# Farm-Level Adoption of New Sorghum Technologies in Tigray Region, Ethiopia

By

**Nega Wubeneh**

M.Sc. Thesis
Purdue University
Dept. of Agricultural Economics
West Lafayette, IN 47907-2056 USA

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# FARM-LEVEL ADOPTION OF NEW SORGHUM TECHNOLOGIES IN TIGRAY REGION, ETHIOPIA

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# ACRONYMS

| | |
|---|---|
| CSA | Central Statistical Authority |
| DAP | Diammonium Phosphate |
| DONAR | Department of Natural Resources and Agriculture |
| EARO | Ethiopian Agricultural Research Organization |
| FAO | Food and Agricultural Organization |
| GDP | Gross Domestic Product |
| ICRISAT | International Crops Research for the Semi Arid Tropics |
| MEDAC | Ministry of Economic Development and Cooperation |
| MLE | Maximum Likelihood Estimation |
| SAERP | Sustainable Agriculture and Environmental Resources Project |
| SG-2000 | Sasakawa-Global 2000 |
| SR | Striga Resistant |
| SSA | Sub-Saharan Africa |
| SWC | Soil and water conservation |
| TLU | Tropical Livestock Unit |
| WFP | World Food Program |

# ABSTRACT

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The adoption of Striga resistant sorghum varieties and inorganic fertilizer of small subsistence farmers was analyzed to identify the farm-level factors determining the farmers' adoption decisions. Separate Tobit regression models were estimated on a survey data of a random sample of 90 farm households conducted in 2001 in Tigray, Ethiopia. Results indicate that access to information, soil type, and farmers' perceptions of technology characteristics and rainfall risk were the factors associated with the adoption of the sorghum cultivars. For the adoption of inorganic fertilizers, adult labor, farm size, manure use and soil type were the factors determining adoption decisions. Farm size and adoption are negatively related as those with small farm area are more likely to adopt inorganic fertilizer and intensive production techniques.

# CHAPTER I

# INTRODUCTION

## 1.1 Background

Attainment of national food sufficiency has become a priority policy objective of the Ethiopian government since the early 1990s. The government launched a large agricultural extension program in 1994 to raise the productivity of smallholders through the use of modern agronomic practices, improved seeds and inorganic fertilizers. The program started with 167 demonstration plots by SG 2000 in 1994. It was taken over by the government and reached to 4 million farmer participants by 2000 (Geogis, et al., 2001). It is one of the agricultural success stories in Sub-Saharan Africa. In 1996, Ethiopia officially exported 60,000 tones of maize to neighboring countries with informal cross-border trade probably equaling another 10,000 tones (SG-2000, 1997).

Ethiopia has a population of 61.7 million with annual growth rate of 3.3%. Agriculture as the main sector of the economy provides more than 80% of employment and accounts for 55% of GDP and 90% of export revenue. Agriculture is still characterized by smallholder subsistence production using traditional technologies. Population pressure and successive land redistributions have reduced holdings to meager sizes. In 1995/96 about 63% of farming households had less than 1 ha of holdings and fewer than 1 percent of the farmers owned holdings larger than 5 ha (CSA, 1996; cited in Demeke et al, 1997).

Yields of most cereals are less than 1.3 Mt/ha (FAO, 2001). Most crops are produced under rainfed conditions as irrigation covers only 2 percent of the 2.4 million ha of potentially irrigable land (Berth, 1998). Despite a substantial growth in the use of inorganic fertilizer during the 1990s (121% increase from 75,000 Mt in 1993 to 167,877 Mt in 1999), only 20% of farmers used fertilizer in 1996/97 and the average consumption at 14kg/ha is one of the lowest in the world (FAO, 2001).

The average cereal production growth rate of 6.5% between 1993 and 1999 is well above the population growth rate and is an impressive achievement. The official statistics indicate that the growth on cereal production is mainly due to expansion of cultivated area rather than productivity gains (Table 1.1). This seems inconsistent with the increase in inorganic fertilizer consumption and the shortage of crop land. But looking at individual crops, significant yield increases were observed especially on teff and maize, the crops on which the extension mainly focused.

Table 1.1 Average Growth Rate (%) of Area, Production and Yield of Major Crops in Ethiopia (1993-2000)

| Crop | Area | Yield | Production |
|---|---|---|---|
| Barley | 2.37 | -2.32 | -0.00 |
| Maize | 6.30 | 3.53 | 10.05 |
| Millet | 10.87 | 3.59 | 14.84 |
| Sorghum | 9.34 | 0.19 | 9.55 |
| Wheat | 6.82 | -1.75 | 4.95 |
| Cereals total | 6.32 | 0.20 | 6.53 |

Source: FAO, 2001

Indeed, while area expansion may provide a short-term solution to meeting the growing demand for food due to population pressure, it is nonetheless an unsustainable practice. Quiñones, *et al* (1998) warn that this practice, especially burning the vegetation to clear the land for agriculture, leads to disastrous environmental consequences, such as soil erosion, weed invasions, impoverished post fire-climax vegetative ecosystem and loss of biodiversity. Already an estimated 50% of all cropland in Ethiopia faces severe soil degradation and erosion (Demeke et al., 1997).

More importantly, Ethiopia continues to suffer from increasingly recurrent droughts and famine. A few years of bumper harvests are followed by debilitating droughts. Ethiopia has been hit by famine in 1972-3, 1984-5 and the most recent one happened in 2000 and 2002 (BBC, 2002). Although the figures vary, reports indicate that currently more than 10 million people are affected by severe drought (ALERT, 2002). The drought is also expanding alarmingly into areas that were traditionally surplus producing. As long as the agriculture is dependent on rainfall, the current practice of deforestation and natural resource management continues and alternative water harvesting and storage techniques are not developed, this would continue in the foreseeable future.

Increasing productivity through use of modern technologies - water harvesting techniques, organic and inorganic fertilizers, improved cultivars, and improved agronomic practices and creating conducive policy and institutional environment is the proposed way for attaining food self sufficiency. Even with the current level of recommended application rates of inorganic fertilizer, under farmers' conditions, a 100 kg of DAP is estimated to yield an additional 3.4 to 7.4 quintals of cereal output per ha (Demeke, et al., 1997).

Sorghum is one of the major cereal crops grown in the semi-arid areas of Ethiopia, mainly for human consumption. Average share of sorghum in the total cereal production and the total cereal area for the 1988-98 period were 15% and 14%, respectively. The average yield of sorghum for the period 1993 - 2000 was only 1.3 t/ha. But the yield potential ranges between 2.5 to 5.0 Mt/ha (Georgis, et al., 2001)

*Striga*[1] infestation of continuously cultivated fields has become a major constraint to sorghum production. The area affected and infestation levels have increased, exacerbated by drought and deteriorating soil fertility (ICRISAT, 1996; Reda, et al., 1997). Heavy infestation can leave the land unfit for cropping and fields have been reported abandoned in the worst affected areas (Quinones, Country director, SG-2000, 1999, personal communication; ICRISAT, 1996). Ejeta et al. (1993) estimate that Striga causes yield losses of 65-70% in sorghum producing areas in Ethiopia. The effects are likely to be long lasting as *Striga* plants produce many millions of seeds that can lie dormant in the soil for up to 15 - 20 years. A single plant produces up to 42,000 of the tiny Striga seeds and one gram contains at least 80,000 seeds (Andrews, 1945; Vallace, 1950 cited in Doggett, 1965)

[1] *Striga* is a parasitic weed that attaches itself to the sorghum roots from where it draws its moisture and nutrient requirements, inhibiting plant growth, reducing yields and in severe cases, causing plant death (ICRISAT, 1996).

## 1.2 Problem Statement

In 1997 the Ethiopian Agricultural Research Organization (EARO) tested and released new *Striga*-resistant sorghum varieties produced by Purdue University to farmers in some sorghum growing areas in Amhara, Tigray and Oromiya regions. The technology package includes the new varieties, modern agronomic practices and inorganic fertilizer.

The cultivars were released to farmers in Tigray region in the 1998 cropping season, while inorganic fertilizer has been promoted since the early 1990s. The problem is, despite the severity of the Striga problem in the area and low yields of crops, the diffusion of the Striga resistant sorghum cultivars and inorganic fertilizer consumption still remain low. This study attempts to answer the questions: what are the determinants of the adoption of the new cultivars and inorganic fertilizer? What policy measures can be utilized to accelerate the diffusion? This study will be the first attempt to determine the extent of adoption of the Striga resistant sorghum cultivars and identify the factors that determine the adoption of both technologies. Such information is critically important in designing policy interventions to influence farmer behavior in ways that accelerate the adoption of the technologies and indicate future research and technology development strategies.

## 1.3 Objectives of the Study

The general objective of this study is to identify factors that affect the adoption of Striga-resistant sorghum cultivars and inorganic fertilizer in the Tahtay-Adiabo Woreda of Tigray.

The specific objectives of the study include:

1. Determine the extent of diffusion of the new Striga resistant sorghum cultivars
2. Identify the farm level factors affecting the adoption of the Striga-resistant sorghum varieties and inorganic fertilizers
3. Identify and recommend policies to promote the diffusion of these technologies.

## 1.4 Organization of the Thesis

The thesis is organized into six chapters. Chapter two reviews the literature on methodology and empirical work from adoption studies. Chapter three describes the study area, the history of introduction of the Striga-resistant cultivars in the Tahtay-Adiabo Woreda and the socioeconomic characteristics of sample farmers. The conceptual and empirical models and method of data collection are presented in chapter four. Chapter five presents the results of the econometric analysis. Finally, chapter six summarizes the main findings, conclusions and policy implications of the study.

# CHAPTER II

## LITERATURE REVIEW

Agricultural technologies have the potential to improve the livelihood of farmers in developing countries by increasing the productivity of land and labor. The success of the Green Revolution in Asia in increasing production and income of farmers through the introduction of modern technologies and practices has been well documented. After the Green Revolution in Asia, there was great enthusiasm to repeat the Asian experience in SSA and substantial resources were channeled to agriculture over three decades (Sanders, et al., 1996).

According to Antle and Crissman (1990) a high priority in agricultural development assistance since the 1960s has been the generation of technology that would enable farmers to increase productivity. Much research has been devoted to the causes of low agricultural productivity and the longer-term productivity gains that may be forthcoming from modern technology, but less attention has been devoted to the process of adoption by low income farmers. However, despite the availability of those proven and promising technologies that can substantially increase productivity, repeating the Asian success in sub-Saharan Africa has proved difficult. Per capita food production in SSA continued to decline (Sanders, et al., 1996). This puzzle spurred interest in the study of the adoption and diffusion of agricultural technologies. Since then several studies show that the simple existence of improved technologies was insufficient to ensure their adoption by small farmers (Sanders, et al., 1996; Finan, 1998).

Vitale (2001) points out that public funding of new cereal technology development will only produce positive returns if farmers choose to adopt them. Determining how farmers make decisions, and the way the new technologies will fit into the farmer's way of thinking, is key to gaining insight into the farmers adoption potential.

Adoption is defined as a mental process in which an individual passes through a series of stages from first hearing about an innovation, called an *awareness* stage, to collecting information about the technology's perceived benefits in terms of its profitability and fit into the farmer's operation, the *evaluation* stage. If the information is found to be adequate and the evaluation is positive, the farmer will experiment with the technology at a small scale called the *trial* stage before he moves to the final full-scale *adoption* stage (Rogers, 1962; cited in Feder, et al., 1985; Nowak, 1983). In making a decision, farmers are assumed to weigh the consequences of adoption of an innovation against its economic, social and technical feasibility (Kebede, 1990). Feder et al. (1985) distinguish between farm level and aggregate adoption of a technology and define farm level adoption as "the degree of use of a technology in long-run equilibrium when the farmer has full information about the new technology and its potential".

Economic studies on technology adoption generally assume a utility maximizing behavior of peasants in modeling technology adoption in a static analysis that relate the degree of adoption to factors affecting it (Feder et al., 1985).

The literature on technology adoption suggests that a wide range of socio-economic, technical and physical factors influence farm-level adoption of technologies (see Feder et al.

1985 for a detailed review). In many studies farmer and farm characteristics such as age, gender, level of education and farming experience; farm characteristics such as availability of family labor, income, farm size, soil quality and access to irrigation and rainfall; institutional factors such as tenure status, access to credit, input and output markets, and extension service are important factors influencing farmers' decisions to adopt new technologies (Feder et al., 1985; Shakya and Flynn, 1985; Kebede 1990; Nichola, 1994).

Following the work of Rogers (1962), risk and risk aversion by small-scale farmers were recognized among the major obstacles to technology adoption in earlier adoption studies (Finan, 1998). Farmers, faced with uncertainty with regard to production risks and adoption of technologies, were unwilling to gamble their immediate short-term subsistence security for the promise of higher yields. Risk aversion is a behavioral factor impeding adoption, but it is accompanied by a multitude of fundamental socioeconomic constraints that similarly limit technological adoption and only by helping farmers overcome this range of constraints can technology adoption in Africa become successful (Finnan, 1998). He further argues that perceived risk interacts with an array of other factors to influence household adoption decisions and thus the reduction of perceived risk alone does not assure successful adoption.

