hectare^{-1}$, seeds in kilograms $hectare^{-1}$, BIOFIX® in grams $hectare^{-1}$, fertilizer and manure in kilograms $hectare^{-1}$, chemicals in kilograms or litres $hectare^{-1}$

P_{ij} = Price of the j^{th} input used by the i^{th} farmer in Kenya shillings per unit (the above units)

It was hypothesized that high gross margin will positively influence the use of BIOFIX® since farmers are assumed to be rational consumers.

3.4.2 Hypothesis test for gross margin

A t-test was used to test the significance of the difference between the gross margin of users and non-users BIOFIX®. The following hypothesis was tested:

Null Hypothesis:

$$H_0: u_1 = u_2 \quad (11)$$

Alternative Hypothesis:

$$H_1: u_1 \neq u_2 \quad (12)$$

Where

u_1= Gross margin for users of BIOFIX®

u_2= Gross margin for non-users of BIOFIX®

3.5 Definitions of variables used in empirical estimations

Table 1: Variables used in empirical estimations

Variable Name	Variable Definition and Description
Dependent variables	
Percep	Perception of BIOFIX® (lowest and highest perception score took a value of 1 and 5 respectively).
User	Usage of BIOFIX® is quantified using a binary variable (User of BIOFIX® = 1, Otherwise = 0).
Packets	The number of packets of Inoculant used in 2011
Inocsize	The area (acres) under inoculated soybean in 2011
Independent variables	
Farmer/household specific variables	
Lnage	Natural log of the farmer's age recorded in years
Gender	Gender was recorded as a dummy variable, representing the sex of the farmer (1= Male, 0= female).
Relationship	Relationship of the farmer to the household head (Head = 1, Otherwise = 0).
HHSize	Household size represents the number of individuals in the farmer's household (continuous variable).
Farm-specific variables	
Cropland	Area under crops (acres) in 2011
Distmkt	Distance from the farm to the nearest produce market (km).
Nlegums	Farmer applies nitrogenous fertilizer (1= Applies, 0 = Otherwise)
Percepnod	How farmers consider root nodules (1= Beneficial, 0 = Otherwise)
Capital endowment variables	
Educ level	Education in categories (None = 0, Primary = 1, Secondary = 2 and College/ University = 3)
Educ years	Years of formal learning as a continuous variable
Lnincome	Log of household income was estimated from both primary and secondary sources in the household. It was recorded in Ksh per annum as a continuous variable.
Institutional variables	
Excont	Number of contacts with organizations promoting BNF in 2011
Group	Membership in soybean producer group was recorded as a dummy variable (1=Member, 0=Otherwise).
Bcredit	Access to formal credit (financial and/ or inputs) was recorded as a dummy variable (1= farmer has gotten credit in the last five years, 0=Otherwise
DistSCC	Distance from the farm to the nearest soybean collection centre (km).
Region variables	
Mumias	1 if the farmer is located in Mumias district, 0 otherwise
Bungoma	1 if the farmer is located in Bungoma district, 0 otherwise
Bondo	1 if the farmer is located in Bondo district, 0 otherwise

3.6 Data Collection and Sampling procedure

The study was carried out in Western part of Kenya, in Bungoma West, Mumias and Bondo Sub-counties. Western Kenya was selected due to availability of soybean farmers who have been working with N2Africa. The choice of sub-counties was purposive based on the number of groups working with N2Africa and agro-ecological zoning. The farmers were stratified into two categories namely, users of BIOFIX® and non-users. A list of farmers in both strata was drawn including soybean farmers in N2Africa program and soybean farmers outside the program making a total of 210 farmers. The sample size was estimated using Cochran (1963:75) method as shown below:

$$n = \frac{Z^2(p)(q)}{d^2} \tag{13}$$

n = Sample size

Z = Statistical certainty, related to the error risk, equals 1.96 for an error risk of 5% level of significant or 95% confidence level.

p = Proportion of farmers who have used inoculants

q = The weight variable and is computed as 1-p

d = desired precision or margin of error, expressed as a fraction of the error risk of 5%

The sampling procedure was done in two stages. First, the three sub-counties were purposively selected based on the sub-counties with the highest number of farmers working with N2Africa and differences in agro-ecological zone. The agro-ecological zones considered were lake-basin, lower midlands and upper midlands. Secondly two sampling frames were developed, one for farmers working with N2Africa and the other one for farmers outside the N2Africa groups. In each sub-county, two farmer groups working with N2Africa in each sub-county were selected, one with the highest membership and the other one with the lowest membership. Farmers in the two groups were listed and online Research Randomizer software used to select farmers to be interviewed through simple random sampling. The non-group members were also listed with the help of N2Africa group members and a random sample drawn using Research Randomizer. The sample for both N2Africa group members and non-group members was drawn proportionally in each sub-county using probability proportionate to size sampling procedure with the number of soybean farmers in each stratum used to calculate the proportions. In total, 210 farmers were interviewed (with 159 drawn from N2Africa groups strata and 59 from non-group members).

Data was collected between May and June 2012 through personal interviews using pretested questionnaires. The information collected included bio-data and information relating to the farm and use of *Rhizobia* inoculants. The prevailing market price was used to value the quantities of fertilizers used, BIOFIX®, chemicals and soybean yields. Labour was captured in man-days and valued based on the opportunity cost.

3.7 Data Analysis

The data was coded and entered in Statistical Package for Social Scientists (SPSS). Descriptive analysis was done using SPSS version 20 and regression using STATA version 11.

CHAPTER IV

4.0 RESULTS AND DISCUSSIONS

4.1 Characteristics of the respondents

Table 2 presents general characteristics of the respondents. Out of the 210 soybean farmers interviewed, the proportion of males to females is 30% and 70% respectively, indicating more females than males grow soybean. The mean age is 47 years showing that soybean farmers have relatively more years of farming experience. The mean household size is 5 while mean distance to the nearest market centre is 8.12 km. The mean distance to the nearest soybean collection center is 2.74 km. The mean education level is 6.83 showing relatively low levels of education while mean household income is Ksh 31,705 per year. The results show 72% of the respondents are members in soybean producer groups and 61% had contact with organizations promoting BNF technologies with an average of 2 contacts in year 2011. This indicates that these organizations play a role in the use and adoption of *Rhizobia* inoculants. Credit (either cash or in form of inputs) was accessed by 45% of the respondents.

