Assessment of Factors Affecting Farmers' Adoption level of Row Planting Technology and Yield Improvement on the Production of Eragrostis Teff [ZUCC.]: The Case of Minjar Shenkora Woreda, Amhara Region, Ethiopia

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A Thesis Submitted to

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This is to certify that the thesis prepared by Behailu Getu, entitled: *Assessment of Factors Affecting Farmers' Adoption level of Row Planting Technology and Yield Improvement on the Production of Eragrostis Teff [ZUCC.]: The Case of Minjar Shenkora Woreda, Amhara Region, Ethiopia* and submitted in partial fulfillment of the requirements for the Degree of Masters of Arts (Geography and Environmental Studies) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

The main objective of this study is to assess farmers' adoption level of teff row planting technology and the consequent improvement of yield and yield component achieved through the application of row planting technology on the process of teff production. Since teff is the most well known and widely consumed grain in Ethiopia for thousands of years, its importance beyond being staple food to the nations of the country is strongly tied to the socio-cultural settings of the country. Even though it is popularly consumed cereal, it was not given due attention the same as that of other grains in improving its productivity in major teff producing areas in the country. However, very recently with the provision of extension service to improve productivity of teff, row planting with the application of modern inputs have been introduced by MoA and its partners. Different reports and the media have reported that teff productivity has been increased wide spreading across the country. Therefore, to evaluate the impact of row planting technology on teff production and its challenges Minjar Senkora District is considered as a pilot area for its major production of teff. The two kebeles of Ararti Zuriyua and Korma are considered as a pilot area with purposive sampling. From the two sample kebeles a total of 113 respondents were considered for stratified and random sampling with 50 adopters and 63 non-adopters. Based on the findings of this study row planting technology improved the teff crop yield whereas its labor cost is very high compared to broadcasting. The quality of teff straw produced through row planting is very low for livestock fodder and construction material method. Due to adoption risk and vulnerability of teff production through row planting technology farmers in the study area prefer the application of broadcasting method of planting on account of its low labor cost, straw quality and application simplicity. The adoption of row planting method of teff sowing can be improved through farmers training in the demonstration centers and provision of row seeder machines.

Keywords: *teff; row planting technology; adoption*

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Acronyms

ATA	Agricultural Transformation Agency
CIA	Central Intelligence Agency
CSA	Central Statistics Agency
DAs	Development Agents
EIAR	Ethiopian Institute of Agricultural Research
FGD	Focused Group Discussion
FTC	Farmers Training Centers
MoA	Ministry of Agriculture
MSDARDB	Minjar Shenkora District Agriculture and Rural Development Bureau
NSZARDB	North Showa Zone Agriculture and Rural Development Bureau
RBoA	Regional Bureau of Agriculture
SPSS	Statistical Package for Social Science
SSA	Sub Sahara Africa
UNDP	United Nations Development Programme

CHAPTER ONE

1 Introduction

1.1 Back ground of the study

Ethiopia's economy is mainly based on agriculture, which accounts for about 46% of the GDP of the nation and 90% of its export earning and hold about 85% of the country's labor force (UNDP, 2002). Eragrostis Teff (Zucc.), is a small cereal grain indigenous to Ethiopia. It is the most preferred staple food by the majority of Ethiopian population. Teff grains are milled into flour and mixed with water in order to form slurry and fermented for two or three days and bake in to a flat soft bread –just like pancake, which is locally known as "Injera" (Haftamu et al, 2009).

Teff is most widely important cereal grain of Ethiopia, which is most probably adopted thousands of years ago before the birth of Christ (Seyfu, 1997). As a result of this it is a part of the society's culture, tradition and food security.

National Academy Science (1996) reported that, nutritionally, Teff has equal, or even more food quality than the other major grains: wheat, barley and maize. Teff grains contain 72.1-75.2% carbohydrate, 14-15% proteins, 11-33 mg iron, 100-150 mg calcium and rich in potassium and phosphorous. As indicated in the same report, the low level of anemia in Ethiopia seems to be associated with the level of Teff consumption as the grains contain high iron. Teff has got high lysine content compared to all cereals with the exception of rice and oats. In addition, its high price in the market, reduction of post harvest management cost, fewer disease and pest problems and sustained demand from consumer are some of the specific advantages that makes Teff important and preferred by farmers (Seyfu, 1997).

Currently Teff covers about 2.7 million hectares of land per year accounting 27% of the total grain production which is more than any other major cereals such as maize 22.7%, sorghum 19% and wheat 16% (CSA, 2010). It is a daily staple food for about 50 million people of Ethiopia accounting more than 60% of the total population of the country. About 82% gross grain production in the country is mainly contributed by cereals in which is about 17 million tons, of this Teff constituted 19.9% during the main season of 2010/11 (CSA, 2010). Despite the abovementioned importance and coverage of large area, the productivity of Teff is very low and it's the average national yield is only 1200 kg /ha which is very low as compared to other major cereals (CSA, 2010). Some of the factors contributing to low yield of Teff are lack of high yielding cultivars, lodging, weed, water logging, low moisture stress and low fertility conditions (Fufa, 1998) and poor grain management practices such as sowing and weeding.

The overall research on improved technologies for the production of Teff has never received an international attention; it is mainly because of the reason that Teff has local importance (Berhan et al., 2011). What makes it more interesting is not only limited international funding, but even national researches on Teff grain are being understaffed. Due to this and other reasons the grain has suffered from lack of in depth knowledge, which intern complicates extension efforts aimed at increasing Teff production (ATA, 2013b). However it has been recently argued that low Teff productivity is partly caused by the traditional sowing method of Teff seed. In tradition farmers' use of Teff seed rate is 25-50 kg per hectare (ATA, 2013a). this practice reduce the amount of grain production mainly due to the uneven distribution of the seed, strong competition among plants for inputs such as water, sun light and nutrients. It is also make weeding difficult after the maturity of the plant (Fufa at al., 2011).currently as a way out for this it has been proposed to lower the amount of seed rate to between 2.5 and 3 kg per hectare which would allow the reduction of competition among seedlings and optimal tillering of the Teff plants. By the technology of row planting or transplanting and weeding can be done much more readily and the lodging incidence is reduced (Chanyalew and Assefa 2013).

According to ATA, in recent years much of Ethiopian farmers have begun planting many of their grains in rows, which includes wheat, maize, barely and sorghum and they also started to realize this technique yields better results, reducing the competition among individual plant, however on Teff which is national grain of the country farmer are still following the traditional way of planting Teff seedling therefore it resulted in Teff grain yield reduction (ATA, 2012).

1.2 Statement of the problem

Teff is a highly valuable grain for Ethiopian people both in production amount and in consumption level. It is a staple food and a source for more than 15% of calories intake by the total population of the country. More than 6 million households' life depend on the production of teff covering the largest agricultural area of the country than any other types of grain, however the amount of production is not as much as its production coverage and value (Berhe et al. 2011).

Teff production system used by the majority of farmers is very backward and traditional, most of the farmers in the country broadcast Teff seeds, i.e. scattering seed by hand, at high seed rates. This impedes Teff yields because of high amount and uneven distribution of the seeds makes weeding difficult and increased competition with weeds and other Teff plants lowers nutrient uptake by the individual Teff plant (Berhe et al. 2011; Fufa et al. 2011). This result in the reduction of Teff yield at the harvesting period. In response to this currently there are some works made in partnerships of Ministry of Agriculture (MoA) and Agricultural Transformation Agency (ATA) farmers are being introduced to modern technologies of row planting of Teff with reduced seed rate and application of other agronomic technologies.

This study intends to assess the achievements made by modern technologies in the improvement of Teff yield and farmers' level of perception towards the application of modern Teff production technologies in the study area. It also assesses and addresses the challenges that farmers faced with the application of row planting of Teff seed with reduced seed rate. Based on the results of this study ways and directions will be provided to policy makers and concerned stack holders in order to improve farmers' adoption level of modern agricultural technologies and enhance teff yield production.

1.3 Objective of the study

1.3.1 General objective

The general objective of this study is assessing the application cost and benefits of row planting technology on Teff grain production and factors affecting farmers' adoption level of teff production through row planting technology in the Minjar Shenkora woreda, Amhara region.

1.3.2 Specific objectives

The purpose of this study is to evaluate the improvement of teff grain yield and yield component productivity under the application of row planting technology and the application level of this technology, therefore the following are specific objectives of this study.

- To evaluate cost and benefit difference on the application of row planting and broadcasting technology on teff grain production.
- To identify factors affecting the application of teff row planting technology in the study area.

1.4 Research questions

A. How do the local people apply the method of row planting on the production of Teff?

B. What were the problems faced by the local people in the application of row planting on Teff?

C. How was the cost and benefit difference of Teff production between row planting and traditional broadcasting methods?

1.5 Significance of the study

The Sub Sahara African (SSA) countries in general and Ethiopia in particular, is repeatedly affected by food security problems due to lack of modern agricultural technologies.

Teff is a source of daily consumption for more than 50 million inhabitants of Ethiopia and occupies up to 30% share of the total area covered by cereals. Farmers mainly produce Teff through traditional broadcasting method with high seed rate of 25-50 kg per hectare, this cause yield reduction and lodging problem of the grain. Row planting method with reduced seed rate to 2.5-3kg per hectare allows minimum competition between seedling and increase tillering of Teff grain.

Berhe et al (2011) have conducted experiments in order to evaluate the potential of row planting with reduced seed rate technologies. The results of the experiments have proved large and positive impacts on Teff yields. Consequently, the Ethiopian government started deploying these new technologies on a very large scale. According to ATA (2013a), in 2013 alone the technologies were introduced to 2.5 million Teff producers through a great effect by national extension system and through farm mass media partnerships.

However, there are lacks of reliable and objective data that measure the impact of these widespread campaigns to promote the use of improved agricultural technologies. The applications of this technology on the ground extremely depend on the farmers' level of adoption. The goal of this paper is to fill this gap and provide evidence on the impact of the promotion of row planting on Teff yields and the attainment of food security at the farm level. It will provide the bases for planning farmers training strategies for the adoption of new agricultural technologies and can be used as a base line for the researchers who want to conduct further study on the problem.

1.6 Delimitation and limitation of the study

In Minjar Shenkora woreda the achievement of revenue and yield improvement of teff production through the application of row planting technology and factors affecting farmers level of adoption of teff cultivation applying row seeding method had not been investigated. Since the technology of row planting of teff with a reduced seed rate was recently being introduced to the farmers in the study area it needs an immediate inquiry of its productivity. I encountered with a number of difficulties while conducting the research. During my field work gathering data from the respondents was a difficult task, this was mainly because of the reason that farmers hesitate and afraid of giving information that may affect their wellbeing. After a month of tiresome frequent discussion on the objectives of the study they had agreed to provide genuine information to the data collectors. Assessing other related problems to row planting technology was impossible due to time and financial constraints. Another limitation of this study is it did not apply multivariate regression.

1.7 Organization of the study

This study was organized in to six chapters. The first chapter provides with an overview which attempts to address and achieve the end results. It is followed with related literature reviews in which previous studies and reports related to the application of row planting technology specifically on Teff grain production are reviewed. The third chapter illustrates the study area with its location, topography, climate, socioeconomic activities, population and grain production characteristics and also it describes the methodologies used to collect relevant data and the ways that collected data are analyzed. The fourth chapter presents the methods and materials. The fifth chapter provides results and discussion and finally chapter six gives conclusion and possible recommendations based on the results of the study.

1.8 Conceptual framework on the adoption of modern technology

Agricultural growth in SSA is considered to be low (World Bank 2008; De Janvry and Sadoulet 2010; Dethier and Effenberger 2012) and it is not much supported and driven by technological change (Benin et al. 2011). SSA has not yet experienced a successful Green Revolution like that of Asia—which was based on the adoption of improved technologies. Such lack of success in Africa has been attributed to underdeveloped agricultural research and extension systems, inefficient and missing markets, lack of infrastructure and institutions, and complex and heterogeneous agro-ecological systems (Otsuka 2006; Barrett 2008; World Bank 2008; Markelova and Mwangi 2010).

Ethiopia as part of SSA is struggling to improve its agricultural productivity through exposing farmers to new and modern grain production systems, and application of agricultural inputs. Teff is the major grain in Ethiopia in terms of production area and level of consumption, though its productivity is very low this resulted in high price of the product in the Teff value chain.

Farmers' adoption level of modern production system- Teff row planting with reduced seed rate is affected by the characteristics of household, access to extension service, level of training provided, provision of row planting mechanization and above all the application cost of row planting method on teff production and also the application cost of teff broadcasting planting method (Figure 1). This intern affects the level of Teff productivity among other things like; input application of fertilizer and selected seed, frequency of land preparation, date of seeding and frequency of weeding.

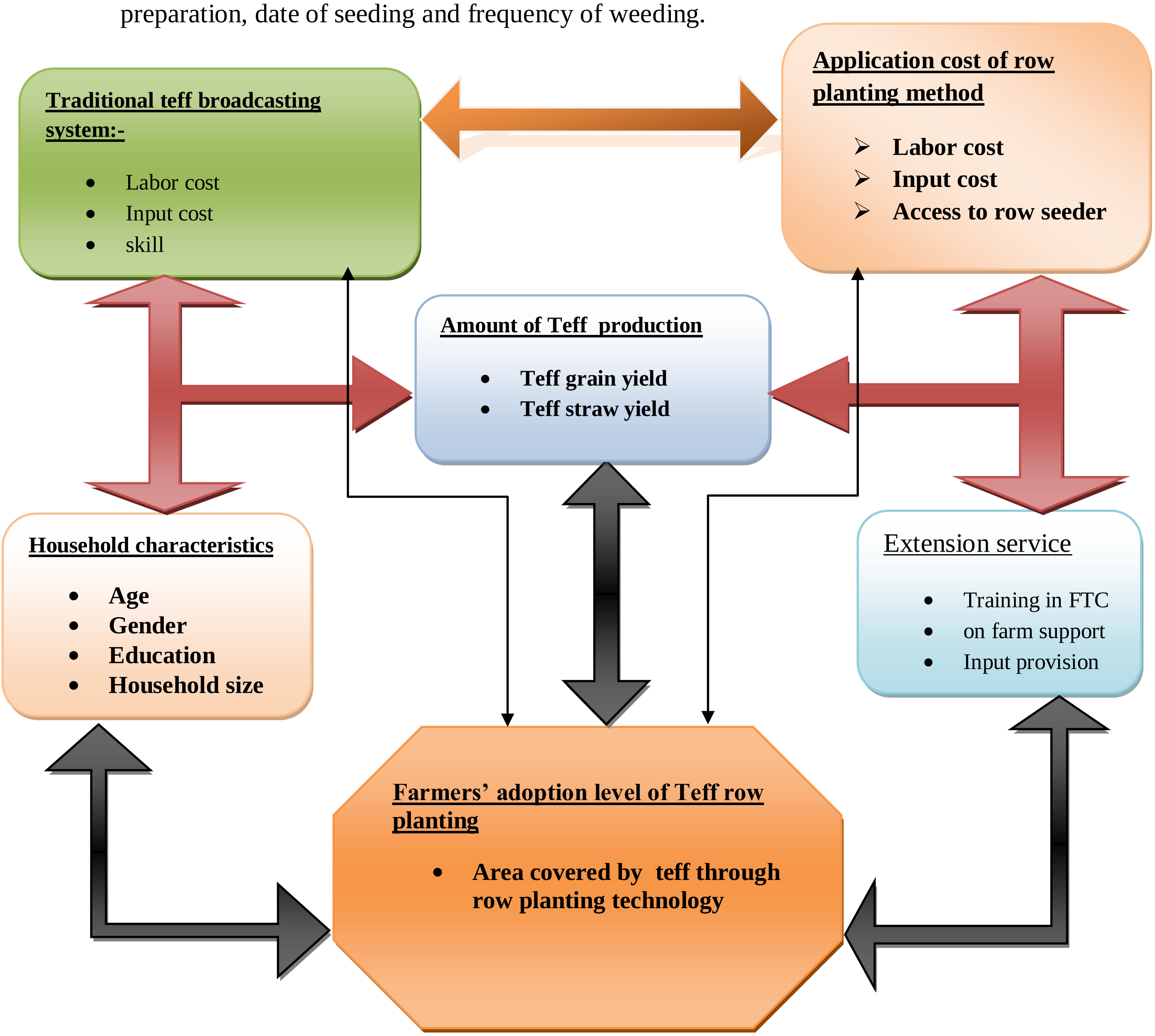

Figure 1: conceptual frame work on the adoption of Teff row planting and yield amount

CHAPTER TWO

2 Literature review

2.1 Paradigms on agricultural technology adoption

In order to explain the major adoption behaviors and determinants agricultural of technology adoption, mainly there are three paradigms focusing on this. These paradigms are the innovation-diffusion model, the adoption perception and the economic constraints models. The main assumption of the innovation-diffusion model is that the new technology is both technically and culturally appropriate but the problem of adoption is one of asymmetric information and very high search cost (Feder and Slade, 1984; Shampine, 1998; Smale et al., 1994). The second paradigm, the adopters' perception paradigm, on the other hand, suggests that the perceived attributes of the technology condition adoption behavior of farmers. This means that, even with full farm household information, farmers may subjectively evaluate the technology differently than scientists (Kivlin and Fliegel, 1967; Ashby et al., 1989; Ashby and Sperling, 1992). Thus, understanding farmers' perceptions of a given technology is crucial in the generation and diffusion of new technologies and farm household information dissemination.

The last economic constraint model contends that input fixity in the short run, such as access to credit, land, labor or other critical inputs limits production flexibility and conditions technology adoption decisions (Aikens et al., 1975; Smale et al., 1994; Shampine, 1998).

2.2 Overview of agricultural technology adoption

Adoption process is the change that takes place within individual with regards to an innovation from the moment that they first become aware of the innovation to the final decision to use it or not (Ray, 2001).

Adoption is a mental process through which an individual passes from first knowledge of an innovation to the decision to adopt or reject and to confirmation of this decision (van den Ban and Hawkins, 1998)**.** According to Feder *et al.* (1985) adoption refers to the decision to use a new technology, method, practice, etc by a farmer or consumer.

Dasgupta (1989) indicate that the decision to adopt an innovation is not normally a single instantaneous act, it involves a process. The adoption is a decision-making process, in which an individual goes through a number of mental stages before making a final decision to adopt an innovation. Decision-making process is the process through which an individual passes from first knowledge of an innovation, to forming an attitude toward an innovation, to a decision to adopt or reject, to implementation of new idea, and to confirmation of the decision (Ray, 2001).

However, as emphasized by Ray (2001), adoption does not necessarily follow the suggested stages from awareness to adoption; trial may not always be practiced by farmers to adopt new technology. Farmers may adopt the new technology by passing the trial stage. In some cases, particularly with environmental innovations, farmers may hold awareness and knowledge but because of other factors affecting the decision making process, adoption does not occur (Ray, 2001).

As indicated by Dasgupta (1989), adoption is not a permanent behavior. Consequently, an individual may decide to discontinue the use of an innovation for a variety of personal, institutional or social reasons one of which could be the availability of an idea or practices that is better in satisfying his or her needs (Ray, 2001).

On the other hand, although farmers often reject an innovation instead of adopting it, non adoption of an innovation does not necessarily mean rejection. Farmers are sometimes unable to adopt an innovation, even though they have mentally accepted it, because of economic and situational constraints (Dasgupta, 1989).

The rate of adoption is defined as the percentage of farmers who have adopted a given technology. On the other hand, the intensity of adoption is defined as the level of adoption of a given technological package. Put it in a different way, the number of hectares planted with improved seed also tested as (the percentage of each farm planted to improved seed) or the amount of input applied per hectare represent the intensity of adoption of the respective technologies (Nkonya *et al*., 1997).

According to Augustine and Mulugeta, (2005), the importance of adoption study is to quantify the number of technology users over time and to assess impacts or determine extension requirements that would help us in monitoring and feedback in technology generation. It also provides further insights into the effectiveness of technology transfer.

2.3 Factors affecting the adoption of technology in Sub-Sahara Africa

The main factors affecting technology adoption among smallholders in Sub-Saharan Africa are assets, vulnerability, and institutions (Meinzen-Dick et al., 2004).

2.3.1 Farmers' level of vulnerability

Vulnerability factors deal with the impact of technologies on the level of exposure of farmers to economic, biophysical and social risks (Meinzen-Dick et al., 2004). Those technologies that have a lower risk have a greater appeal to smallholders who are naturally risk-averse (Meinzen-Dick et al., 2004). It has been conceded that traditional smallholder farmers have their reasons for not adopting untried technologies. Most of the time, such reasons are quite rational (Mazonde, 1993). These farmers are well aware, for instance, that a sudden upswing in the productivity of their fields is likely to deplete the soil nutrients, which would result in much lower returns in the following agricultural season (Mazonde, 1993). In other words, use of high yielding grain varieties is consciously or sub-consciously perceived with prejudice by most traditional farmers (Mazonde, 1993). Application of pesticides is also less frequent for that reason.

2.3.2 Farmers' asset possessions

These factors deal with whether farmers have the requisite physical (material) and abstract possessions (e.g. education) essential for technology adoption. A lack of assets will limit technology adoption (Meinzen-Dick etal., 2004). Researchers, policy makers and development practitioners therefore need to put more emphasis on the development of technologies with little requirements for such material and abstract possessions (Meinzen-Dicket al., 2004). Policy makers and development practitioners should also promote technologies with low asset requirements as they are likely to have higher adoption rates among poor farmers (Meinzen-Dick et al., 2004).