Adesina and Zinnah (1993) identify two major groups of paradigms in earlier studies for explaining adoption decisions - the innovation-diffusion paradigm and the economic-constraint paradigm - and add a third paradigm, which they call the "farmer perception" paradigm. The innovation-diffusion paradigm presents access to information about an innovation as being the key factor determining adoption; while the economic-constraints paradigm contends that economic constraints reflected in asymmetrical distribution of resource endowments are the major determinants of observed adoption behavior (Adesina and Zinnah, 1993; Batz et al, 1999). While the former two paradigms take the appropriateness of an innovation as given, the "farmer perception" paradigm argues that the perceived attributes of innovations also condition adoption behavior.

Adesina and Zinnah (1993) and Adesina and Baidu-Forson (1995) explicitly included farmers' perception of technology characteristics in their model in the study of adoption of improved varieties in West Africa and demonstrated that they are important factors affecting farmers' technology adoption decisions. Batz et al (1999) also analyzed the adoption of 17 dairy technologies in Kenya and found out that the rate and speed of adoption were influenced, among other things, by technology characteristics.

In most cases, agricultural technologies are introduced in packages that include several components, for example, high yielding varieties (HYV), fertilizers, and corresponding land preparation practices. While the components of a package may complement each other, some of them may be adopted independently (Feder et al., 1985). The complementarity between technologies is especially important in the semi-arid environment where unreliable rainfall and depleted soils are major obstacles to the adoption of both inorganic fertilizers and improved crop varieties and raise agricultural productivity.

In such environments, the adoption of soil and water conservation techniques is expected to be a critical prerequisite to the adoption of inorganic fertilizer and ultimately high yielding varieties. Shapiro and Sanders (2002) in a review of natural resource technologies for the semi-arid regions of SSA, present evidences from Burkina Faso and Ethiopia of successful simultaneous use of soil and water conservation techniques and inorganic fertilizer that significantly increased yields. Therefore, it is very important to look at the interaction between various technologies and the relationships between different adoption decisions. However, not many studies look at adoption of technologies in a holistic manner.

# CHAPTER III

# METHODOLOGY AND DATA

In this chapter the conceptual and empirical models for the analysis of farm level adoption of improved sorghum cultivars and inorganic fertilizers and the method of data collection will be presented.

## 3.1 Conceptual Model

The adoption literature shows that adoption of agricultural technologies is affected by a host of socio-economic, demographic, institutional and technical factors; farmers' perception of technology attributes and their attitude towards risk (Feder et al, 1985; Shakya and Flinn, 1985; Kebede, et al, 1990; Adesina and Zinnah, 1993; Nicola, 1994; Adesina and Baidu-Forson, 1995). In addition to farmer and farm characteristics, this study looks at how technical factors (complementary technologies such as SWC and manure use and soil type) and farmers' perceptions of technology characteristics and weather risk might affect the adoption of improved sorghum cultivars and fertilizers.

Adoption is measured as the proportion of sorghum area under new sorghum cultivars and the proportion of cropland fertilized. The choice of the explanatory variables is guided by economic theory and the adoption literature. The explanatory variables can be broadly categorized into farmer and farm characteristics, technical factors and farmer perceptions of technology characteristics and weather risk. Price variables are not included because there is no price variation in the study area as fertilizer is distributed at uniform prices from the same source.

Adult labor is the number of family members in a household aged 13 years and older. No distinction is made between male and female labor, because unlike plowing, the modern agronomic practices related to the cultivars and inorganic fertilizer application do not require strong muscle power. Both improved cultivars and fertilizer are labor-using technologies and increase the labor demand during peak seasons. It is hypothesized that adult labor is positively related to adoption of both technologies. New technologies increase the seasonal demand for labor, so that adoption is less attractive for those with limited family labor or those operating in areas with less access to labor markets (Feder at al., 1985). Labor and farm size are included as separate explanatory variables in the model instead of the land/labor ratio. According to Kazianga and Masters (2001) this approach helps to capture the scale effects that might arise from having more of both in a single household.

The relationship of farm size to adoption of agricultural technologies is an empirical question. The literature on farm size is often mixed because the relationship depends on many other factors such as fixed adoption costs, risk preferences, human capital, credit constraints, labor requirements, and tenure arrangements (Feder and et al., 1985). Farm size can be positively related to adoption because larger farmers can experiment with new technologies on portion of land without severely risking their minimum subsistence food requirement. Moreover, the potential benefits from adoption of new technologies are larger in absolute sense for large farms (Zepeda, 1994). Some authors argue that the positive relationship may be explained by fixed transaction and information acquisition costs associated with the new technologies and that there may be a lower limit on the size of adopting farms such that farms smaller than a certain critical level will not adopt the new technology (Just et al., 1980; Feder and O'Mara, 1981; cited in Feder et al., 1985). Others hold that farm size is an indication of the level of economic resources available to farmers and thus probabilities of adopting improved varieties and fertilizer increase as this resource base increases (Akinola, 1987; Polson 1990).

On the contrary, some studies have found negative relationships between farm size and adoption. Van der Veen (1970, cited in Feder et al., 1985) explains that small farms may farm land more intensively. They have more labor available per unit of land and larger farmers have higher transaction costs to use hired labor.

Livestock herd size is also an indicator of the economic resources available to the farmer. Livestock are sources of traction power, manure, and cash income. Animal traction improves the quality and timeliness of farming operations. Farm animals furnish manure to improve soils and livestock sales generates cash to purchase inputs (McIntire et al., 1985). The introduction of the new cultivars involves complementary management practices including land preparation, row planting and inter-cultivation. Therefore, it is hypothesized that the more livestock a farmer has, the larger the probability of adoption of new cultivars and inorganic fertilizers.

Extension is a way of building the human capital of farmers by exposing them to information that reduces uncertainty (Feder at al., 1985). Direct observations of innovations being used can provide potential adopters with considerable insight into the nature of innovations and probable outcomes (Napier, 1991). In this study, the number of times a farmer is visited by extension agents or farmer's exposure to new information through their contact with local administration are used as a proxies for access to extension information.

Water is the major constraint to agricultural production in the Ethiopian drylands and to successful adoption of fertilizers and improved seeds. Rainfall is highly variable in terms of quantity and distribution and is erratic in terms of onset, cessation and unpredicTable dry spells (Georgis et al., 2001). Moreover due to the nature of the rainfall and slopes, surface runoff rates are very high. Numerous studies have shown that in arid and semi-arid environments the availability of improved varieties alone is not sufficient to increase productivity. Sanders et al. (1996) have documented evidences of successful increases in productivity in West Africa with a simultaneous application of water retention techniques, improved seeds and inorganic fertilizer. Water retention devices reduce surface runoff and increase percolation to improve the soil moisture and hence increase the plants' efficiency of nutrient uptake. They minimize the risk from rainfall failure and encourage farmers to adopt improved varieties and fertilizer by increasing the return to fertilizer. On the heavier vertisols they are used to drain excess water from fields to prevent water logging.

Manure can increase yields by improving the soil organic matter content. It also improves the soil water holding capacity and thus increases efficiency in the use of inorganic fertilizer (Giller *et al.*, 1997, pp178). Sorghum yields were substantially higher for farmers who used manure and inorganic fertilizer in combination, than for those using either of them separately (Wubeneh and Sanders, 2001). Therefore, the availability and use of manure is hypothesized to be positively related to the adoption of both the new cultivars and fertilizer because of the incentive of higher expected incomes.

The decision of whether to adopt modern varieties and inorganic fertilizers depends, among other things, on the physical characteristics of soils. Light and medium textured soils have low moisture retention capacity and thus shorter growing periods, with water moving out of the root zone quickly and therefore not available to the plant (Sanders and McMillan, 2001). On the other hand, heavy crusty vertisols have low infiltration capacity and are prone to water logging problems. Farmers who have soils with low water holding capacity are more likely to adopt early maturing varieties and other technologies that improve the water holding capacity of the soil such as manure. They may also avoid adopting inorganic fertilizers since they can be easily leached away. Because of their water logging problems vertisols may not be suitable to short cycle varieties whose yield can be negatively affected with excess water. However, the heavier soils are expected to have more pay off to fertilizer. Soil type is used as a control variable.

Farmers' subjective perception is critical to understanding technology adoption (Roger, 1962, cited in Finan, 1998). Empirical studies demonstrates that farmers' perceptions of technology characteristics are important factors determining adoption (Adesina and Zinnah, 1993; Adesina and Baidu-Forson, 1995; Batz, et al., 1999). Information on farmers' perceptions of the Striga resistance, yield performance, earliness (and drought resistance) qualities of the new cultivars as compared to the traditional cultivars were collected during the survey. An average index measuring farmers' perception of the technology characteristics of the new cultivars is built from the subjective assessments of these qualities of the cultivars. A favorable assessment by a farmer of more than one of those characteristics is hypothesized to induce adoption of the new sorghum cultivars. The variable is constructed by taking a simple arithmetic mean of the three perception variables, i.e., TECHPRCP = (YIELD + SR + EARLI)/3

Similarly, farmers' subjective perception of rainfall risk is crucial in influencing their decision to adopt new technologies. Some farmers may have exaggerated subjective probability estimates of the risk of rainfall failure. Those farmers would be more inclined to adopt early-maturing cultivars and water retention devices than farmers who have lower subjective probability estimates or avoid use of inorganic fertilizers. So the risk perception is expected to be positively related to the adoption of the cultivars but negatively related to adoption of fertilizers. The variable is used as a proxy for risk aversion.

## 3.2 Sampling and Data Collection

Tahtay Adiabo woreda was selected for the study because it is predominantly a sorghum producing area and it is the only area in Tigray where a systematic seed multiplication, distribution and extension of the Striga resistant sorghum varieties SRN-39 and P-9401 took place.

The sampling procedure is a two-stage stratified random sampling. In the first stage, 5 sample tabias were randomly selected from 11 of the 18 tabias in the Woreda. The remaining 7 tabias were excluded from the sampling frame because no agricultural extension or development work has been done in those tabias since the start of the border conflict with neighboring Eritrea in May 1998. In the second stage, 95 farm households were randomly selected proportionally to the size (number of farm households) of the tabias from the five tabias using simple random sampling technique. Five filled out questionnaires were discarded later for various reasons. The sampling list was obtained from the Woreda and tabia administrations and was updated before sample selection.

### 3.2.1 Data collection

Sample farmers were interviewed using a structured survey questionnaire. The interviews took place at the farmers' households or at central meeting places when villages were inaccessible. The author himself conducted the entire interview in the local language, Tigrigna, to insure the quality of the data and have a better understanding of the farming system. The survey questionnaire is included in the appendix. Crop protection experts from the DONAR Woreda office in Sheraro and local council members and extension agents at the Tabias assisted in arranging appointments with farmers and explaining local customs and practices. A typical interview took two hours.

## 3.3 Empirical Model

Following Kebede (1990), Adesina and Baidu-Forson (1993) and Nichola (1994), in this study, the adoption decision of a technology by a farmer is assumed to be motivated by utility maximization. If the perceived utility of a new technology is larger than that of traditional technology, then the new technology is expected to be adopted. The utility function which ranks the preference of the $i^{th}$ farmer is given by $U(H_{ti}, G_{ti}, N_{ti})$, where $H_{ti}$ is a vector of farmer characteristics like education, experience, extension visits, farm size, etc.; $G_{ti}$ farm specific technical factors such as soil type, slope and physical water conservation structures, etc; and $N_{ti}$ is farmers' perceptions of technology specific characteristics including earliness, Striga resistance, yield, taste, ease of threshing and perception of rainfall risk.