Table 3 presents characteristics of users and non-users of inoculants and a T-test of difference in means. There are significant differences between users and non-users in a number of parameters. Users score high (4.34) on perception of BIOFIX® than non-users (2.81). This indicates that those who have used inoculant have a more positive view of the product than those who have not used. Difference in household size is significant at $p < 0.05$ indicating that users of inoculants have bigger household sizes than the non-users. Users are also closer to the market centers than non-users ($p < 0.01$).

Table 2: Summary statistics of variables used in the empirical estimations

Variable definition	Mean	Std. Dev.
Dependent variables		
Percep	3.68	1.15
Packets	2.17	3.89
Inocsize	0.10	0.18
Independent variables		
Farmer/household specific variables		
Lnage	3.80	0.30
Gender	0.30	0.46
Relationship	0.57	0.50
HHSize	5.41	2.73
Farm-specific variables		
Cropland	1.91	1.44
Distmkt	8.12	3.27
Nlegums	0.19	0.39
Percepnod	0.57	0.50
Capital endowment variables		
Educ years	6.83	3.56
Lnincome	9.89	1.10
Institutional variables		
Excont	2.09	2.76
Group	0.72	0.45
Bcredit	0.45	0.50
DistSCC	2.74	2.18
Number of observations = 210		

As shown in Table 3, users of more users (81%) perceive root nodules beneficial than non-users (25%) ($p < 0.01$). This shows that majority of non-users (75%) do not perceive root nodules as beneficial. Interestingly, non-users have more income than users ($p < 0.01$) which could be attributed to other sources of income by non-users. Users have more contact with organizations promoting BNF technologies than non-users, with mean difference significant at $p < 0.01$. Contact with organizations promoting BNF technologies is expected to contribute positively to farmers' perception and use of inoculants. Mean difference in membership to soybean producer group, access to credit and distance to soybean collection centre is also significant at $p < 0.01$. Mean difference in access to credit could be attributed to access of inputs by users of inoculants who are members in soybean farmer groups. Interestingly, non-users seem to be closer to soybean collection centers, this could be attributed to influence by the collection centers to grow soybeans and sell at the collection centers.

Table 3: Characteristics of users versus non-users of BIOFIX® inoculant

Variable	Users	Non-users	t –values	p-value
Dependent variables				
Percep	4.34	2.81	12.33***	0.000
Packets	3.83	0.0	9.25***	0.000
Inocsize	0.18	0.0	9.13***	0.000
Independent variables				
Farmer/household specific variables				
Lnage	3.83	3.78	1.11	0.268
Gender	0.32	0.27	0.70	0.485
Relationship	0.57	0.56	0.16	0.874
HHSize	5.75	4.98	2.10**	0.037
Farm-specific variables				
Cropland	1.94	1.87	0.34	0.736
Distmkt	7.08	9.48	-5.66***	0.000
Nlegums	0.18	0.20	-0.39	0.697
Percepnod	0.81	0.25	9.47***	0.000
Capital endowment variables				
Educ years	6.65	7.07	-0.86	0.393
Lnincome	9.63	10.22	-4.18***	0.000
Institutional variables				
Excont	3.38	0.40	10.04***	0.000
Group	0.96	0.41	10.03***	0.000
Bcredit	0.54	0.33	3.06***	0.002
DistSCC	3.34	1.95	4.98***	0.000
Region variables				
Mumias	0.30	0.37	-1.07	0.284
Bungoma	0.16	0.56	-6.44***	0.000
Bondo	0.54	0.07	8.93***	0.000
Total number of observations	119	91		

Note: Significance of mean difference is at **5% percent and ***1 percent.

A large number of soybean farmers (69%) are aware of legume root nodules and majority (65%) knows inoculants while (57%) uses BIOFIX® (Figure 1). This indicates a possible relationship between awareness of the existence of inoculants and use since only 8% of farmers who know something about inoculants have not used. Despite awareness of root nodules and inoculants, half of the farmers interviewed were uncertain about usefulness of nodules and 31% unaware of their existence while 7% consider them harmful. This indicates a gap in farmers' knowledge of BNF, which could constrain use of inoculants. Knowledge on the existence, usefulness of root nodules and of *Rhizobia* inoculants is expected to influence intake of inoculants positively.

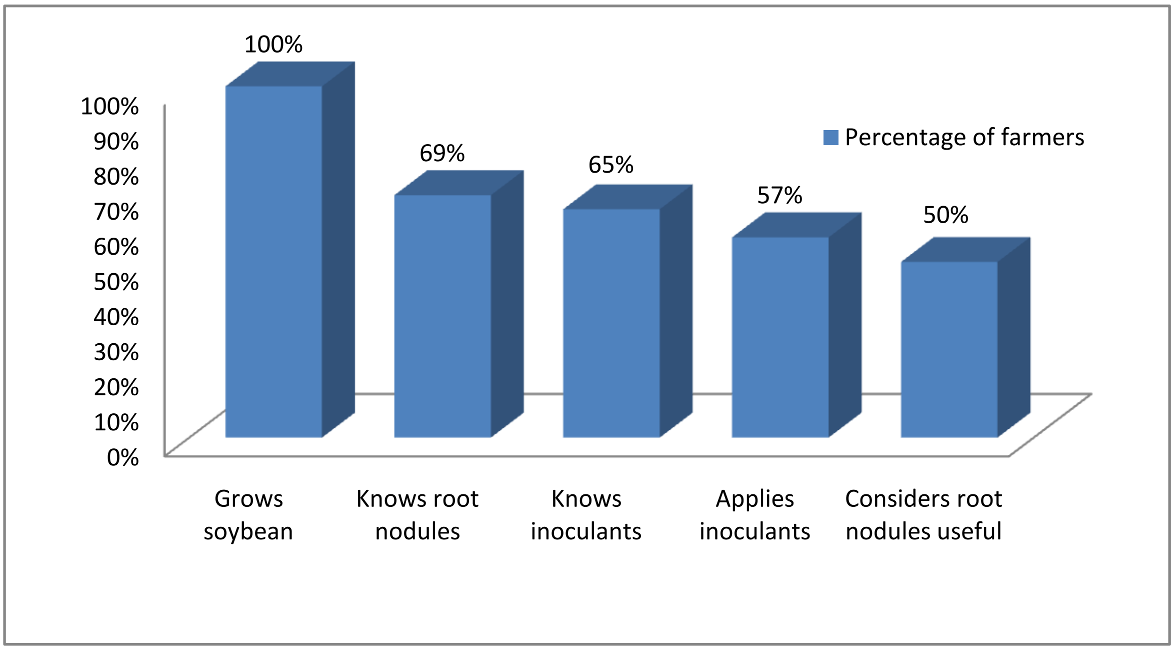

Figure 1: Growing of soybean, awareness of BNF and inoculants use

The main source of knowledge of inoculants is the private extension agents (63.2%) including agents from NGO's and CBO's (Figure 2). This is followed by research organizations (24.3%). Percentage of farmers who heard about inoculants from friends is 5.1% while the rest heard from public extension agents, family members, self-help groups, learning organizations and private companies. No farmer heard about *Rhizobia* inoculants through media such as radio and television. This indicate information dissemination gap among the soybean farmers. Ultimately, the use of different media will enhance quick dissemination of BNF technologies.

