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Assessing the Effect of Plant Density on Yield of Irrigated Potato and Analysis of Input Supply Chains at AdeaBerga District.

BY:

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DEDICATION

This thesis is dedicated to my beloved sister, Teacher Tejitu Diro, whom I lost on 8 October 1990 E.C. May God rest her soul in peace!!!

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ABBREVIATIONS AND ACRONYMS

BN	Branch number
CSA	Central Statistical Agency
DA's	Developmental Agents
FAO	Food and Agricultural Organization
FGD	Focused Group Discussions
HARC	Holeta Agricultural Research Center
ha	Hectare
ILRI	International Livestock Research Institute
IPM	International Potato Management
IWMI	International Water Management Institution
KII	Key Informants Interview
LIVES	Livestock and Irrigation Value-Chains for Ethiopian Smallholders
LN	Leaf number
Masl	meter above sea level
OSRA	Oromo Self Reliance Association
PD	Plant density
PADETS	Ethiopia's particularly Demonstration and Extension Training System
Qt	Quintals
TN	Tuber number
TS	Tuber size
TY	Tuber yield
WAO	Woreda Agricultural Office
WV	World Vision

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ABSTRACT

Potato production and productivity is known to be influenced by various integrated agronomic, input supply and extension system in Ethiopia. Therefore, optimum agronomic practices with a good input supply system would improve potato production. To this end, a study was carried out to asses planting density of potato using field experimentation and to asses input supply system of potato production using survey study in AdeaBerga district.

The Field experiment analyzed the optimum planting density (recommended planting density) versus farmers own practices of plant density on performance of improved potato variety Gudane. Parameters measured were leaf number, branch number, tuber number, tuber size, tuber yield and marketable yield. As result, significant difference between recommended and farmers own planting density was observed for total tuber yield, marketable yield and leaf number. In which Gudane performed best for these traits under recommended planting density. For traits such as branch number, tuber number and tuber size recommended planting density was only better than highest plant density. Therefore, this study indicated that, integration of improved varieties with optimum plant density encouraged more vegetative growth and development that resulted in increased potato yield. Furthermore, using local variety followed by planting using similar population as Gudane produced the least potato tuber yield, which indicated Gudane is high yielder than local variety.
Therefore, to obtain adequate potato tuber yield, potato producing farmers in AdeaBerga district need to be properly apply recommended agronomic practices such as t proper plant population of improved varieties to get good return from potato production..

The survey study was aimed at analyzing input supply chain of potato with specific objectives of assess the input supply and distribution system and related issues affecting potato production of the target communities. The data were collected from both primary and secondary sources. The primary data for this study were collected from fifty four potato producers, three potato seed producing and supplying farmers, three NGO (World Vision, OSRA and LIVES) were interviewed. The analysis was made using descriptive statistics using SPSS software.

This input supply chain analysis pinpointed number of opportunities and constraints influencing the development of the subsector in the district. Based on field study in selected study kebeles and reviewing existing literature, in order to fully exploit the opportunities and minimize the outstanding challenges, the following recommendation is drawn. Develop capacity and capability of seed producing farmers in seed multiplication, marketing and distribution in order to meet the demand for quality and accessible seed of the study area and beyond; build the capacity of farmers' cooperatives for fertilizer and other chemicals supply and also to engage on potato seed production and marketing.

1. INTRODUCTION

Potato (*Solanumtuberosum*L.) belonging to the family *Solanaceae*, is an important food and cash crop as an income sources globally (Fekadu*et al*., 2013). It ranks third as the world most important staple food crop after rice and wheat (Stewart and McDougall, 2012). It is one of the most productive food crops in terms of yields of edible energy and good quality protein per unit area and per unit of time fitting into intensive cropping systems (Burton, 1989). Nutritionally, the crop is considered to be a well-balanced major plant food with a good ratio between protein and calories, and has substantial amounts of vitamins, especially vitamin C, minerals, and trace elements. Due to its correct balance between protein and calories, it is considered as good weaning food (Berga*et al*., 1993). In addition Potato is a source of sustenance for counties like Ethiopia, because it can be stored to provide food during food scarcity times, therefore it is part of both commercial and subsistence agriculture. Recognizing its role in attaining food security, integration of potato including other tuber crops into the food system is currently getting attention by the research and extension systems in Ethiopia (Schulte G., 2013).

Potato crop was first introduced to Ethiopia around 1858 by Schimper, a German botanist (Pankhurst, 1964). Ethiopia is endowed with great potential for potato production, majorly because of good climatic and edaphic conditions for higher potato production and productivity (Endale, et al., 2008). Potato is grown by approximately one million smallholder farmers in four major areas viz., the central, the eastern, the northwestern and the southern highlands of the country. According to Ethiopian central statistics agency (CSA) 2014/2015 survey report, about 67,361.87 ha of land was used for potato production. The major constraints faced by potato producing farmers include the lack of improved variety, low yielding, and disease-resistant and good quality seed potato varieties. Hence, access to good quality and improved seed potato varieties is widely recognized as fundamental to ensure increased production and productivity (Schulte G., 2013). According to the report by Endale and Colleagues (2008), the average tuber yield of potato reaches between 6-8 t/ha in the last 20-30 years.

AdeaBerga is one of the districts in West Shoa zone of Oromia region where potato farming is an important component in the agricultural activity. In this district, potato is cultivated in almost all kebele’s and gives a dependable yield even under adverse agro climate conditions. About 85 per cent of potatoes are cultivated in the high land of this district. Among potato producing farmers 22% of them produce potato using furrow irrigation during the dry season.

While there is immense potential and prospect of potato production, the current yield and productivity of potato at AdeaBerga district even less than national average. The most important factors that influence potato production in the study area include, inadequate supply of improved planting materials, soil type, weather conditions pest and disease and improper agronomic practices such as planting density, water management and fertilization. Furthermore, most potato growers at AdeaBerga do not integrate the use of improved cultivars with proper planting density, fertilization and other agronomic practices for potato production, although there is information available about production packages for the released potato varieties from developing agricultural research institutes such as Holeta. It is known that plant density has an impact on potato final yield by influencing biomass accumulation and subsequently tuber number (Santos and Gilreath, 2004). According to Endale and Gebremedihin (2001), in the absence of optimal plant density practices could significantly affect total tuber yield up to 50% yield reduction.

Apart from agronomic practices input supply and service provision also influence considerably potato production. In input supply Smallholder farmers access their seed potato from three important sources in Ethiopia viz., informal (smallholder farmers), alternative (cooperatives, community-based seed enterprises, NGOs, etc.) and formal (licensed growers, cooperatives, or seed enterprises) seed potato systems (Hirpa*et al*., 2010).

For instance, according to (WAO, 2010) report, post harvest loss was 32% which was mainly attributed to shortage of warehouse to store potato and to less extent due to damage by potato pests, lack of market outlet and lack of road access. Furthermore, extension service provision by development agents (DA's) of the district agriculture office is affected by lack of knowledge of improved agronomic technologies that ultimately affects potato productivity and total yield. In line to this, farmer's interview response report of (WAO, 2010) showed that potato producers get extension service only on general agricultural practices such as on compost making or land preparation but not on specific technical knowhow to increase farmers' production skills. In order to reduce the bottlenecks of potato production and marketing as well as for successful attainment of the country's policy for rapid development in agricultural sector several governmental, non governmental and private sectors are involved in potato production and business. These organizations are involved in various activities and schemes agricultural development of potato production including potato production.

AdeaBerga district agricultural office has been working in the improvement of overall agriculture development including potato production via provision and demonstration of new improved technologies such as new varieties of potato seed, agronomic practices and trainings. In addition to the district agricultural office, other institutes such as Holeta Agricultural Research Center (HARC) and International Livestock Research Institute (ILRI) have been involved in the district's potato production and development.

Holeta Agricultural Research Center has been involved in the development of improved cultivars with the production packages. In addition, HARC has taken part in the training and dissemination of manual on production and processing of potato. For example, HARC trained DA's and selected farmers on the ways of how to prepare various kinds of foods from potato and the ways to decrease post harvest losses using local resources. ILRI is working also with the district agricultural office in the provision of input supply and services to farmers. It focuses mainly on quality seed potato supply and production of potato using irrigation.

Optimizing plant density is one of the most important subjects of potato production management. Because it affects seed cost, plant development, yield and yield components and finally affects quality of the crop. Plant density affected some yield parameters like leaf number per plant, number of tuber per plant, branch number, tuber size, and tuber yield, marketable tubers per plant, marketable tuber weight, number of marketable tubers per plant and number of stems per plant. These parameters were also affected by plant spacing except number of stems per a given land**.**

Despite of the previous efforts made by different stakeholders involved in potato production, still much more assessment of potato production system is needed in order to improve the productivity and to address the increasing demand of potato for markets. The information obtained from such type of studies could lead to a better production approaches to be followed and able to show an efficient cooperation between stakeholders towards increasing productivity and production of high quality potato to markets. Therefore this specific base line study was initiated to assess the production potato under farmer's traditional planting density practice versus recommended planting density of improved cultivar Gudane in irrigated fields and to assess the input supply and service provision of potato at AdeaBerga District West Shoa Ethiopia.

1.1 Statement of the Problem

Agricultural production in Ethiopia is largely rain-fed, which increasingly depends upon erratic and often insufficient rainfall. AdeaBerga District, being areas where smallholder subsistence farmer are living, their major livelihood depends on rain fed agriculture with traditional outdated production practices. To cope with fast growing population of national leveland the study area and the limitation of traditional production, use of modern technology production and proper supply of input for potato production is needed for food security and alleviating rural poverty.

However, many obstacles constrain rapid increase of potato production. Although there were many options to raise the productivity of potato in the study district. Other conditions may not be conducive to input supply development such as unfavorable topography, edaphic factors, distant to markets and inadequate infrastructure, lack of market information and other socio-cultural factors.Proper agronomic practices, identifying irrigation water potentials, choosing possible alternatives and effective input supply chain system were few of options that are never considered by local government and communities.

Improving this sector contributes tothe productivity of agriculture andthus the generation of higher incomes,promotion food self-sufficiency andimproving health condition of the people. Therefore, this study intended to assess the effect of plant density on yield of irrigated potato and analysis of input supply chain at AdeaBerga district, Ethiopia.

1.2 Significance of the study

The study analyzed the entire potato production practice of Improved planted using recommended plant density performance for most agronomic traits considered than farmers traditional practice of plant density.

It also provides existing challenges of input supply, opportunities and entry points in the potato input supply chain. Moreover, this study provides information on the constraints of potato input supply to the producers and identifies opportunities and constraints of potato production chain in the study areas. Therefore, it could shed light on required efforts to enhance the production and utilization of potato at larger scale to bring about economic development in the area. The information generated could also help a number of organizations including: research and development organizations, traders, producers, extension service providers, government and non-governmental organizations to assess their activities and redesign their mode of operations and ultimately influence the design and implementation of strategies. It could also help different actors to identify and analyze new ways of stimulating innovation.