(3.1) $U_{ti} = \beta_i F_i (H_{ti}, G_{ti}, N_{ti}) + e_{ti}, \; t = 1,2 \quad and \quad i = 1, 2,..., N$

where $t = 1$ new technology and $t = 2$ traditional technology

$U =$ the underlying utility function which ranks the preference of the $i^{th}$ farmer

$\beta_i$ = a vector of coefficients

$H$ = a vector of farmer specific characteristics

$G$ = a vector of technical factors

$N$ = farmers' perceptions of technology specific characteristics and weather risk

The utilities $U_{ti}$ are random and the $i^{th}$ farmer adopts the new technology ($t = 1$) if $U_{1i} > U_{2i}$ or if the non-observable (latent) random variable $I^* = U_{1i} - U_{2i} > 0$. The probability that $I_i^* > 0$, i.e., the farmer adopts the new technology, can be written as a function of the independent variables:

(3.2) $P(I_i^* > 0) = P(U_{1i} > U_{2i})$

$$= P[\beta_1 F_i (H_{1i}, G_{1i}, N_{1i}) + e_{1i} > \beta_2 F_i (H_{2i}, G_{2i}, N_{2i}) + e_{2i}]$$

$$= P\,[e_{1i} - e_{2i} > F_i(H_{ti}, G_{ti}, N_{ti})\,(\beta_2 - \beta_1)]$$

$$= P\,(u_i > F_i(H_{ti}, G_{ti}, N_{ti})\beta)$$

$$= F(X_i\beta) \qquad (3.3)$$

where $P$ = a probability function

$u_i = e_{1i} - e_{2i}$ is a random disturbance term

$\beta = \beta_2 - \beta_1$ is a vector of parameters to be estimated

$X$ = a vector of explanatory variables

$F(X_i\beta)$ is the cumulative distribution function for $u_i$ evaluated at $X_i\beta$

In the empirical analysis, factors that determine the adoption of the improved sorghum cultivars and inorganic fertilizer will be examined using a Tobit regression model. The Tobit model is appropriate for models whose dependent variable has a number of its values clustered at a limiting value, usually zero. It uses all observations, both those at the limit and those above it to estimate a regression line, and it is to be preferred, in general, over alternative techniques (Logit or Probit) that estimate a line with only observations above the limit (McDonald and Moffitt, 1980). Moreover, as McDonald and Moffitt (1980) have shown, in addition to the change in probability of adoption due to a percentage change in the independent variables, it provides information on the change in probability of intensity of use once the technology is adopted.

The dependent variables in equations 3.6 and 3.7 below are the proportions of sorghum area under the new cultivars and area fertilized, respectively. They are censored variables, which have a limiting value of zero and values ranging between 0 and 1. The Tobit model is used in a special case where the dependent variable is limited in a range or censored. It was developed by Tobin (1958) to model zero expenditure on consumer durables. A sample is said to be censored if observations on the dependent variable corresponding to known values of the dependent variable are not observable (Maddala, 1983; Mittlehammer, et al, 2000).

The functional form of the Tobit model is defined by Maddala (1999) as:

$$(3.4)\ y_i = \begin{cases} \beta X_i + u_i & if \quad \beta X_i + u_i > 0 \\ 0 & otherwise \end{cases} \qquad i = 1, 2, \ldots, n$$

where $\beta$ is a vector of unknown parameters; $X_i$ is a vector of explanatory variables; $u_i$ are residuals that are independently and normally distributed with mean zero and common variance $\sigma^2$. Zero here is the threshold or censor point. The standard cumulative distribution of the function (equation 4) monotonically translates the values of the attributes of $X_i$ into a probability, which take values between 0 and 1. The cumulative distribution function of the model is as follows:

$$(3.5)\ F(X_i\beta) = \int_{-\infty}^{X_i\beta} \frac{1}{\sigma(2\pi)^{1/2}} e^{-t^2/2\sigma^2}\, dt$$

where t is a random variable which is normally distributed with mean zero and unit variance. When (3.5) is specified as a continuous random variable between 0 and 1 it is known as a Tobit model.

The following regression models will be estimated for the new sorghum varieties and inorganic fertilizer adoption using the Tobit procedure:

(3.6) PSRAREA = f (EXEC, FRMSZ, TLU, FERT, WRT, SOIL, TECHPRCP, RISKPRCP)

(3.7) PFAREA = g (FMLYG13, FRMSZ, EXTEN, WRT, MANURE, SOIL, RISKPRCP, TECHPRCP)

The definition of variables is presented in Table 2.2 below.

Table 3.1 Definition of Variables

| Variables | Definition |
|---|---|
| PSRAREA | Proportion of sorghum area under the new cultivars |
| PFAREA | Proportion of land fertilized |
| FMLYG13 | Number of adults aged 13 years and older in the household |
| EXEC | Binary variable: 1 if the farmer is an official of the local administration; 0 otherwise |
| EXTEN | Number of times the farmer has been visited by extension agents during the season |
| FRMSZ | Farm size, measured in hectares |
| TLU | Tropical livestock unit |
| FERT | Quantity of fertilizer used on sorghum measured in kg/ha |
| MANURE | Quantity of manure used in quintals per farm |
| WRT | Water retention techniques, measured as binary variable: 1 if the farmer is using water retention techniques and 0 otherwise |
| SOIL[2] | Soil type, measured as binary variable: 1 if the soil texture is light and medium (Luvisols, Leptisols and Cambisols); 0 if heavy texture (Vertisols) |
| TECHPRCP | Index measuring the farmers' perception of the characteristics of the new cultivars (explained below). |
| RISKPRCP | Farmer's perception of rainfall risk; measured by farmers' subjective estimates of the probability of poor rainfall years |

All variables in the model except the TECHPRCP were quantified by farmers. TECHPRCP was built as an average index of farmers' subjective assessment of three

[2] Soil type information was collected using farmers' traditional classification. According to Corbeels et al, 2000) the farmers' classification closely corresponds to FAO's classification of soils. Keyih meriet (Luvisols), Chincha or Hutsa (Leptisols), Bahakel (Cambisols) and Walka or Tselim meriet (Vertisols). For

different characteristics of the new cultivars – yield performance, Striga resistance, earliness (drought tolerance) – compared to the traditional varieties. The variables were dummies taking the value of 1 if the farmer believed those qualities of the new cultivars were superior to those of the traditional cultivars, and 0 otherwise.

Risk perception is measured as the farmers' estimate of the probability of occurrence of bad and rainfall years, i.e., farmers' estimates of number bad rainfall years they expect out of ten years.

the econometric analysis, the first three are grouped together on the basis of their texture, compaction, cracking, drainage and moisture retention characteristics.

# CHAPTER IV

# STUDY AREA

## 4.1 Tigray Region

Tigray is the northernmost administrative region of Ethiopia. The region is bounded to the north by Eritrea, to the west by the Sudan, to the south by the Amhara Region and to the east by the Afar Region (see figure 4.1). It covers an approximate area of 80,000 square km. The population of Tigray is 3.1 million and the annual growth rate is estimated at 3.2% (CSA, 1995). The average population density of the region is 39 persons per square km.

Tigray belongs to the African drylands, which is often called the Sudano-Sahelian region (Warren and Khogali, 1992). It is characterized by sparse and highly uneven distribution of seasonal rainfall and by frequent occurrence of drought. Rainfall is variable temporally as well as spatially. Average rainfall varies from about 200 mm in the northeast lowlands to over 1000 mm in the southwestern highlands. The coefficient of variation in annual rainfall for the region is about 28%, in contrast to 8% nationally. Most of the rainfall falls during the "Meher" season from June to September and is most intense during July and August. In some parts there is a short rainy season called "Belg" which falls during the months of March, April and May.


Figure 4.1 Map of Federal Republic of Ethiopia

Various studies identified 13 major soil types in Tigray. These soil types include Cambisols, Rendzinas, Lithosols, Acrisols, Fluvisols, Luvisols, Regosols, Nitosols, Arenosols, Vertisols, Xerosols, Solonchacks and Andosols (Hunting, 1976; Tams, 1974). In the eastern part of the region the soils are mostly developed under arid conditions where the weathering process is slow and as a result very shallow Lithosols are dominant on the steep slopes. Cambisols and vertisols are developed in the higher rainfall areas of the south on alluvium derived from basalt. In the western part of the region, the soil type varies according to the parent material (RCST, 1996). Generally, the soils in Tigray are severely degraded by erosion and loss of fertility (Hagos, et al, 1999).

But Tigray region is also known for concerted soil and water conservation efforts. Each adult person is required by the regional government to contribute mandatory 90 – 180 man-days of free labor annually for the construction and maintenance of communal soil and water conservation structures. Since 1991/92 about 600,000 ha of land has been terraced and 4,600 km of gullies treated (Yibabe and Esser, 1999).

There are three main farming systems in Tigray – mixed crop-livestock farming system, the pastoral system and the mixed pastoral and cereal production system. Mixed crop-livestock system is the dominant system in the highlands whereas pastoral systems are more common in the lowlands. Of the estimated 616,000 farmland holders in Tigray in 1996/97, more than three-fourths were mixed crop-livestock producers (CSA, 1997).

Almost all of the cropland is planted to annual food crops including cereals (teff, wheat, barley, maize, sorghum, millet), pulses (beans, chickpeas, lentil) and oil seeds (sesame, flax, noug) (SAERP, 1997). Two-thirds of farmers do not fallow land mainly due to the shortage of farmland. Average land holding is 1.2 ha and varies from 0.5 ha in the highlands to 2.0 ha in the lowlands. More than 60% of the households have less than 1 ha of holdings (Hagos, *et al.*, 1999).

The SAERP (1997) report also indicates that manure and crop residues are used to maintain soil fertility in Tigray by about 60% of farmers and only about 12% of the farmers use inorganic fertilizers; high costs and lack of knowledge are the main reasons cited by those not using them. A large majority of farmers (90%) practice crop rotation, while less than half practice intercropping. Improved seeds are used by only about one-fourth of the farmers. One fourth of households use pesticides while only about 5% use herbicides. Given the low and erratic rainfall, absence of fallow and low level of input use it is not surprising that yields are very low. Cereal yields are typically less than 1 ton per ha, except under irrigated conditions (Hagos, et al, 1999; FAO, 2000).

Poverty and food insecurity are very severe in Tigray. About 58% of the population lives under extreme poverty (MEDAC, 1998, cited in Georgis and Takele, 2000). In 1996, nearly three-fourths of respondents in the SAERP survey reported being affected at least twice by famine since 1985 (SAERP, 1997). FAO/WFP (2000) crop and food supply assessment report indicates that in 1999 Tigray had a food balance deficit of 179Mt or a per capita deficit of 49kg (FAO, 2000). The deficit is equivalent to 30% of the total estimated annual consumption needs for the region.

Approximately 15% of the crop area is planted in sorghum in Tigray (Reda, 2000). Striga is one of the principal production constraints in cereals and legumes. Several fields have reportedly been abandoned due to heavy Striga infestation, which is exacerbated by poor soil fertility and moisture stress. In Humera, Western Zone of Tigray (Figure 4.2) yield losses of 20 to 100% due to Striga have been observed on sorghum (Negussie, Agronomist, Mekelle Research Center, personal communication). The traditional practices of controlling Striga infestation in the area are hand picking (after flowering and before seed setting), manuring, water retention, and crop rotation.

## 4.2 Tahtay-Adiabo Woreda

Tigray is divided in to four administrative zones- Central, Eastern, Southern and Western Zones and 34 Woredas[3] and 550 Tabias. Tahtay Adiabo Woreda, where this

[3] [3] Woreda is the third of administrative unit next to the regional government and Zone; it is equivalent to a county in the US. Tabia is the smallest level of administration next to Woreda. A typical tabia has between 700 and 1000 households.

study was undertaken, is one of the 9 Woredas in the Western Zone (see figure 4.2). It has an estimated 17,194 farm households. The main crops grown, in the order of their importance in terms of percent of cultivated area in 1999, were sorghum (50%), millet (34%), sesame (9%), maize (4%), cowpea (2%) and small quantities of teff, pepper and peanut (DOANR, 2000). There were 24 extension workers and the number of farmers in the extension program was 3,298. Thus, there was one extension agent for 716 farmers in the Woreda or for 137 farmers in the extension program.

Unlike in the highlands of Tigray where population density is much higher, farmers in this area have slightly larger farm sizes. Sixty-six percent of farmers have holdings between 1.5 and 5.0 ha; and 25% have holdings between 2.5 to 5.0 ha.