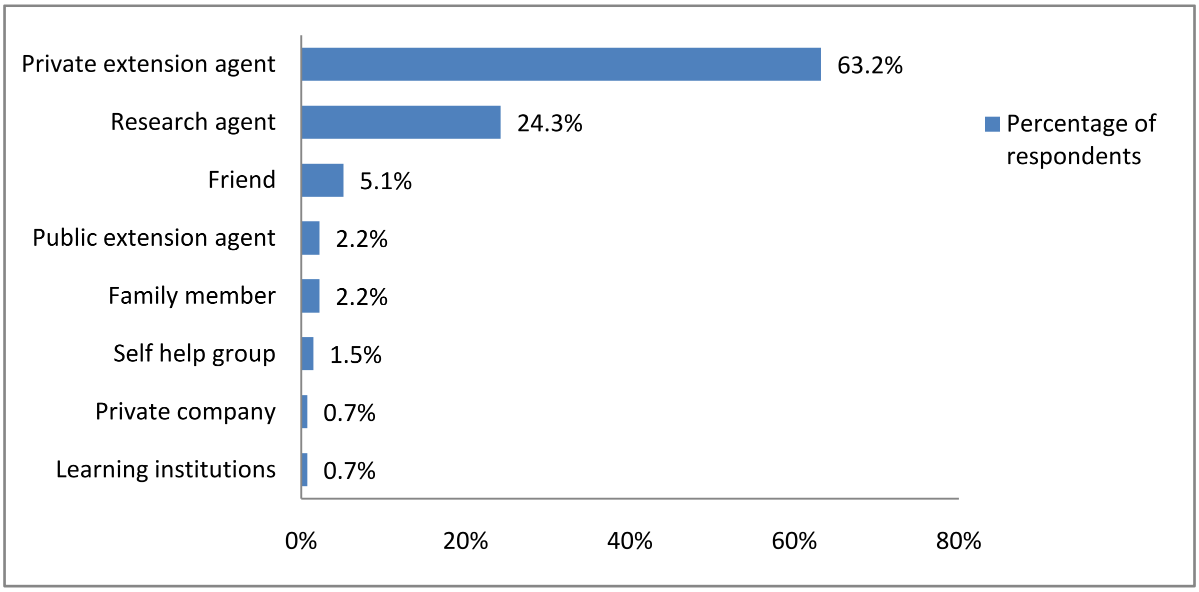

Figure 2: Sources of first knowledge on BIOFIX® inoculant

4.2 Farmers' perception of *Rhizobia* inoculants on soybean production

As shown in Table 4, farmer perception of *Rhizobia* inoculant is influenced by a number of factors. The results indicate that age, use of nitrogenous fertilizers on legumes, number of contacts with organizations that promote BNF, membership in soybean producer group and residing in a certain region significantly influence the respondents perception. The natural log of age ($p< 0.10$) indicates that the younger farmers have a better perception of inoculants than the older farmers do. Younger farmers are more literate and would embrace technologies faster than the older farmers would (Mugwe *et al.*, 2008; Kirui *et al.*, 2010 and and Okello *et al.*, 2012).

The use of nitrogenous fertilizers on legumes influence perception positively ($p < 0.05$), this shows that these farmers would easily compare the benefits of using *Rhizobia* inoculants in relation to fertilizers they use. A unit increment in the use of nitrogenous fertilizers on legumes increases the likelihood of having a positive perception of inoculants by 0.16 units, holding other factors constant. This could be attributed to the saving that would be achieved by using inoculants instead of purchasing the fertilizer. The resources that would go to acquisition of nitrogenous fertilizers can be put into other uses.

Number of contacts with organizations that promote BNF influences perception positively ($p < 0.01$). The marginal effects implies that a unit increment in contact with organizations that promote BNF increases the likelihood of having a positive perception of inoculants by 0.03 units, holding other factors constant. Contact with organizations promoting BNF and membership in soybean producing group enables the farmer to access information on inoculants. Farmers within the soybean groups get opportunity to participate in avenues where there is information such as during demonstrations and field days. In addition, membership in soybean producer group influences perception positively ($p < 0.01$). The marginal effects imply that a unit increment in soy group membership increases the likelihood of positive perception of inoculants by 0.18 units, holding other factors constant.

The location variables show that farmers in Mumias and Bungoma have lower perception of inoculants than in Bondo. The marginal effects imply that a soybean farmer being in Mumias and Bungoma reduces the likelihood of positive perception of inoculants by 0.18 and 0.23 units respectively comparing to their counterparts in Bondo, holding other factors constant. This suggest that farmers who have fewer choices of crops are likely to have a more positive perception of *Rhizobia* inoculants than their counterparts who have several choices (farmers in Bondo have limited choice of crop enterprises compared to Mumias and Bungoma who are in agro-ecological zones with higher rainfall).