1.3 Scope of the Study

There are many physical, biological, climatic and socio-economic factors that influence potatoproduction and yield in the context of farm households. For instance, some of these physical,biological and climatic factors that influence production and yield include: crop management, input management etc. However,this paper hasn’t addressed all these factors. As explained in the introductory part of this paper, potato is produced in almost all kebeles of AdeaBerga district; however, due to time and budgetconstraints, this study focused only on five kebelesin this district that LIVES project focus on namely: MaruChebot, BishanDimo, GatiraNabe, Ula Gora and RejiMokoda.

2. OBJECTIVES

2.1 General Objectives

- To assess the effect of plant density on yield of irrigated potato
- To analyzes the input supply chain of potato

2.2 SpecificObjectives

- To see the effect of plant density on yield of irrigated potato and yield related traits under farmers field,
- To compare and analyze the planting density of potato cultivars on yield and yield related traits between farmers and recommended planting density practices.
- To assess the input supply and distribution system and related issues affecting potato production of the target communities.

3. LITERATURE REVIEW

3.1 History and Overview of potato in Ethiopia

3.1.1 Potato production in Ethiopia

Potato was introduced to Ethiopia in 1858 by a German immigrant, Wilhelm Schimper, adoption by Ethiopian farmers occurred very gradually for several decades (KidaneMariam 1980). The first available potatoes were probably of a very limited genetic base, hence vulnerable to diseases and pests. Cultivation was limited to potatoes growing voluntarily in fields in the colder highlands until wider adoption of the potato occurred at the end of the nineteenth century in response to a prolonged famine (Medhin*et. al.* 2001). In the 1980's IPM introduced the variety "Cara" to Ethiopia. Cara is still the only European variety being planted in some regions due to its great resistance to blight, robustness and yield potential (IPM, 2015).

Potato in Ethiopia is currently planted in around 59,508.67 ha (CSA, 2012). This implies that average yield in the country reaches only 7 t/ha when the potential for small holder is around 25 t/ha. Therefore, this indicated that potato yield is lower in Ethiopia, even it is lower than most potato producing countries in Africa like South Africa and Egypt which produce 34 and 24.8 t/ha respectively (FAO, 2008).There are many factors that have been identified as the causes for this low yield in Ethiopia and most of the East African countries. Some of the production constraints which have contributed to the limited production or expansion of potato in Ethiopia include shortage of good quality seed tubers of improved cultivar, diseases and pests, lack of appropriate agronomic practices including optimum plant density, planting date, soil moisture, row planting, depth of planting, ridging and fertility status(Berga*et al*, 1994).

3.1.2 Major Potato Growing Areas in Ethiopia

In Ethiopia, potato is grown in four major areas: the central, the eastern, the northwestern and the southern. Together, they cover approximately 83% of the potato farmers (CSA 2008/2009). A brief description of each area follows: In the central area, potato production includes the highland areas surrounding the capital, i.e. Addis Abeba, within a 100–150 km radius. In this area the major potato growing zones are West Shewa and North Shewa. About 10% of the potato farmers are located in this area (CSA 2008/2009). Average productivity of a potato crop ranges from 8 to 10 ton ha $^{-1}$ which is higher than the productivity in the northwestern and southern areas. This higher productivity might be due to the use of improved varieties and cultural practices obtained from Holetta Agricultural Research Centre in the central area. In the central area potato is produced mainly in the *belg* (short rain season—February to May) and *meher* (long rain season—June to October) periods. Potato is also grown off-season under irrigation (October to January). Because of the cool climate and access to improved varieties, farmers in this area of the country also produce seed potatoes which are sold to other farmers in the vicinity or to NGOs and agricultural bureaus to be disseminated to distant farmers. The eastern area of potato production mainly covers the eastern highlands of Ethiopia, especially the East Harerge zone. Only about 3% of the total number of potato growers is situated in this area (CSA 2008/2009), but the area is identified specifically because the majority of the potato farmers in this area produce for the market and there is also some export to Djibouti and Somalia. Potato is mainly grown under irrigation in the dry season (December to April). This season is characterized by low disease pressure and relatively high prices (Mulatu*et al*. 2005b).

3.2 Agronomic practices of potato

3.2.1 Agro-ecology

Potato is a temperate or cool season crop which needs a low temperature, low humidity, less wind, and bright sunny days. Humidity and rains are not conducive to potatoes as these lead to insect pests and disease attacks (United States Department of Agriculture, 2010). Also potato offers a wide flexibility in planting to the cultivator. The crop can potentially be grown on about 70% of the 10 Million hectare of arable land in the country (FAO, 2008) located within altitude ranging from 1800-2500 masl and receiving an annual rainfall of more than 600 mm. As a highland country located in the tropics, Ethiopia has very conducive edaphic and climatic conditions for the production of high quality seed potato (Emana and Nigussie, 2011).

3.2.2 Soil type and Management

Potatoes are grown on a range of soils varying from sands to clay loams, all with different water holding capacities. An ideal potato soil is well structured, with good drainage to allow proper root aeration, tuber development with minimal root disease infestation. Potatoes prefer soils with a pH of 5.5 to 7.0 and low salinity. However, in practice potatoes are grown in soil pH's from 4.5 to 8.5 and this has a distinct impact on the availability of certain nutrients. Extreme soil pHs should be adjusted where it is practical to do so. At lower pH values potatoes can suffer from aluminum and other heavy metal ion toxicity, as well as restricted phosphorus or molybdenum availability. At pH values above 7.5, nutrient availability, in particular of phosphorus and the micronutrients, can be reduced, even though high total amounts of these elements may be present in the soil. Liming can ameliorate undesirable, low pH values although care must be taken to ensure that the lime is applied at least 6 months before the potatoes are to be planted. Potatoes are more prone to common scab when grown in high pH soils. In Ethiopia, the ideal soil type is deep and well drained with a silt loam or sandy loam texture. It should be slightly acidic, with loose and friable structure (EARO, 2004).

3.2.3. Cropping system

Potato sole cropping is the most popularly practiced production system in Ethiopia. More than 90% of producers reported that they practice sole cropping. Farmers also occasionally intercrop potato with other crops like maize, cabbage and beans (Mulatu et al., 2005).

Fertilization:

Soil type, crop rotational history and variety will all impact what soil fertility management practices should be. It is good to use soil tests and past crop history for the field to be used when determining what fertilizes materials and rates to use. Be careful to use appropriate application rates as too little or too much can both cause significant yield and quality problems. Excess nitrogen (N) can prolong plant maturity, make vine kill difficult, inhibit proper skin set which will make tubers more prone to soft rot, and reduce dry matter content (specific gravity). Potassium (K) levels are important for tuber quality as low K levels are associated with smaller tuber size, hollow heart, brown center and black spot. High levels of K can reduce after cooking darkening and reduce specific gravity (O'Brien, et al, 2009).

According to EARO (2004), the recommended fertilizer rate is 110kg of N and 90 Kg of P_2O_5 per ha. The placement is Urea 165 Kg/ha (split: half at planting and the rest during flowering DAP 195 Kg/ha Side dressing at the time of planting.

Water management:

Achieving better yield requires an adequate water supply from planting until maturity. The main effect of drought or water stress on potato is yield and size reduction. Frequent irrigation reduces the occurrence of tuber malformation. For the potato, the critical period for water deficit is during tuber development. Water deficit in the early phase of yield formation increases the occurrence of spindled tubers (more noticeable in oval than in round tuber varieties) and, when followed by irrigation, may result in tuber cracking or tubers with "hollow hearts". Avoid water deficits in the middle to late part of the growing period deficits during stolonization, tuber initiation and bulking tend to reduce yield. Allow higher depletion toward the ripening period (a practice that may also hasten maturity and increase dry matter content). Therefore, water supply and scheduling have important impacts on potato growth, yield and tuber quality. For best yields, a 120 to 150 day crop requires from 500 to 700 mm (20 to 27.5 inches) of water (O'Brien, et al, 2009).

3.2.4 Crop protection

3.2.4.1 Weed and pest management

Potatoes are a very competitive crop and can be grown without herbicides if soils are moist enough to encourage weeds to emerge before the potatoes. Most weeds can then be removed by a cultivation that is timed just before potato emergence. A few weeds, however, such as nut sedges and nightshades, cannot be controlled by cultivation because they emerge with and after the potatoes and might be best controlled with crop rotation (Buhler, D. D., and M. L. Hoffman. 2000).

The competitive ability of the potato plant varies considerably among the different varieties. Sometimes disease, lack of nitrogen, air pollution, or climatic changes can alter how these varieties grow. Varieties that are harvested green for chipping have fewer problems with weeds, including nut sedges, invading after early season cultivation because the vine canopy remains until harvest.

An effective weed management program takes into account the type of weeds present, crop rotation, cultivation, available herbicides, and the competitive ability of the potato crop. Competition from early season weeds will reduce yields if they are not controlled within 4 to 6 weeks after potatoes emerge (Dekker, J. 1999). Weeds that emerge after vines have covered the rows usually will not compete with the potato crop; however, they may reduce yields by interfering with harvest and can produce seed that will cause infestation of subsequent crops. Weeds frequently become more serious if crop growth is delayed by adverse conditions early in the season. Weed problems can be reduced by establishing a vigorous stand of potatoes.

3.2.4.2 DiseaseManagement

Early blight (Alternariasolani) and Late blight (Phythophthorainfestans) are major diseases that can have a devastating effect on the crop. Early blight is a problem, particularly in early varieties, spreading from the leaf to young tubers. It can result in severe defoliation, but, if managed correctly, plants can grow away from infestations.

Late blight occurs under cool moist conditions and if left uncontrolled, quickly spreads to the tuber resulting in significant tuber browning and rot.

A range of mosaic viruses also affect potato leaf growth, leading to a drop in yield. Control of the aphid or other carrying vectors, minimizes damage.

In addition, various free-living nematodes and/or potato cyst nematodes can cause significant damage. Wide rotations are needed in some countries to minimize crop loss. Various disease controlling mechanisms are employed in potato farming, such as the use of healthy seed. Care should be taken not to use planting materials from areas where the existence of bacterial wilt is reported, use of resistance/tolerance varieties, Plant in healthy soil, Removal of potato haulms and rotted potato tubers, Weeding, since some disease causing micro-organisms survives in weed, Rouging of wilted and volunteer potato plants, Use of clean farm equipment's, Use of clean and uncontaminated irrigation water, Crop rotation with cereals, legumes and etc, Avoid tomato and other *solanaceous* crops.