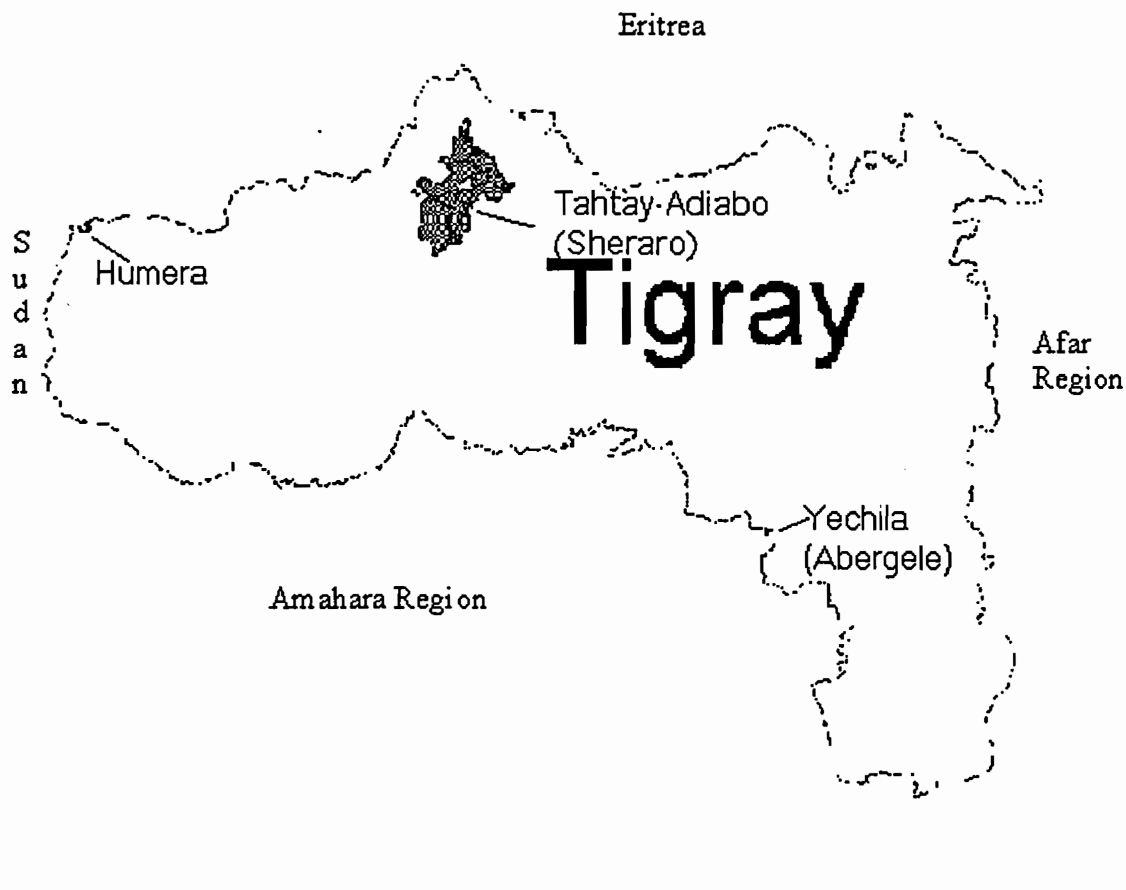


Figure 4.2 Tigray Administrative Region

Use of modern agricultural inputs in Tahtay-Adiabo is minimal even by national standards. In 1999 the average fertilizer consumption was only 5 kg/ha of arable land as compared with a national average of 14kg/ha. The total quantity of other inputs distributed by the department during the same season includes only 234 kg of improved seeds, 3.6kg of powder pesticide and 34 liters of liquid pesticide. Crop yields are also very low. Although farmers described 1999 as a good rainfall year, the 1999 annual report of the DOANR shows that yields were less than 0.8Mt/ha for all crops (see Table 4.1).

Table 4.1 Crop Yields in Tahtay-Adiabo Woreda (1999)

| Crop | Yield (kg/ha) |
|---|---|
| Sorghum | 729 |
| Millet | 660 |
| Maize | 800 |
| Sesame | 264 |
| Cowpea | 400 |
| Pepper | 400 |
| Teff | 256 |
| Peanut | 456 |

Source: Western Zone DOANR office

## 4.3 History of Striga Resistant Varieties in Tigray

The Striga-resistant sorghum varieties (SRN-39, P-9403, and P-9404) were introduced into Tigray in the 1997 season with 3 kg of seed obtained from Purdue University[4].

[4] In 1988, another 5kg of the seed was brought from the Melkasa Research Center (Nazareth) through SG-2000 and was planted on an irrigated 1 ha plot in the Tekeze area with financial and material assistance from GTZ. The yield was estimated to be between 40-60 quintals. However, with the outbreak of the war with Eritrea in the summer of 1998, cattle destroyed the crop because the guard assigned to protect the crop abandoned it.

Tahtay Adiabo Woreda (Sheraro) is the predominant area in which the most systematic seed multiplication and distribution has been carried out. In 1997 the Western Zone Department of Agriculture and Natural Resources (DOANR) multiplied the seed on a 0.5 ha demonstration plot in Sheraro and invited farmers to a field day to see the crop. Eight quintals (100 kg units) of the seed were harvested, of which 6 quintals were distributed to approximately 120 farmers in the Tahtay Adiabo Woreda (about 5kg per farmer). The remaining 2 quintals were distributed in the Central and Southern zones of Tigray.

The farmers who received the seeds were instructed to multiply the seed carefully without mixing the Striga-resistant varieties with other seeds under DOANR supervision. About 180 quintals of the seed were harvested and DOANR purchased the seeds from the farmers by paying 50 Birr ($5.95) more per quintal than the market price. In 1999, the collected seed was further distributed to more farmers in the Tahtay Adiabo Woreda[5]. The following season DOANR failed to purchase the seed from the farmers as promised, and as a result most farmers were discouraged and stopped producing the seed. During the 2000 season no Striga resistant seed was distributed by DOANR. Farmers were using either their own saved seed or seed obtained from other farmers through exchange or purchase. However, this practice would depreciate the quality of the seed as it becomes mixed with traditional varieties.

[5] Of the 180 quintals collected, only 23.5 quintals has been reported as unsold and still in a warehouse in the Adi Hageray Tabia. The DOANR doesn't have records on the number of farmers who have received the seeds. If each farmer received 5 kg to plant ½ ha, this would give 3,130 farmers. Since they were expected to produce seed, they were undoubtedly given more sorghum seed. Note that there may have been more of this seed that was not planted but there is no information. So this is probably an upper limit estimate of the number of farmers receiving this seed.

Only an estimated 8% of the farmers in the five Tabias had obtained the SR cultivars[6] (see Table 4.2 below). The average area planted to the new SR cultivars was 0.3 ha, while the traditional varieties were planted on 1.3 ha. The proportion of sorghum area planted to the new cultivars ranged from 6% to 100%. Out of the sample of 90 farmers, two farmers (2%) planted the new sorghum varieties only; twenty-three farmers (26%) planted both the new and traditional varieties and the remaining sixty-five (72%) planted only the traditional varieties. Approximately 40% of the non-adopting farmers said they were not aware of the existence of the SR cultivars.

Table 4.2 Number of Adopters of SR Cultivars in Five Tabias of Tahtay-Adiabo Woreda, (2001)

| Tabia | No. of households | No. of adopters | % of adopters |
|---|---|---|---|
| Adi Hageray | 111 | 26 | 23 |
| Adi Waela | 1104 | 5 | 5 |
| Atsrega | 936 | 87 | 9 |
| Deguale | 1399 | 62 | 4 |
| Zeban Gedena | 1466 | 189 | 13 |
| Total | 5016 | 415 | 8 |

Source: Wubeneh, 2001, survey data

Generally, farmers appreciated the taste, color, and especially the early maturity qualities of the new Striga resistant sorghums. Although the varieties were primarily released for their striga resistance, due to the shortage of rainfall and recurrence of drought, farmers were more interested in their earliness. The region has very limited capacity for varietal selection and conducting area specific experiments. The DOANR has not done adaptive experiments before releasing the seeds to farmers in Tahatay-

[6] This figure was calculated on the basis of DONAR records of farmers who received the seeds from the DONAR offices and from other farmers. Therefore, the proportion of adopters of 28% in the random

Adiabo Woreda. Some farmers reported problems with planting time and depth of the new cultivars. Farmers initially planted the new varieties in June, at the same time as the traditional varieties, and the crops were exposed to bird attacks because they matured much earlier than traditional cultivars.

Some farmers experienced low rates of seed germination when the seed was covered by the *maresha,* the traditional ox-drawn plow and some farmers also reported weak stalks of the new cultivars that break during strong winds. DONAR later experimented with the planting depth and an 80% germination rate was observed at 3cm depth when the seed was covered by foot rather than the *maresha*. The observed germination rate was only 50% when the depth was 5 cm (Mulugeta Balema, Crop Protection Expert, Western Zone DONAR, personal communication).

## 4.4 Socioeconomic Characteristics of Sample Farmers

Household heads had an average age of 51 years and an average family size of 6 persons, of which 2.6 are adults[7] (Table 4.3). Most of the farmers started farming during their mid teens and have an average farming experience of 34 years. Although there are some farmers who have no livestock or cropland land, sample farmers have an average livestock herd of 6 TLU[8] and have 3.6 ha of farmland. There are however many young landless farmers who get access to land through a sharecropping arrangement where the

sample may not be accurate.

[7] Adult, for this study, is defined as person aged 13 years and older. It is the age at which children usually start helping out in the farm

[8] A Tropical Livestock Unit (TLU) is an animal unit used to aggregate different classes of livestock. One TLU equals an animal of 250 kg live weight.

land owner receives a quarter of the output, but doesn't share the input cost nor make farm decisions.

Owing to a lower population density, the average land holding in the Tahtay-Adiabo Woreda is three times larger than the average for Tigray of 1.2 ha,. This is probably due to the prevalence of severe malaria and high temperatures that can reach up to 40°C during summer season (June – August). But the land is so fragmented that farmers have an average of 3 fields (maximum of 8 fields), with an average walking distance of 26 minutes from the household. Some of the fields are up to four hours walking distance. This can be a serious obstacle to making soil and water conservation investments and to using certain modern technologies and inputs.

Family labor is the main source of farm labor. However, hired labor use is common during the peak season. Farmers used an average of 18 hours hired labor per farm of during the 2001 cropping season.

The small area planted to the new cultivars indicates that farmers are still at the experimenting stage of the adoption process. On average only 9% of the sorghum area or 2% of the total cropland is planted to the new sorghum cultivars. Extension service is the main source of information for farmers on new technologies, followed by information from fellow farmers. Extension agents visited farmers an average of 2 times during the whole 2001 cropping season.

Various soil and water conservation techniques are used in the area. About 88% of the farmers reported that they have some soil and water conservation structures on their fields. The most common soil and water conservation structures are soil and stone bunds. Sixty eight percent of the sample farmers have these structures on their fields.

They have been widely promoted by the regional government since the early 1990's and are built by mobilizing communal labor. Recently introduced conservation structures, becoming popular rapidly, are what are known as trenches, a variation of tied ridges dug manually. They have proven effective in retarding erosion and harvesting run-off water. They are used by about 20% of farmers even though they have only been introduced in the last three years. About 6% of farmers use diversion ditches to harvest run-off.

Efforts to promote the animal drawn tied ridges were not successful because the implement was found to be heavy and awkward to use and thus has been returned to the experiment station for further adaptation (Shapiro and Sanders, 2001). Even though farmers appreciate the importance of the implement, they resorted to using shovels to make the ditches manually. Extension agents estimated that there would be 3 to 4 tied-ridges per tabia. This is approximately 50 to 70 tied ridges in the study area.

Table 4.3 Characteristic of Sample Farmers

| | Minimum | Maximum | Mean | Std. deviation |
|---|---|---|---|---|
| Age of the household head | 24 | 80 | 50.5 | 12 |
| Total family size | 1 | 12 | 5.9 | 2.5 |
| Adult family size | 1 | 9 | 2.6 | 1.4 |
| Years of farming experience | 5 | 66 | 33.5 | 13.1 |
| Livestock Herd size (TLU) | 0 | 20.6 | 6.0 | 4.8 |
| Number of oxen | 0 | 4 | 1.5 | 1.1 |
| Farm size (ha) | 0 | 11.4 | 3.6 | 2.2 |
| Number of fields | 0 | 8 | 3.4 | 1.5 |
| Distance of fields (minutes) | 0 | 240 | 26.2 | 38.1 |
| Total sorghum area (ha) | 0 | 25.8 | 1.5 | 2.7 |
| Area planted to SR varieties (ha) | 0 | .75 | .07 | 0.2 |
| Other income (Birr) | 0 | 16320 | 1956 | 2031 |
| Number of extension visits | 0 | 20 | 2.2 | 3.8 |
| Hired labor use (hours) | 0 | 100 | 17.8 | 21.3 |

Source: Wubeneh, 2001, survey data

For the purpose of this study, an adopter is defined as a farmer who was using the improved sorghum cultivars during the survey time. This is a narrow definition as it doesn't include farmers who were using the technology in the past and discontinued it in the current season for some reason or farmers who have made a decision to use the technology but have not done so as yet. Although information on past use of the cultivars was collected, farmers were not asked if they intended to use them in the future. Accordingly, of the 90 sample farmers, 25 were classified as adopters while the remaining 65 farmers were non-adopters. Following is a comparison of the socio-economic characteristics of adopters and non-adopters.

A t-test for the comparison of household characteristics of sample households shows no statistically significant differences between adopter and non-adopter farmers in most of the household characteristics – age and educational level of the household head, family sizes, livestock ownership and farm sizes. Adopter farmers had an average farm size of 4.2 ha, while non-adopters had 3.4 ha. There were no significant differences in area planted to sorghum, the area of sorghum fertilized and quantity of manure used between the two groups (Table 4.4).