Table 4: Farmers' perception of *Rhizobia* inoculants: Ordinal Logistic parameter estimates

Variable	Coefficient	Standard Error	p-value	Marginal effects		
				Coefficient	**Standard Error**	**p-value**
Farmer specific variables						
Lnage	-0.92	0.48	0.055	-0.16	0.08	0.058
Gender	0.02	0.32	0.944	0.004	0.06	0.944
HHSize	0.02	0.05	0.741	0.003	0.01	0.741
Farm-specific variables						
Cropland	0.06	0.10	0.532	0.01	0.01	0.532
Distmkt	-0.07	0.05	0.168	-0.01	0.01	0.169
Nlegums	0.85	0.39	0.031	0.17	0.09	0.052
Percepnod	0.38	0.31	0.214	0.07	0.05	0.207
Capital endowment variables						
Educ Level	0.14	0.24	0.569	0.02	0.04	0.569
Lnincome	-0.21	0.17	0.220	-0.04	0.03	0.223
Institutional variables						
Excont	0.18	0.07	0.009	0.03	0.01	0.010
Group	1.20	0.36	0.001	0.18	0.05	0.000
Bcredit	0.36	0.30	0.230	0.06	0.05	0.237
DistSCC	-0.05	0.09	0.589	-0.01	0.02	0.589
Region variables						
Mumias	-1.16	0.52	0.026	-0.18	0.07	0.014
Bungoma	-1.53	0.60	0.010	-0.23	0.08	0.004

Number of observations = 210 Prob > chi^2 = 0.0000 Log likelihood = -246.820 Pseudo R^2 = 0.183
Approximate likelihood-ratio test of proportionality of odds across response categories:
$chi^2(45)$ = 37.52
Prob > chi^2 = 0.778

4.3 Factors affecting the use of *Rhizobia* inoculants

A logit regression model was fitted using the binary dependant variable that takes the value of 1 if the respondent has ever used BIOFIX® and 0 if otherwise. The results of the model shows that the data fitted well (R-square = 0.673 and p-value < 0.0001). The results are presented in Table 5.

Table 5: Factors influencing the use of *Rhizobia* inoculants (Logit regression)

Variable	Coefficient	Standard Error	p-value	Marginal effects		
				Coefficient	Standard Error	p-value
Farmer/household specific variables						
Lnage	-1.20	1.25	0.338	-0.25	0.26	0.338
Gender	-0.07	0.67	0.916	-0.01	0.14	0.917
HHSize	-0.06	0.12	0.616	-0.01	0.02	0.617
Farm-specific variables						
Cropland	0.46	0.24	0.057	0.10	0.05	0.058
Distmkt	-0.18	0.11	0.098	-0.04	0.02	0.109
Nlegums	0.38	0.74	0.608	0.08	0.14	0.584
Percepnod	2.75	0.69	0.000	0.55	0.12	0.000
Capital endowment variables						
Educ years	-0.19	0.11	0.090	-0.04	0.02	0.082
Lnincome	0.05	0.42	0.901	0.01	0.09	0.901
Institutional variables						
Excont	0.54	0.18	0.003	0.11	0.04	0.002
Group	3.31	0.85	0.000	0.68	0.12	0.000
Bcredit	0.34	0.62	0.583	0.07	0.13	0.581
DistSCC	-0.16	0.19	0.384	-0.03	0.04	0.386
Regional variables						
Mumias	-2.74	1.14	0.017	-0.58	0.19	0.003
Bungoma	-3.41	1.27	0.007	-0.68	0.17	0.000
Constant	4.34	6.54	0.507			
Number of observations = 210				Prob > chi^2 = 0.0000		
Log likelihood = -46.925				Pseudo R^2 = 0.673		

The results of the Logit model show that area under crop ($p < 0.10$), knowledge of root nodules ($p < 0.01$), contact with organizations promoting BNF technologies and membership in soybean promoting group ($p < 0.01$), and location of the farmer determines the use of inoculants. A unit increment in the area under crops increases the likelihood of using inoculant by 0.10, holding other factors constant. This suggests that farmers accessing larger pieces of land are likely to set aside part of their land for soybean cultivation. Distance to the local market shows a weak level of significance with marginal effect coefficient not significant at ($p < 0.10$), however, the effect of the market is negative indicating that the further a farmer is from the market reduces the likelihood of using inoculants. This could be attributed to less access to information by farmers further from the market. Knowledge of root nodules (for legumes) has positive influence on the use of inoculants.

Farmers who perceive root nodules as beneficial are likely to use inoculants when holding other factors constant. This shows the importance of BNF information as a factor that influence uptake of these technologies. Interestingly, education has an inverse influence on the use of inoculants. Holding other factors constant, increase in education by one unit reduces the likelihood of using inoculants by 0.04. Farmers who are more educated are likely to be investing in other enterprises such as sugarcane and maize. Number of contacts with organizations promoting BNF and membership in soybean producer group has a high positive influence on the use of the technology. A unit increase in contact with organizations promoting inoculants increases the likelihood of using inoculants by 0.11 (holding other factors constant) while group membership contributes 0.68, holding other factors constant. The location variables show that farmers in Bondo are more likely to use inoculants than Mumias and Bungoma, holding other factors constant.

4.3.1 Factors determining the intensity of *Rhizobia* inoculant use

To assess factors determining the extent to which famers use inoculants, Zero Inflated Poisson Regression model was used. The number of packets of BIOFIX® inoculant used in 2011 was used as the dependent variable. Vuong test was used to compare the zero-inflated Poisson model to a standard Poisson model. The z-value is both positive and significant ($p < 0.001$), indicating that the zero-inflated Poisson is a better fit than the standard Poisson. The likelihood ratio test for alpha (Table 6) does not indicate the presence of over dispersion (Alpha = 0 and p value < 0.0001).

The gender variable was dropped since it was highly insignificance, indicating that it does not explain any variability in the model. Relationship of the farmer to the household head was used and is significant at ($p < 0.01$), however with insignificant marginal effect. The results (Table 6) show that a number of factors influences intensity of inoculant use. Among the variables with a positive influence on the number of packets used is the area under crops ($p < 0.01$) and knowledge of the importance of legumes roots nodules ($p < 0.01$). The marginal effects show that a unit increase in the area under crops, expected number of packets is expected to increases by 0.40, holding other factors constant. Farmers who perceive root nodules as beneficial are 2.1 more likely to use more packets of inoculants than those who view the inoculants otherwise, holding other factors constant.

Frequency of contacts with organizations promoting BNF technologies ($p < 0.01$) has also significant influence on the number of packets used. Holding other factors constant, a unit increase in contact with organizations promoting BNF technologies is expected to increase the packets of inoculants used by 0.23. It is expected that more contact with these organizations would enhance sharing of information regarding the technology and accessibility. Contact is enhanced by attendance to group meetings from where the extension officers meet farmers. Farmers who fail to participate in such meetings often get little information and thus lower usage of inoculant.