2.3.3 Institutions

Institutional factors deal with the extent or degree to which institutions impact on technology adoption by smallholders (Meinzen-Dick et al., 2004). Institutions include all the services to agricultural development, such as finance, insurance and information dissemination. They also include facilities and mechanisms that enhance farmers' access to productive inputs and product markets. Institutions also include the embedded norms, behaviors and practices in society (Meinzen-Dick et al., 2004). Researchers and development practitioners should also consider issues that relate to the farmers' exposure to economic, agro-meteorological, biophysical and social shocks in designing technologies for smallholders. Care should be taken to avoid technologies with a high investment cost structure which smallholders cannot afford because they are poor and lack the necessary resources (Meinzen-Dick et al., 2004). Grain insurance can to some extent lessen the risk of farmers' exposure to external shocks (Meinzen-Dick et al., 2004).

Embedded norms, behaviors and practices in society can encourage or discourage adoption of a particular technology by members of that society (Meinzen-Dick et al., 2004). For example, the practice that the production of certain types of grains are the preserve of male members of society can limit the adoption of a particular technology in Sub-Saharan Africa if the grain to be promoted is grown mainly by men. This is because women constitute the majority of rural dwellers in this part of Africa. Clearly therefore, an understanding of local cultural practices and preferences is important if they are to benefit from agricultural research (Meinzen-Dick et al., 2004).

2.3.4 The effect of gender

Results of studies in sub-Saharan Africa have shown that male headed households have more access to land, education, and information on new technologies (Bisanda & Mwangi, 1996). There is a strong association between the gender of the household head and adoption of technological recommendations (Bisanda & Mwangi, 1996). In some countries female-headed households are discriminated against by credit institutions, and as such they are unable to finance yield-raising technologies, leading to low adoption rates (Mkandawire, 1993). There is clearly a case for improving current smallholder credit systems to ensure that a wider spectrum of smallholders are able to have access to credit, more especially female-headed households (Mkandawire, 1993). This may, in certain cases, necessitate designing credit packages that are tailored to meet the needs of specific target groups (Mkandawire, 1993).

2.3.5 The role of stakeholders

It is imperative that agricultural training and extension programmes be intensive enough to promote adoption not only of improved yield-raising technologies, such as improved seeds, but also of fertility-restoring and conservation technologies (Nkonya et al., 2004). Synergies need to be created between government departments, non-governmental organizations, researchers, donors and local communities in implementing programs that promote smallholder farmers' adoption of technologies which can increase agricultural productivity and reduce environmental degradation and the deterioration of soil quality (Rosegrant et al., 2002; Nkonya et al., 2004).

Measures that can be taken to increase adoption of yield-enhancing technologies include: (i) lowering fertilizer costs; (ii) lowering the price of other inputs and raising agricultural product prices; (iii) improving smallholder farmers' access to finance for agricultural development; (iv) adopting a "package" approach to provision of agricultural development technologies; and (v) development and rehabilitation of infrastructure for agricultural inputs and product markets (Nkonya et al., 2004; Rosegrant et al., 2002).

2.3.6 Extension workers' level of training

A major problem in sub-Saharan Africa is that year after year extension workers who are hardly afforded in-service training, and is loosely linked to research; continue to disseminate the same messages repeatedly to the same audience (Mkandawire, 1993). A situation has consequently arisen where the disseminated messages to the majority of the extension audience, have become technically redundant and obsolete (Mkandawire, 1993).

An additional problem is that most extension services tend to focus on the well-resourced, wealthier farmers and perceive farmers as simply agents of change (Mkandawire, 1993).

The major option for increased adoption of technology is to overcome the income/ capital constraint through increased credit provision (Mkandawire, 1993). However, one of the most discernible features around credit in most sub-Saharan African countries is the lack of an educational package linked to credit for small rural producers (Chidzonga, 1993).

The cost of technology is a major constraint to technology adoption (Bisanda & Mwangi, 1996). The elimination of subsidies on prices of seed and fertilizers since the 1990s due to the World Bank-sponsored structural adjustment programs in sub-Saharan Africa has worsened this constraint (Chidzonga, 1993; Bisanda & Mwangi, 1996; Nkonya et al., 1996; Akulumika et al., 1996).

2.4 Characteristics of teff

2.4.1 Teff as a cereal

Teff (*Eragrostis tef*), a cereal grain that is included grass family of Poaceae, Teff is endemic to Ethiopia and it has been widely produced for many centuries (Teklu and Teffera 2005). Teff grain is found widely in most part of the country mainly in the in the altitude ranging from 1800 to 2100 meters above sea level due to this reason Teff can be grown under diverse agro-ecological conditions. The major Teff producing areas are Amhara, Oromia, Tigray and SNNP regions. Teff is concedered as a low risk grain because its vulnerability to pest and diseases is very low (Fufa et al. 2011; Minten et al. 2013). In addition to that Teff can resist to extreme water conditions, as it is able to grow under both drought and waterlogged conditions (Teklu and Teffera 2005; Minten et al. 2013). Teff is mainly planted (sown) during the main *meher* rains between July and November, while harvesting is done in February. In tradition the Teff seeds are broadcasted on a well ploughed land and lightly covered with soil for germination to occur in shorter period of time. During the growing period, several repeated weedings are often required (Assefa et al. 2011).

Teff grain is the most important staple grain in terms of the rate of consumption and amount of production. According to CSA (2013) report during 2012/13 meher rains,22% of the country's grain area was covered by Teff and Teff production activity 6 million farmers have engaged. From this Teff land a total of 4 million metric tons of Teff yield was obtained which accounts for 16 percent of all grain output. CSA (2013) report shows that in 2013, the average Teff yield reached 1.4 tons per hectar with an increase of eight percent from 2012 year average production. According to Taffesse et al (2011) the recent Teff grain yield increase was mainly due to an increase in production area and yield improvement strategies. According to the evaluation made on Teff production for 2012 by Minten et al. (2013) Teff is the most important food grain in the Ethiopia. The value of its commercial surplus is second only to coffee. In addition to its importance as a staple food, Teff straw is important for fodder and use in house construction (Teklu and Teffera 2005).

2.4.2 Consumption of teff in Ethiopia

Teff is used in Ethiopia to produce the nation's staple dish *enjera*. Grinding Teff grain into flour and mixing with water results in a spongy type of pancake. Teff is also used to brew local beer knowen as *tela*. It has high protein, fiber and complex carbohydrates content, relatively low calorie content, and is gluten free (Berhane et al. 2011; ATA 2013c). It accounts for between 11 and 15 percent of all calories consumed in Ethiopia (Berhane et al. 2011, ATA 2013c) and Teff provides about 66 percent of day to day protein intake (Fufa et al. 2011). More than 60 % of the Ethiopian population uses Teff as their daily staple food. It is estimated that per capita consumption grew by four percent over the last 5 years (ATA, 2013c). Teff is highly considered as an economically superior good, relatively more consumed by urban and richer consumers (Berhane et al. 2011; Minten et al. 2013). In urban areas the level of Teff consumption is much higher than that of rural areas with the share of per capita Teff consumption of 23 percent from the total food expenditure in the country, while in rural area this is only six percent. In rural areas, Teff is seen as a luxurious grain consumed only by elders or during special occasions. Growth in average incomes and faster urbanization in Ethiopia are likely to increase the demand for Teff over time (Berhane et al. 2011).

2.4.3 Economic Importance of Tef

Agriculture is a major contributor to the national economy of Ethiopia, representing 41% of Ethiopia's GDP (CIA, 2012). Teff is predominantly grown in Ethiopia as a cereal grain. It is widely grown in both high potential and marginal production areas. During 2009-2010, it was estimated that 3.2 million tons of Teff was produced on 2.6 million hectares of land

(CSA, 2010). These areas include most parts of the Vertisols that suffer from water logging and other non-vertisol parts of the country that suffer from low moisture stress. Teff is grown in almost all regions of the country for home consumption since it is a preferred grain, and for local market since it fetches the highest grain price compared with other cereals and is used as a cash grain by farmers (Seyfu, 1997).

When Teff is grown as a cereal, farmers highly value the straw and it is stored and used as a very important source of animal feed especially during the dry season. Farmers feed Teff straw preferentially to lactating cows and working oxen. Cattle prefer Teff straw to the straw of any other cereal and its price is higher than that of other cereals (Seyfu, 1997). The quantity and quality of residues from various cereal grains vary greatly depending on the grain species. Wheat and barley usually give high straw yields, though of inferior quality. Among cereals, Teff straw is relatively the best and is comparable to a good natural pasture (Bekabil *et al*., 2011).

Seyfu (1997) reported that Teff is not attacked by weevils and other storage pests; therefore it is easily and safely stored under local storage conditions for an extended period of time without attack from storage pests. This results in reduced post-harvest management costs. Seyfu (1997) also stated that the ability of Teff to tolerate and grow under waterlogged conditions is one of its advantages and a characteristic that makes it preferred by farmers.

Despite the domestic preference for Teff, it can be internationally classified as an “orphan” grain given that it has been largely unnoticed by the global scientific community and relatively unimproved by modern production technologies (ATA, 2013b). The major reasons why Teff remains as an important grain in Ethiopia are firstly, it is the diet of most Ethiopians; secondly, it can grow under diverse soil type and climatic conditions like drought-prone or water logged; thirdly, it is a reliable cash grain because if unexpected drought or pest infestation occurs, the field can be re-planted with Teff; fourthly, the straw (chid) is of relatively higher digestibility to livestock (ATA, 2013b).

2.5 Ecology and production areas of teff

Mainly due to its diversified land features Ethiopia has broadly divided its climate into five zones, based on elevation, and each zone has its own rainfall pattern and agricultural production system. In general, the highland (*Dega* and *Weina Dega*) zones contain most of the agricultural areas, while the semi-arid and arid lowlands zones (*Kolla* and *Bereha*) are dominated by livestock in agro-pastoral and pastoral production systems.

A unique nature of Teff is that it grows in almost all regions of the country under diverse agro-climatic conditions: from sea level up to 3,000 meters a.s.l (seyfu, 1993). Much the same as wheat, Teff can be grown in highlands where it is too cold for other major cereal grains such as sorghum and maize. This versatility gives Teff an advantage as it has a wider altitudinal range than any other cereal in Ethiopia. Though, almost most of the country's land has the potential for Teff production, it is mostly cultivated in the mid-altitude areas of the country.

2.5.1 Climatic requirements of teff

The average annual rainfall in Teff growing areas is around 1,000 mm, but the range is varies from 300 to 2,500 mm. Even though, Teff resists moderate drought, but most its cultivators require at least three good rains at the production season of Teff ; first, during their early growth; second, during flowering period; and thirdly, at the time of seed-setting stages, and a total of 200 to 300 mm of water. Some early-maturing cultivars can obtain the 150 mm they need from water retained in soils at the end of the normal growing season. In terms of temperature, while Teff has some frost tolerance, it will not survive a prolonged freeze. It also tolerates high temperatures (at its lower altitudinal range) well above 35°C (Abuhay etal, 2001).

Dry land areas with shortage of rainfall are well secured through the production of Teff. Teff is a reliable cereal during unreliable rainfall, especially during the occurrence of unpredictable dry spells. This makes Teff an important grain for drought-prone and food-insecure areas. Its production is currently expanding to include many drought-prone areas of the country (ATA, 2013b)

2.5.2 Soil Type

Teff is highly adaptable to a wide range of soil types. It has the ability to perform well in black soils and, in some cases, in low soil acidities. In addition, Teff has the capacity to withstand waterlogged, rainy conditions, often better than other cereal grains (other than rice) (ATA, 2013b).

2.5.3 Major Teff Producing Regions

In Ethiopia, (Table 1) Teff is mainly produced in vast areas of Amhara and Oromia, the total area covered by Teff in these regions are 1,014,268 ha and 1,289,405 ha respectively (CSA, 2011).With smaller quantities in SNNP and Tigray. There are 19 major Teff-producing zones in the country. Within Amhara, the East Gojam, West Gojam, North Gonder, South Gonder, North Wollo, South Wollo, North Showa, and Awi zones are the major producers of Teff. The Central and South Tigray zones are the major zones in Tigray. In Oromia, the major zones include East Shoa, West Shoa, Southwest Shoa, North Shoa, East Wallaga, Horo Guduru Wollega, Jimma, Illuababora, and Arsi (ATA, 2013b).

Table 1: Teff production by high-producing regions

Region	**Area (ha)**	**% share of total area planted**	**Production (ton)**	**% share of total production**	**Yield (ton/ha)**
Tigray	165,804	6.01	209,507	6.02	1.264
Amhara	1,014,268	36.77	1,279,108	36.75	1.261
Oromia	1,289,405	46.74	1,671,803	48.04	1.297
SNNPR	265,377	9.62	296,759	8.53	1.118
Benishangul	23,648	0.86	23,107	0.66	0.977
Total/average	2,758,502	100	3,480,284	100	1.262

Source: CSA (2011), Agricultural Sample Survey: Area Planned and Production of Major Grains, Meher

2.6 The process of teff production

2.6.1 Teff planting

Ethiopian farmers use the method of broadcasting for sowing Teff seeds. This is mainly due to the very small seed size of the seeds of the grain which makes row planting difficult. Typically, the farmers apply between 25 to 50kgs of Teff seeds per hectare. In addition, in order to enhance germination, Teff needs moderate soil compaction to make the seedbed firm and flat so as to prevent the soil surface drying quickly which causes seed desiccation (Fufa et al., 2001). In most parts of the country, soil compaction of Teff field is done using cattle, sheep, goats and/or donkeys and sometimes humans.

Depending on the method of planting used, farmers should reduce seed rate from 30-50 kg/ha to 3-5 kg/ha for row planting, and to as low as 0.5 kg/ha for transplanting. By doing this, versus traditional broadcast planting, seedlings will be less crowded and suffer from less competition for sunlight, water, and other nutrients, which will enhance tillering capacity and tiller survival, thus increasing the grain yield and total biomass production (ATA, 2013b).

Seyfu (1997) reported that about 15-55 kg of Teff seeds is sown per hectare under different conditions. If a manually or motor-driven broadcaster or drill is available, a lower seed rate (about 15 kg/ha) is recommended. According to Tareke (2008) planting seedlings on a flat bed and transplanting them into the field showed a promising result. For example, it reduces the seed rate from the broadcasting method and in the new method 2-2.5 kg/ha would be enough for a hectare. The yield of transplanted Teff has a fourfold increase. Moreover, it increases tiller number, producing strong tiller culms and it increases number and quality of seeds. As the researcher explained, the yield of the broadcasting plot was 500-1200 kg/ha, On the other hand, the transplanted ones gave 3,400-5,100 kg/ha with a fourfold increase in grain yield. In addition, the straw yield also increased from the transplanted grain.

2.6.2 The effect of planting time on teff yield

The effect of planting time varied severely across regions. As regions have distinct rainfall paterns. Amhara region had higher than average yield improvements for farmers who planted early. Farmers planting before the second week in July experienced weekly averaged yield increment from 72% to 104%, while farmers who planted during the traditional planting period saw weekly average yield increases between 45% and 71%. The general trend saw farmers who planted later with relatively smaller yield increases compared to those who planted during the traditional season and earlier (ATA, 2013a).

According to the study made by ATA (2013a) in Oromia farmers who planted three weeks early experienced slightly higher average yield increases than during the traditional planting period. In this three week period before the traditional planting period farmers had 66% to 90% average yield increases in comparison to 67% to 72% increases through the traditional planting time. Farmers who planted 4-5 weeks early experienced lowest average yield increases, 20% to 51%, which were even lower than those farmers who planted in late August and September.

In SNNP and Tigray early planting yield increases were especially irregular, sometimes negative, and sometimes extremely high. The sample size of farmers in these regions was considerably smaller than Oromia and Amhara, which is a likely contributor to the irregular results. For SNNP farmers who planted during the traditional planting period saw the most consistently high average yield improvements of 69% to 72%. Farmers in SNNP who planted early saw fluctuations between 37% decreases in average yield to 178% increases (ATA, 2013a). In Tigray some key data points were missing and the sample sizes were extremely limited for early planting. Farmers who planted in the third week of July and between the second and fourth week in August had the highest average yield increase ranging from 67% to 74%.

The yield effects of early planting should be studied with the relatively small sample size. Less than 10% of the validated farmers planted before the traditional planting period, and some of the yield increases are likely affected by transplanting. Furthermore planting times are geographically specific, depending on rainfall patterns and thus data collected across a wide geographic area may be misleading (ATA, 2013a).

2.6.3 Seedbed preparation and sowing method of teff

In most parts of Ethiopia, Teff is grown during the main rainy season (*meher*); though there are places where Teff is grown during *belg* season. By its nature, Teff is a labor-intensive grain and farmers currently use a high tillage frequency compared to other cereal grains grown in Ethiopia. The reason for the high tillage frequency is that the Teff seed is very small and thus germination is difficult in heavy, unbroken soil (Bekabil *et al*., 2011). Similarly, Seyfu (1997) reported that Teff field is ploughed two to five times depending on the soil type, weed conditions and water logging. The same author explained that, heavy clay soils need ploughing more frequently than loam or sandy soils. Fields with high weed populations receive more ploughings than those with fewer weeds. Generally, the tillage frequency is not consistent from region to region, from soil type to soil type and from farmer to farmer.

In most parts of the country, soil compaction of Teff field is done using cattle, sheep, goats and/or donkeys and sometimes humans (Bekabil *et al*., 2011). Teff needs moderate soil compaction to make the seedbed firm, prevent the soil surface from drying quickly which causes seed desiccation and enhance germination (Fufa *et al*., 2001; TARI, 2007). In addition, trampling of the seedbed is also practiced to free the seedbed from weeds by turning them under (Seyfu, 1997).

2.6.4 Spacing and grain performance

According to Lopez-Bellido *et al*., (2003, 2005) a given plant density is considered optimum, when it provides the maximum number of podding nodes per square meter. Plants show extreme plasticity, responding remarkably in size and form to environmental conditions. Compensatory mechanisms of many grain species such as tillering or branching allow similar levels of dry matter accumulation per unit area to be achieved from a range of planting density. Smith and Hamel (1999) indicated that branching and/or tillering are important characteristics by which plants may adapt their size to the availability of resources.

According to Tareke (2008), best results came from spacing and row sowing increases tiller number, producing strong and fertile tiller culms, and increase the number of seeds/panicle of Teff. Seeds should be planted or drilled in uniformly with 20 cm between rows. This provides ample space for seedlings and enables easier weeding. Furthermore, Tareke (2008) reported that more dramatic yield obtained when spacing is combined with three types of fertilizers such as DAP+Urea, DAP coated with Zinc and Copper micronutrients and a rice fertilizer known as Sucube commonly used in Mali which contains NPK , Zn , S, and Mg.

2.6.5 Depth of sowing and its agronomic importance

Aberra (1992) discussed the significance of sowing depth as an important factor in grain management practices. Sowing at about 6 cm into moist soil offers a better opportunity for the grains to tolerate a short drought period and to increase grain yield because of better establishment compared with seed planted shallow (2-3 cm). The influence of agronomic practices such as depth of sowing is little or no known in Teff. Nevertheless, as Tareke (2008) explained, sowing depth is known to be important traits affecting seedling emergence, grain stand establishment and performance.

2.7 Input application for teff grain

2.7.1 Supply and distribution of fertilizer in Ethiopia

Only two types of fertilizer, urea (46:0:0) and Diammonium Phosphate (DAP – 18:46:0), are used in Ethiopia. Both have shown steady growth in use by farmers over time. There are three distinct patterns of use of fertilizer in Ethiopia. First, the intensity and prevalence of farmers' use of fertilizer varies across regions. Between 2005 and 2010, Oromia and Amhara accounted for 70 percent of total fertilizer consumption, with Oromia alone accounting for about 40 percent. Of the other two major cereal growing regions, the shares of SNNP and Tigray were only 10 and 3 percent, respectively. (IFPRI, 2012)

In Ethiopia, the supply and distribution of agricultural inputs has been in most part owned and run by the government. While private retailers held a majority share of the market in the early 1990s, the public sector and cooperative unions have become almost the sole distributors of inorganic fertilizer (i.e. DAP and Urea) since 2000 (DSA, 2006). According to Spielman et al. (2011), while the Agricultural Input Supply Enterprise (AISE) had a market share of less than 50 percent during the mid and late 1990s, it had regained the majority share by 2001 when private sector wholesalers, except for the holding companies, disappeared from the scene. As of 2004, the public sector accounted for over 70% of distribution, with private dealers accounting for only 23% of sales nationwide (EEA/EEPRI, 2006). According to the report, public sector supply channels have also changed; whereas extension agents previously managed distribution, the responsibility was shifted to Woreda input supply offices and cooperatives in recent years. Currently, cooperative unions supply fertilizers in the country with AISE acting on the union's behalf in aggregating annual demand and importing. This is done to overcome collateral requirement problems in importing fertilizer have that hindered the private sector involvement.

2.7.2 Application of fertilizers

According to reports of ATA (2013a) consistently in Amhara, Tigray, Oromia and SNNP DAP application recommendations were matched while urea application fell short. DAP application rates varied from 99kg/ha in Amhara and Tigray to 100kg/ha in SNNP with relatively small standard deviations in comparison to urea. Tigray experienced the highest standard deviation of 6.5kg/ha in DAP application, however, still that was more consistent than urea standard deviations. Urea application ranged from the lowest average regional application of 86kg/ha in SNNP to the highest of 91kg/ha in Tigray. Urea application rates were also highly variable with a standard deviation across the four regions of 24.6kg/ha. Tigray came closest to meeting urea recommendations, though was most inconsistent in meeting DAP recommendations. No strong trend appears between planting method and fertilizer application. Regardless of broadcasting, row planting or transplanting, validated farmers applied similar amounts of fertilizer.