The number of times a farmer has been visited by extension agents and income from sources other than crop production (other income)[9] were significantly larger for the adopters. Adopters were visited twice as much as non-adopters by extension agents during the season. Adopters reported an average annual off-farm income of Birr 1,088 ($131.1), while non-adopters reported Birr 91 ($10.8). The higher off-farm income for

[9] Other income includes income from sale of livestock, petty trade, sharecropping or renting land, and sale of beverages.

the adopters means less risk in adoption of technologies. Generally, the adopters had more resources and better access to public services. When food aid was quantified by the market price and added to the off-farm income, the difference was highly significant with adopters reporting an average income of Birr 3,025 ($360.5), while non-adopters reported income of Birr 1,473 ($175.6).

Adopters also used significantly larger quantity of hired labor (25 hours) than non-adopters (14 hours). There is no evidence that adopters had larger subjective probability of rainfall risk estimates than non-adopters by the adopters to influence their decision to adopt the early maturing new sorghum cultivars. The difference was not statistically significant.

Table 4.4 Comparisons of Some Characteristics of Adopters and Non-Adopters

| Variable | Adopters (n = 25) | Non-adopters (n = 65) | t-ratio |
|---|---|---|---|
| Age | 51.14 | 50.26 | 0.323 |
| Family size | 6.50 | 5.65 | 1.487 |
| TLU | 6.80 | 5.59 | 1.116 |
| Farm size (ha) | 4.16 | 3.38 | 1.556 |
| Sorghum area (ha) | 1.33 | 1.59 | -0.415 |
| Sorghum area fertilized (ha) | 0.10 | 0.11 | -0.181 |
| Manure use (Quintals) | 13.13 | 13.66 | -0.593 |
| Number of extension visits | 3.54 | 1.67 | 2.220** |
| Other income (Birr) | 1087.96 | 91.40 | 3.529*** |
| Hired labor used (hours) | 25.43 | 14.45 | 2.335** |
| Farmers' subjective estimates of number of poor rainfall years out of ten | 4.19 | 3.79 | 0.306 |

Source: Wubeneh, 2001, survey data
**, significant at 5%, ***, significant at 1%

A chi square analysis was used to compare some qualitative characteristics of the adopter and non-adopter farmers. Accordingly, sixty-one percent of adopters reported actively participating in various committees of local administrations compared to only 27% of non-adopters and the difference is highly significant (Table 4.5). The adopters had more contacts with extension agents, attended more development-related meetings and thus had more information about new technologies. A significantly larger proportion of adopters (89%) participated in on-farm trials, while only 55% of the non-adopters did so. Similarly, the difference between the proportion of adopters and non-adopters who had taken credit in the season is significant; 68% for adopters compared to only 45% of non-adopters.

The difference in the proportion of farmers using physical water retention devices was not significant. There are some private efforts, but basically the structures are built and maintained collectively on both private as well as communal lands. The regional government actively promotes and mobilizes annual campaigns for soil and water conservation work. Hence the structures are fairly pervasive and there is no significant difference in their use between adopters and non-adopters.

Although the difference is not statistically significant, a larger proportion of the adopters receive food aid. It is evident from the statistics that the adopters command relatively larger economic resources, get more extension visits, participate in local administration, have higher cash incomes and, more importantly, hire more labor.

Prevalence of food aid raises questions because of its implication on local prices and consequently on adoption of new technologies. Food aid dampens local grain prices discouraging use of purchased inputs like fertilizers and also creates a dependency syndrome. Moreover, the food aid in the study area was not linked to a food-for-work program to promote soil and water conservation programs, for building of local infrastructure or technology diffusion to extricate farmers from dependency in the long run.

Table 4.5 Comparison of Proportions of Some Farmer and Farm Characteristics

| | Adopters | | Non-adopters | | Chi-square |
|---|---|---|---|---|---|
| | No | % | No | % | |
| Number of Farmers: | | | | | |
| -Participating in local administration | 17 | 61 | 17 | 27 | 9.097*** |
| -Having physical water retention devices | 23 | 82 | 49 | 79 | 0.117 |
| -Using inorganic fertilizer | 18 | 64 | 28 | 45 | 2.823* |
| -Using fertilizer on sorghum | 7 | 25 | 11 | 17 | 0.635 |
| -Took loans in the 1992 season | 19 | 68 | 28 | 45 | 3.982** |
| -Participate in on-farm trials | 25 | 89 | 34 | 55 | 10.136*** |
| -Used purchased seed | 7 | 25 | 7 | 11 | 2.796* |
| -Used hired labor | 25 | 89 | 41 | 66 | 5.289*** |
| -Receive food aid | 22 | 79 | 49 | 72 | 0.002 |

Source: Wubeneh, 2001, survey data
*** Significant at 1%, ** Significant at 5%, * Significant at 10%

To help determine the probability of the adoption of the Striga resistant varieties, farmers were asked to give their subjective estimates of the number of years of bad, average and good rainfall out of a total of ten years depending on the onset and distribution. Farmers expect late onset of the rainfall 3.9 years out of ten (39% of the time) during which the new short season cultivars could be useful as the growing period becomes shorter for the traditional sorghum cultivars (Table 4.4). In these years, the shorter season SR cultivars would be expected to become very important and to be relied on after the early rains failed[10].

[10] With adequate rainfall and manuring of the crop Striga was not a serious problem. Local extension estimates were only 5 to 8% losses in 2000 from Striga.

Table 4.6 Summary of Farmers' Estimates of Number of Years of Bad Rainfall in Ten Years

| Number of years of bad rainfall | Frequency | Percentage |
|---|---|---|
| 1 | 2 | 2.3 |
| 2 | 8 | 9.4 |
| 3 | 27 | 31.8 |
| 4 | 26 | 30.6 |
| 5 | 13 | 15.3 |
| 6 | 5 | 5.9 |
| 7 | 3 | 3.5 |
| 8 | 0 | 0 |
| 9 | 1 | 1.2 |
| Weighted average | 3.86 years | |

Source: Wubeneh, 2001, survey data

The Striga resistant cultivars were part of the DONAR extension package in 2000 including inorganic fertilizer (50 kg/ha of DAP and 50 kg/ha of Urea) and other improved agronomic practices such as row planting, hand weeding and intercultivation. The use of inorganic fertilizer was much more common on finger millet than on sorghum. Farmers prefer to use fertilizer on millet because it is applied with broadcasting and thus requires much less labor than sorghum. Moreover, millet has a relatively higher market price compared to sorghum and the crop residue from millet is good animal feed. The average market price for the period 1997-2000 for sorghum and millet were, respectively, Birr 120 ($14.29) and Birr 135 ($16.07) per quintal.

In spite of the availability of inorganic fertilizers in the region, none of the Striga resistant sorghum adopters used inorganic fertilizers in the 2000/2001 season and only 19% (16 of the 85) farmers[11] producing local sorghums employed this input. With adequate rains at the start of the season fertilizing the local, longer season cultivars would give higher returns than on the shorter season, new cultivars (Reda, et al., 1997).[12] The major reason is the risk of rainfall failure, which induced farmers to adopt the early maturing cultivars. Another reason is that the new cultivars would not be in the field long enough to benefit from the fertilization as they mature quickly. Farmers clearly recognized this advantage of local, longer season cultivars (Wubeneh and Sanders, 2001).

Most farmers realized the benefits of using fertilizer but were unable to use it for various reasons (Table 4.7). The most important reasons were lack of adequate labor and/or draft animals and the risk of rainfall failure. About 27% cited labor shortage as their reason, 20% shortage of draft animals and 19% risk of rainfall failure. Only 1.3% of the farmers complained about high prices of fertilizer.

Table 4.7 Farmers Reasons for not Using Fertilizer on Sorghum

| Reason for not using fertilizer on sorghum | Percent |
|---|---|
| Shortage of labor | 26.6 |
| Shortage of draft animals | 20.3 |
| Too risky because of erratic rainfall | 18.8 |
| Shortage of both labor and draft animals | 6.3 |
| Prefer to use manure on sorghum | 6.3 |
| Higher return from millet | 3.1 |
| Unable to find fertilizer | 1.6 |
| Other reasons | 15.6 |

Source: Wubeneh, 2001, survey data

Animal traction has been in use for centuries in Ethiopian agriculture and it is a pervasive practice. The traditional Ethiopian plough is drawn by a pair of oxen. But not all farm households own a pair of oxen. Out of the 90 households sampled only 48

[11] This inorganic fertilizer was combined with manure and was used on an average area of 0.5 ha.
[12] There were also local short season cultivars in the region.

households (53.3%) have two or more oxen, 21 (23.3%) have only one ox and the remaining 21 (23.3%) had no ox at all.

Farmers who have no oxen get access to draft animals in exchange for their labor through a traditional arrangement known locally as *lifinti.* Male farmers who have no draft animals provide labor for one day to farmers who own a pair of oxen and in exchange they get access to use the pair of oxen to plow their own land for two days, i.e., one man-days of labor exchanged for two-oxen days. Farmers with only a single ox would pair up with other farmers who own a single ox and each of them use the pair for an equal number of days.

However, the fact that a farmer doesn't own draft animals does not necessarily suggest that he/she is poor. The author had interviewed a few innovative farmers who do not keep oxen because they have devised an innovative way to get access to draft animals. Those farmers take loans from the micro credit institute just before the start of the season for the purchase of a pair of oxen. They use the oxen during the peak season and sell them at the end of the season and pay back the loan immediately. Since they use the oxen for a short period, they are able to resell them at prices close to the purchase price and repay the loan before interest accumulates. Feed, veterinary and other costs related to keeping the oxen are avoided. The farmers explained that the oxen are not useful to them the rest of the year they could instead use the feed to keep dairy cows.

## 4.5 Sorghum Yields

The average yield of the local cultivars for farmers using neither manure nor inorganic fertilizer was 461kg/ha; 527kg/ha for farmers using manure only; 577kg/ha for farmers using inorganic fertilizer and 838kg/ha for farmers using both manure and inorganic fertilizer (Table 4.8). Note that yield data refer only to farmers utilizing these inputs. Inorganic fertilizer and manure use was concentrated on the land near the homestead. But farmers reported total yields of either the new or the traditional varieties from all plots because they combine all sorghum during threshing. Farmers also tend to understate their yields for fear of losing food aid. Approximately 72% of the sampled farmers receive food aid.

Table 4.8: Average Sorghum Yields ofFarmers Using Different Fertilization Techniques (kg/ha)

| Variety | No Manure and no fertilizer | Manure only | Fertilizer only | Manure plus fertilizer |
|---|---|---|---|---|
| Traditional | 461 (14) | 521 (49) | 577 (3) | 838 (16) |
| Striga resistant | 305 (7) | 635 (18) | - | - |

Source: Wubeneh, 2001, survey data

Note: 1. figures in parentheses are number of observations

2. These are not response function yields, but aggregate yields for a farm

## 4.6 Partial Budget Analysis

Partial budget analysis is a simple way of determining whether a proposed change in a farm operation will increase, decrease or not change net income. It analyzes the positive and negative effects of the proposed change on a farm operation. In this case the proposed change is replacing one ha of traditional sorghum area with the new Striga resistant sorghum cultivars.

Five-year experimental data (1996-2000) on yield of traditional and new sorghum varieties was obtained from EARO research stations in Abergele and Sheraro in Tigray.

The station yield data was discounted by 50% to approximate on-farm production conditions. Based on the experiment station and survey yield data and farmers' subjective estimates, five states of nature were defined and probabilities were estimated for each state of nature. The five states of nature are very good, good, average, moderately bad and very bad rainfall situations. The same market price of 120 Birr/quintal is used for both the traditional and new sorghum varieties based on information obtained from the survey.

Crop residues play an important role as animal feed and inorganic fertilizers in a mixed crop livestock production system. Farmers take into consideration the biomass yield in the valuation of new crop cultivars. Although no feed market was available in the study area, the value of crop residue is imputed at its opportunity cost using price data from similar markets in other areas in Tigray at 3 Birr/Quintal.

In the scenario where the state of nature is moderately bad or very bad, planting the new cultivars alone results in a net revenue gain of 192Birr/ha and 500Birr/ha, respectively. When the rainfall is in the range of very good to average, planting the new varieties alone would result in a net revenue loss of Birr 1203/ha to 100Birr/ha as a result of lower grain and crop residue yield of the new cultivars in those states of nature (Table 4.9).

Overall, the expected revenue from an operation that plants only the traditional cultivars is Birr 1833/ha while from the new cultivars, it is only 1520 Birr/ha, resulting in an expected loss of revenue of 312 Birr/ha. When the revenue is calculated without including the biomass yield (see figures in parentheses), the expected revenue is still smaller for the new cultivars, but gap in the expected revenue narrows down to only Birr 90/ha.