3.2.4.3 Harvesting and post harvest handling

Farmers carry out different activities in potato production before and after harvesting. According to survey study by Endale et al, (2008), the majority (95.7%) of potato producing farmers practiced dehaulming before harvest. Regarding the time of dehaulming, 61.2% of participant farmers carried it out 15 days before harvesting, and 14.9%, 10.4%, and 4.5% of the respondents carried it out 5 days, 10 days, and 20 days before harvest, respectively. Curing is a process that encourages the potato to naturally heal its wounds and it significantly reduces the incidence of postharvest rot. Most (82.9%) of the farmers cured their potato tuber seed before storage, of these 56.9% of the respondents cured for 5 days. About 22.4%, 15.5%, and 5.2% of the respondents cured their tuber seed for 1–3, 10, and 15 days, respectively. The methods of curing were different among the respondents. The majority (55.2%) of the farmers spread seed tubers on the ground outdoors outside the store to expose them to sunlight for drying. About 32.8% of the respondents spread the tuber seed on the ground and sun drying by frequent mix up of the tubers, and then separate soil from the tuber after drying. About 12% spread the tubers in cellars or floors inside the house before storage (Endale et al, 2008).

3.3 Effect of plant density on potato growth and yield parameters

The optimizing of plant density is one of the most important subjects of potato production management, because it affects seed cost, plant development, yield, and quality of the crop (Bussan *et al*., 2007). Plant density in potato affects some of the important plant traits such as total yield, tuber size distribution and quality (Zabhi*et al*, 2011). The effects of plant density on various morphological and yield parameters is described below.

3.3.1 Branch number

Population density had a highly significant influence on the subsequent development of branch number. Branch number was reduced at high plant density level, 90 by 15 cm increasing significantly at 90 by 30 cm and 90 by 45cm of between row and within row spacing respectively. Under more intensive competitive conditions like those experienced at the highest density level of 90 by 15 cm, there is an earlier on set of inter plant competition for growth resources such as light, water and nutrients, this resulted in a decrease in relative growth rate. Limited space for root and tuber expansion consequently reduced branch number and development at the high density spacing levels (Wurr*et al*., 1993).

3.3.2 Tuber number

Similarly, tuber number is one of yield components of potato that affected by plant density, As reported by Getachew*et al*., (2013) significantly highest number of tuber per plant (10.93) was recorded at the wider intra row spacing of 40 cm whereas the lowest number of tubers per plant (6.7) was obtained at closer intra row spacing of 10 cm. This indicates that optimum plant density should be used inorder to obtain maximum tuber number.

3.3.3 Tuber size

Increase in plant density decreases main tuber size probably because of plant nutrient elements reduction, increase in inter species competition and large number of tubers produced by high number of stems (Khajehpour, 2006). Increase in density probably increased competition between and within plants and hence, led to decrease in availability of nutrients to each plant and, consequently, resulted in decline of mean tuber weight Ali (1997) and Berga (1990) also reported that stem number per plant and tuber number per plant are positively related; however, average tuber weight increased with wider spacing.

3.3.4 Tuber yield

The yield of seed potato can be maximized by using optimum plant population (O'Brien and Allen, 2009). In line to this several authors indicated that reduced plant population was shown to increase yield. For instance major yield components mean tuber weight and tuber yield per plant significantly decreased as planting distance closer due to increasing inter plant competition. In wider intra row spacing there could be minimum competition among plants for space and resources and also better plant exposure for high radiation interception that increased the photosynthetic efficiency finally increased number of tubers per plant (Getachew*etal*., 2013). In similar manner (Zamil*et al*., 2010) also indicated that the wider intra row spacing gave the highest number of tuber per hill.

Intra-row distance of 20 cm increases total tuber number and weight, and tuber weight per plant and the marginal return rate increased by 13% when intra-row distance decreased from 35 to 25 cm. EARO (2004) also determined that is little difference in yield between intra-row spacing of 25 and 30 cm for all varieties released so far in Ethiopia, and the 30-cm intra-row and 75-cm inter-row spacing are accepted as standard.

3.3.5 Marketable Tuber Yield

At the wider intra row spacing due to the presence of minimum competition, plants absorbed the sufficiently available resources and intercepted more light. This increased their photosynthetic efficiency for higher photo assimilate production and ultimately resulted in increased more marketable tuber yield (Getachew*et al*., 2013). Similarly, Zaag*et al. (*1989) also reported that marketable tuber yield increased in the wider intra row spacing.

3.4 Input Supply Chain of potato

It is taken to mean the physical flow of goods that are required for raw materials to be transformed into finished products. Supply chain management is about making the chain as efficient as possible through better flow scheduling and resource use, improving quality control throughout the chain, reducing the risk associated with food safety and contamination, and decreasing the agricultural industry's response to changes in consumer demand for food attributes (Dunne, 2001).

3.4.1Input suppliers of potato

Potato producing farmers in Ethiopia, get seed from different sources. For instance, in the majority of the sample producers used their own seed. The others of farmers get seed from Research Center, Cooperatives and Non Governmental Organizations. Regarding fertilizers, some farmers used only organic fertilizer (manure and compost) while some farmers used both inorganic and organic fertilizers depending on the land size allocated to potato and the soil fertility status as perceived by the farmers. Potato growers obtained fertilizer from either cooperatives or private traders. Pesticides are supplied mostly by private vendors. Only 49% of the sample farmers responded that they applied fertilizer to potato field (Endale et al. 2008b).The reason indicated for not using fertilizer were the use of organic fertilizer and high fertilizer price.

In Ethiopia there are community based seed supply systems which are undertaken by the community with technical and financial assistance of NGOs and breeding centers. There are also farmers' research groups (FRG) and farmers' field schools (FFS) in the central and northwestern areas of Ethiopia which are involved in seed potato production (Bekele et al. 2002). They are formed by the Ethiopian Institute of Agricultural Research (EIAR). Some members of FRG and FFS in the central area of Ethiopia became specialized seed potato growers (Gildemacher et al. 2009b). These "specialized" commercial seed potato producers are local smallholder farmers. These farmers are producing better quality seed tubers than other farmers but these may still not be of standard quality. From 2002 to 2003, also some efforts were made in the southern area of Ethiopia to multiply seed potatoes by individual farmers with technical and financial assistance from breeding centers and NGOs. The alternative seed potato system supplies about 1.3% of the total supply (Gildemacher et al. 2009b). In the formal seed potato system seed tubers are produced by licensed private sector specialists and cooperatives. There is no public formal seed potato supply system in Ethiopia. The contribution of the formal seed potato system to the overall seed tuber use in Ethiopia is very meager as both the private sector and the cooperatives are at the incipient stage. Very recently, two seed potato producer cooperatives were established and two more are under the process in the central area of Ethiopia. The Ethiopian Seed Enterprise (ESE) is not involved in seed potato production and supply because of its limited capacity (Bekele et al. 2002).

Government suppliers input in packets in the frame work of Ethiopia's particularly Demonstration and Extension Training System (PADETS). Such packets contain high yielding seeds, fertilizers and extension services. In 2010/11 3.6 million (28% of total) holders cultivating crops used the extension package on 2.2 million ha land (18 % of the land area) (CSA, 2011b).for potato growers these percentage are 12 and 15 % respectively. The impact of these packages is significant. Zerfu and Larson (2011) concluded that high transport costs (either fertilizer to the farmers or final products to the consumer markets), limitation in complementary markets for credit and assurance, adverse climate and illiteracy limit the adaptation of fertilizers. It is likely that these factors also incurable low adoption of improved seeds as well as crop protection agents. The packets are sold on credit after a down payment of 10 to 35%. Fertilizer is bought for almost two third on credit and the remaining part on cash (Zerfu and Larson 2011)

3.4.2 Potato support service providers

Some service providers extend service beyond one function and others are limited to a specific function. For instance, agriculture offices provide service at input level; production and processing levels. Whereas NGOs participate in input supply and Research Center supports seed as credit.

Agricultural development office provides agricultural extension services to farmers through development agents. The office provides advisory service, facilitate access to inputs and provide technical support in crop protection. One should note that there is no specialized extension services for potato growers except that potato is considered as just one of the vegetables. Application of knowledge of general agriculture is not sufficient. In a similar approach some potato warehouses constructed by the farmers were found not suitable for potato due to its position relative to sun rise and design (Berga et al, 1993).

3.4.3 Potato Seed Chain

According to the survey of Emana and Nigussie (2011) in SNNPR and Tigray seed potato farmers 50 to 57% their seed to other farmers. The formal potato supply chain is in the infant stage. The study of Gildermacel et al (2009) showed that 44% of the Ethiopian farmers renewed the seed. The dominant source of new seed was the village market (69%), Neighboring (14%) and specialized seed growers (16%) provided the remaining part. Ethiopian farmers make no distinction between ware and seed potatoes. They also fetched the same prices. To remediate this seed needs labeled by a seed certification system that has yet to be set up for the emerging large scale potato production system. For small scale production informal inspection needs to be set up for through which the seed quality improves gradually through time. There is a lack of awareness what good quality seed may entail. Awareness creation can be done throughout demonstrations. Storage varies through 3 to 8 months and infrastructures are inadequate. Road infrastructure problem can partly overcome by decentralization. This will strongly shorten the average distance the seed needs to travel (Abraham T, 2013).

3.4.5 Functionaries in the supply chain

The potato supply chain consists of various components along the chain. A farmer is one of the most important components in the supply chain. Potato is a preferred crop for the farmers because of the low input costs and less duration of cropping among other reasons. The returns to these small holders and their ability to access markets will be critical towards ensuring an efficient supply chain (Emana and Nigussie, 2011).

3.5 Overview of the Ethiopian potato supply chain

According to Hirpa et al 2010, the Ethiopian potato supply chain and the major actors are shown below.

Research center - the Potato Research Division of national or regional research centers are responsible to disseminate the technology to the potato growers. Accordingly, newly released varieties are delivered to selected potato farmers called "specialized seed growers". The improved seed is then multiplied by the seed growers with the intention of further disseminating the technology to the ware potato growers. There is a close link between the research division and the specialized seed growers (Sperling and McGuire, 2010).

Specialized seed growers – These are seed growers organized as farmer field schools (FFS), farmer research groups (FRG) or seed cooperatives by the potato research division in the highland areas. They get improved seed from the national or regional research center (as a gift). After multiplication, the specialized seed growers largely sell the seed to NGOs and agriculture offices who in turn give the seed to the ware potato growers in other regions. So far the role of traders (wholesalers and retailers) in linking the specialized seed growers with the ware potato growers has been very minimal.

The informal seed market- This is the market where the majority of ware potato growers source potatoes to be used as seed. Over 98% of ware potato growers' buy seed from informal sources (Gildemacher*et al.*, 2009). For the informal market, the name of the variety and the area of production are important for the ware potato growers.