2.7.3 Recommended rate of fertilizer application in teff

Overall, fertilizer is applied to ~50% of land planted to Teff. The recommended rate of fertilizer application in Teff production is 100kg of DAP/ha and 100kg of urea/ha as set bythe Ministry of Agriculture (Kenea et al., 2001). During the field visits, it was learned that in the Adaa area, the farmers use the recommended rates of fertilizer application (i.e. 100kg of DAP and 100kg of urea per hectare). Similarly, the farmers in theDejen area were found to use the recommended rate of fertilizer application forTeff. However, in the Bachoo and Shashemene areas, farmers' practice of using fertilizer was found to be below the recommended rate. In the Bachoo area, farmers apply about 90kg of DAP and 50kg of urea per hectare of Teff. According to the farmers' response, this is due to the fertility level of the soils in the area, in that higher fertilizer application rates result in increased lodging. On the other hand, in the Shashemene area, farmers apply 50kg of DAP and 25kg of urea per hectare of Teff. The under-application of fertilizers in this area was attributed by farmers to the high prices of fertilizers. However, previous studies showed that major factors affecting Teff fertilizer application rates are water logging, seasons of planting, grainping history, and weed growth (Kenea et al., 2001). Complex fertilizers with major and minor elements (e.g., N:P:K:S + Zn + Cu) have been shown to increase both grain and straw yields. Proper types and rates of fertilizer application will promote fertile soil that supports healthy growth of Teff plants.

2.7.4 Herbicides application in teff

As Teff is grown under a wide range of climatic and soil conditions, it is exposed to a wide range of weeds that affect its production and productivity. Among the annual grass weeds, *Strigahermonthica* and *Partheniumhysterophorus*are increasingly reported to affect Teff production. The literature shows that countrywide, Teff yield losses due to weeds (if there is uncontrolled weed growth) range between 23% around the Debrezeit area to 56% in Shewa (Fessehaie and Tadele, 2003). As a result, Teff weeding is a laborious task that is critical for productivity. Hand-weeding is the most widely used practice to control weeds in Teff production. In addition, the use of 2-4-D herbicide at a recommended rate of 1 liter per hectare can help control broadleaf weeds. However, this herbicide has been banned in almost all countries in the world. In Ethiopia, its continued use has produced a new generation of 2-4-D tolerant broadleaf weeds; thus, new types of herbicides are urgently required.

2.7.5 Improved teff Seed

According to Abebe (2000), beginning from 1970, a number of improved varieties of Teff seed have been produced and distributed for farmers' utilization. Most of the materials used by the National Teff Improvement Program come from the 4,300 Teff accessions preserved in the Institute of Biodiversity Conservation (IBC). On-station yield levels for improved Teff ranged between 13 to 36 quintals per hectare while farm-level yield levels for Teff ranged between 12 and 25 quintals per hectare. Thus, the yield gap between experimental and farm farmers' conditions can be as high as 12 quintals per hectare, showing substantial potential for yield improvement if farmers are able to adopt some of the practices developed on station. In 1970 three improved Teff seed varieties were released having on-station average yield ranging between 18-28 quintals per hectare; these varieties were DZ-01-354, 99 and 196. In 2002 other selected seeds were distributed, these were DZ-01-1281, 1285 and 1681 with range of yield 24-26 quintals per hectare on-station production. In 2005 DZ-Cr-387 or Quncho, DZ-1868 and DZ-2423 Teff seed varieties were released, among the three DZ-Cr-387 or Quncho was the most widely distributed and adopted by farmers in current times; DZ-Cr-387 or Quncho variety allow on-station production as high as 27 quintals of Teff per hectare (Bekabil et al, 2011).

2.7.6 Farmers access to teff seeds

According to Seyfu (1997), most Ethiopian farmers use traditional landraces of Teff that are distributed all over the country. Local cultivars such as GeaLamie, Dabi, ShewaGimira, Beten and Bunign, which are early maturing varieties (<85 days), are widely used in areas that have a short growing period due to low moisture stress or low temperature. The same types of varieties are also used in areas where double grainping is practiced and that have adequate rainfall. In the highly productive and major Teff producing regions of Gojjam and Shewa, and in other regions where environmental stress is not severe, local cultivars such as Alba, Ada and Enatit are widely grown. Improved varieties of Teff are increasingly becoming popular in major Teff growing areas of Ethiopia, though adoption is currently limited due to different reasons.

The formal 'commercial' and the informal (saved or bought) seed sectors are the two most important sources of Teff seeds for farmers in the country. The supply of the open pollinated varieties' seed, including Teff, has been dominated by the Ethiopian Seed Enterprise (ESE) (more than 85%) over the past few years (Spielman et al., 2011). At the farmers' level, the supply and distribution of seeds is undertaken via the cooperative unions. However, there is low demand for improved seeds of open pollinated grains including Teff among farmers (Spielman et al., 2011).

2.7.7 Recommended seed rate of teff

Seyfu (1997) reported that about 15-55 kg of Teff seeds is sown per hectare under different conditions. If a manually or motor-driven broadcaster or drill is available, a lower seed rate (about 15 kg/ha) is recommended. According to Tareke (2008) planting seedlings on a flat bed and transplanting them into the field showed a promising result. For example, it reduces the seed rate from the broadcasting method and in the new method 2-2.5 kg/ha would be enough for a hectare. The yield of transplanted Teff has a fourfold increase. Moreover, it increases tiller number, producing strong tiller culms and it increases number and quality of seeds. As the researcher explained, the yield of the broadcasting plot was 500-1200 kg/ha, On the other hand, the transplanted ones gave 3,400-5,100 kg/ha with a fourfold increase in grain yield. In addition, the straw yield also increased from the transplanted grain.

2.8 The introduction of row planting in Ethiopia

In 2009, however, while working with Sasakawa Africa Association, and the staff at the Debre Zeit Agricultural Research Center, Dr. Tareke Berhe (the ATA's Teff Director) began experimenting with another way. The research was launched with the question of if row planting worked for most other grains, why couldn't it work for Teff grain? In the process challenges were significant, as Teff seeds are extremely small in size, making the prospect of planting them individually a daunting task. Through trial and testing, however, Dr.Tareke and the Debre Zeit Agricultural Research Center confirmed what they suspected: reduce the seed rate to a mere 3-5 kg/hectare, plant them in rows, and yields go significantly up – with stronger, taller plants producing stronger stalks, and more grains per stalk. By reducing the seed rate and planting in rows, it was found that farmers could potentially double their Teff yields. Unfortunately a host of factors, including a lack of modern planting technologies, limited agricultural extension resources, and a resistance to adopting practices that seem counterintuitive has, in the past, resulted in low adoption rates for these types of technologies (ATA, 2012).

However, the federal and regional infrastructure has been strengthened in recent years to tackle many of these challenges. As such, during the main planting season of 2011, the Ministry of Agriculture (MoA), the ATA, and the Regional Bureaus and extension system initiated a large scale trial of these new technologies. Demonstrations were made with 1,430 farmers and 90 Farmer Training Centers (FTCs), which resulted in 50-80% yield improvement compared to the national averages. Based on the success of these initial trials, the Transformation Council and the Ministry of Agriculture encouraged the Regional Bureaus of Agriculture (RBoA) to popularize these technologies in high-yielding zones during the 2012 planting season. A target was initially set to reach 70,000 farmers, however, given the clear impact potential these technologies held, it was then agreed to more than double the target number of farmers, in a catchment area that included nearly 2.5 million farming households. Attempting to achieve this massive objective in such a condensed timeframe took a monumental effort on the part of all stakeholders involved, particularly the extension workers and the regional agriculture bureaus. Over the course of just three weeks, in June/July 2012,26,472development agents, Subject Matter Specialists, and regional staff in 6,734 high-producing Teff *kebele*s in the four major agricultural regions (Amhara, Oromia, SNNP, and Tigray) were trained in the new agronomic practices. They in turn then passed on this knowledge to nearly 500,000 farmers at training sessions held at Farmers Training Centers (FTCs) throughout the regions (ATA, 2012).

During the 2012 planting season, 161,847 farmers immediately implemented these new technologies, with preliminary indications of yield increases at or well above the trial results (50-80% over national averages). Additionally, the more than 300,000 other farmers who were trained on these new technologies but did not adopt them in 2012 provide an excellent starting point for additional scale-up during the upcoming 2013 planting season (ATA, 2012).

2.8.1 Yield improvement under new teff technologies

According to ATA report (2013) most of the farmers who employed new Teff technologies experienced yield increases across all regions. Row planting and transplanting technologies produced especially high yields, on average increasing yields by 70% from the national average of 12.6 quintals/ha to 20.9 quintals/ha. In Amhara and Oromia transplanting produced the highest yields followed by row planting and broadcasting. Transplanting in these two regions produced the highest regionally averaged yields of any technology with 23 quintals/ha. In SNNP and Tigray row planting produced the highest average yields of 22 and 21 quintals/ha respectively. Transplanting in SNNP and Tigray produced the second highest average yield, with broadcasting producing the lowest in comparison to the other two technologies. The ATA report reviled that across all regions broadcasting showed the lowest yields, though with the exception of SNNP broadcasting still achieved significantly improved yields over the national average. In Tigray for instance broadcasting yields were 17 quintals/ha, a 30% increase over the national average. As planting method was only one component of the Teff technology package, this increase in yield from broadcasting compared to the national average can be attributed to the other components of the package (i.e. quncho seed, reduced seed rate, etc.) (ATA, 2013a).

2.8.2 Teff broadcasting method (High seed rate)

For broadcast sowing, very poor establishment percentages are common, often falling below 50 percent (Oyewole et al, 2010). Part of this is due to rough seedbeds, poor seed covering and poor contact between seed and moist soil. Additionally, where seed is hand harvested and stored on-farms, quality can be poor because of storage at high temperature and moisture. Sticks, stones and weed seeds reduce quality further. With such poor seed, farmers have to use very high seed rates to obtain adequate plant populations. The optimum seed rate for broadcast grains can be twice that for drill-sown grains. Maximum yield in broadcast grains is also likely to be lower. This in part is because applied fertilizer is mixed through the soil rather than placed near the seed as in drilling, so is less directly accessible to plant roots.

For germination to occur in seeds there is the need for row seeded to be in perfect contact with the soil to facilitate water uptake (Oyewole et al, 2010). Broadcasting does not bring seed in perfect contact with the soil for water uptake (Oyewole et al, 2010), which must have accounted for the observed reduction in mean stand count among broadcast plots in comparison with the broadcast. The broadcasting system with poor quality of seed, poor soil fertility, and seed rate which is 25-50 kg/ha which make the mature plant to lodge i.e. fall over. All these things affected the production of Teff (Tareke, 2008). A research was conducted at Debrezeit Agriculture research center by using 25kg/ha but the result was very low as comparing to row sowing. The yield of the broadcasting plot was 500-1200kg/ha on the other hand the transplanted ones have given 3,400-5,100kg/ha. This shows the new the row planting has a four-fold increase in yield.

One of the risks associated with higher plant populations is the increased potential for lodging which can impact yield and quality. This may be particularly true under high yield environments like the Red River Valley. When using higher seeding rates, growers are advised to select semi-dwarf and shorter-straw varieties or varieties with very strong straw strength. Another consideration of higher plant stands is a thicker canopy which may lead to higher disease pressure. Scouting will be important during the season to monitor disease pressure in case fungicide applications are warranted (Tareke, 2008).

2.8.3 Teff row planting (reduced seed rate)

It has been argued recently that low Teff productivity is partly caused by the way farmers sow Teff seed. Traditionally, farmers broadcast the seed using a rate of 25–50 kg per hectare (ATA 2013a). This practice reduces yields because of the uneven distribution of the seeds, higher competition between plants for inputs (water, light and nutrients), and difficult weeding once the plants have matured (Fufa et al. 2011). As a solution, it has been proposed to reduce seed rates and to plant seed in rows or to transplant seedlings (as is often done for rice, for example). Reducing the seed rate to between 2.5 and 3 kg per hectare allows for reduced competition between seedlings and optimal tillering of the Teff plants. By row planting or transplanting the seeds, land management and especially weeding can also be done more readily and the incidence of lodging is reduced (Berhe et al. 2011, Chanyalew and Assefa 2013).

The belief in the potential of reduced seed rate technologies to increase Teff productivity is the outcome of on-station agronomic research. The System of Teff Intensification (STI) — based on the insights of the System of Rice Intensification (SRI) experience (Moser and Barrett 2006) — assessed the impact of different planting methods on Teff yield (World Bank 2012). Experiments in research settings1 showed that when Teff was transplanted in rows and appropriate types of fertilizer were used, Teff yields were on average three times higher than yields obtained when using traditional broadcasting. Transplanting improved yields over broadcasting because it increased the number of plant tillers, produced stronger and fertile tiller culms, and the number of seeds per panicle increased (Berhe et al. 2011).

2.8.4 Seeding rate and amount of yield

It is believed that low seeding rates would result in higher yields compared to yields achieved by using higher seeding rates. Broadcast planting tends to result in higher seeding rates; however, row planting may improve yields by allowing for lower seeding rates (as well as adoption of other agronomic practices). While row planting is considered as one of the potential techniques to increase yield levels, farmers are not aware of the practice as row planting technology has only very recently been developed and tested for Teff. The adoption of row planting is likely to be slowed by its technical challenges: given the small size of the teff seed, row planting is most effectively carried out with a planting machine, which controls the seed rate, or through transplanting which is both unfamiliar to farmers and labor-intensive. An alternative may be mechanical broadcasters, if these achieve a reduced seed rate (Bekabil et al, 2011)

CHAPTER THREE

3 Profile of the study area

3.1 Bio-physical feature of the study area

3.1.1 Location and size

This study mainly focused and conducted in the Minjar Shenkora district, which is one of the 24 woredas located in the North Shewa Zone, southern part of Amhara region. The geographical location of the study area extended from $8^0$42’46’’ N to $9^0$7’37’’ N latitude and from $39^0$12’57’’ E to $39^0$46’53’’E longitude (Figure: 2).

Minjar Shenkora district, locating farther to the southern part of North Shewa Zone, is bounded by Hagere Mareyam and Berehet woredas in the north direction and the remaining boundary of Minjar Shenkora is shared with parts of Oromia region in the west, south and east directions.

The study area is located towards the south direction of Debre Birehan-the administrative town of North Shewa Zone- with a distance of 260 km. Minjar Shenkora district is situated towards eastern direction of the capital city of Ethiopia, Addis Ababa having a distance of 130km between them.

Minjar Shenkora district is composed of a total of 29 *kebele*s, among them the 27 *kebele*s are part of rural area while the rest two *kebele*s are included in to the parts of urban areas; Korma and Ararti Zuriya are the two sample rural *kebele*s selected for the purpose of this study, the two *kebele*s are found in the distance of 140.5 km and 130 km far from Addis Ababa respectively.

Disregarding their area size Balchi and Ararti are the only two towns located in the Minjar Shenkora district. The so called Ararti town is administrative center of Minjar Shenkora district; being very small town the area size of Ararti is 1.9 square km or 191.39 hectares wide. The town is found at the heart of Ararti Zuriya rural *Kebele*.

Minjar Shenkora district holds the total area of 1,595.83 square kilo meters or 159,682.9 hectares of land, out of this total area the share of cultivated agricultural land is 34.98% or 55,860.38 hectare whereas the other 65.02 % of the area of Minjar Shenkora district is covered with non agricultural land use activities.

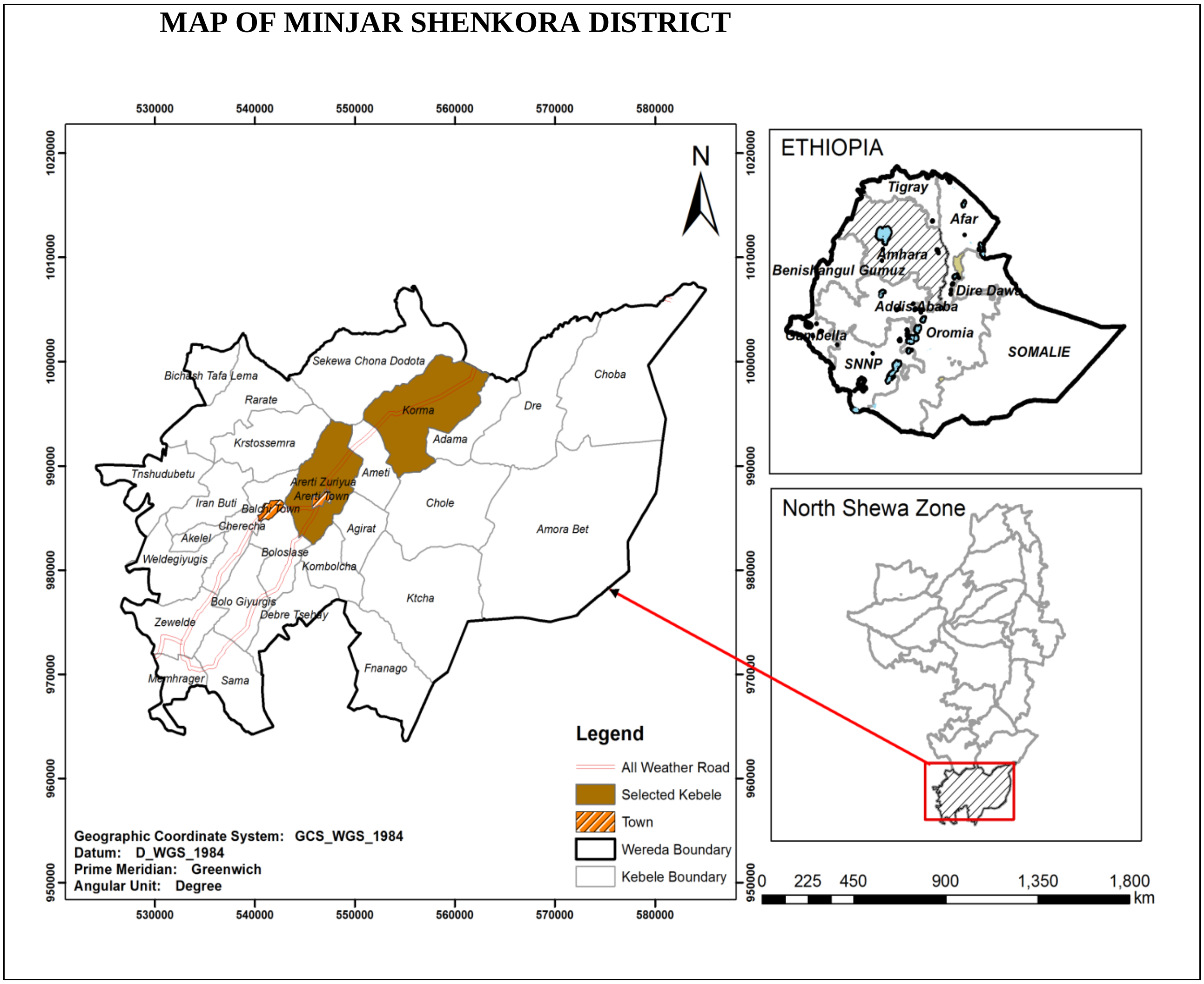

Figure 2: Map of Study area.

3.1.2 Relief and soil type

Even if there are various types of landscape in the Minjar Shenkora district, most of the study area is covered with relatively flat surface plane relief type, it holds 84% of the total area of the locality. Due to its very low degree of steepness the area has a very great potential for the application of modern agricultural mechanization, it also minimize the problem of soil erosion and flood, where as it may be affected by water lodging. According to MSDARDB information 14% of the study area is hilly and only 2% of the total area of Minjar Shenkora district is overlaid with mountains.

Based on the information from MSDARDB the vast area of the topography of Minjar Shenkora district lies on the average altitude of 1710 meters above sea level, because of this most of the relief located under the woinadega climatic condition. The altitudinal range of the study area ranges between the lowest point of 1040 meters asl to the highest point of 2380 meters asl. Due to this vast altitudinal range the study area accommodates three agro climatic regions Kola, Woinadega and Dega. Korma and Ararti Zuriyua are the two randomly selected sample *kebele*s; Korma *kebele* ranges between 1640-1800 meters above sea level and the topography of Ararti Zuriyua *kebele* range between 1640-1840 meters above sea level.

According to MSDARDB Minjar Shenkora district has different soil types suitable to harvest various kinds of grains. The most dominant soil type in the study area is brown soil its coverage in the woreda (district) is about 46.5% of the total area. Even though their area coverage is very low there are also other types of soils, these are gray soil, black soil and red soil possessing the share of the total area 19.5%, 19% and 15% respectively.

3.1.3 Climate of the study area

Climate has a great effect in shaping the day to day social, economic and cultural activities of human beings. Consequently varies types of climate diversified the societal way of life.

Since Ethiopia is a mountainous country the distribution of temperature and rainfall varies mainly depends on the altitudinal variation as a result there are five agro climatic zones in the country.

The topography of study area is found between the ranges of 1040 meter and 2380 meters above sea level. Consequently due to this range of altitude the study area is composed of three agro climatic regions- Kola, Woinadega and Dega. According to the MSEARDB (Table 2) report largest area of the Minjar Shenkora district is found under the woinadega agro climatic region accounting about 70.9 % of the total area. While the rest of the study area lies under kola and Dega climatic regions accounting 24.8 % and 4.3 % share of the total area respectively.