Thus, the new sorghum cultivars result in an increase in revenue only in adverse rainfall situations and replacing the traditional cultivars with the new cultivars is expected to result in a net loss of revenue because of the lower yield of the new cultivars and a low probability of moderately bad and very bad rainfall situations compared to average and above average rainfall situations. Therefore, it would not be profitable for farmers to entirely replace their traditional cultivars with the new striga resistant cultivars. Rather, they can benefit from using the Striga resistant cultivars as portfolio strategy along with the traditional cultivars to cover themselves for adverse rainfall conditions.

Table 4.9 Distribution of Yield and Revenue per ha of Traditional and New Sorghum for an Average Farm under Different States of Nature

| State of Nature | Estimated Probability | Traditional | | | Striga Resistant | | |
|---|---|---|---|---|---|---|---|
| | | Grain Yield (Q/ha) | Biomass (Q/ha) | Revenue (Birr) | Grain Yield (Q/ha) | Biomass (Q/ha) | Revenue (Birr) |
| Very good | 0.10 | 16.5 | 236.1 | 2688 (1980) | 10.5 | 75.1 | 1485 (1260) |
| Good | 0.20 | 14.0 | 200.3 | 2281 (1680) | 13.0 | 93.0 | 1839 (1560) |
| Average | 0.40 | 12.5 | 178.9 | 2037 (1500) | 11.0 | 78.7 | 1556 (1320) |
| Moderately bad | 0.20 | 7.5 | 107.3 | 1222 (900) | 10.0 | 71.5 | 1415 (1200) |
| Very Bad | 0.10 | 3.0 | 42.9 | 489 (360) | 7.0 | 50.05 | 990 (840) |
| Expected Revenue[13](Birr/ha) | | | | 1833.0 (1350) | | | 1520.6 (1290) |

Source: Reda (2002)
Notes: (1). Q = quintals is equivalent to 100 kg weight (2) Figures in parentheses are income without including value of biomass (3). Expected revenue is calculated as a sum of the product of probabilities of states of nature and revenues

## 4.7 Gender Issues

There were 15 female-headed households in the whole sample of which 3 were adopters of the new cultivars. Generally, the female-headed households were less endowed with assets than their male-headed counterparts (Tables 4.9 and 4.10). The female-headed households had significantly smaller family sizes, including adult labor, number of livestock, farm sizes and cash incomes. As a result of their smaller cash incomes, their use of hired labor was significantly lower than male-headed households (6 hours vs. 20 hours). But the difference in ownership of draft animals was not statistically significant. This allows the female farmers to exchange their oxen for labor with male farmers who have one or no oxen.

There is no evidence of bias against the female farmers in terms of access to extension services, credit, communally built soil and water conservation schemes or access to food aid. Moreover, there is no significant difference in use of purchased inputs (fertilizers and seeds). However, the use of manure is significantly smaller for the female-headed households, probably due to shortage of manure (since they have fewer livestock) and less adult labor available to haul and apply the manure.

Significant difference was also observed in the farmers' subjective estimates of probability of bad rainfall years out of ten years. The male farmers estimate was a mean of 3.8 years out of ten while the female farmers' estimate was a mean of 4.7 years.

Table 4.10 Comparison of Characteristics of Male- and Female-Headed Households

| Variable | Male (75) | Female (15) | t-value |
|---|---|---|---|
| Age of household head | 50 | 51 | -0.188 |
| Total family size | 6 | 4 | 3.639*** |
| Adult family size | 3 | 2 | 1.978** |
| Livestock (TLU) | 6 | 4 | 1.828* |
| Number of oxen | 2 | 1 | 1.360 |
| Farm size (ha) | 4 | 3 | 1.938** |
| Other income (Birr) | 2107 | 1201 | 2.720*** |
| Hired labor used (hours) | 20 | 6 | 2.364** |
| Number of extension visits | 2 | 2 | 0.791 |
| Subjective probability estimates | 4 | 5 | -2.2119** |

* significant at 10%, ** significant at 5%, *** significant at 1%
Note: Figures are rounded to the nearest tenths
Source: Wubeneh, 2001, survey data

[13] Assuming identical production conditions have been applied for the both the traditional and new cultivars, then the cost per ha is assumed to be the same for both cultivars and ignored for the analysis. Therefore, only the revenue aspect of the partial budget will be considered in the analysis.

Female farmers were much less involved in local administration and so was their participation in on-farm demonstration than their male counterparts. Significantly lower proportion of the female farmers used hired labor than the male farmers despite the fact that they have shortage of family labor, probably because they have smaller cash incomes.

Table 4.11 Comparison of Characteristics of Male- and Female-Headed Households

| | Male (n=75) | Female (n=15) | Chi-square value |
|---|---|---|---|
| Adopters of improved cultivars | 25 (33) | 3 (20) | 1.04 |
| Participating in on-farm trials | 53 (71) | 6 (40) | 5.21** |
| Participating in local administration | 32 (43) | 2 (13) | 4.58** |
| Using hired labor | 59 (79) | 7 (47) | 6.55** |
| Took loan | 41 (55) | 6 (40) | 1.08 |
| Using manure | 59 (88) | 8 (53) | 4.22** |
| Having soil and water conservation | 60 (80) | 12 (80) | 0.00 |
| Receiving food aid | 59 (79) | 12 (80) | 0.01 |
| Using inorganic fertilizer | 40 (53) | 6 (40) | 0.89 |
| Using fertilizer on sorghum | 14 (19) | 4 (27) | 0.50 |
| Using purchased input | 10 (13) | 4 (27) | 1.69 |

Figures in parentheses are percentages
* significant at 10%, ** significant at 5%, *** significant at 1%
Source: Wubeneh, 2001, survey data

# CHAPTER V

# RESULTS

This chapter presents the results of the maximum-likelihood estimates of the Tobit model of the determinants of adoption of the improved sorghum cultivars and inorganic fertilizers. The chapter is divided into two sections. The first section presents the results of the model for the improved cultivars while the second section discusses the results of the model for the inorganic fertilizers.

Descriptive statistics of both the dependent and independent variables (mean and standard deviation) in the models are presented in Table 5.1.

Table 5.1 Descriptive Statistics of Variables Used in the Empirical Model

| Variable | Mean | Standard deviation |
|---|---|---|
| PSRAREA | 0.08 | 0.18 |
| PFAREA | 0.08 | 0.10 |
| FMLYG13 | 2.60 | 1.47 |
| EXTEN | 2.22 | 3.82 |
| EXEC | 0.40 | 0.49 |
| FRMSZ | 3.66 | 2.26 |
| TLU | 5.98 | 4.80 |
| FERT | 0.10 | 0.24 |
| MANURE | 13.40 | 13.28 |
| WRT | 0.80 | 0.40 |
| SOIL | 0.46 | 0.50 |
| TECHPRCP | 0.14 | 0.25 |
| RISKPRCP | 3.90 | 1.40 |

Note: See Table 3.1 for variable description

## 5.1 Farm Level Adoption of New Sorghum Cultivars

In the Tobit model on the adoption of new cultivars (Table 5.2), farmers' participation in local administration was a significant variable in explaining adoption of the new sorghum cultivars. The variable was used as a proxy for access to information in place of the number of extension visits. The new cultivars were introduced relatively recently (1998 season) and many of the sampled non-adopter farmers didn't know that the cultivars existed.

From the preliminary interviews, many of the adopters appeared to be "model" farmers involved in the localities as militias and members of various committees such as development committee, etc. So a question on whether a farmer participates in the local administration was included in the questionnaire. Those farmers who answered affirmatively had more information about potential gains from new technologies through frequent contacts with extension agents and NGOs and attendance of development related meetings than their peers.

Jabbar et al (2000) in a study of factors affecting participation in community watershed management found that farmers' membership in peasant association executive increased their participation in the program. This underscores the importance of access to information about new technologies and practices as a determinant of adoption.

It was indicated earlier that there is only one extension agent for 716 farmers in the Woreda. Moreover, because of lack of means of transportation, extension agents have to walk long distances to reach farmers. So, it is also possible that extension agents seek out and work more closely with those "progressive" and easily accessible farmers. When the number of extension visits was substituted for the EXEC variable, it was not significant.

The coefficient of farm size is not statistically significant in explaining adoption of the cultivars. Similarly, livestock ownership was not significant but the coefficient has a negative sign. Livestock are generally considered a symbol of wealth and farmers with large livestock herd sizes tend to focus more on their livestock operations and pay less attention to their crop production.

Among the technical factors included in the model, only soil type was significant. Farmers prefer to plant the early maturing sorghum cultivars on the shallower soils that have poor water holding capacity. Water infiltrates rapidly and the growing period on these shallow soils is shorter. Thus planting early-maturing (drought resistant) varieties on those soils, such as the ones under investigation, is consistent with theoretical expectation. Whereas on the heavy vertisols the drainage is poor and water logging negatively affects the yield of the short season cultivars.

There is no evidence suggesting that use of water retention devices explains the adoption of the cultivars[14]. Soil and water conservation devices, notably dirt and stone bunds, promoted by the regional government are pervasive in the study area such that there was no significant difference in use of the technology between adopters and non-adopters of the cultivars.

Likewise, inorganic fertilizer use was not significant in explaining adoption of the cultivars. None of the farmers used inorganic fertilizer with the new cultivars during the

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[14] Water retention devices are complementary to improved varieties and fertilizer and their simultaneous application has been shown to substantially increase productivity (Sanders et al., 1996 pp. 39; Georgis, *et al.*, 2001).

survey season. The adopters are interested in the short season cultivars mainly because of moisture problem. Application of inorganic fertilizer in the absence of adequate moisture is risky as it could burn the crop. In addition, the farmers purchase the inorganic fertilizer on credit which they have to pay back after harvest. Therefore, the risk of crop failure and indebtedness play a major role in their decisions. The relatively shorter period of maturity (45-60 days) of the new cultivars is also important as they cannot stay long enough in the soil to fully benefit from fertilization.

Both variables relating to farmers' perceptions, i.e., their perceptions of the technology characteristics and rainfall risk are significant variables explaining the adoption decisions. These results are consistent with the choice of the shallower soils for planting the varieties and avoidance of fertilizer use. If farmers tend to have higher subjective estimate of probability of rainfall failure, it would follow that they adopt early maturing and drought tolerant cultivars. These short season cultivars have yield advantages over the traditional cultivars principally in bad rainfall years and are used as a portfolio mix combined with the traditional cultivars.

Table 5.2 Estimated Results of MLE Tobit Model for Adoption of SR Sorghum Cultivars in Tahtay Adiabo Woreda Of Tigray, Ethiopia

| Variable | Normalized coefficient | Asymptotic Standard error | Asymptotic T-ratio |
|---|---|---|---|
| Independent variables | | | |
| EXEC | 0.91937 | 0.36225 | 2.6176** |
| FRMSZ | 0.11155 | 0.080914 | 1.3786 |
| TLU | -0.037326 | 0.042092 | -0.88678 |
| FERT | 0.80013 | 0.71296 | 1.1223 |
| WRT | 0.30112 | 0. 48708 | 0.61822 |
| SOIL | 0.80792 | 0.37410 | 2.1597** |
| TECHPRCP | 3.9719 | 0.68805 | 5.7727*** |
| RISKPRCP | 0.25748 | 0.12635 | 2.0379** |
| INTERCEPT | -3.8584 | 1.0200 | -3.7827*** |
| Log-likelihood function | -15.309278 | | |
| Log-likelihood ratio | 3.697 | | |

Mean square error = 0.19853257E-01
Mean error = 0.26605625E-02
Squared correlation between observed and expected values = 0.41176
***, significant at 1%, **, significant at 5%
Source: Model results
Note: See Table 4.1 for variable description

To check for the robustness of the coefficient estimates a restricted model was estimated after dropping the insignificant variables from the model. Both the individual coefficient estimates and the log-likelihood ratio test were stable. Thus, the model is a good estimate and the variables - farm size, livestock herd size, use of fertilizer and water retention devices - do not, indeed, explain significant variation in the adoption of the new cultivars.

McDonald and Moffit (1980) have shown that the Tobit model, in addition to predicting the probability of adoption, provides information on the intensity of level of use of the technology once the adoption decision is made. Thus the regression coefficients can be disaggregated to determine the change in the probability of adoption and the expected level of use intensity of the new varieties, for those farmers who have already adopted, for a percentage change in the $k^{th}$ variable at the mean level, i.e., elasticities of adoption and expected level of use intensity. For the dummy variables, the values are the changes in the dependent variable in response to a change in the dummy independent variables from zero to one.

Following the McDonald and Moffitt (1980) the coefficient estimates were decomposed into the effects of changes in the independent variables on probability adoption of the cultivars and the expected level of use intensity. The estimated elasticities are reported in Table 5.3. They are estimates of the percentage changes in the adoption of the sorghum cultivars and use intensities to 1% change in the explanatory variables. The estimates show elastic adoption responses to changes in all the significant explanatory variables and elastic responses in intensity of use of the cultivars to changes in farmers' perception of both technology characteristics and weather risk. In all cases, marginal changes in those variables increase the probability of adoption of the Striga resistant sorghum more than the intensity of use of the varieties. For instance, involvement in local administration increases the probability of adoption by 1.3% while it increases the intensity (measured by the percentage of area under the cultivars) of using the cultivars by 0.7%. Having a non-vertisol soil increases the probability of adoption of the cultivars by 1.3% while it increases the use intensity by 0.7%. See McDonald and Moffitt (1980) for details of decomposition of the regression coefficients into elasticity of adoption probability and expected use of intensity.