Table 6: Factors determining the intensity of *Rhizobia* inoculant use: Zero Inflated Poisson Regression Model

Variable				Marginal effects		
	Coefficient	Standard Error	p-value	Coefficient	Standard Error	p-value
Farmer/household specific variables						
Lnage	-0.15	0.21	0.477	0.05	0.93	0.954
Relationship	0.36	0.12	0.003	0.66	0.53	0.208
HHSize	0.04	0.02	0.032	0.09	0.12	0.452
Farm-specific variables						
Cropland	0.15	0.03	0.000	0.40	0.20	0.049
Distmkt	-0.01	0.02	0.550	-0.37	0.12	0.003
Nlegums	0.02	0.14	0.884	0.94	0.74	0.202
Percepnod	0.73	0.17	0.000	2.08	0.62	0.001
Capital endowment variables						
Educ level	-0.19	0.10	0.031	0.66	0.47	0.156
Lnincome	0.10	0.06	0.124	-0.47	0.41	0.247
Institutional variables						
Excont	0.05	0.02	0.007	0.23	0.11	0.041
Group	-0.43	0.31	0.173	2.10	0.33	0.000
Bcredit	0.14	0.11	0.177	-0.23	0.54	0.667
DistSCC	-0.10	0.04	0.031	-0.64	0.24	0.008
Regional variables						
Mumias	-0.18	0.21	0.389	-2.08	0.61	0.001
Bungoma	-0.12	0.23	0.601	-2.59	0.57	0.000
Constant	0.58	0.95	0.535			

Number of observations = 210 — Non zero observations = 94
Prob > chi^2 = 0.0000 — Zero Observations = 116
Log pseudo-likelihood = -302.455 — Likelihood ration of chi^2 = 122.17
Voung test of ZIP verses standard Poisson: z = 3.43 — Pr>z = 0.0003
Likelihood-ratio test of alpha=0 — Prob> $chibar^2$ = 0.000

Soybean market (proxied by distance to soybean collection centers) has an inverse effect on the number of packets used ($p < 0.05$) implying that the further a farmer is from soybean collection centre, the lower the intensity of use (Table 6). Marginal effects indicate that a unit in the distance from the soybean collection centre reduces the expected packets of inoculants used by 0.64. This indicates that accessibility to soybean market is a key factor in the intensity of *Rhizobia* inoculants use.

4.3.2 Factors determining the level of *Rhizobia* inoculant use

The area under inoculated soybean in 2011 was used as the dependent variable in the Tobit regression model. This was used to determine the level of BIOFIX® use and compare the results with ZIP. Table 7 shows the model fits the data reasonably well (p-value < 0.0001 and R^2 of 0.76).

The results show that among the institutional variables, frequency of contacts with organizations promoting BNF technologies and group membership have high positive significant influence on the acreage under inoculated soybean (p values <0.01) while the distance to collection centers have high negative significant influence on the acreage under inoculated soybean ($p < 0.01$) (Table 7). Knowledge of root nodules for legumes also has a high positive significant ($p < 0.05$) influence on the acreage under inoculated soybean while education shows a positive but weak influence on the acreage planted with inoculated soybean ($p < 0.10$). It is expected that a unit increase in contact with organizations promoting BNF would contribute 0.03 units' increment in the area under inoculated soybean, while holding other factors constant. More contact with these organizations enhances sharing of information regarding the technology and accessibility. Contact is enhanced by attendance to group meetings from where the farmers are met by extension agents. Farmers who fail to participate in such meetings often get little information and thus lower usage of inoculant. Soybean market (proxied by distance to soybean collection centers) indicates that the further a farmer is from soybean collection centre by one unit, the level of use would reduce by 0.04, holding other factors constant. This shows that accessibility to soybean market is a key factor in the level of *Rhizobia* inoculants use. For a unit increase in knowledge of legumes root nodules, there is a 0.11-point increase in the area under inoculated soybean, holding other factors constant.

Table 7: Factors determining the level of *Rhizobia* inoculant use: Tobit regression

Variable	Coefficient	Standard Error	p-value
Farmer/household specific variables			
Lnage	-0.01	0.08	0.946
Relationship	0.02	0.05	0.714
HHSize	-0.01	0.01	0.439
Farm-specific variables			
Cropland	0.03	0.02	0.118
Distmkt	-0.01	0.01	0.155
Nlegums	0.03	0.07	0.728
Percepnod	0.11	0.05	0.042
Capital endowment variables			
Educ level	0.04	0.02	0.094
Lnincome	0.02	0.02	0.347
Institutional variables			
Excont	0.03	0.01	0.000
Group	0.40	0.09	0.000
Bcredit	0.01	0.04	0.802
DistSCC	-0.04	0.01	0.004
Regional variables			
Mumias	-0.22	0.08	0.006
Bungoma	-0.41	0.10	0.000
Constant	-0.37	0.37	0.321
Number of observations = 210		Prob > F =	0.0000
Log pseudo-likelihood = -24.328		Pseudo R^2 =	0.760

4.3.3 Effect of the Institutional factors on the use of BIOFIX®

The Wald test for joint significance of the institutional coefficients [Membership in soybean promoting group; access to formal credit; contact with organizations promoting BNF technologies and market for soybean (proxied by distance to the nearest soybean collection centre)] gives a Wald value of 34.29 and a p-value < 0.0001, indicating that institutional factors jointly affect the use of BIOFIX®.

4.4 Profitability of *Rhizobia* inoculants on soybean production

The overall average soybean yield is 775 kg ha^{-1} for both users and non-users of *Rhizobia* inoculants (Table 8). The difference in yields between farmers who inoculate their soybeans and those who do not is highly significant ($p<0.01$) which could be attributed to better farming skills and improved inputs by users who have more contact with extension service providers. Farmers who inoculate their soybean get an average yield of 864 kg ha^{-1} while those who do not inoculate harvest 686 kg ha^{-1}, an increase of 26% that could be attributed to inoculation and other factors such as improved seed and better management. According to FAO (2008), an average yield of 800 kg ha^{-1} of soybean in Kenya was reported which is still low since research has demonstrated that it is possible to obtain soybean yields of 3,000 – 3,600 kg ha^{-1} from improved varieties of soybean and with good management practices. Nevertheless, our findings compare closely with those of FAO (2008).