3.6 Key actors and their roles of potato supply chains

Input supply chain actors are those individuals or institutions who take ownership of a product, through the exchange of money or equivalent goods or services, during the transaction process of moving the product from conception to the end user. Individuals or firms providing a service without taking ownership of the product are considered as service providers. The identified primary actors of potato input supply chain are: potato producers; traders; brokers; processors; retailers; and consumers. Support providers are district office of Agriculture, cooperatives, research centers, credit associations and NGOs. These key actors and their roles are described below.

3.6.1 Producers

The small scale producers are the key actors who are directly involved in potato production activities. They are generally smallholder producers having different land size. They perform most of the value chain functions right from farm inputs preparation on their farms to post harvest handling and marketing. The major value chain functions that potato producers perform include land preparation, growing/planting/, protecting [from weed, pest/disease], harvesting and post-harvest handling.

Sometimes producers sold potato at farm gate. If potato is sold at the farm gate, all aforementioned activities are performed by the buyer. Some traders go to the producer's field and negotiate about price, purchase it and eventually transport the potato to urban markets. But potato sale at the farm gate is not very common. The majority of post-harvest activities like sorting, grading, packing, storing, transportation, loading and unloading, are done by the producers themselves. After that potatoes are collected in sacks of various sizes ranging from 50 to 100 kg and transported to the nearby local market for sale (Zerihun et al, 2014)..

3.6.2 Wholesalers

Wholesalers in the local market are closely working with local traders/collectors to buy the potato collected in bulky and sell it to other wholesalers in other cities. Wholesalers at local market sell potato through brokers in different cities of the country. They started collecting potato from local traders or order them to collect only when they got call from brokers. Brokers play crucial role in potato marketing system by facilitating potato transaction by linking local wholesalers with regional and national wholesalers. According to Hirpa et al 2010, one of the wholesalers at the local market, the brokers sometimes go beyond facilitation of transaction and tend to set prices and make extra benefits from the process. They do not follow proper business conduct and as a result they constrain the marketing system more than they facilitate. Wholesalers mostly purchase in bulk from the districts, transport and sell the produce in Addis Ababa. These traders are also involved in the purchase of improved seeds and sell it to producers in the local places.

3.6.3 Local traders /collectors

They collect potatoes from producers assemble them in one place and then sell it to wholesalers or transport it to other towns. These local traders collect potato for wholesalers and wholesalers pay small fee for their services. However, every cost is covered by the wholesalers themselves. Local traders can also purchase potatoes by themselves and store them for some time, negotiate the price with wholesalers and sale it when necessary. But this form of business is highly risky according to local traders because they do not have guarantee for market and they will lose if the market price goes down. This shows that they are highly dependent on the willingness of wholesalers to sale the collected potatoes if they do not agree on the price in advance.

Sometimes, the producers themselves have to bring the potatoes to the wholesalers store houses but that is not significant. However, the losses from damage to the potatoes due to poor storage, the limited supply of potato from producers and wholesalers insistence on high quality discouraged (Zerihun et al, 2014).

Collecting wholesalers– they are long distance traders located close to the potato growing regions. They buy directly from growers and supply to the central market and to other major cities in the country. They mostly purchase potatoes from (commercial) growers at farm gate.

Stationedwholesalers– These are the buyers located at the central market. They buy potatoes from collecting wholesaler in bulk and then resale to retailers, hotels, restaurants, and cafes.

3.6.4 Retailers

Retailers are key actors in potato supply chain. Small traders that buy potatoes in smaller quantity from wholesalers located at the central market place and who ultimately sell to household consumers. They are the last link between producers and consumers. They mostly buy from wholesalers and sell to urban consumers. Sometimes they could also directly buy from the producers. Retailers not only sell potato but also trade other vegetables. Consumers usually buy the product from retailers as they offer according to requirement and purchasing power of the buyers. But the producers transported their ware or seed potato to the nearby market and sell it to rural and urban consumers. However, in towns local retailers/vendors buy potatoes from producers and sell to consumers through their grocery stores and open market. Since most of the institutional buyers (universities, hospitals, colleges, hotels, prisons, etc) purchase a bulk quantity of potatoes directly from producers or wholesalers, the quantity of potatoes sold by the retailers in a day is generally less (Zerihun et al, 2014).

3.6.5 Consumers

Potato consumers are individual households (rural and urban dwellers) and institutions. However, there is preference in potato varieties and size. Restaurants, hotels and higher institutions prefer bigger potato size whereas households prefer medium size potato. Both individuals and institutions prefer local varieties. Improved varieties are preferred only for seeds. The researcher (Zerihun et al, 2014) observed that the demand for improved varieties is increasing from time to time since producers need to grow improved varieties and sell it for seed with relatively better price but the supply is very limited.

3.7 Seed Potato Source and Renewal

The seed potato system in Ethiopia is characterized by limited availability and use of commercially traded high quality seed (Gildemacher, 2012). The informal seed potato system in the country supplies about 98.7% of the required seed tuber by smallholder farmers (Gildemacher*et al*., 2009b). Seed potato in the smallholder farmer's cropping system is the by-product of ware potato, that is, farmers leave the potato that cannot be used for sell and consumption in the soil to be used as planting material. Most farmers usually renewed the seed stock that they are using as planting material after 3 to 4 years (that is, from 6-8 production seasons) of use (Gildemacher*et al*. (2009a).

The smallholder farmers propagated potato vegetatively by tubers and the seed tuber for planting is obtained from different sources. For the majority of smallholder farmers in Ethiopia, own produced and saved tubers is the most important source of seed because of its known quality, timely availability and economic attractiveness. However, this source has different problems with regard to sanitation during storage and degeneration as a result of tuber-borne diseases. In this respect, medium and rich farmers were found to have good understanding of the negative effect of using part of ware potato as planting material. It seems however that they do not practice positive selection and allocate separate plot for seed tuber production (Emana and Nigussie, 2011).

The other equally important source of seed tuber is the one obtained through the social relationships with neighbors, friends and relatives in the same and neighboring localities. These sources supply good and known quality seed because it is related with the existing moral economy of the society. But because of the high level of disease infestation, some farmers usually prefer to receive seed through purchase or sharecropping (that is, a contractual relationship between a farmer who owns a plot of land and another farmer who supply necessary production inputs (seed, fertilizer, etc.) to divide the produce into two equally) arrangement from farmers outside their locality. This preference is associated with receiving planting tuber with relative good health and agronomic characteristics; which in turn is related with differences in agro-ecological with zones of acquisition and less disease pressure. To secure seed with good characteristics, farmers usually use information related with vegetative progress of the crop obtained through their social networks. Sometimes, farmers themselves may physically go to the neighboring localities to monitor the progress of the crop at vegetative stage (Emana and Nigussie, 2011). Once convinced, farmers may request the owners of good looking potato to leave reserve seed for sell after harvest.

Seed obtained through sharecropping arrangement is also a good source of seed especially for poor farmers who do not have money to buy seed and other inputs from the market. However, for those who do have money the local market is important but the quality of the seed source is unreliable. This was a repercussion of the fact that in the market there is low trust on seed quality between buyers and sellers. As a way of minimizing mischievous act in the local market, farmers usually use their own knowledge and kinship networks to obtain better quality seed that could enable them to create trust and confidence of obtaining higher yield in the ensuing production season. According to Sperling and McGuire (2010), farmers have mostly preferred to use their social ties and networks to secure seed because they wish to avoid transaction costs associated with requesting and obtaining quality seed.

3.7.1 Seed selection criteria

Farmers usually exercise some level of rational behavior in using informal seed supply chain to minimize their risk and maximize benefits (Sperling and McGuire, 2010). Majority of farmers in Ethiopia do not practice in-field selection of the best plants for seed; but they use different product and variety related criteria for selecting their potato seed from harvested tubers. By far the most frequently cited criterion pursued by farmers is potato size. They usually prefer to plant small sized seed because it enables them to cover large spaces or plots. This preference is directly related to the reduction of cost of production.

Equally important criterion stated by farmers in the selection of potato seed is the level of sprout. They usually prefer to purchase and plant medium sprouted seed. Because highly sprouted seeds have already finished their food and as a result there is nothing to feed the emerging plant. Besides, long sprouts are highly liable to damage and splitting-off from tubers. The seed with no or low level of sprout is also not preferred; because it has not finished its dormancy when sowing and as a result it takes more time to emerge and to be harvested. Still some farmers used to mention the area where the seed originated as important selection criterion. This is related with the problem of more disease infestation in some localities than others. Few farmers also mentioned potato grown on reddish soil (that is, on Nitosoil) is preferable for seed purpose. This, according to respondents, is related with the moisture content and agro-ecology of the source. Potato obtained from such type of well drained soil is expected to have medium level of moisture contentwhich is one of the preferred attributes of potato seed.

3.7.2 Seed potato storage

Potato postharvest loss in Ethiopia is estimated to range from 30-50% (Endale*et al*., 2008b). The most prevalent mode of potato storage methods in include storing tubers loose on in-house floor, bed like structure located under roof, postponed harvesting (leaving the potato un harvest in the soil for sometime or until next season), sacks and pits. From those modes of storage, in-house floor is the most common. In this case farmers heap the harvested potato loosely in untidy, less ventilated and dark bedroom and/or floor of house salon.

Some farmers are also found to store their potato on the bed-like structure. In relation to this, study done by Hirpa*et al*. (2010) showed that 33% of the farmers in Banja district are found to use this structure. The use of this type of storage structure is also found to vary across seasons. That is, during rainy cold season farmers use this structure to store the harvested potato and then transferring it to in-house floor during dry season to protect it from spoilage and drying. This is true because most farmers own houses with corrugated iron roofs, so that it creates high temperature and low humidity in the stored potato during dry season. In addition, they usually prepare the bed-like structure near the house ceiling. This modes of differentiated temperature in different periods of storage will affect storage shelf-lifeof potatoes thereby causing increased transpiration (water loss) and respiration **(**dry matter loss) (Wustman and Struik, 2007).

A study by Gildemacher*et al*. (2009a) shows that, 50% of potato farming households in Ethiopia practiced postponed harvesting. Farmers practicing such storage method in the study sites used to store their seed for up to six months. Other studies (for example, Endale*et al*. (2008b) also witnessed that in cooler highlands using such method, potato tuber can be kept for up to four months without major quality deterioration. But this method is associated with the problem of accumulation of tuber-borne diseases (Endale*et al*., 2008a). The practice of such storage method was also found to vary among wealth groups. That is, most of the time medium and rich farmers, who do have relatively sufficient landholding size in areas where there is no access to irrigation water, are found to practice such storage method.

The last type of storage practiced by smallholder farmers is the pit method. This method is practiced by very few farmers that cultivate the local cultivar. They store this variety in a pit to protect it from drying so that it will be used as a seed for the next production season.