Table 5.3: Elasticities and Marginal effects at Sample Means

| Variable | Adoption Probability | Expected level of use intensity |
|---|---|---|
| Elasticities | | |
| FRMSZ | 1.3835 | 0.7330 |
| TLU | 1.5437 | 0.8179 |
| | | |
| Maginal effects | | |
| EXEC | -0.8455 | -0.4480 |
| FERT | 0.3322 | 0.1760 |
| WRT | 0.9063 | 0.4802 |
| SOIL | 1.3946 | 0.7389 |
| TECHPRCP | 2.1095 | 1.1177 |
| RISKPRCP | 3.7948 | 2.0107 |

Note: For the dummy variables, the values reported are changes in the dependent variable in response to a change in the binary variable from zero to one.

## 5.2 Farm Level Adoption of Fertilizer

The MLE Tobit regression results reported in Table 5.4 show that adult family size, farm size, extension visits, manure and soil type are the most important factors conditioning farmers' decisions to adopt inorganic fertilizer. The significance of adult family size indicates that households with larger number of adult family members are more likely to adopt fertilizer than smaller sized households. Generally two kinds of inorganic fertilizer application methods are used - broadcasting method which is usually used to dress the crop with urea and the second method is a more labor-intensive method in which small dose of fertilizer is placed around the seed after row planting. The latter technique increases the labor requirement during peak seasons and households with limited supply of family labor may be constrained to use fertilizer.

Farm size is a highly significant variable explaining the adoption of fertilizer. The negative sign of the variable indicates that smaller farms are more likely to use intensification using inorganic fertilizer to compensate for their smaller land size. Households with large farms tend to prefer extensive production methods probably because they can afford to fallow part of their land and use crop rotation to replenish the fertility of the soil.

Access to information measured by number of extension visits is also significant in influencing adoption decision. Farmers' participation in local administration, which was used as a proxy for access to information in the adoption of the cultivars, however, was not significant in the fertilizer adoption model. Unlike the new sorghum cultivars, inorganic fertilizer technology was introduced much earlier and thus most farmers are aware of the technology. A hands-on demonstration of use of the inorganic fertilizer application and related management practices through extension service is more important in influencing adoption and sustained use of the technology.

There is no statistical evidence that use of water retention devices influence adoption of inorganic fertilizer. The sign of the coefficient is consistent with the expected complementarity of water retention and inorganic fertilizers. Water retention devices reduce the risk from variable rainfall and increase the potential gain from inorganic fertilizers in the semi-arid environment by capturing surface runoff and increasing infiltration to improve soil moisture and the nutrient uptake of plants. On the heavy vertisols they can be used to drain excess water and prevent logging. Use of water harvesting structures built mainly by the communal and to some extent by individual effort has become so pervasive that there is no significant variation in the use of the technology between adopters and non-adopters of inorganic fertilizers.

Manure use, as hypothesized, was significantly positively related to fertilizer use. Farmers using more manure also are more likely to use inorganic fertilizers. Manure is complementary to inorganic fertilizer and their simultaneous application has been shown to enhance yield performance (section 3.4.) In addition to replenishing soil fertility, manure also improves the water holding capacity of soils, thus facilitating nutrient uptake of plants. A more favorable environment (better soil and water availability) increases the expected utility of income from modern production and, hence, increases the probability that a farmer will adopt the new technology (Feder *et al.*, 1985).

Soil type is significant in explaining inorganic fertilizer adoption and it has the expected negative sign. It indicates that farmers are more likely to apply inorganic fertilizer on the heavy vertisols where the payoff could be higher as opposed to the shallower soils which have low moisture retention capacity. Consistent with the case of the sorghum cultivars, the physical characteristics of soils (texture) and hence the water retention capacity, *inter alia*, influences the adoption of inorganic fertilizers.

Although farmers' subjective estimate of probability of rainfall had the expected negative sign, it was not statistically significant.

Table 5.4 Estimated Results of MLE Tobit Model for Adoption of Inorganic Fertilizer in Tahtay Adiabo Woreda of Tigray, Ethiopia

| Variable | Normalized coefficient | Asymptotic Standard error | Asymptotic T-ratio |
|---|---|---|---|
| Independent variables | | | |
| FMLYG13 | 0.20265 | 0.10098 | 2.0068** |
| FRMSZ | -0.22693 | 0.76984E-01 | -2.9477*** |
| EXTEN | 0.83570E-01 | 0.32509E-01 | 2.5707** |
| WRT | 0.13945 | 0.33015 | 0.4224 |
| MANURE | 0.25902E-01 | 0.10276E-01 | 2.5206** |
| SOIL | -0.52770 | 0.26371 | -2.0011** |
| RISKPRCP | -0.63765E-01 | 0.10008 | -0.6372 |
| INTERCEPT | 0.33516 | 0.56439 | 0.5939 |
| Log-likelihood function | -2.0941595 | | |
| Log-likelihood ratio | 0.535484 | | |

Mean square error =0.77807751E-02
Mean error = -0.41727183E-02
Squared correlation between observed and expected values = 0.24336
***, significant at 1%, **, significant at 5%, *, significant at 10%
Source: Model results

To test for the goodness of fit of the model the restricted model is estimated after dropping the insignificant explanatory variables from the model. The LR ratio and the individual coefficients show that the coefficient estimates are stable and the dropped variables do not explain a significant amount of variance of the adoption of inorganic fertilizer.

The decomposition of coefficients using the McDonald and Moffit (1980) technique for the inorganic fertilizer adoption model is reported in Table 5.5. As in the case of the improved cultivars, changes in the explanatory variables have more effect on the adoption than the intensity (measured by the percentage area fertilized) of use of inorganic fertilizer. The elasticity for farm size shows elastic adoption response to change in farm size. A 10% increase in the availability of adult family labor increases the probability of adoption of inorganic fertilizer by 9% and the expected level of use intensity by 6%. A 10% increase in the farm size decreases the probability of adoption of inorganic fertilizer by 14%. Unlike the case of the sorghum cultivars, the change in the probability of adoption of inorganic fertilizer due to a change in the number of extension visits is not elastic. A 10% change in the number of extension visits increases the probability of adoption by only 3% and the expected use intensity by only 2%. That is probably because farmers are already aware of inorganic fertilizer due to its earlier introduction than the sorghum cultivars.

Table 5.5: Elasticities and Marginal effects at Sample Means

| Variable | Adoption Probability | Expected level of use intensity |
|---|---|---|
| Elasticities | | |
| FAMILYG13 | 0.9031 | 0.6272 |
| FRMSZ | -1.4117 | -0.9804 |
| | | |
| Marginal effects | | |
| EXTEN | 0.3126 | 0.2171 |
| WRT | 0.1887 | 0.1310 |
| MANURE | 0.5112 | 0.3550 |
| SOIL | -0.4095 | -0.2219 |
| RISKPRCP | -0.4225 | -0.2934 |

Note: For the dummy variables, the values reported are changes in the dependent variable in response to a change in the binary variable from zero to one.

# CHAPTER VI

# CONCLUSIONS

Only 8% of the farmers in the Tahtay-Adiabo Woreda have adopted the Striga resistant sorghum cultivars. Although the new cultivars were produced and promoted for their Striga-resistance quality, farmers were more interested in their earliness. This is not because Striga is not a problem, but drought has been the most significant agricultural problem in Western Tigray. Moreover, Striga problem is aggravated by lack of soil moisture and poor soil fertility.

EARO trials at three stations and farmers' accounts indicate that with good rainfall and improved soil fertility, the traditional long-season varieties give a higher yield and biomass than the Striga resistant cultivars and Striga infestation is significantly reduced. Thus farmers are adopting the Striga resistant sorghum cultivars only as a portfolio strategy for use alongside the traditional cultivars to protect themselves in bad rainfall years.

The expected benefit of higher yields of the traditional varieties is larger than the Striga resistant varieties during years of moderate and good rains. According to farmers' own estimates, they expect moderate and good rains approximately 61% of the time. This means that longer season varieties that respond better to the good rainfall and fertilization condition in those years increase the productivity and income of farmers. Thus in addition to stabilizing the yield and incomes of farmers during the bad years researchers have to generate new technologies to increase productivity during the moderate and good year in order to extricate farmers from subsistence farming and cycles of poverty.

The small areas of plots the farmers allocated to the Striga-resistant cultivars indicate that the diffusion process is still at the early stage. A large number of influential farmers among the adopters point to unequal access of farmers to extension information as extension agents tend to choose to work with those "model" farmers at the neglect of others less influential farmers. Nearly half of the non-adopters reported that they were not aware of the existence of the Striga-resistant cultivars. Therefore, the extension program should work more on exposing the non-adopter farmers to the new technologies.

In contrast, inorganic fertilizer was introduced earlier than the new sorghum cultivars and the knowledge is not restricted only to a few influential farmers. Repeated visits and demonstrations by extension agents are more important to convince farmers of the benefits of using inorganic fertilizer.

At the time of the survey, extension of the Striga-resistant cultivars was suspended after farmers lost interest following DOANR's failure to fulfill its promise to purchase the seeds from the farmers. To ensure the adoption of technologies, the extension program has to concentrate on persuading farmers about the potential benefits of new technologies instead of providing unsustainable monetary incentives. In the case of the Striga-resistant varieties, the usefulness of the cultivars as a risk portfolio for use in times of bad rainfall is can be promoted.

Farmers look for specific technology characteristics when making adoption decisions. The earliness and grain characteristics were the most desirable traits of the new cultivars sought by farmers. On the other hand, higher yields, larger biomass and thicker stalk for wind resistance were the qualities they preferred in the traditional varieties. Varieties combining the desirable characteristics of higher grain and biomass yields of the traditional cultivars with Striga resistance quality could be more successful. Therefore, researchers may need to look into possibilities of building of Striga resistance through breeding into the traditional longer season sorghum cultivars.

The expected interaction between the new cultivars and associated technologies such as soil and water conservation structures, and inorganic fertilizer was not observed quantitatively. The model results showed that the soil and water conservation structures do not explain the adoption of the improved cultivars nor inorganic fertilizer. Soil and stone bunds, promoted since the late 1980s, are very common conservation structures. They were mainly exogenously promoted by the regional government and built by communal effort and thus they are pervasive. Consequently, there is no significant difference in the use of these technologies between adopters and non-adopters of the sorghum cultivars as well as inorganic fertilizers.

Manure is commonly used in the study area, but it is mostly limited to fields around the homestead. Farmers who use more manure have a higher probability to adopt inorganic fertilizer. In addition to supplementing the inorganic fertilizer with more soil nutrients, manure also improves the soil density (water and nutrient retention capacity) and thus increases the pay off to inorganic fertilizer. Fuel wood is relatively more abundant in Tahtay-Adiabo compared to the other parts of Tigray. Hence there are less competing alternative uses for manure and farmers can use it to fertilize their land. Thus, increasing awareness and demonstrating to farmers on more effective application of manure are expected to increase the likelihood for adoption of inorganic fertilizers.

Tigray region has a very limited capacity to conduct adaptive trials and varietal selection. Consequently the Striga-resistant seeds were released to farmers before major potential agronomic problems had been addressed. Some early adopters suffered crop losses to bird attacks because, unaware that the new varieties mature earlier, planted them with the traditional long-season varieties the same time in July. As a result, the crops were exposed in isolation to bird attack. Some farmers also encountered low germination rates because of inappropriate planting depth. Those issues have contributed to discouraging some early actual and potential adopters. Therefore, the region needs to develop human and physical capacity to do adaptive trials and to be able to make recommendations specific to varying agroecological conditions. This may not necessarily mean generating new technologies, but at least competence to evaluate available technologies before dissemination.

Soil type was one of the factors affecting farmers' adoption decision for both the new cultivars and fertilizers again implying the need for the region to develop capacity to give specific extension advice to farmers, as opposed to blanket recommendations on fertilizer dosages, improved varieties and type of water management structures. Farmers reported that due to water logging, the yield of the short-season new varieties is negatively affected on Vertisols.

Creating new markets for the new sorghum might accelerate the diffusion of the cultivars. For instance, in Humera the grain qualities of the new varieties were found desirable for making pastries and thus command a premium over the traditional cultivars.

If the current tension is diffused and relations with neighboring Eritrea are normalized and the road infrastructure to Sudan is improved, it might create export market opportunities and hence higher price incentives for farmers.