Gross margin for farmers who inoculate their soybeans is significantly higher than that of non-users, i.e., Ksh. 21,651 and 13,641 ha^{-1} respectively. The p-value for test of difference in means of gross margin for users and non-users was 0.01. This suggests that the gross margin for users of BIOFIX® is significantly higher than that of non-users. The difference in the cost of gunny bags is also significant ($p<0.01$), this could be due to the requirement of more gunny bags by users to accommodate the extra yields. The difference in the cost of fertilizers and weeding is also significant ($p<0.05$) with farmers who use inoculants spending more on fertilizers implying the use of more planting fertilizers than non-users. Surprisingly, farmers using inoculants spend less on weeding than non-users. This could be attributed to closing of canopy by healthier soybeans, resulting to less weed competition.

Table 8: Gross margin for soybean: users and non-users of BIOFIX® inoculant

Variable	BIOFIX® users		BIOFIX® non-users			
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**t-value**	**p-value**
Output						
Yield Kg Ha^{-1}	864	348	686	207	4.61***	0.000
Returns Ha^{-1}	43194	17401	34300	10347	4.61***	0.000
Variable costs in Ksh Ha^{-1}						
Seeds	2826	695	2,934	632	-1.18	0.239
Fertilizer	1655	2598	923	2053	2.28**	0.024
Chemicals	218	817	165	686	0.51	0.608
BIOFIX®	225	251	0	0	9.81***	0.000
Gunny bags	482	184	381	103	4.99***	0.000
Labour						
Land preparation	4,274	956	4,284	762	-0.09	0.931
Planting	1,129	221	1,127	214	0.04	0.967
Weeding	7542	1447	7905	1140	-2.03**	0.043
Spraying	39	151	36	154	0.15	0.879
Harvesting	3153	1680	2903	1482	1.14	0.254
Total Variable Cost Ha^{-1}	21543	4396	20659	3390	1.65	0.101
Gross Margin Ha^{-1}	21652	17372	13641	11117	4.06***	0.000

Note: Significance of mean difference is at **5% and ***1%.

CHAPTER V

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary and Conclusions

In sub-Saharan Africa, the use of *Rhizobia* inoculants by the smallholder farmers remains low despite the demonstrated benefits of using the technology. In Kenya, a commercial *Rhizobia* inoculant has been developed and marketed as BIOFIX®, the only commercial legume inoculant available in East Africa. The aim of this study was to examine how farmers perceive the BIOFIX® inoculant, factors that drive its use and its profitability among the smallholder farmers. It uses data collected from 210 soybean farmers in three regions of Western Kenya namely; Bungoma West in Bungoma County, Mumias in Kakamega County and Bondo in Siaya County. Regression techniques were used to assess factors influencing perception and drivers of BIOFIX® inoculant use and partial budget analysis techniques to examine the profitability.

This study finds that perception of *Rhizobia* inoculants is different between users and non-users of the technology. Farmers who have used it will rate its use and benefits higher than those who have not used. Users are more knowledgeable in BNF technologies than non-users and this influences their uptake and perception of *Rhizobia* inoculants. Perception is affected by a number of socioeconomic and institutional factors that include farmer's age, use of nitrogenous fertilizers on legumes, number of contacts with organizations that promote BNF, membership in soybean producer group and residing in a certain region.

The study finds institutional factors [Membership in soybean promoting group; access to formal credit; contact with organizations promoting BNF technologies and market for soybean (proxied by distance to the nearest soybean collection centre)] jointly affecting the use of BIOFIX® inoculant. The decision to use *Rhizobia* inoculants is affected by the area under crop, distance to the market, knowledge of root nodules, contact with organizations promoting BNF technologies, membership in soybean promoting group and location of the farmer. Intensity of use is influenced by the area under crops, knowledge of the importance of roots nodules in legumes, frequency of contacts with organizations promoting BNF technologies, group membership and distance to collection centers and region where farmer is located.

The study also finds the use of *Rhizobia* inoculants to be profitable, holding other factors constant but with a high disparity in gross margins between farmers. The disparity is driven by difference in yields achieved.

5.2 Recommendations

The following recommendations are made:

- Need to strengthen capacity of local organizations (i.e. farmer owned producer groups and CBO's) to promote use of *Rhizobia* inoculants. These local organizations are sources of information to their members since they are channels for passing soil fertility improvement information from researches as well as linking their members to markets. Other channels of passing information and knowledge of soil fertility improvement technologies need to be explored i.e., use of radio, television and mobile phones.
- Involvement of other players offering extension services such as the public sector in promotion of inoculants and specifically BIOFIX® is crucial to reduce reliance on funded projects, which is not sustainable. In addition, there is need for greater marketing of the technology by the local agro-dealers and their alignment with soybean production groups.

- Importance of markets as drivers of technologies uptake has also been observed in this study, which implies that there is need to strengthen the output market. This demonstrates the link between promotion of BNF technologies and the markets. Contract marketing needs to be encouraged by promoters of BNF as part of the value chain, this can be done by building capacity of produce market actors.
- This study also show that more effort to promote inoculants need to be put in legume growing regions that have fewer enterprise choices.
- This study recommends future research on assessing profitability of inoculants on various legumes such as climbing beans, French beans and greengrams among the smallholder farmers. This information will be useful in informing future research on inoculants in relation to the profitability and market availability of the crops.
- This study also recommends future research on the impact of inoculants use on the household level.

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APPENDICES

APPENDIX I: PARTIAL CORRELATION COEFFICIENTS

Variable	Ln Age	HHH	HH-Size	Crop land	Dist mkt	N legumes	Percep nod	Educ	Ln income	Ex cont	Group	B credit	Dist SCC	Mumias	Bungoma
LnAge	1.000														
HH	0.213	1.000													
HHsize	-0.027	0.015	1.000												
Cropland	0.158	0.204	0.101	1.000											
Distmkt	-0.041	0.005	0.050	0.207	1.000										
Nlegumes	-0.080	0.035	-0.131	0.107	-0.025	1.000									
Percepnod	-0.017	0.006	0.172	0.001	-0.186	-0.027	1.000								
Educ	-0.408	0.157	0.142	0.185	0.118	0.061	0.126	1.000							
Lnincome	-0.107	0.212	0.067	0.296	0.322	0.245	-0.203	0.259	1.000						
Excont	0.094	0.168	0.225	0.118	-0.109	-0.033	0.338	-0.009	-0.073	1.000					
Group	0.079	0.086	0.130	-0.060	-0.270	-0.056	0.266	-0.066	-0.151	0.419	1.000				
Bcredit	0.005	-0.025	0.208	-0.025	-0.083	-0.011	0.188	0.027	-0.002	0.149	0.286	1.000			
DistSCC	0.092	-0.047	-0.072	-0.187	-0.517	-0.027	0.226	-0.107	-0.373	0.027	0.207	0.112	1.000		
Mumias	-0.118	0.176	-0.115	0.097	0.024	0.364	-0.095	0.145	0.395	0.220	-0.097	-0.190	-0.110	1.000	
Bungoma	-0.030	-0.088	0.037	0.114	0.517	-0.156	-0.258	0.034	0.196	-0.312	-0.210	0.135	-0.541	-0.500	1.000