Notwithstanding their widespread use, these traditional storage methods have contributed to reductions in seed quality through weight loss, excessive sprouting and pest and disease infestation (Gachango*et al*., 2008). Moreover, these storage methods are associated with different problems viz., heaping loosely or stacked in sacks that creates pressure on individual seeds, storing in untidy and limited space that limits ventilation or aeration, storing potato in the same room with household members (no differentiated storage), placing household appliances on the stored potato and storing in areas where there is no light. In addition to the above stated problems, farmers do not clean the premises well between storage periods. This poses the risk of contamination or creates the possibility of disease transfer from one season to the next.

3.7.3 Potato seed sprouting

Potato growing farmers in Ethiopia do not remove haulms which greatly improves sprouting of potato seed (Alemayehu, 2011). Farmers usually applied different techniques to break dormancy and stimulate timely sprouting of seed potato. Those who do access irrigation water in their land mostly require optimally sprouted seed than those without access to irrigation. In those plots with no supplementary irrigation farmers prefer to plant less sprouted potato seeds to wait for the rain fall. To assure the readiness of seed potato for planting on time, farmers usually practice different sprout facilitation methods like putting the potato into sacks and covering the potato with dry soil, grass or crop residues before two to three weeks prior to planting time.

Irrigation (February to May) to residual (August to December): Potato produced using irrigation in the production period of February to May serves farmers as seed input for the residual production (August to December). Here the gap between the two production seasons is not enough to break the dormancy of the seed potato. Temperature, water supply and the photoperiod during storage are important environmental factors that regulate sprouting behavior (Sonnewald, 2001). As a result, farmers practice sprouts facilitating mechanisms mentioned above because of cold weather and short gap for breaking dormancy. Moreover, potato produced in this production period serves as an input to the second round of irrigation-based production (November to February).

Residual (August to December) to rain fed (March to July): Even though the gap between these two production periods is not sufficient enough for breaking tuber dormancy, the sprout facilitation effort of farmers coupled with warm weather could facilitate sprouting. This kind of sprout facilitation methods have contributed to reductions in seed quality, excessive sprouting and pest and disease infestation (Zerihun et al, 2014).

Rain fed (March to July) to irrigation (November to February) : The gap between these two production periods is enough for normal sprouting even at the current storage practice of smallholder farmers in Ethiopia. The tuber remained in the soil for long time feeding its own stored food and which has also finished its dormancy period is either planted immediately after harvest or kept for a couple of weeks. It seems that the possible accumulation of diseases on such types of seeds as compared to others and its effects on yields are rarely understood by the different farming community (Zerihun et al, 2014).

3.8 Factors Affecting Agricultural Production and Farm Income

3.8.1 **Household characteristic of farm operators**

The household characteristics consist of many variables that affect the agricultural production of farm operators. Some of these variables are: age, gender, education level, family size, landholding size and possession of oxen, as reviewed below.

Education: Research findings have indicated the importance of education is significant in agricultural production and income. For example, Asfaw&Admassie (2004) reported that the conventional factor of production such as growth of stock, of capital and labour were unable to explain fully the growth in national income. Formal education enhances farmers’ engagement in environmental programs and methods for the sustainability of agriculture (Burton, 2013). Education is also believed to stimulate economic growth by enhancing the productive capability of farmers as well as eliminating the customs that are contrary to growth (Asfaw, &Admassie, 2004). There is agreement that the accumulation of knowledge through education is an important factor for economic development (Asfaw, &Admassie, 2004).

Gender: Gender refers to socially constructed roles and relationships of women and men in a given culture or location (Adeoti, Cofie, &Oladele, 2012). In enhancing agricultural production and income, the full participation of men and women is very important. Women tend to be the major players in the farm labour force engaged in production, harvesting and processing activities (Jafry, &Sulaiman, 2013).It is also known that the majority of food is produced by women farmers and they are responsible for fulfilling the basic needs of the family. Studies have also indicated that women farmers are more environmentally conscious compared to men farmers (Burton, 2013). Women farmers are also challenged by the absence of capital, information and access to markets which prevents them from producing enough to fulfill the basic necessities (Jafry, &Sulaiman, 2013).

Age, family size, landholding size: Agricultural production is influenced by other household characteristics such as the farm operator's age, family size and landholding size. The age of the household head is a proxy variable for the farming experience of farm operators. Farmers are highly dependent on their previous knowledge of farm practices in cultivating different crops. Experienced farmers are expected to enhance the productivity of their holdings. However, it is not without limit as older farmers lack the required physical strength on the farm and lowers the probability of technology adoption (Burton, 2013).

Land is the most critical natural resource for countries like Ethiopia where the agricultural sector is the engine of the national economy (Amsalu, 2006). Farm operators with larger landholding sizes would have a better farm income if sufficient family labour was available. This leads to an increased demand for children who can work on the land (Kim, &Park, 2009). It is not possible to expand the landholding size without matching it with an increase in the size of the household. Hence, households with larger families face a challenge to feed each of the family members and this will have its own negative effect on the nutritional status of the family (Olayemi, 2012).

Possession of oxen : Historically, for thousands of years, oxen have been recognized as the first draft animals to serve human beings, to cultivate land and pull heavy loads (Bryant, 2010).The possession of oxen determines the farming ability of farm operators because if farmers do not have oxen they would be obliged to rent out their land to other farmers. In this case, farmers would enter into sharecropping. This further diminishes the production and income of the household as the yield is shared with oxen owners. There are advantages associated with owning oxen. Oxen owners can cultivate and sow their land at the right time. This has a positive impact on the productivity of land. In addition, oxen could also be rented out on a daily payment basis to till the land for other households. Therefore, they may serve as a source of additional income for the owners (Kim, &Park, 2009).

3.8.2 Agricultural production technologies

Agricultural production technologies include biological and chemical technologies. Specifically, these technologies include chemical fertilizers and selected seeds or High Yielding Varieties enhancing technologies. Farmers use these technologies in order to enhance the production and productivity of the land. It is also indicated that, for poor farmers, adoption of technology places new demands on their limited resource base (Kamruzzaman, & Takeya, 2008).

Chemical fertilizer: The major reasons for low fertilizer use could be because of demand and supply factors (Crawford et al., 2003). On the demand side, farm households may not accept the profitability of fertilizer use; alternatively, they may accept it as profitable but too risky in financial terms. Fertilizer input may also be too risky for farmers because the level of input use is determined before the onset of the rainy season which is uncertain

Other possible reasons for lack of profitability could be due to high input prices or low output prices because of high transportation costs, policy interventions or non- competitive behavior of marketing agents (Crawford et al., 2003). The problem may not be profitability but rather the inability of farmers to pay for goods and services due to limited access to credit to finance fertilizer purchases (Crawford et al., 2003). On the supply side, the high costs at the source by importers and local manufacturers may limit the access to fertilizer (Crawford et al., 2003).

Improved seeds: Alemu, *et al* (2008) stated that improved seeds can cause a remarkable improvement in agricultural productivity and production for small-scale farmers in Ethiopia if they are combined with modern science and modest changes in farmers' cultivation practices. As the improved seeds are small, farmers are more concerned about the characteristics of the seeds rather than the price. The farmers may reduce costs by saving and using the seed varieties for the following production year (Rohrbach, Minde, &Howard, 2003).

Credit markets/agricultural loans: Agricultural credit is described as banking finance for primary production, processing and trade of agricultural products, and the production and distribution of inputs (Soutsas, 2011). Poor farmers have very little chance to borrow from the formal sector because they rarely have collateral acceptable to banks. They may not have clear title deeds for the land they cultivate but even if they do, rural land markets may not function well enough for land to be considered a "bankable" asset (Kindness, &Gordon, 2001).Smallholder farmers may have access to credit from Micro-credit institutes which do not have the collateral requirements. Micro-credit schemes are often associated with group lending where peer pressure is an effective substitute for collateral and group members may take action to prevent one member from defaulting (Kindness, &Gordon, 2001).

3.9 Factors affecting Input Supply Chains of seed potato

The supply of quality seed tubers is insufficient. All the seed potato systems operating in Ethiopia have problems in undertaking their functions as a seed system (Hirpha et al., 2010). The major problems reported are poor in health, unsuitable physiological age, poor genetic quality, impurity (varietal mix-up), and physically damaged and inappropriate seed size. The major constraints faced by smallholder farmers include the lack of improved, high yielding, disease resistant and good quality seed potato varieties. Hence, access to good quality and improved seed potato varieties is widely recognized as fundamental to ensure increased production and productivity (Schulte-Geldermann, 2013).

On the production side, the main constraints expressed are: high susceptibility to diseases, limited knowledge of seed quality features, and limited technical knowledge (Chadha et al. 2008). These constraints suggest two types of interventions: technical education/training of end users of seeds and other inputs, and provision of plant protection inputs for farmers.

The main constraints regarding input supply were low input demand, lack of access to farm inputs, and lack of good quality seed. These constraints offer opportunity for various interventions such as: alternatives for development of input markets, provision of good quality seed, and input price regulation and control to guarantee fair prices for quality seed. Lack of marketing services such as processing and packaging were also seen as major constraints (Nenguwo 2004).

Disease: Late blight [*Phytophthorainfestans (Mont.) de Bary]* is common in all potato growing areas of Ethiopia. It is the most important and damaging potato disease worldwide. Because of the use of home saved seed, use of seed potatoes of unknown origin from local markets, limited use of resistant varieties, poor storage practices like leaving potato underground un-harvested and only limited adoption of haulm killing and selection practices by farmers, the seed tubers used by most potato producers are of poor quality.

Seed potato physical damage: Physical damage includes cuts, bruises and holes, inflicted on tubers during harvesting, storage, packaging and transportation. Use of sharp/long fork tools to dig out tuber, throwing potato during harvest, packing potato in sack and transporting on donkey back, piling one sack on another and transporting, unsafe loading and unloading from contribute to physical damage of potato seed (Bekele et al. 2002).

Use of potato seeds of unknown origin: Farmers usually use varieties of unknown origin and improved varieties are not available to the majority of the farmers. Long dormancy period of potato (stored for more than 3 months in eastern parts of Ethiopia) and lack of well sprouted good quality seed potato tubers are also among key potato seed problems frequently raised by potato growers. Potato growing farmers in Ethiopia do not usually remove haulms which greatly improves sprouting of potato seed (Assefa, 2011). According to Assefa (2011) farmers are key innovators especially in enhancing potato seed quality by controlling dormancy by removing the flowers after tuber maturity and maintaining the tuber in the soil (Endale et al. 2008b).

The major factors that influence potato production include, inadequate supply of improved planting materials, soil type, weather conditions pest and disease and improper agronomic practices such as planting density, water management and fertilization (Schmitz, 2005).