Table 2: Distribution of agro climatic zone of Minjar Shenkora district

Agro climatic zones	Altitude in meters	Area coverage in hectare	Area coverage in %
Dega	2300-3300	6,866.3647	4.3
Woinadega	1500-2300	113,215.1761	70.9
Kola	500-1500	39,601.3592	24.8

Source: MSDARDB (2014)

According to North Shewa Agricultural and Rural Development Bureau, Minjar Shenkora district has annual average temperature range between 13.21^0c and 23.02^0c.

The amount of rainfall is collected in Ararti meteorology station, which is located in the administrative town of the study area. Whilst on the contrary there is no complete yearly rainfall data compiled by National Meteorological Agency (NMA) since the year 2005. As it is depicted on Table 3, based on five years (2000-2004) average rainfall data from NMA, Minjar Shenkora district receives the highest rainfall amount per annum in the summer season from June to August or locally known as Kiremt, its share is composed of 65 % of the total rainfall. It is during summer season that most agricultural activities are carried out and the main grains in the area are produced by the local farmers. The second highest amount of rainfall in the study area is recorded in the spring season from March to May or locally known as Belge, it covers 16.6 % of the total rainfall that the local area obtains in a year. In autumn (locally Tsdey season) from September to November months Minjar Shenkora district receives 12.95 % of rainfall per year. Whereas in winter season (locally it is called Bega) is very dry having a share of 5.44 % out of the total rainfall in a year.

Table 3: Average rainfall amount of Minjar Shenkora district (2000-2004)

Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**total rainfall**
2000	0	0	21.2	36.1	41.6	54	241.5	189.1	79.5	49.7	44.6	8.1	2765.4
2001	0	24.3	125.4	15.6	40.2	40.2	248.7	167	33.2	1.1	0	5.6	2702.3
2002	3.8	0	51.1	31.5	0	8.1	165.8	199.8	112.4	0.8	0	44.1	2619.4
2003	29.5	25.7	10	71.2	7.5	63.3	327.3	348.6	74.7	0	0	47.5	3008.3
2004	24	4.4	81.9	129.9	0.2	15.9	262	266.1	53.1	26	42.5	0.4	2910.4
Average	11.46	10.88	57.92	56.86	17.9	36.3	249.06	234.12	70.58	15.52	17.42	21.14	799.16

Source: National Meteorological Agency (2014)

As it is revealed on figure 3 the main rainy season in the Minjar Shenkora District ranges from June up to August months (summer or locally known as *kiremt*) it is at this time that teff is cultivated in the area.

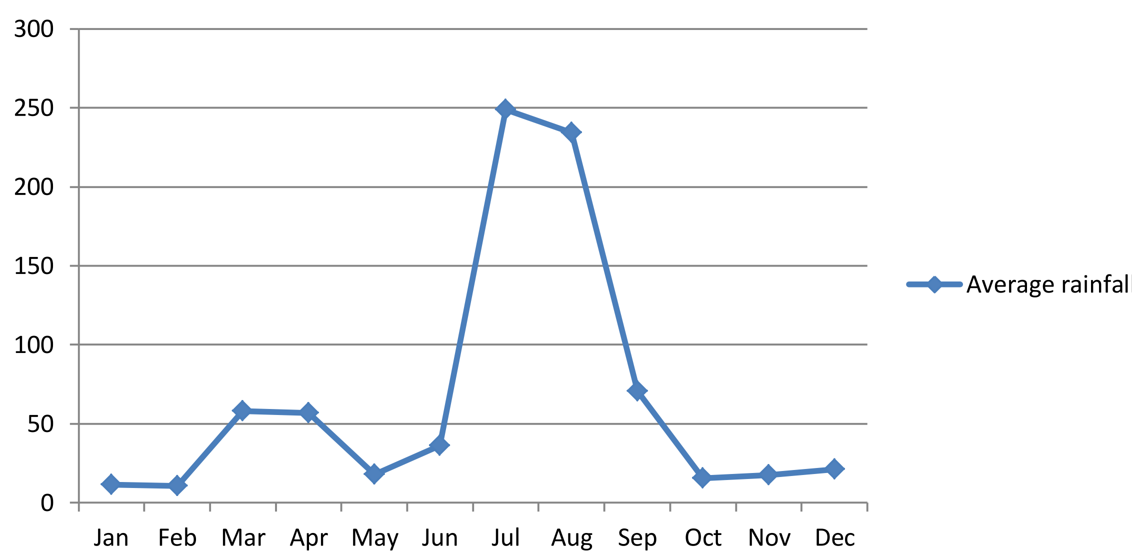

Figure 3: The average rainfall distribution of Minjar Shenkora district

Source: NMA (2014)

3.2 Socio-economic conditions

3.2.1 Economic activities

According to the Central Statistics Agency (CSA) of Ethiopia (2007) census report on Amhara region, the total population of MSW is 128,879. The number of rural dwellers of the study area is 116,642, which holds the largest portion of the total population of the whole area. As a result of this the livelihood of the largest number of households in the area depends on the agricultural activities which accounts about 93.72 % (Table 4) of the total number of household in the study area. A very small number of the total population of the area depend on other non-agricultural activities like trade, handcraft and daily laborer the portion of house hold engaged in these are 3.9%, 1.16 % and 0.60 %. While the rest 0.60 % of the total house hold depend on other socio-economic activities.

Table 4: Household economic activities engagement of Minjar Shenkora district

Nº	Economic activities	Number of House Hold	Percentage of House hold
1	Agriculture	31505.85	93.72
2	Trade	1311.063	3.90
3	Handcraft	389.957	1.16
4	Daily laborer	205.0637	0.61
5	Other	205.0637	0.61
Total		33617	100

Source: CSA and North Shewa Zone Finance and Economic Development Plan Office 2013estimation.

Since agriculture is the major economic activity in the study area the main grains produced are Teff, Chickpea, Wheat and Lentil. Minor grains produced with a very small quantity in Minjar Shenkora district are Barley, Maize, White bean and beans.

Among the 24 woredas in the North Shewa Zone, Minjar Shenkora is the well known area for its highest Teff production. According to the report made by MSDARDB in the

2013/2014 croping season in the study area a total of 55,860.38 hectares of agricultural land was covered with varies grains. According to the data on Table 5, in the study area 19,152.27 hectares of agricultural land was covered by the production of Teff. The total amount of Teff harvested in the area is about 420,839.1 quintals, this is the highest yield amount recorded among all woredas in the North Shewa Zone, as a result Minjar Shenkora district is the leading woreda (district) in Teff production.

Table 5: Main grains production in the study area in 2013/2014 grainping season

Nº	Major types of grains	Amount of grain production(In quintals)	Agricultural area covered	
			In hectare	In percent
1	Teff	420839.1	19,152.3	34.28
2	Wheat	600601.6	11,120.24	19.9
3	Chick pea	235580	5,322.52	9.53
4	Lentil	95032.2	4,204.13	7.53
5	Barley	59576.7	2,402.89	4.30

Source: MSDARDB (2014)

Teff is the main grain of the study area and in the past five years it covers great share of agricultural land in the district. Amount of teff production is very high compared to other grains in the district. In this year teff grain productivity is 21.97 which is less than the last year's productivity that was 24.85 (Table 6).

Table 6: Five years teff grain area coverage, yield and productivity in Minjar Shenkora District

Year(E.C)	Area covered by teff(ha)	Teff yield (quintals)	Teff productivity
2001/02	19,410	237,540	12.24
2002/03	14,675.05	329,363.7	22.44
2003/04	19,943.6	510,921.32	25.62
2004/05	19,744	490,803.41	24.85
2005/06	19,152.27	420,839.068	21.97

Source: MSDARDB (2014)

The ethnic distribution in the population of the Minjar Shenkora district comprises few ethnic groups which include Amhara and Oromo as well as some immigrants from other parts of the country. Among the languages used in the study, Amharic is spoken as a first language by 95% of the population and 5% of the population speaks Oromo.

According to the 2007 census report of CSA, there are different numbers of religions followed the population of the study area, the most dominant religion is Orthodox having followers of 94% of the total population; while other religions like Islam, Protestant and Catholic religions also have followers in the area accounting 5.73%, 0.25%, and 0.002% of the total population respectively, in addition to these, traditional believers are 0.0031% of the population.

3.2.2 Demographic features

Based on the 2007 census result conducted by Central Statistics Agency (CSA), (Table 7) the rural area of Minjar Shenkora woreda has total population of 116,642 of which 60,895 or 52.2% are males and 55,474 or 47.8% are females. The total urban dwellers of the study area is 12,237 of this 6,023 or 49.2 % are males and 6,214 or 50.8 % are females (CSA, 2007).

Table 7: Urban and Rural population of Minjar Shenkora district in 2007

Area	Male	Percentage	Female	Percentage	Total	Percentage
Urban	6,023	49.22	6,214	50.78	12,237	9.49
Rural	60,895	52.2	55,747	47.8	116,642	90.51
Total	66,918	51.93	61,961	48.07	128,879	100

Source: CSA (2007)

According to recent population number projection made by Central Statistics Agency (CSA) (2012) the total population of Minjarna Shenkora woreda residing in the rural area is estimated to be 125,600 of which 65,571 are males and 60,029 are females. The total urban population of the study area is estimated to be 15,039 of which 7,402 are males and 7,637 are females.

Comparing the total population number reported in 2007 census by to that of the projection made in 2012, the total population of the study area have been increased within the past six years in a rapid manner from 128,879 to 140,639; therefore when there is rapid population increase the need for food and additional income also rises consequently, as a solution in order to satisfy increasing demand population, grain production should be improved with the application of agronomic packages through different and new agricultural technologies of transplanting, using reduced seed rate and row planting methods. Based on the 2012 CSA projection report on Minjar Shenkora district the population density of the study area was 93.1 persons per square kilometer.

Based on the 2007 population census result of CSA the study area has the total of 24,941 rural households, which is distributed among the 27 rural *kebele*s. The total household number of the two sample *kebele*s of Korma and Ararti Zuriyua are 768 and 1,286 respectively.

CHAPTER FOUR

4 Methods and materials

4.1 Research design

In order to assess different factors affecting the adoption level of row planting technology on teff crop production between high-adopters and low-adopters and also to evaluate the cost and benefit variation between broadcasting and row planting technology in the process of teff production comparative research design used.

4.2 Types and sources of data

Data for this study was captured from two sources which were primary and secondary data. The majority of primary data was collected from selected farmers through focused group discussion (FGD), structured interviews and field observation. Other informants-zonal and district agricultural experts, *kebele* administrators and development agents (DAs) - were also source of primary data. In addition documents, annual grain production and input application reports from NSZARDB and MSDARDB; population census reports from CSA; purchased climatic data from head office of Ethiopian Meteorological Agency and experiments and research reports on Teff from Ethiopian Agricultural Transformation Agency (ATA) were used as sources of secondary data.

4.3 Sampling Procedures

Based on the annual grain report of 2005/2006 E.C cropping season made by Northern Shewa Zone Agriculture and Rural Development Bureau (NSAZRDB), among the 24 districts with in the administrative zone Minjar Shenkora has reported to be the leading district on the application of row planting technology on Teff grain production covering about 1,565.3 hectares of land. Beside this the researcher knows the area well and speaks the local language. In order to assess the effectiveness of row planting technology on the productivity of teff grain; Minjar Shenkora district was selected as study area (Appendix-A). Minjar Shenkora district is divided in to 27 rural *kebele*s with a total household number of 24,941 (CSA 2007).

For the purpose of this study multi stage sampling technique was employed to select sample farmers from probability sampling method. In the first stage, two *kebele*s were selected as study samples, namely, Ararti Zuriyua and Korma; with the total number of household of 1,286 and 768 respectively (CSA, 2007). Selection was made through the use of the introduction and application level of Row planting technology on Teff grain production. The application level of row planting method on Teff production in the two sample *kebele*s is very high compared to other *kebele*s in the study area; according to MSDARDB both Ararti Zuriyua and Korma constitute the largest number of household head in the application of row planting technology on Teff grain production. The two sample *kebele*s were better introduced to the method of row planting technology on Teff grain production. Based on the estimation of MSDARDB, Ararti Zuriyua and Korma *kebele*s hold the largest area of agricultural land of all 27 rural *kebele*s with in the district covered by Teff grain produced through row planting method accounting 252 and 150 hectares respectively.

The second stage, the criterion to select sample households was farmers' adoption level of row planting technology by area of the land covered with teff through row planting method. With the support of DAs and *kebeles'* administrators, using the list of farmers' name with the area of farm land they covered with teff through row planting technology, farmers in the two sample *kebeles* were categorized in to high-adopters and low-adopters. For this study farmers who had applied row planting on the production of teff on the area more than 0.25 hectare were leveled as high-adopters whereas those who applied this technology on the area less than 0.25 hectare were leveled as low-adopters. Therefore sample households were classified and randomly selected from the available list. As it is indicated on Table 8, a total of 113 sample households from the two *kebele*s were selected of which 50 were high-adopters and 63 were low-adopters.

A proportional allocation formula was employed to select respondents from each sample *kebeles* and each farmer's category. Therefore, 31 and 19 high-adopters were selected from Ararti Zuriyua and Korma *kebeles* respectively while the numbers of low-adopters were 40 and 23 from Ararti Zuriyua and Korma *kebeles* respectively.

$$n \times \frac{Ni}{N}$$

Where: Ni- The total household heads in each *Kebele*

N- The total household heads in the sample *Kebele*

n- Sample size of households in the study area.

Table 8: Distribution of study Samples by *kebele* and head of household characteristics

Kebele	Farmers' type	Total number of HH	Sample household
Ararti Zuriyua	High-adopters	561	31
	Low-adopters	725	40
	Total	1286	71
Korma	High-adopters	348	19
	Low-adopters	420	23
	Total	768	42
Total		2054	113

Source: *kebele*s' administrative offices (2014)

4.4 Methods of data collection

The following data collection tools were employed for the purpose of gathering relevant data for further analysis.

4.4.1 Field observation and informal interviews

Field observation was conducted from the time of proposal preparation and continued through the whole processes of data gathering in order to assure the validity of acquired data. It was conducted by the researcher aiming to understand the local communities farming practice, adoption level of new agricultural technologies and to evaluate the access to package provision for teff grain production. On his way the researcher took notes on soil color, topography of the land, land use and on the type of on farm support provided by DAs.

Informal interviews were carried out in infrequent manner with the farmers met occasionally for the purpose of getting information to produce a structured questionnaire which is used as a major tool for data gathering.

4.4.2 Structured interviews

The major instrument used for data collection was structured interview with questions which are carefully constructed. On the bases of information acquired during informal interview with farmers and field observation, and from readings of related literatures structured questionnaire (Appendix-B) was constructed for the data collected from classified and randomly sampled 113 household heads. Five enumerators were selected, for collection of data through structured questions, among them two were college graduates and the other three were high school graduates. Before the actual implementation of the survey enumerators were given training and evaluated for the clarity and reliability of the questions; in doing so ambiguous and unrelated questions were dropped while valuable questions were added.

4.4.3 Focused group discussion

Focused group discussion used as means of triangulation with questionnaire data collection method. The main aim of FGD is to cross examine the level of adoption of row planting technology on teff grain production, to evaluate yield improvement acquired through new modern teff technologies and identify major bottle necks hindering farmers from the application of row planting method in teff production. The researcher presented various open ended questions to the participants which were carefully conducted from the structured interview. With the help of DAs and local elders the total of twenty-three farmers participated in two focused group discussions in each kebeles.14 farmers were participated in the FGD in Ararti Zuriyua *kebele* (five of them were the so called ‘model farmers’) and 9 farmers participated in FGD in Korma *kebele* (three of them are the so called ‘model farmers’). The participants in the FGD are composed of elders, young people and women.

Figure 4: Focused group discussion with the local farmers in Ararti Zuriyua *kebele*

Source: survey data (2014).

4.4.4 Key informant interview

Purposively the researcher selected 16 respondents who can be able to provide detail information regarding on the application of row planting technology on teff grain production and the consequent teff yield and yield component improvement achieved in the study area. These include eight development agents from sample *kebeles,* three officers from district agriculture and rural development bureau and five village leaders.

4.5 Methods of data analysis and presentation

Both qualitative and quantitative methods were used in order to analyze collected data through questionnaires and focused group discussion. The quantitative data collected from the sample respondents were encoded in to SPSS (Statistical Package for Social Science) version 20.

Simple descriptive statistics such as percentage, mean, frequency and cross tabulation were used for analysis. In order to test significance difference among variables independent sample t test and chi square test were used. Excel spread sheet was also used to analyze the qualitative data gathered through focused group discussion, key informant interviews and discussion held with DAs (development agents) were summarized to a manageable manner by grouping the same responses in to the same category. Based on this analysis comparison was made on cost and benefit of teff grain production between row planting and traditional broadcast planting technologies of teff. The study has also analyzed the major factors affecting the application of row planting technology on teff cultivation in the study area.

CHAPTER FIVE

5 Results and discussion

5.1 Socio-economic conditions of the respondents

5.1.1 Household size of the respondents

Household size of the respondents in both sample kebeles may affect the adoption of planting teff in rows. Because planting teff in rows requires high labor cost households with large family size may have a greater chance of adopting this technology while households with small family size may find it very impossible to apply row planting technology.

As table 9, displayed that about 31% of the total respondents had a small household size ranging between one up to three family members, among these 20.35% and 10.62 % of respondents were in Ararti Zuriyua and Korma *kebeles* respectively. Due to this the majority of respondents had small family size this may negatively affect the application of row planting technology. About 27.4 % of the total respondents had medium household size composed of four up to seven members of family, of these 15.93 % were from Ararti Zuriyua and 11.5 % were from Korma *kebeles*. Among the total respondents 41.59 % had large family size ranging between eight and ten members, the numbers of respondents in each *kebeles* with the same family size were accounting 20.35 % and 11.5 % in Ararti Zuriyua and Korma *kebeles* respectively.

Table 9: Household size of the respondents

Kebele	Household size						Total	
	1-3		4-7		8-10			
	Nº	%	Nº	%	Nº	%	Nº	%
Ararti Zuriyua	23	20.35	18	15.93	30	26.55	71	62.8
Korma	12	10.62	13	11.5	17	15.04	42	37.2
Total	35	31	31	27.4	47	41.59	113	100

Source: Survey data (2014)

5.1.2 Age structure of the respondents

Age structure of the respondents beside other factors could affect their willingness to apply new agricultural technologies including row planting.

The age structure of the sample respondents in this study are grouped in to three different age categories these were youth (20-40 years of age), adults (41-60 years of age) and old farmers (61-70 years of age). As Table 10, revealed that 33.6 % of the total respondents were within age group 20-40 years old among these 25.7 %and 7.5 % of the total respondents were from Ararti Zuriyua and Korma *kebele*s respectively whereas the majority of the respondents were adult with age of 41-60 accounting 56.6 % of the total, among these 32.7 % and 23.9 % of the total respondents were from Ararti Zuriyua and Korma *kebele*s respectively. The number of old respondents is much smaller than the other age groups this is mainly because of farmers at their old age retire from farming activities and pass their land holdings to their children, as a result they were accounting 9.7 % of the total respondents of these 4.4 % were from Ararti Zuriyua and 5.3 % were from Korma *kebele*.

Table 10: Age structure of respondents

Kebele	Age of household head						Total	
	20-40		41-60		61-70			
	Nº	%	Nº	%	Nº	%	Nº	%
Ararti zuriyua	29	25.7	37	32.7	5	4.4	71	62.8
Korma	9	7.9	27	23.9	6	5.3	42	37.2
Total	38	33.6	64	56.6	11	9.7	113	100

Source: survey data (2014)

5.1.3 Gender of the respondents

Female headed and male headed households are not the same in the application of new farming technologies. Therefore the gender of household head may have a great deal of effect on the application level of row planting technology. As it is revealed on Table 11, 77.87 % of the total respondents were male and among them 51.32 % and 26.55 % were from Ararti Zuriyua and Korma respectively. Number of female headed household respondents' accounts 22.12 % of the total participants and among these 11.5 % was from Ararti Zuriyua and 10.62 % were from Korma.

Table 11: Gender of the respondents

Kebele	Gender of household head				Total	
	Male		female			
	Nº	%	Nº	%	Nº	%
Ararti Zuriyua	58	51.32	13	11.5	71	62.8
Korma	30	26.55	12	10.62	42	37.2
Total	88	77.87	25	22.12	113	100

Source: survey data (2014)

5.1.4 Educational status of the respondents

Education and application level of improved farming activities are positively related. Educational status of a farmer may directly affect adoption and application of new agricultural technologies. Table 12, shows that the majority of respondents did not attended any kind of education among them 20.4 % (Ararti Zuriyua) and 11.5 % (Korma) were illiterates who cannot read and write, since the majority of respondents did not have any access to education the adoption process of new modern technologies may be affected negativly. While 23.9 % (Ararti Zuriyua) and 9.7 % (Korma) of the total respondents even though did not attend any formal education, they can read and write. 11.5 % and 12.4 % of the total respondents in Ararti Zuriyua and Korma respectively had attended primary education (1-6). The number of respondents who had attended junior (7-8) and senior (9-12) high school education were very small in number in both sample *kebele*s. 3.5 % and

1.8 % of respondents respectively from Ararti Zuriyua and Korma had graduated from junior high school and the same number of respondents 3.5% (Ararti Zuriyua) and 1.8% (Korma) had joined senior secondary education.