APPENDIX II: QUESTIONNAIRE

SURVEY QUESTIONNAIRE
FARMER PERCEPTIONS, ADOPTION AND PROFITABILITY OF BIOFIX® ON SOYBEAN *(GLYCINE MAX)* PRODUCTION

Questionnaire No:			

SURVEY QUALITY CONTROL

Enumerator's name: _

Date: _ _ / _ _ /_ _ _ _ Start time: _ _ h _ _ End time: _ _ h _ _

Approved: YES / NO

Date entered: _ _ / _ _ /_ _ _ _ Entered by: _

A. General Information

1. Name of the respondent ……………………………………………………………..………
   (The respondent should be the person directly involved in planting soybeans).
2. Sex of the respondent 1. Male 2. Female
3. County
   ……………………….District……………………………………Division…………
   Location………………………………Sub location…………………………
   Village……………………………………….
4. GPS of the
   Homestead…………………………………………………..Elevation…………………
   Agro-ecological Zone (AEZ)…………………………………..
5. Period which the respondent has operated the farm…………………
6. Distance to the main road……………………………(km) nearest market………..(km)
7. Distance to the nearest soybean collection centre (if any)………………..………(km)

B. Household profile

First name	Last name	Sex	Age	Sources of income and Estimated income				Marital status	Parenthood	Education level	No. of Years in School	Years of farming experience
		1. Male 0. Female	Years	Primary 1= Farming 2= Business 3= Farm Worker 4= Civil Servant 5= Casual Worker 6= Retired 7= Student 8 = Remittances 9= Others (specify)………...		Secondary (Same as primary)		What is the marital status of the HH member: 1= Married monogamous 2= Married polygamous 3= Divorced 4= Separated 5= Widowed 6= Single	Relationship of the member to the HH head: 1= Head 2= Spouse 3= Son 4= Daughter 5= Parent 6= Grand Child 7= Son/ daughter in law 8= Relative 9= Servant 10= Others (Specify)……...	Highest level of education achieved by the HH member: 1= Primary 2= Secondary 3= College 4= University	No. of years spent at the highest level	
				Source	Income (Kshs)	Source	Income (Kshs)					

C. Assets

1. Land asset

Total land controlled ……………………….Acres Land with title deed……………………….Acres

Access to title deed by the household head: Accessible ☐ not accessible ☐

	Owned (Acres)	Rented in		Rented out		Communal (Acres)
		Acres	Cost	Acres	Cost	
Land under homestead						
Land occupied by livestock buildings						
Crop land						
Open pasture						
Timber land/ forestry						
Unused land						

2. **Physical assets other than land**

Asset name	Number currently owned	Year bought/built	Current value(KSH)
1) Donkey/ Ox-cart			
2) Sprayer(pump)			
3) Wheel barrow			
4) Bicycle			
5) Motorbike			
6) Motor vehicle			
7) Plough			
8) Mobile phone			
9) Standard weighing scale			
10) Store for farm produce			
11) Radio/radio cassette			
12) Television (TV))			
13) Sofa set			
14) Tables			
15) Water pump			
16) Other (specify)….....................			

D. General crop farming

Crop (Key enterprises)	Total Acreage				Total Yield				Quantity sold				Price/ unit			
	2010		2011		2010		2011		2010		2011		2010		2011	
	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR
Maize =1 Beans =2 Sorghum =3 Cow peas =4 Soybeans =5 Greengrams =6 pigeon peas =7 Irish potatoes =8 Sweet potatoes =9 Sugarcane =10 Coffee =11 Tea =12 Mangoes =13 avocadoes =14 oranges =15 pineapples 16 Bananas = 17 Cabbages =18 Kales =19 Carrots =20 Tomatoes =21 Others (Specify) ………………………………………………																

(Soybean and other legumes grown must be captured)

D1. What is the total land that is usually allocated to soybean production ……………………………………….acres

D2. What is the yield for soybean in normal season based on the above acreage…………………………………….Kgs

E. General livestock farming

Key enterprises	No. of Units				Outputs (Quantity sold)		Average Price/ unit	
	2010	Value (Ksh)	2011	Value (Ksh)	2010	2011	2010	2011
Cattle Calves								
Heifer								
Lactating cows								
Bulls								
Goats Dairy								
Local breed								
Sheep								
Chicken								
Rabbits								
Others (specify)…………………..								

F. General Labour

1. How many family members provide labour in the farm?

   Adult Men……………………………… b) Adult Women …………………………… c) Children…………………………...….

2. Do you normally use hired labour? 1. Yes ☐ 0. No ☐

   If yes, in which activities and how many days per year (average)

Activity	**Average number of days in a year**
Land preparation	
Planting	
Manure/ fertilizer application	
Weeding	
Spraying	
Harvesting	

G. Awareness of Biological Nitrogen Fixation and inoculants

1. For the legumes mentioned in section C above, do you know about legume root nodules? Yes ☐ No ☐
2. If yes, do you consider them 1. Harmful 2. Useless 3. Beneficial 4. Never bothered?..
3. Do you know about legume inoculants? Yes ☐ No ☐
   a. If yes, when did you hear/learn about inoculants?......................... (Year)
   b. How did you know about Inoculants?...

1) Family member	2) Public extension agent	3) Brochure	4) Friend
5) Research Agent	6) Radio	7) Television	**8)** Newspaper
9) Private extension agent	10) Any other (Specify)……………		

4. Have you ever inoculated legume seed? Yes ☐ No ☐
5. If yes, which legume(s) did you inoculate?..

a. Did you use an adhesive? Yes ☐ No ☐ (which one)?..

b. Did you inoculate this Season (March/April 2012)………………………past season (Oct/Nov 2011)……………………………………………. If you did, kindly give us the following information.