While food aid is provided out of necessity to help farmers with short term consumption shortfalls, its targeting criteria and its long term impacts need to be examined carefully. There is a lot of evidence that food aid depresses local grain prices and creates a disincentive to adoption of new technologies. Targeting carefully only the most needy households and linking food aid to soil and water conservation activities and building of local infrastructure might help with the long-term objective of food security and extricating farmers from dependence.

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# APPENDICES

## Appendix A: Performance of Striga Resistant Varieties

Table A.1. Grain Yield (Q/ha)

| Variety | 1996 | | 1997 | | 1998 | | |
|---|---|---|---|---|---|---|---|
| | Abergele | Sheraro | Abergele | Sheraro | Abergele | Sheraro | Sirinka |
| P-9401 | 15 | 27 | 27 | 23 | 20 | 20 | 21 |
| P-9403 | 19 | 24 | 7 | 19 | 17 | 18 | 21 |
| SRN-39 | 20 | 26 | 8 | 18 | 18 | 16 | 21 |
| Average | 18.00 | 25.67 | 14.00 | 20.00 | 18.33 | 18.00 | 21.00 |
| Local check | 16 | 27 | 4 | 17 | 27 | 12 | 23 |

Source: EARO Report to INTSORMIL, May 2001

Table A.2. Plant Height (cm)

| Variety | 1996 | | 1997 | | 1998 | | |
|---|---|---|---|---|---|---|---|
| | Abergele | Sheraro | Abergele | Sheraro | Abergele | Sheraro | Sirinka |
| P-9401 | 109 | 132 | 97 | 117 | 141 | 117 | 125 |
| P-9403 | 127 | 123 | 89 | 136 | 142 | 118 | 126 |
| SRN-39 | 119 | 127 | 99 | 132 | 178 | 134 | 141 |
| Average | 118.33 | 127.33 | 95.00 | 128.33 | 153.67 | 123.00 | 130.67 |
| Local check | 194 | 253 | 95 | 254 | 317 | 248 | 226 |

Source: EARO Report to INTSORMIL, May 2001

Appendix B: Farm Survey Questionnaire

# Farm-level Adoption of New Sorghum Technologies in Tigray Region, Ethiopia

## Household Survey Questionnaire

Department of Agricultural Economics
Purdue University
West Lafayette, IN 47906
USA

Name of respondent: ______________________________

Relationship to the head of the household_______________

Date of interview Day:______Month:_______Year:______

Date checked: Day:______Month:______Year:__________

Date entered: Day:______Month:______Year:__________

Tabia: ____________________Code:_________

Kushet : __________________ Code :_________

Altitude ____________ masl

Distance of the household from the nearest town in walking hours _______

Distance of the household from the nearest all weather road in walking hours

_______

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## 1. General

### 1.1 Household composition (start with household head)

| ID No | Name | Sex | Age | Relation to HH head | Code | Level of education | Major occupation | Works on the farm? Yes/no |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
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1.2 Farming experience of HH head ________ years

1.3 Does the hh head participate on on-farm trials? Yes ☐ No ☐

1.4 Is the hh head an official of the local administration? Yes ☐ No ☐

## 2. Household Assets

### 2.1 Livestock ownership

| Type of animal | Code | Number |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

### 2.2 Land

| Field no. | Size (ha) | Soil type | Code | Cultiv-ated in 1992? Yes/no | Tenure status | Code | Distance from the hh (walking hours) | Slope | Has water conservation? Yes/No |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
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## 3. Land Use

### 3.1 Crop production and Sales in 1992 season

| Crop | Code | Variety | Code | Area (ha) | Production (kg) | Qty Sold | Total Value |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
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**3.2 Crop production in the last five years**

| Crop | Code | Variety | Code | 1991 | | 1990 | | 1989 | | 1988 | | 1987 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Area | Prod. | Area | Prod. | Area | Prod. | Area | Prod. | Area | Prod. |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
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3.3 Water conservation practices in the last five years

| Year | Used any physical water conservation? Yes/No | If yes, type of conservation technique | Who initiated the idea? | Who constructed it? |
|---|---|---|---|---|
| 1992 | | | | |
| 1991 | | | | |
| 1990 | | | | |
| 1989 | | | | |
| 1988 | | | | |

**4. Adoption of Striga-resistant Varieties**

4.1 Did you grow striga-resistant sorghum varieties this season? Yes ☐ ☐

No

**If answer is no, go to number B.1**

A.1 If yes, when did you start growing? Year__________

A.2 How did you know about the striga-resistant sorghum varieties?

a. from development agents_________

b. from other farmers______________

c. from mass media______________

d. Other (specify)________________

A.3 How much of your land area was under striga-resistant sorghum varieties this season ___________ha

A.4 Have you grown these varieties more than once? Yes ☐ No ☐

A.5 Has your sorghum area under these varieties

a. Increased_____________

b. Decreased_____________

c. Remained the same__________

d. Varies from year to year_________

A.6 If you did not grow the varieties more than once what was your reason?

________________________________________

________________________________________

________________________________________

A.7 What is the source of the striga-resistant variety seeds?

| Source | 1992 | 1991 | 1990 |
|---|---|---|---|
| BOA | ____ | ____ | ____ |
| SG-2000 | ____ | ____ | ____ |
| Other farmers | ____ | ____ | ____ |
| NGOs | ____ | ____ | ____ |
| Village retailers | ____ | ____ | ____ |
| Other (specify)__________________ | | ____ | ____ |

____

A. 8 In the season you grew the striga-resistant varieties did you get all the seeds you wanted?

Yes ☐ No ☐

A.9 If no, please indicate the amount you wanted and the amount you got at prevailing prices in the last three seasons.

| Year | Amount desired (kg) | Amount obtained (kg) |
|---|---|---|
| 1992 | ______________ | ______________ |
| 1991 | ______________ | ______________ |
| 1990 | ______________ | ______________ |

A.10 If the amount you wanted to buy would be available at higher price, are you willing to pay the higher price?

Yes ☐ No ☐

A.11 Do you save your own seeds from your striga-resistant varieties?

Yes ☐ No ☐

A.12 If yes, for how many seasons have you done that continuously? _______

A.13 Do you use fertilizer on sorghum? Yes ☐ No ☐

A.14 If yes, please indicate the area fertilized under Striga-resistant and other varieties in the last five seasons?

| | Area of sorghum fertilized (ha) | |
|---|---|---|
| Year | Striga-resistant | Other varieties |
| 1992 | | |
| 1991 | | |
| 1990 | | |
| 1989 | | |
| 1988 | | |

A.15 Is your fertilizer application rate

a. larger than the recommended rate______

b. smaller than the recommended rate______

c. same as the recommended rate_______

A.16 If your rate is different from the recommended rate, what is the reason?

______________________________________________

______________________________________________

A.17 Compared to 5 years ago, your use of fertilizer has

a. increased ______

b. decreased ______

c. remained the same ______

d. varies from year to year_____

A.18 In all the last three seasons were you able to get all the fertilizer you wanted?

Yes ☐ No ☐

A.19 Fertilizer use in the last five years

| Year | Fertilizer type | Code | Unit | Code | Quantity | Unit Price | Source |
|---|---|---|---|---|---|---|---|
| 1992 | | | | | | | |
| | | | | | | | |
| 1991 | | | | | | | |
| | | | | | | | |
| 1990 | | | | | | | |
| | | | | | | | |
| 1989 | | | | | | | |
| | | | | | | | |
| 1988 | | | | | | | |
| | | | | | | | |

A.20 What are your reasons for not using fertilizer on sorghum?

a. unable to find fertilizer______

b. too expensive_______

c. too risky_______

d. other (specify)_____________________________

A.21 Are there other management practices that you use with the striga-resistant variety and not with other varieties?

Yes ☐ No ☐

A.22 If yes, please indicate these management practices: (check as many as apply)

a. land preparation_____
b. timely weeding _____
c. raw planting _____
d. other (specify) ________________________

A.23 Were these management practices recommended to you?

Yes ☐ No ☐

A.24 Do you manure your fields? Yes ☐ No ☐

A.25 Manure application in the last five years

| Year | Unit | Code | Quantity | Source |
|---|---|---|---|---|
| 1992 | | | | |
| 1991 | | | | |
| 1990 | | | | |
| 1989 | | | | |
| 1988 | | | | |

A.26 If you don't use manure, what are your reasons?

a. distance of the fields ____
b. shortage of fuel wood ____
c. I don't have sufficient amount ____
d. Other (specify) ________

A.26 In your opinion what are the advantages of the striga-resistant variety?

a. higher yield______
b. grain quality______
c. drought tolerance _____
d. Striga resistance _____
e. other (specify)____________________

A.27 In your opinion what are the disadvantages of the striga-resistant variety?

______________________________________________

______________________________________________

B.1 Have you ever cultivated striga-resistant sorghum varieties?

Yes ☐ No ☐

**Note :If yes, go to B.2, if no, go to B.4**

B.2 If yes, what are your reasons for not adopting striga-resistant sorghum varieties?

a. unable to find the seed_____
b. seed too expensive_____
c. price of output lower compared to other varieties_____
d. prefer grain quality of other varieties______
e. threshing problems______________________________
f. Other (specify)______________________________

**If one of the reasons given was that you were unable to find the seeds, please answer the following question)**

B.3 If striga-resistant variety seeds were available at a higher price, how much would you be willing to pay to get them?

3 x the price of sorghum grain____ 4 x____ 5 x____ 6 x ____ 7 x ____ 8 x ____9 x____

10 x____ more than 10x____

B.4 If you have never cultivated striga-resistant sorghum variety, do you know that it exists?

Yes ☐ No ☐

B.5 What factors influenced your decision to cultivate the other sorghum varieties?

a. yield stability ____
b. grain quality ____
c. availability of seeds ____
d. price of the output ____
e. others (specify)________________________

________________________

**5. Revenues**

**5.2 Income from livestock sales in 1992**

| Type of animal | Code | No. sold | Price per animal | Total value | No bought | Price paid per animal | Total value |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
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**5.3 Income from other sources**

| Source | Code | Person-days (if applicable) | Amount received | Units | Code | Value per unit | Total value |
|---|---|---|---|---|---|---|---|
| Off-farm work | | | | | | | |
| Food for work | | | | | | | |
| Food aid | | | | | | | |
| Remittance | | | | | | | |
| Hiring out oxen | | | | | | | |
| Renting/sharecropping out land | | | | | | | |
| Sale of handicraft | | | | | | | |
| Sale of beverage | | | | | | | |
| Gifts | | | | | | | |
| Other (specify) | | | | | | | |

**6. Cost of production in the 1992 season**

| Item | Code | Unit | Code | Quantity | Cost/Unit | Total cost |
|---|---|---|---|---|---|---|
| **Seeds :** | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| **Fertilizer** | | | | | | |
| | | | | | | |
| | | | | | | |
| **Pesticides** | | | | | | |
| | | | | | | |
| | | | | | | |
| **Labor** | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| **Oxen** | | | | | | |
| | | | | | | |
| **Implements** | | | | | | |
| | | | | | | |
| | | | | | | |
| **Others** (specify) | | | | | | |
| | | | | | | |

**7. Credit and Extension**

7.1 Did you take loans this cropping season? Yes ☐ No ☐

**If answer is no, go to 7.5**

7.2 If the answer is yes, please fill out the following,

| Loan no. | Source | Code | Amount received | Units | Code | Purpose | Code | Interest rate (annual) | Period of loan (months) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

7.3 How do you buy inputs?

a. use own funds only____

b. buy on credit only ____

a. combination of own fund and credit____

7.4 How much did you have to borrow (total from all sources) in the past three seasons to finance purchase of seeds and fertilizer?

| Season | amount borrowed (Birr) |
|---|---|
| 1992 | ________________ |
| 1991 | ________________ |
| 1990 | ________________ |

7.5 If you didn't take loans, what was the reason?

a. fear of being indebted _____

b. lack of collateral _____

c. I have own sufficient funds_____

d. absence of lender ______

e. other (specify)________________________

7.6 What are the sources of your information about new farm technologies (check as many as apply)

a. radio ____

b. extension agents _____

c. NGOs _____

d. Other farmers ____

e. other (specify) ________________

7.7 How many times have you been visited by an extension agent in the 1992 cropping season? ________ times.

8. For sorghum, between which dates do you consider the onset of rains to be

| | After | Before |
|---|---|---|
| a. Early | ______ | ______ |
| b. Normal | ______ | ______ |
| c. Late | ______ | ______ |

9. What sorghum varieties do you plant in the following rainfall situations?

| Rainfall situation | Variety 1 | Variety 2 | Variety 3 | Variety 4 | Variety 5 |
|---|---|---|---|---|---|
| Early | | | | | |
| Normal | | | | | |
| Late | | | | | |

Out of ten years, how many of them do you expect to be

a. years with early onset low rainfall ________

b. years with normal onset of rains _______

c. years with late onset of rains _______