Price Situation: According to Zerihun N., et al, (2014), Local informal markets reflect the type (ware or seed) and quality of potato by showing price differential. During non-planting times the price of these two types of products are almost equivalent ranging between Ethiopian Birr (ETB) 140 to 200 per quintal. However, during planting times the price of ware potato remained relatively stable while the price of seed potato showed high variation. The price of seed potato in the market ranges between ETB 240 to 360 per quintal two to four weeks prior to planting times and when planting time further approaches good quality seed may cost up to ETB 500 per quintal. This is especially so during August (residual moisture), November (irrigation) and March (rain fed) planting seasons. Moreover, when farmers purchase seed from neighboring localities using their social networks, they pay a price premium of ETB 10-20 per quintal above the market price for good quality planting material.

The price of potato seed is a function of different factors, the most important being quality of seed, delivery time (planting or non-planting time; working or non-working days), quantity of seed delivered to and demanded in the market (number of farmers who supplied and demanded seed potato) and type of seed variety. It is during non-planting times that the traders collect good-looking tubers to store and sell when the demand for seed escalates.

Cost of Potato production and provision of credit: Compared to other food crops, production of potatoes is capital-intensive, requiring the purchase of large quantities of bulky seed and the application of high-cost inputs such as fertilizers and pesticides. With limited access to credit and few means of mitigating the risks of taking out loans, small-scale farmers find it difficult to compete in potato production (Emana B, 2008).

Information Flow: Farmers can obtain information on name, source, yielding ability, marketability and food quality of varieties and production practices from various sources, such as family members, neighboring farmers, extension agents, NGO employees, researchers, and potato traders. Gildemacher et al. (2009a) found that about 58.7% of the farmers in North Shewa and West Shewa zones of the central area and East Hararghe zone of the eastern area of Ethiopia obtain information on the aforementioned characteristics of varieties from farmers in their own community. Tesfaye et al. (2008) found that the majority of the farmers (62%) in the central area of Ethiopia obtained information on improved potato technologies from Holetta Research Centre, whereas 33% obtained it from fellow farmers and only 4% from the office of agriculture. Own community and research centers like Holetta Agricultural Research Centre are the major sources of information for seed potato technologies.

Part I. Field Experiment

4. MATERIAL AND METHODS

4.1Materials

The activities of this study were conducted both in field experiment and field survey. The first activity was field experimentation for the assessment and comparison of planting density of cultivars on irrigated potato fields. The second activity consisted of field survey on input supply chains of potato production in the study district.

4.1.1 Description of the study area

The study was conducted at AdeaBerga district West Shoa Zone of Oromia Regional state (figure 1) which is 65km from the central city Addis Ababa, on the way to Mugger Cement Factory during the irrigation cropping season of 2015.

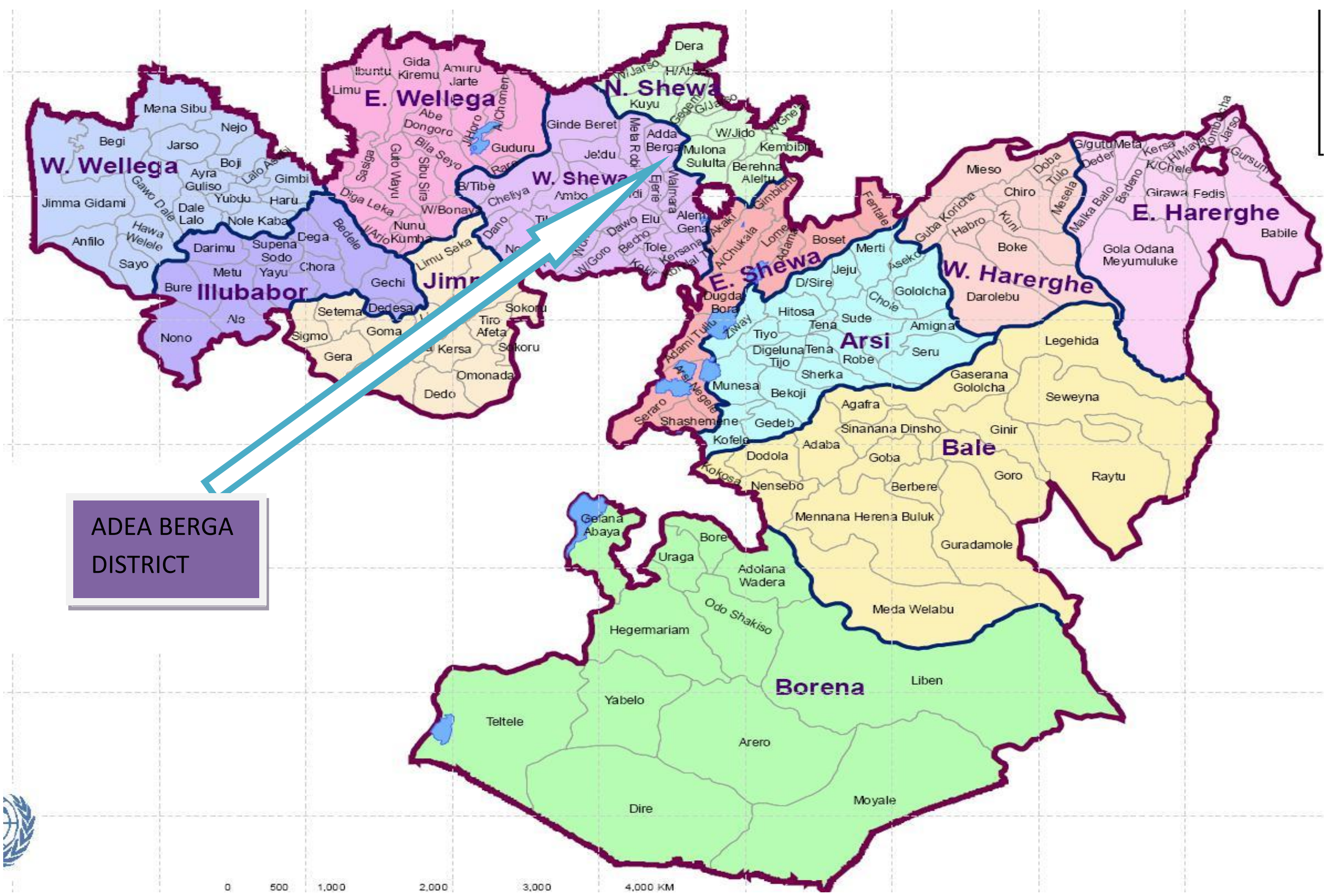

Figure 1 Location of AdeaBerga District from Oromia Regional state Map

The district classified in to three agro-climatic zones namely Dega 29%, Woynadega 34% and Kola 37% with average temperature of 10-25^{o}C and annual rainfall 918-1450mm rainfall pattern. It is located at an elevation of 1371-3169 meters above sea level (AdeaBerga District Agricultural Office, 2010).

AdeaBerga district has a total area of about 79,835 hectare. Of this land irrigated land is about 1669ha. The average land used for vegetable crops in the district is 1300 hectares. The district crop production data shows that the total area allocated to potato production in 20114/2015 was estimated to be 899ha and total production for rainy season and for irrigation was 50,402qt and 9,456qt respectively.

4.1.2 Experimental set up and design

To compare the traditional planting density practices used by the farmers and recommended planting density for improved cultivar Gudane, Five farmers who use their own planting density practices of the improved cultivar Gudane were selected from mid altitude areas of potato growers at the district.

To compare the planting density used by the farmers and the recommended planting density, replicated plots of Gudane adjacent to farmer's plots were planted with recommended planting density in three replications. Furthermore, Local variety was planted in three replicated plots using recommended rate to evaluate the performance difference between Gudane and Local variety under similar planting density.

4.1.3 Experimental procedure

All field experimental plots were uniformly managed to avoid variation except planting density. Each plot had a size of 9m^2 (3m x 3m) and the space between plants for recommended plant density was 30 cm and between rows was 70cm. The distance of 50cm was maintained between plots. Well sprouted uniform tuber seeds were planted.

The plant densities and row spacing used were:

Farmer 1= 51282 plants with spacing of 30cm x 65cm

Farmer 2= 55554 plants with spacing of 30cm x 60cm

Farmer 3= 57140 plants with spacing of 25cm x 70cm

Farmer 4= 59540 plants with spacing of 25cm x 65cm

Farmer 5= 63332 plants with spacing of 20cm x 78cm

Recommended plant density for Local and Improved=47619 plants with spacing of 30cm x 70cm

In order to asses farmers adoption of improved agronomic practices such as planting density, group discussion was held with farmers to collect information about their experience on why they deviate from recommended planting density.

Cultivars used

1. Potato variety Gudane was used for the experiment since it is one of the potential potato cultivars in the district that is used by potato growers.
2. Local Variety was used to compare genotype difference since it was used by farmers in the district.

4.1.4 DataCollected

Sample collection was conducted from each farmer's field using quadrant sampling 3m X 3m. Three replicated different samples were collected randomly from each farmer's field.

The following data were collected

- Leaf number per plant: Total number of leaves counted from each potato plant in the plot
- Branch number : Total number of primary branches counted from each potato plant in the plot
- Number of tuber per plant : Immediately after harvesting total number of tubers counted from each potato plant in the plot
- Tuber size : All tuber were measured its size in centimeter (cm) unit from each potato plant in the plot
- Tuber yield in qt/ha: All harvested tuber of potato from each potato plant in the plot measured in kg and changed to hectare and quintal.
- Marketable yield: number of tubers counted from each potato plant in the plot that the size was greater than 30 cm.

4.1.5 Statistical analysis

The data collected were summarized and entered into Excel spreadsheets and the analysis was conducted by using t-test. In addition, farmers view on planting density and potato yield were summarized and analyzed using descriptive statistics. In order to determine the degree of association between plant density and agronomic data collected, Spearman correlation coefficient was calculated using SAS proccorr procedure (SAS, 2009).

Part II Field Survey

4.2 Data collection and methodology

Data on input supply chains and service provision were gathered using checklist and questionnaire prepared for stake holders involved in potato production and input suppliers.

4.2.1 Source and Method of Data Collection

The data were collected from different sources; both secondary and primary data sources were considered. Data were collected through questionnaire from actors such as farmers, traders (wholesalers and retailers), consumers and support providers (Research, Agricultural office and NGOs). For each actor a separate questionnaire was prepared. The primary data were collected from individual interview using pre-tested questionnaire and checklist. The primary data for this study were collected from 54 randomly selected potato producer households from five kebeles that LIVES project focus on, 3 potato seed producing farmers, 3 NGO (World Vision, OSRA and LIVES).

For the selected five kebele's, Focused Group Discussions(FGDs)interview of farmers were conducted to collect primary information on production, input supply chains and post harvest handing issues. Data from this source were focused on inputs sources and constraints. In the 5 Kebeles that "LIVES" project focus on, two FGDs gender based of 10-12 farmers per kebele were considered for the interview.