Table 12: Educational status of the respondents

Kebele	Educational level of household										Total
	Illiterate		read and write		1-6		7-8		9-12		
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	
Ararti Zuriyua	23	20.4	27	23.9	13	11.5	4	3.5	4	3.5	71
Korma	13	11.5	11	9.7	14	12.4	2	1.8	2	1.8	42
Total	36	31.9	38	33.6	27	23.9	6	5.3	6	5.3	113

Source: Survey data (2014)

5.1.5 Land holding condition of the respondents

Land holding size of the respondents did affect greatly the level of farmers' adoption of teff row planting technology. Table 13 reveled that about 41.59 % of the total respondents possess small portions of landholdings measuring less than one hectare, this mostly force farmers not to take any risk by applying new farming technologies, among them sample farmers owning land holdings less than the size of 0.5 hectare accounts about 16.81% of this 12.4 % and 4.42 % are from Ararti Zuriyua and Korma respectively.

Number of respondents possessing land holdings with area of 0.5 – 1 hectares are 24.78 % of the total sample farmers, out of these 18.58% and 15.93 % are from Ararti Zuriyua and Korma in respective manner. The majority number of the total respondents with a share of 41.6 % hold farm land having size between 1and 2 hectares, among these 25.66 % are from Ararti Zuriyua and 15.93 % are reside in Korma *kebele*. Whereas the numbers of farmers possessing land above two hectares were only 16.8 % of the total respondents, among these

5.31 % and 11.5 % were resided in Ararti Zuriyua and Korma *kebele*s respectively. This implies that most of the respondents' land holding size is small so it may had a negative effect on the application level of row planting on teff crop production.

Table 13: Respondents land holding size

Kebele	Land holding in ha								Total	
	<0.5ha		0.5-1ha		1-2ha		>2ha			
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%
Ararti Zuriyua	14	12.4	22	19.47	29	25.66	6	5.31	71	62.8
Korma	5	4.42	6	5.3	18	15.93	13	11.5	42	37.2
Total	19	16.81	28	24.78	47	41.6	19	16.8	113	100

Source: survey data (2014)

5.2 Factors affecting application of modern teff production technologies

In the study area many factors did affect farmers' level of application of teff production through row planting these are categorized in to household related factors, institutional factors and technological factors.

5.2.1 Household related factors

5.2.1.1 Household size

According to the data acquired from FGD most of the respondents suggested that the house hold size of the respondents significantly affects the respondents' adoptability to row planting technology. Since teff row planting technology in the current situation is labor intensive method of production as it can be seen on figure 5, households with large family size were able to provide more number of labor assistance from the family members.

Figure 5: Labor requirement of teff row planting technology

Source: MSDARDB (2013)

As a result of this among the high-adopters of the newly introduced teff seeding technology most of them had large family size. Table 14 depicted that from the total of respondents 41.6 % had large household size ranging between eight up to ten family members, among these 26.5 % were high-adopters of teff row planting technology while 15.04 % were low-adopters. From this it can be concluded that household size had a positive effect on application of row planting on teff seeding process. 27.43 % of the total respondents had a medium household size with family members of four up to seven among these 11.5 % had applied the method of row planting whereas 15.93 % did not produce teff through this seeding method. According to the data on (Table 14) 30.97 % of the total respondents had very small household size composed of a minimum of one and a maximum of three family members, among these high-adopters were accounting only 6.2 % while low-adopters of row seeding were 24.78 % of the total respondents of the study.

Table 14: The effect of household size on adoption rate of row planting

House hold size	High-adopter		Low-adopter		Total	
	Nº	%	Nº	%	Nº	%
1-3	7	6.2	28	24.78	35	30.97
4-7	13	11.5	18	15.93	31	27.43
8-10	30	26.5	17	15.04	47	41.6
Total	50	44.2	63	55.75	113	100

Source: survey data, 2014

On the bases of the data from FGD and key informant interview it can be concluded that as the number of family members increases the application level of row planting technology also increases whereas since respondents with small household size cannot provide enough amount of labor from the family their application level of row planting technology was very low. Even though they were few in number, low-adopters with large family size did not apply teff row planting mainly as the result of influence on household head from family members by denying labor assistance and only by focusing on the downside aspects of the technology this was due to fear of crop failure from family members especially children.

As it is depicted on figure 6, in the case of high-adopters household family size and level of adoption of row planting technology is strongly and positively related. In the case of low-adopters household family size had a negative relationship with the application rate of row planting.

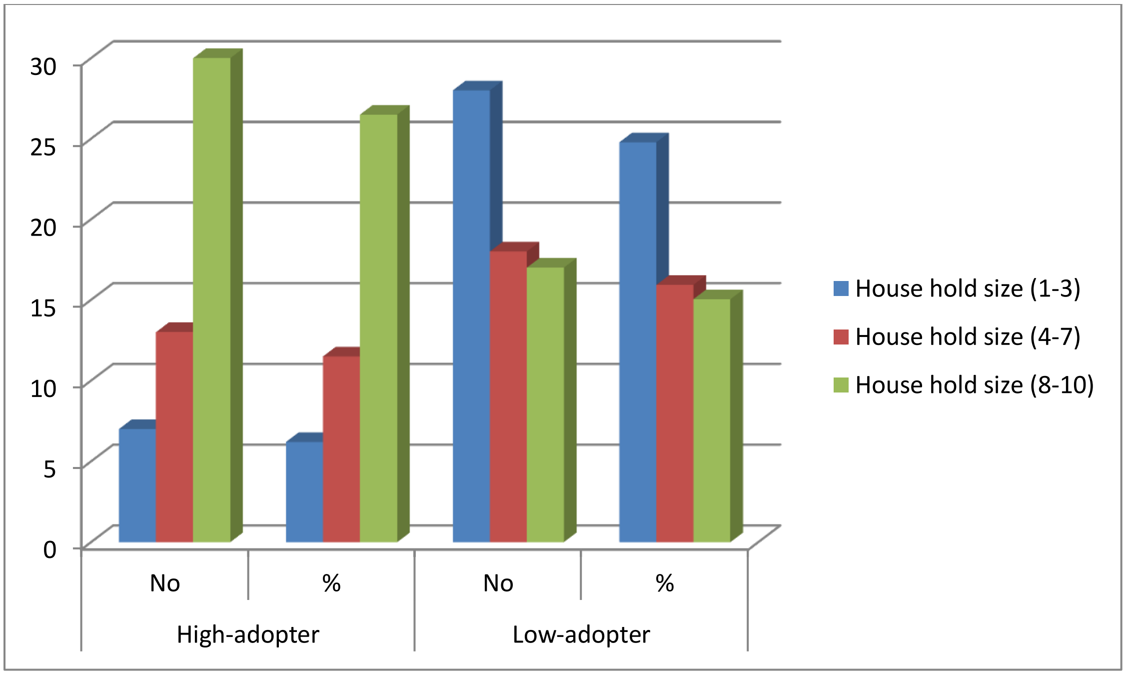

Figure 6: Application level of row planting and household size

Source: survey data (2014)

5.2.1.2 Age structure and land holding

During FGD most youth respondents found it very difficult to adopt teff row planting technology which is mainly resulted from the fact that their land holdings were very small in size so they did not want to take risk of applying teff row planting technology.

Table 15 depicted that 33.63 % of the total respondents were youth categorized with in age group ranging between 20-40 years of age. The youth low-adopters exceed the high-adopters within the same age group by 26.31 %. Therefore the majority of youth did not adopt the technology of row planting this is resulted from the fact that young respondents owned less amount of land (Table 16) through crop sharing, inheritance and rent; therefore youth are poor and highly vulnerable to the risks of adopting row planting technology.

Table 15: Age category of household heads and adoption of row planting

Age category of household heads	Adoption of row planting method				Total	
	High-adopter		Low-adopter			
	Nº	%	Nº	%	Nº	%
20-40	14	12.38	24	21.24	38	33.63
41-60	33	29.20	31	27.43	64	56.64
61-70	3	2.65	8	7.08	11	9.73
Total	50	44.25	63	55.75	113	100

Source: survey data (2014)

The majority of adult respondents applied row planting method in teff production compared to the rest of age group categories (Table 15) they accounts about 29.2 % of the total respondents and 66 % of the total high-adopters. Adult farmers accounting about 43.55 % of the total respondents possessed landholding measuring more than 1 hectare (Table 16). 9.73 % of the total respondents were grouped in old age category (61-70 years old), among them only 2.65% applied the technology and 7.08 % hesitated the application of row planting technology this was mainly due to the conservative nature of the group and lack physical strength and shortage of labor support.

Table 16: Age of household head and land holding

Age of household head	Size of land holding								Total	
	<0.5ha		0.5-1ha		1-2ha		>2ha			
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%
20-40	13	11.5	15	13.27	10	8.85	0	0	38	33.63
41-60	5	4.4	12	10.62	30	26.55	17	15	64	56.64
61-70	1	0.9	1	0.9	7	6.2	2	1.8	11	9.73
Total	13	11.5	32	28.3	49	43.36	19	16.8	113	100

Source: survey data (2014)

As it was revealed on Figure 7, youth respondents owned small amount of land holdings this made them more unprotected to the risks of adopting row planting method whereas adult farmers between age group of 41-60 years of age were better-off and they are less vulnerable to the risks of adopting new farming technologies.

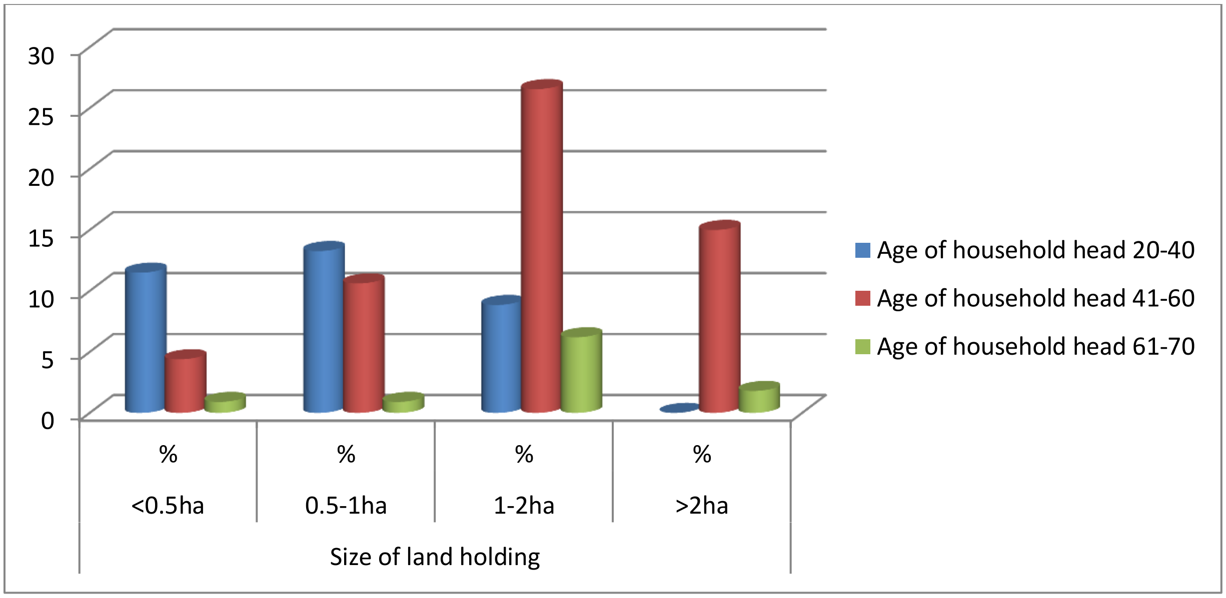

Figure 7: Size of landholding and age of household heads

Source: survey data (2014)

5.2.1.3 Educational status and application level of row planting on teff production

As it is uncovered on Table 17, 31.85 % of total sample respondents were categorized under the educational level of illiterate among these 26.5 % produce teff using traditional broadcasting method of seeding and the remaining 5.3 % apply row planting; this implies that the level of adoption of row planting method is highly affected by the level of education, farmers with low educational attainment had low application level of new farming methods. As the local farmers' educational attainment level increases farmers' willingness to adopt row planting technology at the same time increases. Even though the frequency respondents who had attended high school education were very low but their adoption level of row planting on teff crop production was by far better than the other categories.

Table 17: Educational level and adoption of row planting method

adoption of row planting	Educational level of household										Total	
	Illiterate		read and write		Grade 1-6		Grade 7-8		Grade 9-12			
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%
High-adopter	6	5.3	15	13.27	21	18.58	3	2.65	5	4.4	50	44.25
Low-adopter	30	26.5	20	17.7	20	17.7	3	2.65	1	0.9	63	55.75
Total	36	31.85	35	30.97	41	36.28	6	5.30	6	5.3	113	100

Source: survey data (2014)

As it is easily displayed on Figure 8, as the educational level decreases the number of high-adopters becomes very low and low-adopters increase. The opposite is true as the level of education increases high-adopters also increases and low-adopters minimized. This is due to the level of understanding and adoption willingness is positively related with educational level and as a result respondents with high level of educational attainment were more open to new ideas and modern agricultural production technologies.

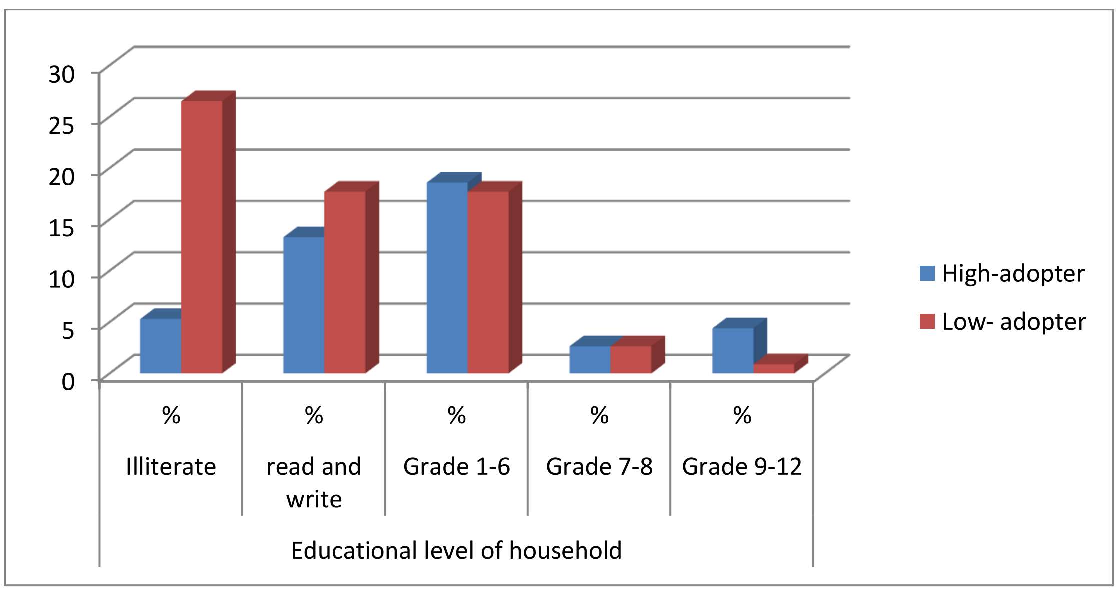

Figure 8: Educational level and level of adoption

Source: survey data (2014)

5.2.1.4 Gender of the respondents and application level of teff row planting method

Gender of the respondents had a great effect on the application level of row planting technology on teff crop production. Based on the survey results female headed respondents found it very difficult to adopt row planting method in the process of teff production in the study area, mainly as result of low labor support. Table 18, displayed that 22.12 % of respondents are female headed households, and among them only 5.31 % applied the technology where as the rest 16.81% (which means 76 % of the total female headed households) did not adopt the method. Although other factors also influence the level of adoption, male headed households had adopt the technology better than female headed households, this is mainly due to male headed households had better access to labor support and wealth (i.e. landholding).

Table 18: Gender of respondents and application level of teff row planting

Gender of the respondents	Adoption of row planting method				Total	
	High-adopter		Low-adopter			
	Nº	%	Nº	%	Nº	%
Male	44	38.94	44	38.94	88	77.88
Female	6	5.31	19	16.81	25	22.12
Total	50	44.25	63	55.75	113	100

Source: survey data (2014)

5.2.1.5 Soil type

Most of the respondents with black soil on their field plant teff seeds through the application of broadcast planting method for this Table 19, depicts that among the total of 36 farmers with black soil on their field 26 respondents apply teff production through broadcasting method. Whereas only 10 number of farmers apply row planting on black soil. This implies that Black soils (vertisols) mostly have a great tendency sticking its particles which made it very difficult for human movement at time of work and it is very impossible to dig row lines in order to open furrows for the application of row planting.

Table 19: Amount of seed and soil type

Adoption Of row Planting	Soil Type	Amount of seed applied (kg/ha)										Total	
		< 10		10-20		20-30		30-40		40-50			
		Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%
Low-adopter	Black	0	0	0	0	5	4.42	9	7.96	12	10.62	26	23
	Brown	0	0	4	3.54	23	20.35	10	8.84	0	0	37	32.74
	Total	0	0	4	3.54	28	24.78	19	16.81	12	10.62	63	55.75
High-adopter	Black	0	0	10	8.85	0	0	0	0	0	0	10	8.85
	Brown	13	11.5	26	23	1	0.9	0	0	0	0	40	35.4
	Total	13	11.5	36	31.85	1	0.9	0	0	0	0	50	44.24
Total	Black	0	0	10	8.85	5	4.42	9	7.96	12	10.62	36	31.85
	Brown	13	11.5	30	26.54	24	21.23	10	8.84	0	0	77	68.14
	Total	13	11.5	40	35.39	29	25.66	19	16.81	12	10.62	113	100

Source: survey data (2014)

According to FGD data respondents insinuate that mostly brown soils and in some cases black soils have the nature of swelling and creating wholes beneath the surface allowing air passage after it exposed to small amount of rain water. As result when the soil swell it will lifts the seed up ward and exposed it to air and lead to the crake of the planted teff seeds and affect seed germination. In response to this most of the respondents apply high seed rate in order to minimize the risk of teff grain failure. Table 19 displayed those non-adopters accounting 52.21 % of the total respondents apply high amount of seed rate ranging between 20 up to 50 Kg/ha. High-adopters of row planting technology also did not use the recommended amount of teff seed which is 3-5 Kg /ha rather high-adopters accounting 35.39 % of the total respondents apply seed rate ranging between 10 to 20 kg/ha. Figure 9 revealed that low-adopters apply seed rate measuring between 40-50 kilograms of teff seed per hectare on black soil type whereas high-adopters apply seed rate measuring between 10-20 kg per hectare. This implies that standardized application of row planting technology is difficult to apply under different soil type and amount of seed rate that farmers sow vary under different soil type in order to avoid risk of crop failure and reduction of fodder amount and quality.

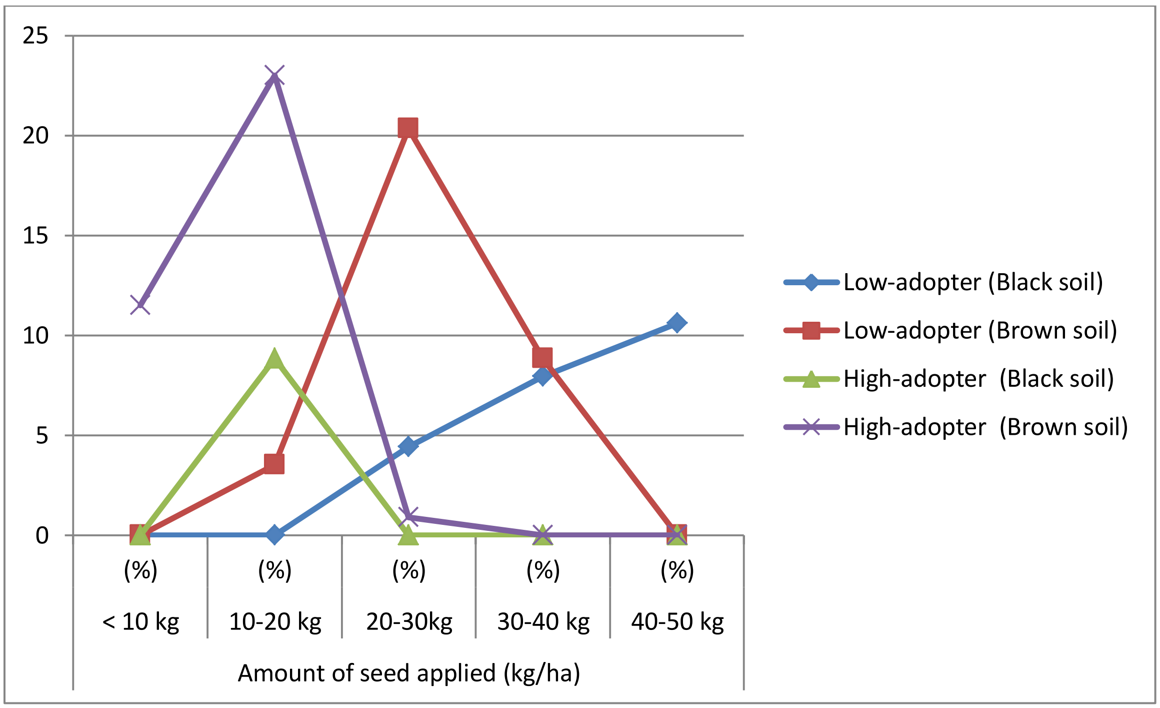

Figure 9: Amount of seed applied based on soil and farmers type

Source: survey data (2014)

5.2.2 Institutional factors

5.2.3 Farmers level of training

Farmers in order to adopt any new agricultural technologies they should first exposed to them through trainings at FTC (Farmers Training Centers) or Demonstration Centers. Based on the data gathered from DAs through interviews shows that farmers are trained mainly to bring skill development and attitudinal change on the application of row planting technology of teff grain, though due to the lack of prior farmers' experience and resulting fear and hesitation negatively affect the adoption level of row planting and in addition to that lack of in depth practical training before farmers went to teff planting practice on their field.