Season	Name of inoculant (brand name)	Source	Quantity	Price	Did you use it all or have you stored any. 1= All 2= stored some (ask to see package)	Did you observe a response to applying inoculant? 1=Yes 0=No	Do you plan on inoculating the next crop? 1=Yes 0=No
March/April 2012							
Oct/Nov 2011							

6. If No (i.e. the farmer has never used Inoculant) what are the reasons?...
   1= Lack of information
   2= Lack of inoculant
   3= Land constraint
   4= Lack of seeds
   5= Lack of finances
   6= Lack of market for outputs (yields)
   7= Not interested
   8= Other (Specify)………………………………………

7. Do you apply nitrogen fertilizer? Yes ☐ No ☐

8. If yes, do you apply N fertilizer to legumes? Yes ☐ No ☐

9. If yes, which one?

Activity	**Fertilizer name/s**	**Amount / rate of application**
Planting		
Topdressing		

10. Can you identify a visible symptom of nitrogen deficiency? Yes ☐ No ☐

11. If yes, a) Which ones?...
b) On which crops do you observe it most?..
1. Cereals 2. Legumes 3. All 4. Others (specify)……………………………………….

12. Evaluation of attributes of Inoculant

Attribute		**Perception of Inoculant**					
		Very high	High	medium	Low	Very low	**Comments**
Increases crop yield in:	Soybean						
	Common Beans						
	French beans						
	Cowpeas						
	Groundnuts						
	Pasture (Specify)…………						
Cost							
Profitability							
		Very easy	Easy	Slightly difficult	difficult	Very difficult	
Ease of use							
		Very good	Good	medium	Poor	Very poor	
Compared to nitrogenous fertilizers (i.e. CAN)							

H. Soybean production Inputs cost

What soybean production inputs did you use last year (2011) and what was their cost?

Input type	Short rains		Long rains	
	Count / Quantity	Price/ wage (Kshs)	Count / Quantity	Price/ wage (Kshs)
Fertilizers				
Bush clearing				
Family labour	………………Man days		………………Man days	
Hired labour	………………Man days		………………Man days	
Ploughing				
Tractor	…………………acres			
Ox plough	…………………acres			
Family labour	………………Man days			
Hired labour	………………Man days		………………Man days	
Planting				
Family labour	………………Man days		………………Man days	
Hired labour	………………Man days		………………Man days	
1st weeding				

Input type	Short rains		Long rains	
	Count / Quantity	Price/ wage (Kshs)	Count / Quantity	Price/ wage (Kshs)
Family labour	………………Man days		………………Man days	
Hired labour	………………Man days		………………Man days	
Ox-plough	…………………acres			
2nd weeding				
Family labour	………………Man days		………………Man days	
Hired labour	………………Man days		………………Man days	
Ox-plough	…………………acres			
Pest and disease control				
Chemical (Price/kg or litre)	1. 2. 3. 4.	1. 2. 3. 4.	1. 2. 3. 4.	1. 2. 3. 4.
Family labour	………………Man days		………………Man days	
Hired labour	………………Man days		………………Man days	
Harvesting				
Family labour	………………Man days		………………Man days	

Input type	**Short rains**		**Long rains**	
	Count / Quantity	Price/ wage (Kshs)	Count / Quantity	Price/ wage (Kshs)
Hired labour	………………Man days		………………Man days	
Post harvest Processing				
Family labour	………………Man days		………………Man days	
Hired labour	………………Man days		………………Man days	

I. Marketing information

1. Did you sell your soybean crop last year? (2011). 1. Yes ☐ 0. No ☐
2. If yes to question G1 above, what quantity, at what price and where?

Quantity (Kgs)		**Price (Kshs)**		**Where**	
SR	**LR**	**SR**	**LR**	**SR**	**LR**

3. Are you under a contract with a buyer? 1. Yes 0. No.
4. If yes, are you comfortable with the price set 1. Yes 0. No. Please give reasons for your answer……………………………………
5. Do you honor the agreement to sell to the buyer? 1. All the time 2. Sometimes 3. Never
6. Is the agreement honored by the buyer? 1. All the time 2. Sometimes 3. Never

7. Credit facilities

Source of credit in the area / institution offering credit	Type of credit 1= Cash 2= In-kind 3=Others (specify)	Have you ever borrowed? 1= Yes 0= No	If Yes When [year]	Purpose	Have you repaid 1= Yes 0= No	If no, Why	Can the source fund purchase of BIOFIX® 1= Yes 0= No	If you have never borrowed funds, is it possible for you to borrow from the specified source to fund inputs acquisition?

8. Institutional support

1. Participation in group activities

Group name	Who is a member of the group among your household members? 1= Head 2= Spouse 3= Son 4= Daughter 5= Parent 6= Grand Child 7= Son/daughter in law 8= Relative 9= Servant 10= Others (Specify)………………………	Group activities 1= Crop production (Specify)……………………..……….. 2= Marketing (specify products)……………………………….. 3= Acquisition of farm inputs (specify Inputs)………………………………….. 4= Table banking/ Merry go round 5= Others (Specify)………………………………..	When did you/ any of your household member join the group

2. Organizations offering extension services / technology promotion

Name of the organization	Type of services offered 1= Training on crop production 2= Training on marketing 3= Farm inputs 4= Marketing linkages 5= Offer market for produce 6= Offer research services 7= Others (Specify)…………………	Who is a member of the institution among your household members? 1= Head 2= Spouse 3= Son 4= Daughter 5= Parent 6= Grand Child 7= Son/daughter in law 8= Relative 9= Servant 10= Others (Specify)………..	Distance from the farm to the organization

3. Direct contact with organizations involved in promotion of Rhizobia inoculants.

Name of the organization	Activity done during contact	Number of interactions for last two years	
		2010	2011

4. **State the reliability of the following information sources regarding BIOFIX®:**

Source	1 = reliable; 0= not reliable)
Public Extension service providers	
Private extension service providers	
Fellow farmers	
Public Researchers	
Private Researchers	
Radio	
Television	
Print media: Newsletters/ pamphlets	

THANK YOU

5. Comments by the enumerator according to his/her own judgment.

1. How did the respondent give the information?..1=Willingly 2=With Persuasion
2. How reliable is the information?... 1=High 2=Medium 3=Low