The secondary data sources were Agricultural Office, NGO and cooperative unions were interviewed for input data such as seed, fertilizer, pesticides and herbicide for potato farming. Visits to farms during farming and post harvest activities by farmers were made to observe the practices of harvesting and post harvest activities.

4.2.2 Data Analysis

The data collected from different sources were coded and entered into SPSS and Excel spreadsheets for analysis. Descriptive statistics were used to analyze and present the data. Mapping and analysis of supply chain were also conducted to discern the roles and functions of actors along the chain.

5. RESULT AND DISCUSSION

5.1 Tuber Yield Responses Of Gudane And Local Varieties Planted At The Same Plant Density

This study was conducted in order to examine whether potato performance and production under farmers traditional practice of plant population density is different from recommended plant population density on released potato variety of Gudane. Hence, the effect of farmer's practice of population density versus recommended population of Gudane was analyzed for agronomic traits and yield of potato. Further genotype difference between Gudane and Local variety was compared that were planted using recommended population density. Generally the results of this experiment indicated that when Gudane planted using recommended plant density (47619/ha) showed better performance for most agronomic traits considered than farmers traditional practice of plant density particularly to dense planting (63332/ha). Moreover, the productivity of Gudane was highest using recommended plant density as compared to farmer's plant density practice.

Table1.LSD Comparison between mean yields of the treatments

Treatments	Mean Yield qt/ha	Difference from control	LSD value	
			5%	1%
1	480	115.5	80.08**	107.8
2	450	145.5	75.08**	101.1
3	396	199.5	66.07**	8.00
4	402	193.5	67.07**	90.35
5	384	211.5	64.07*	8.3
6	361	234.5	60.04*	81.13
Control	595.5	-	-	-

** = significant at 1% level *= significant at 5% level

5.2 Effects of plant density on agronomic traits

5.2.1 Leaf number

Plant population density differences showed significant differences on leaf number of Gudane (table 2). The result showed that the highest leaf number 82.8 was recorded from recommended plant density of improved cultivar Gudane. A t-test also showed that Gudane under recommended plant density was significantly different from all other farmer plant density practices considered. Similarly, Gudane had significantly higher leaf number than local variety. Under dense plant density, 59540/ha and 63332/ha of Gudane, leaf number was not significantly different from Local variety that is planted in recommended rate of 47619/ha (Table 2). This result suggests that density strongly influences leaf number.

Table2. t-test and standard deviation for the effect of plant density on leaf number

Potato variety	Plant density/ha	Mean leaf no./plant	Standard deviation
Gudane	51282	74.53ab	2.2
Gudane	55554	75.8ab	0.91
Gudane	57140	69.6b	1.4
Gudane	59540	69.46b	1.1
Gudane	63332	69.86b	0.8
Gudane	47619 (Recommended population density)	81.86a	2.2
Local Variety	47619 (Recommended population density)	70.4ab	1.15

5.2.2 Branch number

Generally, the result of this experiment showed an increase of branch number as plant population decreases from 63332.3 to 55554 per ha under the farmers field. However, using lower plant density as in recommended plant density on Gudane exhibited highest branch number 7.7. In addition, branch number of Gudane at recommended plant density was significantly higher than only to dense planting 63332/ha. Branch number of Gudane was also significantly higher than Local under recommended population density (Table 3).This result might suggests that branch number is affected when planting density becomes more than 63332.2/ha.

It is known that under more intensive competitive conditions like those experienced at the highest density level, there is an earlier on set of inter plant competition for growth resources such as light, water and nutrients, this resulted in a decrease in relative growth rate (Thornton et al., 2007). Limited space for root and tuber expansion consequently reduced branch number and development at the higher density spacing levels.

Table 3: Standard deviation and t-test for the effect of plant density on branch number per plant

Potato variety	Plant density/ha	Mean Branch no per plant	Standard deviation
Gudane	51282	6.7ab	1.5
Gudane	55554	7.2ab	1.7
Gudane	57140	5.7b	2
Gudane	59540	6.3ab	1.7
Gudane	63332	5.7b	0.1
Gudane	47619 (Recommended population density)	7.7a	0.8
Local Variety	47619 (Recommended population density)	6.3ab	1.3

5.2.3. Number of tuber per plant

Higher number of tubers per plant 5.9 was obtained from recommended plant density of Gudane, whereas lowest total number of tubers per plant 4.2 was recorded at recommended plant density of Local cultivar. Number of tuber per plant of Gudane planted with recommended plant density 47619/ha was significantly different from farmers practice of planting with high density 63332.2/ha. Therefore, in wider spacing such as at recommended rate for Gudane tuber number will be maximized, due to minimum competition among plants for space and resources that would increase number of tuber per plant. In similar manner Getachew et al., (2012) indicated that wider intra row spacing produced maximum tuber number per plant.

Supporting the results, study by Gulluoglu&Arioglu, (2009) indicated space availability has an imposing effect on number of tubers formed i.e. the greater the space, the higher the number of tubers formed.

Table 4: Standard deviation and t-test for the effect of plant density on Number of tuber per plant

Potato variety	Plant density/ha	Mean Number of tuber/plant	Standard deviation
Gudane	51282	5.3ab	1.4
Gudane	55554	5ab	1.4
Gudane	57140	4.4b	1.1
Gudane	59540	5.1ab	1.6
Gudane	63332	4.3b	0.4
Gudane	47619(Recommended population density)	5.9a	0.6
Local Variety	47619 (Recommended population density	4.2b	1

5.2.4. Tuber size

Tuber size of Gudane (22.7cm) was highest under plant density of 57140/ha that was also significantly different from recommended plant density of 47619/ha (20.7cm). Similarly tuber size Gudane under plant density of 57140 was significantly different from Local variety planted using recommended plant density 47619/ha. Furthermore, this result indicated that tuber size was more affected by plant density than genotype differences between Gudane and Local variety.

Table 5: Standard deviation and t-test for the effect of plant density on tuber size

Potato variety	Plant density/ha	Mean Tuber size (cm)	Standard deviation
Gudane	51282	20.8ab	1.6
Gudane	55554	17.9ab	3.7
Gudane	57140	22.7a	1.7
Gudane	59540	21ab	1
Gudane	63332	20.4ab	1.6
Gudane	47619 (Recommended population density)	20.7ab	0.2
Local variety	47619 (Recommended population density)	18.4c	2.1

5.2.5. Tuber yield

This study indicated plant density influenced tuber yield. Recommended plant density has given highest yield (595.5qt/ha) as compared to other plant densities practiced by farmers. However, this result do not agree with previous studies result that indicated in wider intra row spacing yield per hectare was reduced due to insufficient number of plants grown per hectare (Getachew et al., 2012; Mahamoodbad et al., 2011; Zamil et al., 2010). The optimum plant density identified for Gudane was 47619 plants/ha, so that this density might have gave sufficient number of plants to produce maximum tuber yield.

Among considered farmers practice of plant density, plant density (51282plant /ha) gave high yield (480qt/ha) followed by plant density (55554plant /ha) that gave (450qt/ha), while more dense plant density planting (59540plant/ha) and (63332plant/ha) gave low yield (402) and (384) respectively.

The result of this study indicated that potato tuber yield depends on plant density which influences plant to plant competition for available water and nutrients. According to previous reports, decrease the spacing between plants or increase plants density more than desirable affects crop yields, due to increased competition between the plants so that plants will reduce the amount of dry matter (Zamil et al., 2010).

Generally farmers that practiced Gudane variety with high plant population had lower yields than Gudane variety with optimum plant density had the highest potato tuber yields. In line to this Bussan et al., (2007) recommended that, in order to maximize yield performance in potatoes, it is recommended that specific seed sizes should be planted at specific plant population densities. This suggests that the degree of yield depends on response to optimum plant populations

Table 6: Standard deviation and t-test for the effect of plant density on tuber yield

Potato variety	Plant density/ha	Mean tuber yield (qt/ha)	Standard deviation
Gudane	51282	480b	2
Gudane	55554	450c	3.5
Gudane	57140	396d	5.3
Gudane	59540	402d	7.2
Gudane	63332	384d	1.6
Gudane	47619 (Recommended population density)	595.5a	2
Local variety	47619 (Recommended population density)	361d	2.04

5.2.6. Marketable yield

The present study showed that marketable yield was influenced by planting density (Table 7). When comparing farmer's practice of plant density with recommended plant density on marketable yield, marketable yield (592.5qt/Ha) was higher when Gudane planted according to recommended density than farmers practice. However, marketable yield (357.5qt/ha) of Local variety was lower than Gudane (592.5qt/Ha) when both planted using recommended density. Similar to tuber yield marketable yield was also lower when Gudane planted in increased plant density, for example in farmers plot where plant density was 63332plant/ha marketable yield was 378qt/ha. Generally the result of this study indicated that highest marketable yield recorded at optimum spacing was attributed to more tubers produced at desirable plant population per hectare.

Table 7: Standard deviation and t-test for the effect of plant density on marketable yield

Potato variety	Plant density/ha	Mean marketable yield qt/ha	Standard Deviation
Gudane	51282	474.5b	2.3
Gudane	55554	444c	4.8
Gudane	57140	390.5d	5.9
Gudane	59540	395.5d	7.4
Gudane	63332	378d	0.6
Gudane	47619(Recommended population density)	592.5a	0.49
Local variety	47619(Recommended population density)	357.5d	0.95

In terms of marketable yield the result showed that increasing plant population decreases marketable yield that is attributed to smaller tuber size. This indicates that at wider intra row spacing the presence of minimum competition, plants might have absorbed the available recourses and intercepted more light. Hence, this might have increased their photosynthetic efficiency for higher photo assimilate production and ultimately resulted in increased more marketable tuber yield (Tesfaye*etal*.2010). Similarly Dwelle and Love (1993) concluded that in closer intra row spacing bulking rate of individual tubers decrease and this resulted in smaller tubers and lower marketable tuber yield .In contrast at narrower intra row spacing there is high competition among plants for resources and leads to small size tuber which is undesirable on market.

5.3 Association Of Population Density With Agronomic And Yield Traits Of Potato

The present study showed significant and negative correlations between population density with agronomic traits considered and potato yield. For example population density was negatively correlated with marketable yield (-0.92) followed by with total yield (-0.92) and with tuber number (-0.89). However, Population density was not significantly correlated with tuber size. This result indicated that around the sample area level of plant population significantly affect agronomic traits which bring to final yield. Increase in plant density inversely proportional to leaf number, branch number, tuber number, tuber yield and marketable yield but not tuber size of potato.

Table 8. Pearson correlation coefficients between population density and agronomic traits

Agronomic traits							
	PD	LN	BN	TN	TS	TY	MY
PD		-0.87*	-0.82*	-0.89*	0.043ns	-0.92**	-0.92**
LN			0.94**	0.88*	-0.38ns	0.97**	0.97**
BN				0.91*	-0.54ns	0.89*	0.89*
TN					-0.21ns	0.94**	0.94**
TS						-0.17ns	-0.17ns
TY							0.99**

NB * and ** indicates significance at 5% and 1% probability level where as ns indicates non significance.