Based on the information displayed on Table 20, 76.9 % of farmers who adopt row planting on larger farm size received training on preparation and application of water plastic bottle seeders and 45% of low-adopters took the same training about the same technology in the FTC which has at the 95% confidence interval and 0.001 p-value there is a significance difference between high-adopters and low-adopters. Therefore high-adopters have got better number of access to training in application of plastic seeder. On reduced seed rate application training was given in FTC for 67.5 % and 51.5 % of high-adopters and low adopters respectively and there is a significance difference between high-adopters and low-adopters attending this training at p-value of 0.001. By DAs training on proper use of seeding depth and width between rows was provided to 87 % of high-adopters and 37% of the low-adopters. On the techniques of row planting training was provided for 84 % and 57% of high-adopters and low-adopters respectively. In the both trainings on row planting and seeding depth and width the numbers of farmers attending from the two categories are significantly vary at 95% confidence interval (with the value of X^2 of 9.405 and p-value of 0.002). This implies that the number of trainings provided to farmer had significantly affected the application level of row planting technology. Beside row planting methods farmers in the study area were encouraged to apply the method of transplanting of teff seedlings and the number of farmers who engaged in this method accounts 31% and 24% of high-adopters and low-adopters respectively there is no significant difference exhibited between them (with p-value of 0.335). From these it can be concluded that most number of high-adopters had access to trainings provided.

Table 20: Types of trainings provided

Type of training	High-adopter		Low-adopter		**Significance test**	
	Nº	%	Nº	%	**X^2**	**P-value**
Preparation and application of plastic bottle seeder	38	76.9	29	45	10.372	0.001
Reduced seed rate	34	67.5	32	51.3	11.765	0.001
Seeding depth and width	44	87	37	59.5	9.405	0.002
Row planting	42	84	36	57	9.405	0.002
Teff transplanting	16	31	15	24	0.939	0.335

Source: survey data (2014)

Both groups of farmers were given training on the application of the other teff production technology called teff transplanting. Although according to the information gained through FGD teff transplantation in the study area has never been adopted which is attributed to the lack of water for germination of teff seedlings in the area as it can be seen on Figure 10 most of the rivers are dry in seasons other than summer and besides the technology is also requires high labor cost.

Figure 10: Ashal River in Korma *kebele* (photograph by the author 2014)

Source: Survey data (2014)

As Table 21 displayed that about 68.1% of the total respondents acquire knowledge about row planting technology on teff production through oral orientation provided by DAs at

FTC, this constituted 86% of high-adopters and 54 % of low-adopters. Whereas 42.9 % of the total low-adopters are exposed to the knowledge of row planting method through contact with colleagues, this had created knowledge gap because of lack of scientific explanations. Since the majority of low-adopters did not receive training from well trained DAs, their knowledge depth about the benefits of row planting technology is very low; as a result their knowledge level had a significant effect on the process of adoption of the technology. Almost 100 % of the total respondents did not get any kind of practical training about row planting technology on teff cultivation in demonstration centers rather their own farm land became demonstration center at the time of farming activities. Therefore it can be concluded that farmers' lack of practical experience negatively affect their level of adoption of the technology.

Table 21: Knowledge source of row planting

Knowledge source of row planting technology	Adoption of row planting method				Total	
	High-adopter		Low-adopter			
	Nº	%	Nº	%	Nº	%
Colleagues	7	14	27	42.9	34	30.1
DAs oral orientation at FTC	43	86	34	54	77	68.1
Mass media	0	0	2	3.1	2	1.8
Practical Training at Demonstration center	0	0	0	0	0	0
Total	50	100	63	100	113	100

Source: Survey data (2014)

5.2.4 Access to extension services

Extension services are very important and effective to enhance the productivity of teff grain in the study area. Based on the data gathered from DAs, they pointed out that they spent much of their working time on farmers' field. They also frequently visited the working progress of farmers on the field and provide skill training and knowledge transfer. Beside all these farmers obtained free labor support on the application of row planting technology from DAs.

Extension services such as visits from DAs were received among the compared groups at different frequencies (Table 22). Higher frequency of visits by DAs on farmers' field was received by high-adopters of row planting technology, accounts 62 % among the group. They were offered a visit from DAs whenever they need assistance. Whereas only 11.1% of the low-adopters of row planting method on teff production obtained a visit from DAs at the time they need. Beside this almost 25.4 % of the low-adopters of teff row planting method had never been visited by DAs at all, while this is also true for about 4% of high-adopters. These very significant frequency differences of DAs visit was attributed mainly to their eagerness to provide much attention to the high-adopter farmers who willingly apply row planting on teff cultivation on larger physical extent of their farm land. From this it can be concluded that the frequency of visit by DAs had a significant effect on the adoption level of teff row planting technology. The majority of high-adopters had received higher frequency of DAs' visit compared to that of low-adopters. According to the data from key informant interview DAs were very ambitious to report the effectiveness of row planting technology on teff crop production therefore they provided much attention and support for high-adopters of the technology.

Table 22: Frequency of extension services received by teff producers

Access to extension service	Adoption of row planting method				**Significance test**	
	High-adopter		Low-adopter			
	Nº	%	Nº	%	x^2	**P- value**
Once per week	10	20	13	20.6	37.200	0.000
Once per month	7	14	27	42.9		
Every time I demand services	31	62	7	11.1		
Never been visited	2	4	16	25.4		
Total	50	100	63	100		

Source: survey data (2014)

5.2.5 The effectiveness of trainings

Most of the local farmers did not trained in the demonstration center underwent through their actual practical participation, because of this and due to farmers were not provided with any kinds of incentives like grain provision from safety net program, even though they were given an extensive oral orientation from DAs, they were passive in adopting the technology to their farm. Land based on the data from FGD and key informant interview one of the major factors contributed to farmers' vacillation on adoption of row planting technology was their fear of crop failure. As a result of this the district and *kebele*'s administrative officers and DAs forced farmers to apply the row planting method during teff production. Based on the data gathered through FGD and key informant interview, unwilling nature of farmers and force applied by district officers and DAs created a game of 'hide and sick' among them due to this reason many farmers sow teff using traditional broadcasting method on their field in the night time when no DAs can appear on the field, which created another problem of unproportionable seed distribution over the field resulted from lack of visibility. As Table 23 displayed among the high-adopters of the technology about 52% of the respondents put row planting method into practice as the result of imposition from DAs.

Table 23: Adoption willingness of row planting method

Reason for the application row planting	High-adopters				Total	
	'model farmers'		*Other farmers*			
	Nº	%	Nº	%	Nº	%
Willingly	11	68.75	9	26.47	20	40
Imposition from government officers	4	25	22	64.71	26	52
Fear of penalty	1	6.25	3	8.82	4	8
Total	16	100	34	100	50	100

Source: Survey data (2014)

Whereas the leaders of *one to five* farmers associations or the so called '*model'* farmers totally accounting 16 in number among the high-adopters, 68.75% did adopt row planting on teff grain willingly without imposition from government officers. According to the data gathered from FGD and key informant interview it was attributed to the reason that '*model'* farmers did get better support from district officers and DAs. The following case study may unveil the situation why '*model*' farmers apply row planting on teff cultivation.

> "*Wondiye Aklile is one of the so called model farmers residing in Ararti Zuriyua kebele, in a village called Solomon Hager. He sews teff seed on 0.75 hectares of his own teff farm land through row planting method. He had received an extensive supports from DAs on how to seed teff in rows using water plastic bottles, reduced seed rate application, implementation of packages and he was also provided with an opportunity to visit other farmers' field. As a result of these upholds he applied 2kg of teff seed per hectare, DAP 1 q/ha and urea 0.5q/ha as recommended and he harvested 26 q/ha of teff yield in the 2005/2006 E.C cropping season. He was given support to own two water reservoirs and by using the water, he cultivated onion two times in a year and earned 30,000 Birr of an additional income over the main rainy season production."*

As a result most of '*model'* farmers apply new modern technologies and can handle any kind of risk mainly as a result of the support and their economical strength

5.2.6 Technological factors

5.2.7 Application simplicity of broadcast planting method

Mainly due to its uncomplicated application nature of traditional broadcasting planting system farmers tended to held on it. According to the data revealed on (Table 24) of the total of respondents 48.67 % suggested that they prefer broadcast planting method mainly as a result of low labor cost and 58.7 % of the total low-adopters mainly argued that the labor expense of broadcasting method is very low so that they choose it over row planting method. 35.4% of the total respondents argued that broadcasting planting method is very easy to apply.

Table 24: Application reason of broadcasting method of teff planting

Reason of broadcasting planting application	Adoption of row planting method				Total	
	High-adopter		Low-adopter			
	Nº	%	Nº	%	Nº	%
easy to apply	24	48	16	25.4	40	35.4
to avoid risk of grain failure	5	10	5	7.9	10	8.8
to harvest high amount of yield	3	6	5	7.9	8	6.19
low labor cost	18	36	37	58.7	55	48.67
Total	50	100	63	100	113	100

Source: survey data (2014)

Teff broadcasting method is a simple seeding method with no complexity and its application does not require any kind of training or specialization rather any one with prior farming experience can perform it. As Table 25 displayed that about 55.7 % of the total respondents replied that application of broadcasting method is not complex it can be performed by any elders in a family while 37.17% of the respondents replied that application of broadcasting method requires skill from attained from farming experience.

Table 25: Skill of broadcasting planting

Adoption level	who broadcast teff						Total	
	Anyone in the family		Elders in the family		Skilled person			
	Nº	%	Nº	%	Nº	%	Nº	%
High-adopter	3	2.65	29	25.66	18	15.9	50	44.24
Low-adopter	5	4.42	34	30.09	24	21.23	63	55.75
Total	7	6.19	63	55.75	42	37.17	113	100

Source: survey data (2014)

5.2.8 Teff seeding time

Based on the data gathered through FGD and key informant interviews most of the respondents suggested that due to the very small nature of teff seed; teff is mainly and traditionally sown mostly when the soil moisture exceeds its saturation point and the field turned to muddy and sticky, this intern based on the nature of the soil may affect the level of application of the row planting technology by hindering the manipulation of row seeder machine.

Based on the data on (Table 26) teff planting practice in both sample *kebele*s and by the majority number of high-adopters and low-adopters done after one and half month passed following the entrance of the main rainy season of summer (locally called *kiremt*). 84.07 % of the total respondents conduct teff seeding within the time interval from 3rd to 4th week in month of July, among them 37.17% and 46.9% are high-adopters and low-adopters respectively. Due to the reason that teff is planted at the time of high amount of rain water is in the soil, it is very difficult for the local farmers movement at seeding time and opening furrows for seed bed. As a result of this teff seeding time had a significant effect on the level of adoption of teff row planting technology.

Table 26: Teff planting time

Type of farmer	Teff seeding time				Total	
	1st -2nd week in July		3rd-4th week in July			
	Nº	%	Nº	%	Nº	%
High-adopter	8	7.07	42	37.17	50	44.25
Low-adopter	10	8.85	53	46.9	63	55.75
Total	18	15.92	95	84.07	113	100

Source: survey data (2014)

5.2.9 Teff seeding space and depth

When teff is planted through row planting technology the seed bed is recommended not to be deeper than 2-3 cm below the surface. This is chiefly due to size of its seed does not allow it to grow if it is buried deeper. And at the same time there should be space of 20 cm interval left among each row lines in recommendation. As it can be seen on Figure 11, the area left among rows will minimize the competition among individual plants for nutrients from the soil, water and sun light so that productivity will be improved.

Table 27 depicts that the majority of high-adopter respondents accounting for 61.18 % use the size of their traditional plow instrument, having width ranging from 30-35 cm, in order to divide consecutive row lines in the study area this intern increase the open space left between rows and lead to the wastage of farm land and provides large space for high amount of weeds growth. This problem was mainly attributed to the low access of modern row planter mechanizations (see Table 31). As a result it had a negative implication on the farmers' willingness to the adoption of row planting of teff crops and it also affect the area of farm land that farmers covered with teff through row planting method.

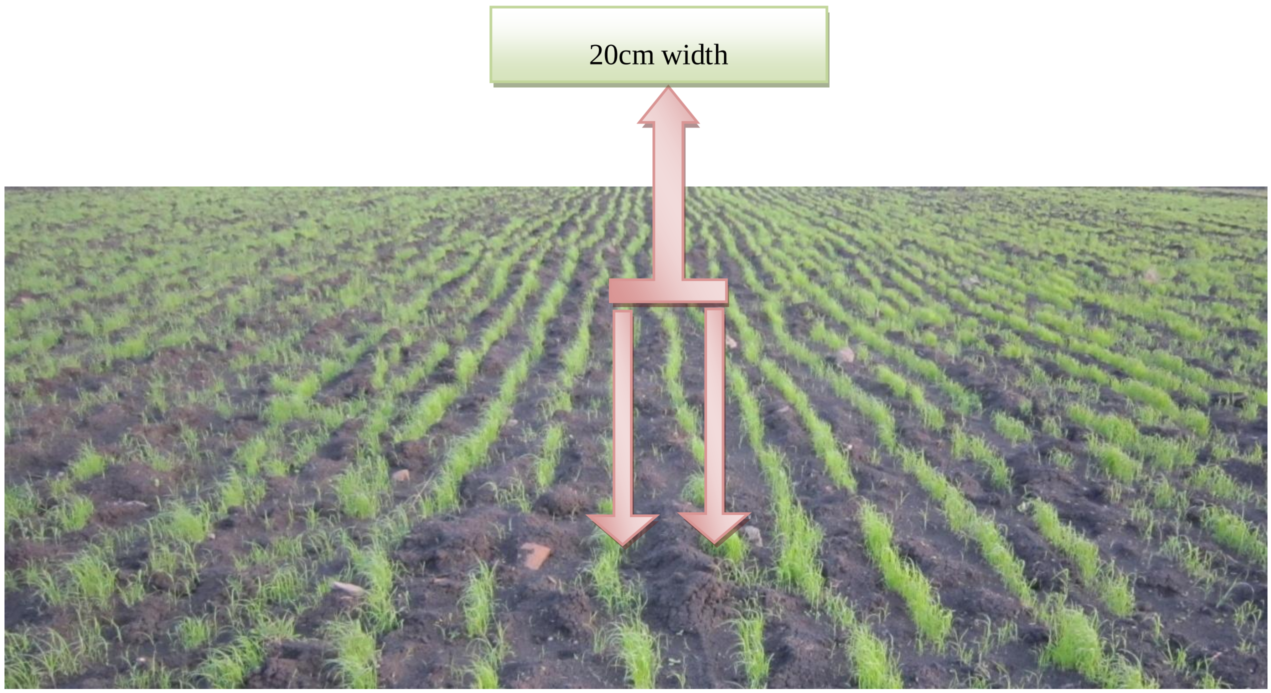

Figure 11: Recommended width interval among rows

Source: survey data (2013)

Table 27, also revealed that among the total of high-adopters of row planting technique 56% planted teff seed on furrows opened by traditional plow with a length of 20-25 cm depth in to the ground. Unless the seeds are planted very carefully it may fall deeper and may not grow at all whereas 40% of the high-adopters specifically follow the recommended seeding depth.

Based on the information from FGD and key informant interview, the respondents suggested that many farmers who had planted teff seed deeper than 3 cm depth as a result it extended the growing period of teff. Therefore many farmers turn and plow their land and sow other types of grains that can grow in short period of time. This was mainly due to the fact that teff seeding on appropriate depth requires farmers' in-depth knowledge and high labor demand.

Table 27: Intervals between rows and depth of seed bed

Intervals between rows	Width in cm	Number of respondents	
		Nº	%
As recommended	20	23	46
Width of plow	35	23	46
No knowledge	-	4	8
Total		50	100
Seed bed depth	Depth in cm		
As recommended	2-3	20	40
Depth of plow	20-25	28	56
No knowledge	-	2	4
Total		50	100

Source: survey data (2014)

5.2.10 Application of packages with row planting

Teff row planting technology applied together with other packages of applying herbicides, fertilizer and improved seed.

A. Herbicide

Since the space interval left among rows is wide enough to provide open space for the germination of high amount of weeds therefore farmers applying row planting method should also adopt the package of herbicide application. However as it was revealed from data through FGD herbicides are provided to farmers by private sellers. As a result this created limited access of herbicide effective on grass like small leaved weeds (locally known as '*asindabo'*) with similar size of teff . Beside this farmers' low purchasing power affected the application level of herbicide, as a result in the study area weeding is widely done through manual labor. As it is uncovered on Table 28, among the total of respondents 84.07 % did not applied herbicide this intern influenced the adoption of row planting technology mainly because of its high weeding labor cost (see Table 32).

Table 28: Application level of herbicides

Adoption level of row planting	Application of herbicide				Total	
	Applied		Did not applied			
	Nº	%	Nº	%	Nº	%
High-adopters	13	11.5	37	32.7	50	44.24779
Low-adopters	5	4.4	58	51.3	63	55.75221
Total	18	16	95	84	113	100

Source: Survey data (2014)

B. Fertilizer

Fertilizer application as it can be seen on table 29 while 15 % of the total respondents that sowed fertilizer in rows were high-adopters of teff row planting technology whereas low-adopters of this method did not plant fertilizer in rows. When farmers applied row planting teff seed at the same time fertilizer (DAP) also needs to be planted in rows this requires additional labor power. This implies that due to additional cost of fertilizer application most of the respondents suggested that teff row planting method was not suitable for them to adopt.

Table 29: Methods of fertilizer application and adoption of row planting

Adoption level of row planting	Method of fertilizer application						Total	
	Broadcasting		Row planting		Both			
	Nº	%	Nº	%	Nº	%	Nº	%
High-adopters	12	10.61	15	13.27	23	20.35	50	44.25
Low-adopters	45	39.82	0	0	18	15.92	63	55.75
Total	67	50.43	5	13.27	41	36.28	113	100

Source: Survey data (2014)

C. Improved seed

Based on the data from the key informant interviews farmers' application of selected or improved teff seed did not affect the adoption level of teff row planting technology this was due to the fact that both high-adopters and low-adopters of row planting technology applied selected seed called *kuncho.* According to FGD the respondents suggested that, Even though '*kuncho*' had low quality of baking and the *injera* which made from it easily get dried, it is widely applied by both high-adopters and low-adopters.

5.2.11 Availability of row seeder machine

In order to apply row planting technology seeds should be sown proportionally with equal amount and recommended distance. Based on the data from FGD, DAs mainly focused on promoting water plastic bottles (Figure 12) as a major mechanization technique for seeding teff in rows.

Figure 12: Water plastic bottle row seeder introduced by DAs

Source: Survey data (2014)

Table 30, shows that among the total adopters of row planting technology in the study area 84% used water plastic bottle as a seeder machine while 14 % of the same group of farmers used their hands to plant teff in rows.

Table 30: Type of row seeder

Farmers category	Type of row planter mechanization						Total	
	Row planter machine		Water plastic bottle		Hand			
	Nº	%	Nº	%	Nº	%	Nº	%
High-adopter	1	2	42	84	7	14	50	100

Source: survey data (2014)

Even though the majority of farmers applying row planting on teff production used water plastic bottle as a row planter, based on the information from focused group discussion most of the respondents complained about its application which causes a great physical pain on the back of the person due to his/her bending position while seeding and it also hurt thumbs of its users (see Figure 5). It also lacks precision in the amount of teff seeds falling in to the row and at the same time the plastic bottles easily deformed and lose its original shape as a result of the pressure applied on it in order to push teff seeds out in to the furrow. Therefore these application problems associated with water plastic row seeder negatively affected the adoption level of teff production through row planting technology.

Based on the data revealed on Table 31, the majority of the respondents (40.7 %) suggested that the reason for not applying row seeder machine was lack of access to the instrument while about 17.7 % of the respondents dissatisfied by its performance because of its traction problem on wet and muddy vertisol this is due to the reason that teff is planted on very wet soil (see Table 21), therefore the row seeder machine is not effective since its performance of seeding teff depend on its mechanical system connected to the motion of its wheels.

Table 31: Availability of row seeder machine

Kebele	Reason for non application of row planter machine								Total	
	Expensive		Not suitable for Small landholding		Traction problem on muddy soil		not available			
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%
Ararti Zuriyua	10	8.85	18	15.92	14	12.39	29	25.66	71	62.83
Korma	9	7.96	10	8.85	6	5.3	17	15.04	42	37.17
Total	19	16.81	28	24.77	19	17.7	46	40.7	113	100

Source: survey data (2014)

As it can be seen on figure 13, due to its physical nature of the machine respondents with fragmented and small parcels of landholdings (Table 31) could not adopt this machine therefore it was very difficult to apply row planting technology of the purpose of teff production because of mechanization problem.

Figure 13: Teff Row seeder machine introduced by Ethiopian Institute of Agricultural Research (EIAR)

Source: survey data (2014)

5.2.12 Quality of teff straw

Farmers produce Teff not only for its grain but also for its straw which is widely and mainly used for the purpose of animal fodder and also construction materials (Bekabil: 2011). Due to this reason teff farmers give high value for the quality of teff straw equally with that of grain production this is because livestock is very important for livelihood of the local farmers.

The amount of teff straw gained through the application of row planting method is very much higher in quantity than it was produced through traditional broadcasting method, though the quality is very low. Based on the information gathered using focused group discussion, the majority of the respondents pointed that the quality of teff straw produced through row planting method is very poor and its market value also very low compared to that of teff straw produced through broadcasting method (see Table 34). The stem of the teff straw produced through the method of row planting is very tick and very strong which makes it very difficult for the animals' digestion (Figure 14). As a result animals do not intend to feed on much of the straw produced through raw planting technology and neither can it be used as an input for construction material mainly due to its stem size. Since live stock has a great value to the livelihood of respondents, consequently the local farmers looking for good quality of straw for livestock fodder and other purposes they tend to produce teff crop through the application of traditional broadcasting method.


Figure 14: Teff straw

Source: survey data (2014)

5.3 Cost and benefit analysis of broadcasting and row planting method

The two teff production systems have their own costs and benefits which are grouped in to labor costs for different agricultural practices, input costs composed of fertilizer and seeds, and revenue or output gained from yield of teff grain and teff straw. A daily laborer in the study area in average was paid 70 Birr per day. The value of teff was 3,500 Birr per quintal, DAP fertilizer was 1,350 Birr per quintal and urea fertilizer was 1,271 Birr per quintal.

5.3.1 Teff Production labor Cost of broadcast and row planting methods

During focused group discussion most of the respondents suggested that the major problem hindering them from application of row planting method is the amount of labor cost it requires is very high. As a result for most of poor farmers and farmers with small family size it was very difficult to adopt cultivation of teff using row planting technology.

The largest cost share of teff production through broadcast planting technology (Table 32) is number of man power invested for teff weeding accounting 27.41 % of the total production cost this was mainly due to most of the works of weeding is done with hand and therefore in average 25 persons per hectare of teff farm land were engaged for weeding activities on teff grain produced through broadcasting this was due to lack of access to herbicide (see Table 28). Both harvesting and threshing took the second highest cost in the production of teff using the traditional method. Both have an average share of 25 % of the total cost each. Average of 23 persons per hectare of land worked on both harvesting and threshing of teff yield and yield components.

The highest cost of teff cultivation through row planting did come from weeding activity covering about 34.94 % of the total labor cost. In average 45 persons did engage in the practice of weeding. The second highest labor cost on the application of row planting method was effluence from threshing activities which took the share of 19.77 % of the total average labor cost. In average 25 persons per hectare engaged in this activity. Due to inaccessibility to thresher machine, teff threshing is done through manual labor and animal force.

Teff seeding through row planting technology was very labor intensive practice demanding more than six folds of man power compared to the traditional broadcasting technique. 15.09 % of labor cost was invested on seeding activity of row planting and in average 19 persons per hectare of land participated on teff seeding work. Whereas teff seeding activity through the application of broadcast planting method requires the lowest labor cost covering only 3.2 % share of the total cost. In average 3 persons per each hectare of teff farm land participated on the farm practice of seeding. Due to this variation seeding activity in both types of teff production shows a very great deal of significance difference compared to other labor costs (at 95 % confidence interval, p-value = 55.764 and t-value=0.000).

Table 32: Labor cost of broadcasting and row planting of teff

Types of labor cost	**Broadcast planting method**			**Row planting method**			**Significance Test**	
	Average labor input amount applied/ ha	Total average amount of cost (Birr/ha)	Share (%)	Average labor input amount applied/ha	Total average amount of cost (Birr/ha)	Share (%)	**t-value**	**P-value**
Land preparation (Man-days)	9	632.22	9.94	10	709.80	7.76	1.953	0.053
Seeding (Man-days)	3	265.56	4.17	19	1380.40	15.09	55.764	0.000
Weeding (Man-days)	25	1744.44	27.41	45	3194.80	34.94	42.422	0.000
Harvesting (Man-days)	23	1594.44	25.06	20	1443.4	15.79	2.949	0.004
Threshing (Man-days)	23	1596.67	25.09	25	1807.4	19.77	4.351	0.000
Gathering and pilling (Man-days)	7	530.00	8.33	8	607.6	6.65	3.467	0.001
Total cost (Birr)		**6,363.33**	100		**9143.4**	100		

Source: Survey data (2014)

Figure 15 depicts that the labor cost of row planting method were very high at every farming practices with the exception of the cost of harvesting which was a bit lower than the same cost of broadcasting method. Most of the respondents suggested that the growing pattern of teff grain made it more manageable and easier at the time of harvesting compared to the growing pattern of teff grain through broadcasting method which covered almost every inch of area of farm land.

A very high labor cost gap between the two teff seeding methods was exhibited on seeding and weeding activities. Based on the information from the key informant interview, such cost difference emanated from degree of the area coverage of farm land by teff seed. Through broadcasting method since most of the area of the farm land was covered by seed with minimum opening space left as a result weeds had less chance of growing so that weeding cost at the same time minimized. While with the application of row planting method large open space intervals of the farm land left between row lines which aggravated the germination of high amount of weed growth consequently labor cost of weeding was much higher. As the Figure 15, shows that the labor cost of seeding of row planting method is much higher than the number of labor required for the same practice on the broadcasting method.

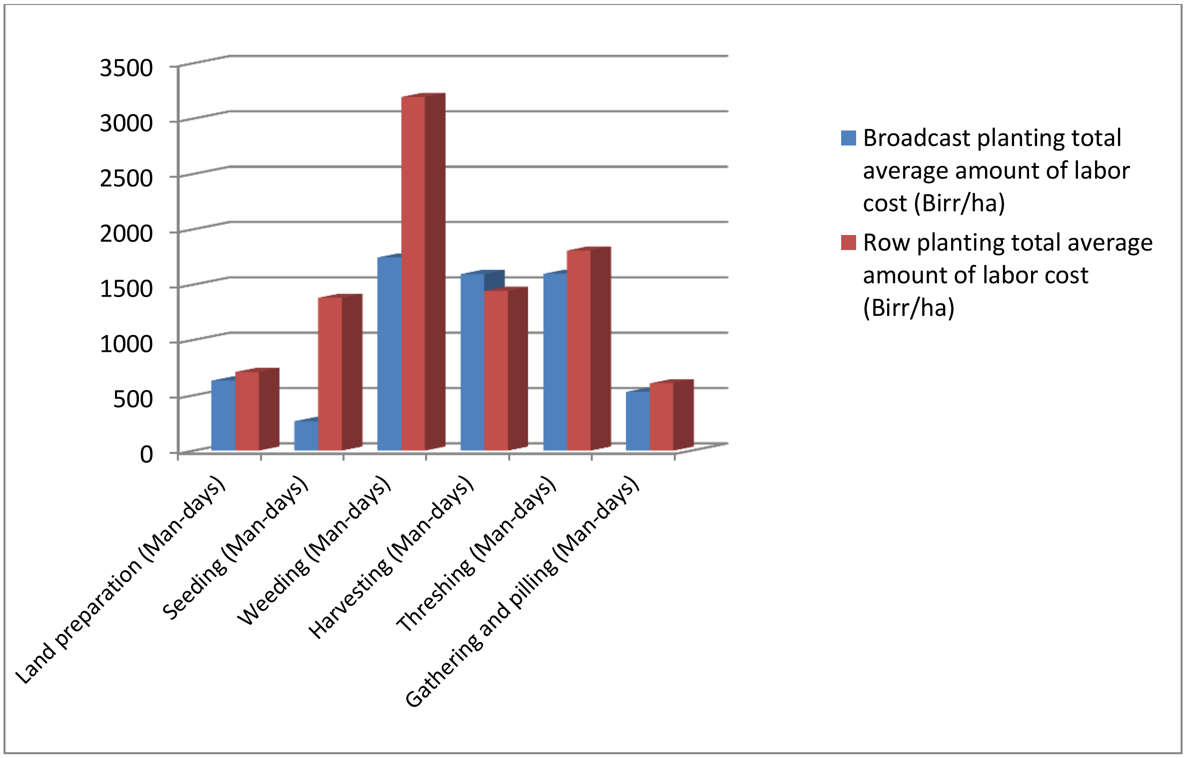

Figure 15: Labor cost of row planting and broadcasting teff planting per hectare

Source: survey data (2014)

Row planting method totally costs 9,143.4 Birr per hectare while broadcasting method of teff production requires a total of 6,363.33 Birr per hectare for production labor cost. The labor cost of row planting method is by 30.4 % larger than the traditional broadcasting method of teff cultivation, as the result traditional teff production method has less labor expense mainly on weeding and seeding farm activities while teff production through application of row planting method requires high labor cost on the same farming practices. Hence in conclusion due to its high labor cost farmers, with low purchasing power and small household size were not willing to adopt row planting method of teff production.

5.3.2 Input cost of teff production through broadcasting and row planting method

The type of teff production technique used by the respondents had effect on the cost of input application. Using broadcasting method of teff planting, the highest input cost amount (Table 33) was required for the application of DAP fertilizer accounting 53.51% of the total input cost. Average amount of DAP applied per hectare was 0.706 quintal (which was lower than the recommended amount of DAP i.e. 1 quintal per hectare). The second highest input cost for teff cultivation through traditional broadcasting method emanated from the cost of seed, it accounts 27.12 % of the total input cost. Per hectare of land in average of 32.19 kilo grams of teff seed was planted through broadcasting method.

Table 33: Input cost of teff production through broadcasting and row planting method per hectare

Types of input	**Broadcast planting method**			**Row planting method**			**Significance Test**	
	Average input kg /ha	Total average cost (Birr/ha)	Share (%)	Average input kg /ha	Total average cost (Birr/ha)	Share (%)	**t-value**	**P-value**
Teff seed	32.19	482.857	27.12	13.19	197.92	12.07	15.481	0.000
Fertilizer (Urea)	27.1	344.784	19.37	33.1	420.19	25.63	2.037	0.044
Fertilizer (DAP)	70.6	952.5	53.51	75.6	1,021.41	62.3	1.319	0.190
Total cost		**1,780.14**	100		**1,639.52**	100		

Source: Survey data (2014)

For teff grain production through row planting method the highest input cost was needed for DAP fertilizer covering 62.3 % (Table 33) of the total input cost. In average the respondents applied 0.706 quintal of DAP fertilizer which was lower than the recommended amount (i.e. one quintal per hectare). While the next highest input cost of teff grain production through row planting method came from application of urea fertilizer covering 25.63% of the total input cost. Whereas the cost of seed in this teff planting method was much lower accounting only 12.07 % of the total input cost.

The total input cost of teff production in broadcasting method is larger than that of row planting method. The average expense for input application in teff cultivation through traditional broadcasting and row planting methods are 1,780.14birr and 1,639.52 birr respectively; however the input cost difference between the two planting methods is very small only about 7.8%, significant difference (at 95% confidence interval, t-value=15.481 and p-value=0.000) is observed in the application of teff seed which is larger in the case of broadcasting technology due to high seed rate application (see Table 22). Therefore in terms of input application row planting method is less expensive than that of broadcasting technology.

5.3.3 Teff grain yield and yield component out put

Teff grain productivity partly and mainly depended on the type of production system applied. In broadcasting method of planting the average teff grain yield obtained per hectare of land (Table 34) was 17.1 quintals which accounts 91.44 % of the total average amount of yield acquired. The average total amount of teff grain yield harvested from broadcasting method of production in birr was 27,625.06. According to the data achieved at the time of focused group discussion the yield of teff straw produced through broadcasting in quantity was much less than that of produced through row planting method, although due to its high quality for animal fodder and construction material its value was by far better so that it covers 16.54 % of the total average yield and in average per hectare of land 4,570.06 birr gross income generated.

Through row planting production technology in average 23.85 quintals of teff grain yield produced per hectare of land which accounts 91.44 % of the total average gross income and in average it encores 32,197.5 birr per hectare. This was much better than the amount of yield achieved through broadcasting method. The amount of teff straw yield achieved through row planting was very high in quantity but its value was very low compared to that produced using broadcasting, it accounts 8.54 % of the average total gross income.

Among the income achieved using both teff production technologies the highest significance difference registered on teff straw (at 95% confidence interval, p-value= 0.000 and t-value = 28.702).

Table 34: Yield out put through row planting and broadcasting methods

Types of output	**Broadcast planting method**			**Row planting method**			**Significance Test**	
	Average yield obtained (q /ha)	Total average yield (Birr/ha)	Share (%)	Average yield obtained (q/ha)	Total average yield (Birr/ha)	Share (%)	**t-value**	**P-value**
Teff grain yield	17.1	23,055.00	83.46	23.85	32,197.50	91.44	12.662	17.1
Teff straw	-	4,570.06	16.54	-	3,015.08	8.54	28.702	
Average total yield		**27,625.06**	100		**35,212.58**	100		

Source: Survey data (2014)

From these data it can be concluded that yield of teff grain produced through row planting technology is much higher than that is produced through the traditional broadcasting method while yield of teff straw obtained through row planting technology is much higher in quantity than it is produced through broadcasting method but in terms of quality teff straw produced by using broadcasting method is more valuable in its usage for livestock fodder and construction material than that of produced using row planting.

5.3.4 Total teff grain production cost against revenue from teff grain yield and yield component

As it was depicted on Table 35, the total labor cost of both row planting and broadcasting teff production technologies shows significance difference, by that it means that in terms of labor cost the application of row planting technology is very expensive. This has negatively affected the farmers' adoption level of this new modern teff production technology. This appears on the very beginning of farm practice, therefore farmers easily loss hope in its application. While the input cost difference between the two technologies is not significant.

The total teff production cost in row planting is 10,782.92 Birr while the same cost in the application of teff broadcasting technology is 8,143.47Birr. The net revenue output of row planting technology is much higher than broadcasting method. Except the amount of teff straw production

Table 35: Net revenue of row planting and broadcasting technologies per hectare

Types Cost of production	**Broadcasting planting**	**Row planting**	**Significance Test**	
			t-value	**p-value**
Labor cost (Birr)	6,363.33	9,143.4	30.133	0.000
Input cost (Birr)	1,780.14	1,639.52	1.807	0.073
Total cost (Birr)	8,143.47	10,782.92	22.609	0.000
Revenue				
Teff grain revenue(Birr)	23,055.00	32,197.50	12.662	0.000
Teff straw revenue (Birr)	4,570.06	3,015.08	28.702	0.000
Total revenue (Birr)	27,625.06	35,212.58	10.502	0.000
Net revenue(Birr)	**19,481.59**	**24,429.65**	6.824	0.000

Source: Survey data (2014)

As it can be easily understand from Figure 16, revenue from row planting adoption on teff production is profitable and it will be much larger if it is properly applied.

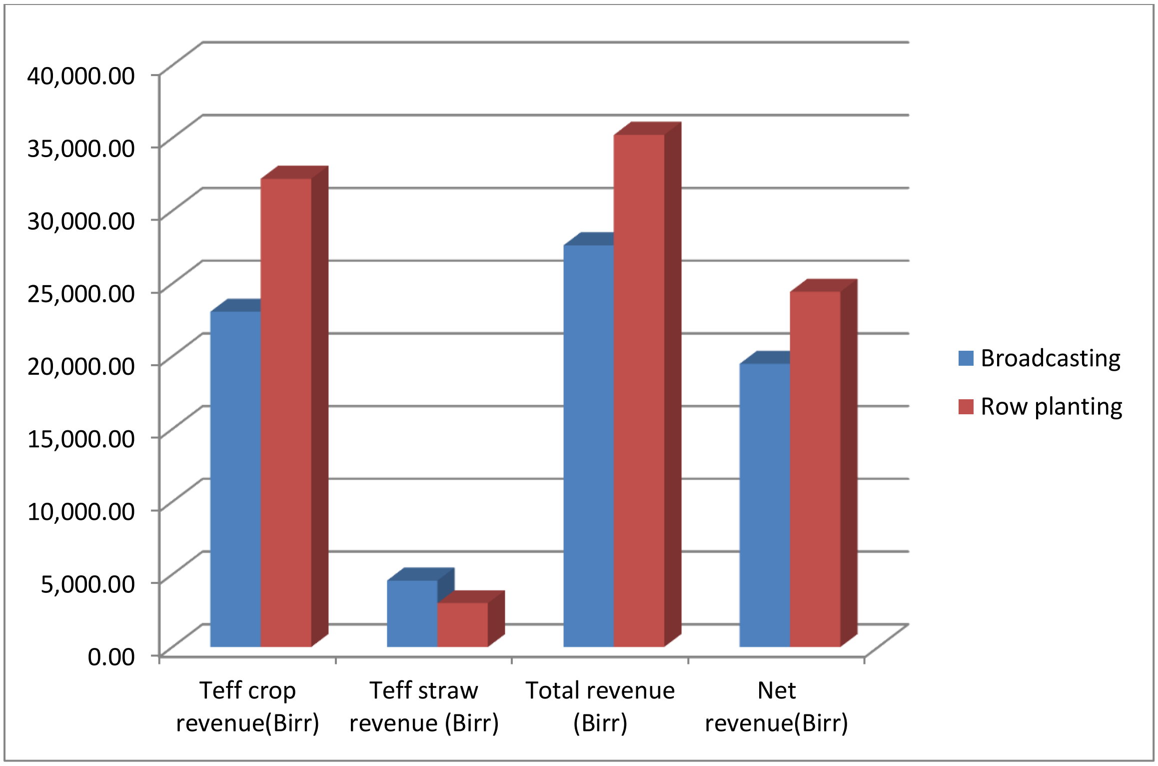

Figure 16: Revenue from row planting and broadcasting per hectare

Source: Survey Data (2014)

The net revenue acquired from teff production through row planting technology is by 20 % larger than the same net revenue earned from teff cultivation using traditional broadcasting method. Therefore it can be concluded that teff production through row planting is much profitable than any traditional teff cultivation method whereas its labor cost is very high.

Although teff cultivation through the application of row planting technology can generate better amount of revenue compared to that of broadcasting method, the local farmers' adoption level of this technology was very low. This was due to the fact that row planting method requires high labor cost, low straw quality, lack of access to mechanization and lack of in-depth practical training at demonstration centers.

CHAPTER SIX

6 Conclusion and recommendation

6.1 Conclusions

This study compares the production cost and benefit differences achieved from teff production through row planting and traditional broadcast planting methods. And it also assesses factors that affected the local farmers in the study area on the application level of row planting in teff crop production.

- **Benefits:** the cost benefit analysis indicated that the amount of net revenue earned per hectare of land from production of teff crop through modern row planting technology is significantly higher than that was produced through the traditional broadcasting method with 20 % difference. The input cost of teff production through row planting technology is lower than that of broadcasting method. This cost difference exhibited on the amount of teff seed rate applied by row planting technology is significantly lower than the amount of seed rate applied through the traditional broadcasting method.
- **Quality of fodder production:** since livestock is very important in the livelihood of local farmers teff is produced not only for its grain but also for its straw whereas teff straw produced through the application of modern row planting technology is very poor in its quality for livestock fodder and construction material. Animals do not feed on much of teff straw produced through row planting technology mainly due to high amount of nutrients it took up, teff crop cultivated through row planting technology have a very thick and strong stem.
- **Adoption of the row planting technology:** The application level of row planting technology by the local farmers had been affected greatly by size of land holding, gender, age structure and educational levels of the household heads. The majority of youth household heads relatively had smaller land holdings and small family size as a result due to fear of crop failure risk their application level of row planting technology was very low. Education and application of row planting were positively related, respondents with better educational level had applied row

planting method on teff grain production. Since teff production using row planting method is labor intensive activity the size of household had direct effect on its adoption therefore households with large family members applied the technology while the majority of respondents with smaller household size found it impossible to apply it.

- **Soil type:** The major types of soils in the study area are black and brown soils with swelling characteristics in the case of exposure to small amount of rain due to this reason teff seeds planted through broadcasting method has no any depth in to the ground therefore it easily lifted up and due to openings and passages created beneath the surface resulted in the exposure of seeds to air, consequently the teff seeds will dried up and crack then this affect germination of the seed. In order to avoid these problems the local farmers applied very high seed rate in both planting methods.
- **Extension service:** Adopters of row planting technology had better access to trainings, compared to non-adopters, on application of plastic bottle row seeder, application of reduced seed rate, appropriate width and depth of seeding, row planting and transplanting by DAs, this result in a significant difference in the application of teff row planting technology. Most of the trainings were provided mainly through oral orientation of DAs in the FTC not through the farmers' direct practical participation in demonstration centers. At the same time the frequency of extension service provided by DAs to adopters of the row planting technology is higher than that was provided to the non-adopters. Farmers are not supported with any safety net programmes to minimize risk adoption of row planting.
- **Drawbacks of row planting:** Most of the respondents applying row planting technology on teff production, did not left the recommended space (20 cm) among rows, as the result of lack of access to row seeder machine rather they left 35 cm of distance between each rows by using the width of traditional plow instrument. Due to large opening spaces left among rows the amount of weeds increases and at the same time agricultural lands were wasted. Some of the respondents planted teff seed much deeper than it was recommended (2-3 cm) using the length of traditional plowing tool which ranges up to 25 cm, this resulted in delayed germination of teff

seeds or sometimes due to the smaller size of teff seed at this depth it never germinate, therefore many respondents did not adopt row planting. Those who had planted teff in rows due to the length of time it took for germination fearing they may ended up empty handed, they plowed their land once covered with teff seed and sow crops that can be harvested in short period of time.

- **Row planting mechanization:** the major row seeder machine used for seeding teff in rows was water plastic bottles as row seeder. It causes a great physical pain on the user and due to misuse by farmers it deformed and cannot minimize the amount of seed rate. It was very difficult to apply teff row seeder machine manufactured by Ethiopian Institute of Agricultural Research (EIAR) mainly because of it had traction problem on wet and muddy soil and it is not appropriate to the poor because of low purchasing power and fragmented landholding therefore such types of technology needs economic of scale. As a result of this problem adoption of row planting technology is negatively affected.
- **Labor demand:** labor cost in the application of row planting technology is significantly very high compared to the labor cost expense of broadcasting method of teff production. Teff production through the method of row planting technology requires high labor cost on the agricultural practices of seeding and weeding compared to that of broadcasting planting method. Therefore row planting technology is less attractive to be adopted by farmers with low family size and poor farmers who cannot afford hired labor.
- **Packages of row planting technology:** since the application of teff row planting provide a wider space among rows for the growth of weeds in higher amount compared to broadcasting, farmers were advised to apply herbicides. Whereas due to low access to effective herbicides on grass like weeds and low purchasing power farmers cannot afford to apply herbicide. Therefore this negatively influence on the adoption process of modern teff planting technology. Fertilizer application in row planting technology requires additional cost of labor. This is because of the reason that when teff seeds planted in rows DAP fertilizer also planted in rows along with teff seeds.

6.2 Recommendations

Based on the results of this research, the following core points are presented as recommendations in order to improve the application level and revenue gained from row planting technology in the process of teff grain production.

- Teff is produced not only for its grain but also for its straw. Teff straw has a great value for livestock fodder and source of construction material. Since teff straw produced through row planting technology is poor in its quality farmers should be organized in their farm associations and provided with support by the district and kebeles' agricultural bureaus to produce grass for their livestock fodder on uncultivable common land using rain water in the summer (rainy) season and in the dry season by harvesting water constructing reservoirs
- Even though net revenue of row planting method is better than that of traditional broadcasting method, the application of row planting technology requires high labor cost on weeding compared to that of the traditional method due to application of manual labor. Therefore in order to improve adoptability of row planting method the concerned government agricultural bureau should provide farmers with access to more effective types of herbicides for grass like weeds as a result it will minimize the costs of weeding and increase revenue.
- Forcing farmers to adopt any kind of agricultural technology will not bring the expected outcome rather it may aggravated their rigidity not to accept any new farming technologies. Therefore in order to improve farmers level of adoption of teff row planting method DAs should provide farmers with more practical trainings under farmers' direct participation in the demonstration centers. At the same time in order to increase the support from family members, the *kebeles'* educational and agricultural bureaus in collaboration should train students in the school about the benefits of row planting of teff crop; this may increase labor support that household heads obtained from their family.
- Due to the swelling nature of the soil type of the study area row planting technology is appropriate in terms of seeding depth and seed rate application. In order to solve the problems of adopting of the recommended width among rows and the recommended depth of sowing teff seed and at the same time to minimize the labor cost of seeding in rows.

Modern seeder machines, other than water plastic bottles, with good performance under any types of soil and landholding sizes should be made readily available to the local farmers.

- Row planting technology is not appropriate to the poor with fragmented landholding and small labor support because of risk of crop failure. Therefore, governmental and non-governmental extension programs have to provide farmers with safety net programs and other incentives in order to minimize risk of adoption.
- In order to attain food security of the nation policy makers should devise more effective farmers' training mechanisms and provide more applicable teff production mechanizations effective on the process of teff production.
- Based on the results of this study further researches can be performed in the future in order to improve teff productivity.

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Appendices

Appendix-A

ተ.ቁ.	ወረዳ	29/1/2006 በመስመር መዝራት										
		ጠቅላላ በመስመር መዝራት እቅድ	ጠቅላላ በመስመር የተዘራ	አፈፃፀምበ %	ማሽላ	ገብስ	በቆሎ	ቢራ ገብስ	ጤፍ	ስንዴ	ምስር	ባቄላ
1	ደ/ብርሃን	1652	81.0	4.9		13.3				7.569		11.113
2	ባሶና ወረና	11373	901.7	7.9	4.5	49.14			18.8	46		103.59
3	አንኮበር	5112	793.1	15.5	77.2	30.6	52.2	14.03	300	57.6	1	23.313
4	ሞጃና ወደራ	230	476.8	207.3		20.5			307	118.25		31
5	ጣርማበር	6041	838.0	13.9	25	37	27		311	49		30
6	ቀወት	7691	7439.3	96.7	3897	74	39.5		2672	133	5	36
7	ሸዋሮቢት	1992	1571.0	78.9	571		39		550			
2	ኤፍራታ	7910	3634.9	46.0	1484.9	15.875	660.15		875.01	34.75	0.5	1.75
9	አንጾኪያ	5462	2610.9	47.8	297.3	7.12	93.77		1107.6	9		1.5
10	ግሼ	2391	381.0	15.9		58.5			36	191	2.35	72
11	መንዝ ቀያ	3013	287.2	9.5	9.462	4.913	1.36		91.036	14.441	0.365	22.248
12	መንዝ ጌራ	3033	408.8	13.5		102.8	1.5		0.375	31.15		51.8
13	መንዝ ላሎ	539	217.5	40.4	35	15.52			27.95	41.44		25.6
14	መንዝ ማማ	1892	1021.9	54.0		69		1	55.31	107	0.29	26.3
15	አንጉለላና ጠራ	4693	153.7	3.3	4.625	23			1.75	17	0.29	19
16	አሳግርት	4600	864.0	18.8	11.032	102	14.465		376.35	124.98	2.506	28.66
17	ሀገረ ማርያም	9043	1715.8	19.0	12.375	176.25	42.5		647	517.25	0.5	182.5
18	ምንጃር ሸንኮራ	18997	8232.8	43.3		27.89	291.42		1565.3	2180.4	132.44	158.1
19	በረ¤ት	3098	673.3	21.7	74.075	22.93	**28.44**		307.14	44.447	6.05	5.785
20	ሲያደብር	3112	1565.0	50.3	65				1500			
21	ሞ/ጅሩ	8619	1702.5	19.8	391.75				1307.5	0.587		2.625
22	እንሳሮ	8555	5278.6	61.7	4665.9				603.72	6.02		3
23	መርሃቤቴ	18333	2950.1	16.1	1391.2		28.63		1434.6	36.88		40.08
24	ሚዳ	12720	5261.5	41.4	1915	10.75	307.5		1988.3	436.75		59.25
	ድምር	150101	49060.0	32.7	14932	861	1627	15	16084	4205	151	935

Source: NSZARDB (2014)

ተ.ቁ.	ወረዳ	ሽንብራ	አተር	በርበሬ	ማሾ	ቦለቄ	ለውዝ	ትንባሆ	ድንች	ስኳር ድንች	ሽንኩርት	ሌሎች የጓሮ አትክልቶች
1	ደ/ብርሃን											
2	ባሶና ወረና		3.13	61					173		344	98.5
3	አንኮበር			15.25					188		33.625	0.25
4	ሞጃና ወደራ											
5	ጣርማበር			100					16		210.0	33
6	ቀወት			12.5					19.25		551	
7	ሸዋሮቢት			6				137			222	46
2	ኤፍራታ			166				110	2		263	21
9	አንጾኪያ			19.6			2.66		5.5	300	718.8	48
10	ግሼ		2									19
11	መንዝ ቀያ		0.03	35.25								107.42
12	መንዝ ጌራ								82.75		87.375	51
13	መንዝ ላሎ		1							6.75	56.5	2.5
14	መንዝ ማማ			3					265		478	17
15	አንጉለላና ጠራ											88
16	አሳግርት											204
17	ሀገረ ማርያም		0.5	10.25					38		75.13	
18	ምንጃር ሸንኮራ		8			9.61					2645.1	23
19	በረ¤ት	13.5		40.953	1.75	6.26			13.625	13.8	68.21	4.375
20	ሲ.ያደብር	1191.5										
21	ሞ/ጅሩ	35.5										
22	እንሳሮ											
23	መርሃቤቴ			8.38					1	1	7	1.3555
24	ሚዳ			252	75				4		192	21
	ድምር		15	730	77	16	3	247	834	322	5964	796

Source: NSZARDB (2014)

ተ.ቁ.	ወረዳ	ተሳታፊ አ/አደሮች										
		ል/ቡድን	1ለ5	ግንባር ቀደም			ሌላ			ጠቅላላ ተሳታፊ		
				ወንድ	ሴት	ድምር	ወንድ	ሴት	ድምር	ወ	ሴ	ድምር
1	ደ/ብርሃን	13	17	35	5	40	2		2	37	5	42
2	ባሶና ወረና	895	4475	869	142	1011	2204	96	2300	3073	238	3311
3	አንኮበር	542	2710	567	210	777	710	120	830	1277	330	1607
4	ሞጃና ወደራ	221	396	264	15	279	174	16	190	438	31	469
5	ጣርማበር	285	1382	1600	105	1705	1025	51	1076	2625	156	2781
6	ቀወት	481	2080	4851	226	5077	4687	217	4904	9538	443	9981
7	ሸዋሮቢት	49	136	1225	22	1247	459	14	473	1684	36	1720
2	ኤፍራታ	580	2996	3306	368	3674	2623	380	3003	5929	748	6677
9	አንጾኪያ	354	1052	2084	148	2232	1566	83	1649	3650	231	3881
10	ግሼ	431	1687	1129	139	1268	1990	136	2126	3119	275	3394
11	መንዝ ቀያ	209	626	1028	95	1123	603	159	762	1631	254	1885
12	መንዝ ጌራ	52	281	489	24	513	95	6	101	584	30	614
13	መንዝ ላሎ	98	262	240	11	251	156	17	173	396	28	424
14	መንዝ ማማ	113	545	217	25	242	115	19	134	332	44	376
15	አንጉለላና ጠራ	189	352	402	26	428	326	18	344	728	44	772
16	አሳግርት	144	665	573	79	652	431	32	463	1004	111	1115
17	ሀገረ ማርያም	341	1625	2575	190	2765	1950	191	2141	4525	381	4906
18	ምንጃር ሸንኮራ	752	3562	5290	318	5608	6408	576	6984	11698	894	12592
19	በረ¤ት	61	108	504	11	515	233	6	239	737	17	754
20	ሲያደብር	461	1406	3021	241	3262	4906	884	5790	7927	1125	9052
21	ሞ/ጅሩ	485	2425	1302	45	1347	1047	143	1190	2349	188	2537
22	እንሳሮ	305	1350	1807	126	1933	2586	172	2758	4393	298	4691
23	መርሃቤቴ	342	1754	1412	68	1480	849	45	894	2261	113	2374
24	ሚዳ	621	3105	5025	1275	6300	3275	1540	4815	8300	2815	11115
	ድምር	8024	34997	39815	3914	43729	38420	4921	43341	78235	8835	87070

Source: NSZARDB (2014)

Appendix-B

A, Questionnaire number ____

Interviewed by ______________________________________

Date of interview: Date________________________________

Month _________year ________________________________

B, Geographical situation of the household

Tabia (kebele)____

Kushet (village)_______________________________________

C, Household category

1= Adopter 2= Non adopter

I. Respondents household Characteristics

1. Socio-demographic characteristics

1.1. Age of the household head_____________

1.2. Sex of the household head 0=male 1=female

1.3. Size of household ______________________

1.4. Educational level of the household head

1, Illiterate 4, junior school (7-8)

2, Read and write 5, Secondary school (9-12)

3, Primary school (1-6) 6, Other specify _____________________

1.5. Are you a model farmer?

1=yes 2=No

2. Occupation status of the HH members

2.1. Did you produce teff in the 2005/2006 E.C cropping season?

1=yes 2=no

2.2. Are your family members of the household engaged in teff farming activities?

1=Yes 2=No

2.3. If "yes", how many members of your family?_________________________

II. Access to institution, technology, land and capital

3. Household access to technology

3.1. Have you ever been visited by development agent?

1=yes 2=no

3.2. If "yes", what type of input/information do you get from development agent on teff production?

Nº	The type of assistance	Tick	Number of extension contact	Number of field days attended(use code)	How relevant is the information		
					Very relevant	Quite relevant	Not relevant
				A1			
1	The application of row planting with reduced seed rate						
2	The application of teff transplanting						
3	Fertilizer application						
4	Application of improved teff seed						
5	Water plastic seeder preparation and application						
6	Teff seeding depth and width between rows						
7	Credit management						
8	Soil and water conservation technical support/advise						
	Total						

Code A1: 1=once per week

2 =once per month

3=every time I demand service

4=never been visited

III. Household livelihood

4. Source of household income

4.1. Do you earn any income outside agriculture?

1=yes 2=no

4.2. If “yes”, household source of income other than agriculture

Nº	Source of income (use code)	Amount of income (in birr)
	B1	

Code: B1- source of income

1=salary obtained from employment in activities other than agriculture yield by any member of the house hold

2=from the sale of fuel wood

3=from trade

4=from the sale of timber

5=from the sale of handicraft product

6=from free food aid

7=from cash for work and food for work

8=from remittance

9= If other, specify ____________________________

4.3. Did you produce teff on 2005/2006 E.C cropping season?

1=yes 2=no

4.4. If ‘yes’, the amount of teff crop yield and yield component

Nº	Method of planting	Area covered with teff (ha)	The amount of Teff crop yield (q/ha)	Total value of teff straw (birr)
1	Row planting			
2	Broadcasting planting			
	Total			

IV. Household resource endowment

5. Farm land characteristics

5.1. How many hectares of farm land do you own in 2005/2006 E.C cropping season?

1=less than 0.5 ha   3=1ha-2ha

2=0.5ha- 1ha   4=more than 2 ha

5.2. Source (means) of majority farm land ownership in 2005/2006 E.C cropping season?

1=inherited   4=crop sharing

2=the state   5=common land

3=rented   6=if other,

specify___________________

5.3. Slop category of your farm land?

1=flat   3=moderately steep

2=gently undulating   4=very steep

5.4. Did the slop of your farm land affect the application of row planting

1=yes   2=no

5.5. If ‘yes’, explain the reasons.

____

____

____

____

5.6. Soil type of your farm land in average?

1=black 3=brown

2=Reddish 4=grayish

5=if other, specify______________

5.7. Did the type of soil affect the amount of seed used?

1=yes 2=No

5.8. If 'yes', explain the reason

____

____

____

____

V. Teff planting methods

6. Modern teff planting methods applied in 2005/2006 E.C cropping season.

6.1. Do you have information about row planting method of seeding?

1=yes 2=no

6.2. If "yes", how did you know about row planting method of seeding?

1= colleagues 4= mass media

2= DAs oral orientation at FTC 5= If other, specify_____

3=training at demonstration centers

6.3. Did you apply row planting method of seeding on teff crop production in 2005/2006 E.C cropping season?

1=yes 2=no

6.4. If "yes", why did you apply it?

1= willingly 4=pressure from colleague

2= imposition from government 5=fear of penalty from authority

3=through safety net program 6=other specify _____________

6.5. How much centimeters did you left as spacing between rows?

1=as recommended 3=no knowledge

2=with the width of plow 4=if other specified ________________

6.6. If your answer for question 6.5 is ‘2’, how much centimeters is your plow wide?__________________

6.7. How was the depth of seeding?

1=as recommended   3=no knowledge

2=with the length of plow   4=if other specified ___________

6.8. How much centimeters deep into the ground can dig your plow?_______________

6.9. If you did not left spacing between rows as recommended, the reason:

____

____

____

____

6.10. How do you perceive the effectiveness of raw planting method of seeding on the improvement of teff crop production?

1=very good

2=good

3=poor

4=if other, specify ____________________

6.11. How was the quality of teff straw produced through row planting method?

____

____

____

6.12. Describe the benefits and drawbacks you have encountered on the application of row planting method on teff seeding.

Advantages

____

____

____

Disadvantages

____

____

____

6.13. Did you apply transplanting of teff seedlings on your field on 2005/2006 E.C cropping season?

1=yes 2=no

6.14. If your answer is "no", what was the reason?

1=no need 4=have no information

2=high labor cost 5=if other, specify ____________________

3=shortage of water

6.15. If your answer for question (6.12) is "yes", describe the advantages and disadvantages.

Advantages

____

____

____

Disadvantages

____

____

____

7. Traditional broadcasting teff planting method

7.1. Did you apply broadcast method of teff seeding?

1=yes 2=no

7.2. If "yes", what was the reason?

1=easy to apply 4=low labor cost

2=to avoid risk of crop failure 5=suitable for my land

3=to harvest large yield amount 6=if other, specify____________

7.3. Who conduct the work of planting through broadcast method?

1=any one in HH 3=skilled person in HH

2=adult person in HH 4=other specify ___________

7.4. How do you describe the amount of tef yield production through broadcasting method?

1=high 3=low

2=moderate 4=other specify__________

VI. Input application

8. Fertilizer application

Nº	Types of fertilizer	Have you used fertilizer in 2005/ 2006 cropping season? 1=yes 2=no	Method of fertilizer application 1=broadcasting 2=row planting	Unit cost (birr/kg)	Amount of fertilizer applied (q/ha)	
					For teff field covered by broadcasting planting	For teff field covered by row planting
1	Urea					
2	DAP					
3	Manure					
4	Compost					
	Total					

9. Application of teff seed

9.1. What type of teff seed did you apply?

1=local 2=improved

9.2. Amount of seed applied

Nº	Types of seed	Unit cost (birr/kg)	Amount of seed applied (Kg/ha)	
			For teff field covered by broadcasting planting	For teff field covered by row planting
1	Local			
2	Improved			
Total				

10. Application of herbicide

10.1. Did you apply herbicide?

1=yes 2=no

10.2. If 'yes', the amount of herbicide applied

Nº	Types of herbicide	Unit cost (birr/liter)	Amount of herbicide applied (liter/ha)	
			For teff field covered by broadcasting planting	For teff field covered by row planting

10.3. If your answer for qusion (10.1) is 'no', what was the reason?

1=very expensive 3=it is not effective

2=not available 4=if other, ________________

11. Amount of labor cost used in 2005/2006 E.C cropping season

11.1. Did you get labor assistance from peoples, other than your family members?

1=yes 2=no

11.2. If your answer is "yes", how did you get the labor assistance?

1=on crop sharing basis

2=exchange of labor with relatives or neighbors

3=hired labour

4=if other, specify_______________________________

- If you used hired labor, its cost in birr /person /day is _________________

11.3. If your answer for question (11.1) is 'yes', the amount of labor applied

Nº	Practice	For teff field covered by broadcasting planting		For teff field covered by row planting		Cost (in birr)
		Number of persons engaged	Number of days	Number of persons engaged	Number of days	
1	1st field preparation					
2	2nd field preparation					
3	3rd field preparation					
4	4th field preparation					
5	Seeding					
6	1st Weeding					
7	2nd Weeding					
8	3rd Weeding					
9	Harvesting					
10	Gathering and piling					
11	Threshing					
Total						

VII. Farming activities

12. The time of farming activities

12.1. When did you produce teff?

1=meher 2=belge

12.2. If your answer for question (13.1) is "meher", when did you plant teff seed?

1=3rd -4th weeks in June 4=1st - 2nd weeks in August

2= 1st - 2nd weeks July 5=if other,_________________

3= 3rd -4th weeks in July

13. Application of farming mechanization

13.1. What type of mechanization did you use to plant teff in rows?

1=row seeder machine 3=hand

2=water plastic 4=if other, ________________

13.2. If you plant teff in rows using water plastic, what are its advantages and disadvantages?

Advantages

____

____

____

Disadvantages

____

____

____

13.3. If you applied row seeder machine, what were the advantages and disadvantages?

Advantages____

____

____

Disadvantages

____

____

13.4. If you did not apply row seeder machine, what was the reason?

1=expensive 4=not available

2=Not suitable for Small landholding 5=if other, specify _______

3=traction problem on muddy soil

13.5. Did you use thresher machine?

1=yes 2=no

13.6. If ‘no’, what was the reason?

1=expensive

2= not available

3=no need

4=if other, specify ___________

D E C L A R A T I O N

I hereby declare that the thesis entitled ***Assessment of Factors Affecting Farmers' Adoption level of Row Planting Technology and Yield Improvement on the Production of Eragrostis Teff [ZUCC.]: The Case of Minjar Shenkora Woreda, Amhara Region,Ethiopia*** has been carried out by me under the supervision of Dr. Yohannes G/Michael, Department of Geography and Environmental Studies, Addis Ababa University, Addis Ababa during the year 2013/14 as a part of Master of Art in Geography and Environmental studies specialized on Land Resource Management. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

BEHAILU GETU DESTA

Signature: ________________________

Addis Ababa University

Addis Ababa

Date: June, 2014

C E R T I F I C A T E

This is certified that the thesis entitled ***Assessment of Factors Affecting Farmers' Adoption level of Row Planting Technology and Yield Improvement on the Production of Eragrostis Teff [ZUCC.]: The Case of Minjar Shenkora Woreda, Amhara Region,Ethiopia*** is a bonafide work carried out by Behailu Getu Desta under my guidance and supervision. This is the actual work done by Behailu Getu Desta for the partial fulfillment of the award of the Degree of Master of Art in Geography and Environmental studies specialized on Land Resource Management from Addis Ababa University, Addis Ababa, Ethiopia.

Dr. Yohannes G/Michael

Signature: ________________________

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