5.4 Farmers Response To The Effect Of Population Density On Tuber Yield

In order to assess farmer's perception of potato plant density on tuber yield, group of farmers were requested to identify the performance of recommended potato plant density over farmer's practices ofplant density. In general the farmers view analysis indicated that plots that are planted according to recommended plant density were better than farmer's practice of traditional planting density. However, farmers were reluctant to practice the application of recommended plant density. As explained by framers, they were reluctant due to extra time incurred and human power utilization in order to apply according to recommended plant density.

Farmers have identified the following areas of benefits by comparing recommended plant density to farmer's traditional potato plant population during group discussion.

1. Cultural practice differences: - Yield from plots planted with recommended plant population had better yield than farmer's traditional planting density that was due to cultural management differences.
2. Plant density: - Furrow irrigation is the principal water source during off season, in order to reduce water speed down the slope, farmers use narrower row spacing.

Finally farmers were asked on their view if they are going to use planting density for Gudane as per recommended planting density. As a result, 78.6% of the respondents told that they are convinced by the differences and would like to use recommended potato plant population for the future, while the rest 21.4% respondents were either not convinced or could not identify differences between plots with different plant population.

5.5 Socioeconomic Characteristics of Potato Producers

The demographic and socioeconomic characteristics of the sample respondents characterizing potato production presented in Table 8. The total sample size of farmer respondents handled during the study was 54 (18.5% female). This may indicate that the majority of potato producers were male headed household taking part in crop production & management activities in the district.

The descriptive analysis indicated that the respondents were different in age, farming experience, family size, total land holdings and educational level (Table 9). Male headed households had almost similar farming experience (20.7 years) compared with farming experience of female headed households (21.2years). This indicates that both male and female headed households have similar experience on potato production and they are around the same positioned in adopting new technologies. A study conducted by Ayelech (2011) indicated that farmers with longer farming experience are expected to be more knowledgeable, skillful and more successful in their production. Abraham (2013) indicated that farming experience and the amount of supply have positive relationship with vegetable production. Thus, farming experience is expected to have positive relation with input supply of potato in the study areas.

Table: 9. Demographic & socioeconomic characteristics of producers (categorical variables)

Variables	Attributes	Total (N=54)		χ2-test
		N	%	
Sex	Female	10	18.5	0.27
	Male	44	81.5	
Education level	Illiterate	5	9.3	0.45
	Literate	49	90.7	
Marital status	Married	44	81.5	0.92
	Unmarried	3	5.6	
	Divorced	4	7.4	
	Widowed	3	5.6	

Chi-square analysis showed that there is significant variation among the producers with Demographic & socioeconomic characteristics of producers (sex, educational level and marital status). This variation leads producers a gap on production in terms of using modern technology, effort on agronomic activity and skill. The average households head age was 47.22 years with an average family size of six (Table 10).

Table 10: Demographic & socioeconomic characteristics of producers (continuous variables)

Variables	Male respondents		Female respondents		t-test
	Mean	SD	Mean	SD	
Age (years)	46.75	7.2	49.3	7.0	-3.98*
Family size (number)	5.9	1.50	5	2	-2.65*
Experience (years)	20.7	8.3	21.1	6.1	-4.32*

Note: * is statistically significant at 5% probability levels and SD is standard deviation.
Source: Own computation from survey result, 2015

There is significant difference among respondent in family size and farm experience on potato production. This could lead to differences in production performances of households, as the cultivation of potato requires labor. The results also revealed that male and female headed households differ in family size. On average, male headed households have relatively larger family sizes (5.93) than the female counterpart (5.0). Because the availability of labor determines the timely land preparation and other farming practices, under such circumstance it is expected that the performance of male households in potato farming is higher than female headed households.

About 5.56 percent and 3.7 percent of sample male and female headed households did not have formal education. The male headed households are characterized by more proportion in attending higher level formal education (grade 9) than the female (grade 7) counterparts. These differences could affect their capacity and willingness to adopt improved varieties, as it affects their communication skill and understanding of pertinent information and technology important for the sub sector.

Based on the survey result, the average land holding of the sample households was found to be 3.45 hectares with standard deviation of 0.56. The mean crop land of sample potato producer was 2.75 ha. In the year 2014/15, the mean average irrigable land of sample household was 0.38 ha. Land used for potato by all respondents during the survey year was 30.25 hectares with variety separation Gudane got 62.8% while the remaining 29.8 %, 5.9 %, and 1.7% covered by the varieties Jalene, Menagesha and Belete respectively.

Traders play crucial role in potato supply chain in the area by facilitating potato transaction through linking producers with retailers, a wholesaler with another wholesaler, and producers with consumers and wholesalers with retailers. Retailers were the key actors in potato supply chain in the district. They are the last link between producers and consumers. They mostly buy from wholesalers and sell to the product in smaller quantities to the urban consumers. They have business experience ranging from 5 to 23 years with an average experience of 14 years. The retailers engaged in potato trading for an average of 6 months per year though they also trade other vegetables to diversify their business. Sometimes they could also directly buy from the producers. Consumers buy the product from producers and retailers as they offer according to requirement and purchasing power of the buyers. During the market visit, it was observed that retailers carry small amount of potato compared to beet root, onions and other vegetables.

Livelihood Mechanisms of Local Communities

Data from district agricultural office shows that in the year 2014/15, the average land used for vegetable crops in the district is 1300 hectares. During the survey year overall land under potato was 899 hectares. But, major cereal crops like teff, barley, wheat, maize and pulses like bean and lentil were dominantly grown on the farm of the households in the district. Livestock rearing is another important income generating source that almost all the sample households were engaged. The mean number of oxen holding was 3.11with standard deviation of 0.81which is relatively smaller compared to the large land holding allocated for farming purpose, the average livestock holding and continuous expansion of crop land.

The results indicated that farmers in the study district travel 24 minutes on average to reach their farm plots whereas, on average they travel about 33.7 minute to access market place. Travel time and access to market place could affect their benefit that they can get from the potato farming since farmers whose their home was nearest to farm area, market and development centers.

Table: 11.Average travel distance in minutes to farm area, market and development centers.

Access points	Minimum	Maximum	Mean	Standard deviation
Farm area	5	40	24	8.8
Market (nearest)	10	60	37.7	11
Farmers Training Center	5	40	23.6	10

Agricultural development office provides agricultural extension services to farmers through development agents. For instance, agriculture offices provide advisory service on modern technologies like use of improved seed, input level, access to inputs, production management and provide technical support in crop protection of agricultural products. These awareness creation activities usually provided at farmers training centers. However, the farmers should walk 23.6 minutes on average to reach this center.

5.7 Potato Production in the Study Area

5.7.1 Crops Mainly Produced and Rank of Importance

The crops grown in the study area include: cereals, potato, garlic, pepper, beet root, cabbage, and onion. Few households (22.2 %) also engaged in fruit production such as the cultivation of apple, orange and lemon. The local communities also involved in planting of trees around their homestead, particularly *Eucylptusgloblus* to generate income and diversify their livelihood means.

5.7.2 Criteria Used To Rank the Varieties

Different varieties of potato used in the study area. Among criteria used to prioritize the potato varieties majority of sample households farmers rank Gudane variety first and very few of them (3.85%) rank second in terms of productivity, market value, maturity period, perish ability, low input usage and disease tolerance

92.4% of sample household ranked Jalene variety second in terms of productivity, market value, low input usage and less time to maturity while 3.6 ranked third in terms of less perishable.

86.7% of sample household rank Belete variety first in terms of productivity and disease tolerance. In terms of market value 100% of them rank Belete variety first. On variety Menagesha, interviewer rank fourth in all criteria except low in input usage. This result shows that above half interviewer rank the varieties familiarized before as first and second like Jalene, Gudane and Menagesha than newly introduced variety like Belete. The reason was Belete variety was not familiarized to the area widely up to the time of survey.

Table: 12Criteria Used To Rank the Varieties

Criteria	Verities												
	Gudene			Jalene			Belete				Menagesha		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Yield performance	50	2	2		52	2	2							54
Disease tolerance	50	22			51	2	2							54
Market value	52	2				54	1	25						54
Less time to maturity	3	51		50	2	2		2	50					54
Less requirements of input	16	28	10			54				54	50	2	2	
less perishablity)	50	3	1		40	14		2	50				11	42

NB:-Numbers refers number of replies.

5.7.3 Potato Varieties, Sources and Yield Performance

The dominant potato verities used by farmers are Gudane, Jalene, Menagesha and Belete. On average, Gudane, Menagesha and Belete varieties cover a land area of 0.43, 0.3 and 0.25 ha per household per year, respectively (Table 13). The result indicated that Belete variety was superior in yield (415 qt ha^{-1}) followed by Gudane (337.9 qt ha^{-1}), Jalene (307.3 qt ha^{-1}) and Menagesha (284.3 qt ha^{-1}).

As general local communities concluded ranking Gudane first, Jalene second, Belete third and Menagesha fourth. These above result proportions shows that Gudane, Jalene and Menagesha varieties take time to adopt around sample area staring from 1996 EC (Menagesha variety) up to date and above half of producer familiarize to these varieties. In the reason Belete variety was newly introduced in 2006 EC not only to the sample area but also to the district by Holleta agricultural Research Center. Because of this large number of household did not the performance of the variety.

Table: 13 .Average areas (ha) per crop per year of potato varieties produced in 2014/15

Varieties	Minimum	Maximum	Mean	Range	Standard deviation	Yield(qt/ha)
Gudane	0.25	0.75	0.43	0.5	0.12	337.9
Jalene	0.25	0.5	0.3	0.25	0.1	307.3
Menagesha	0.25	0.25	0.25	0.25	0.25	284.3
Belete	0.25	0.25	0.25	0.25	0.25	415

The respondents mentioned that they obtain seeds of potato varieties from research centers, market and from NGOs. For example, 67% of the respondents mentioned that they got Jalene from research centers whereas 27 and 7% of the respondents obtained from market and NGOs respectively.

Potato seed producers in the highlands of Ethiopia are supported by Ethiopian Institute of Agricultural Research (EIAR), and the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) (Medhin G, et al, 2001). These organizations have formed a monitoring and evaluation body to supervise seed production in Ethiopia, which is recognized by the Ethiopian government.

Potato in the study district is produced in rain fed and irrigation scheme. Major productions come from rain fed and irrigation in the district. From sampled respondents about (61%) them produce in both rain fed and irrigation seasons whereas 38.8% of them produce only under irrigation. Study by Bekele and Eshetu (2008) reported that potato growers in Ethiopia usually produce potato in offseason despite the high potential yield in longer of rainy seasons. The result also shows amount of seed and labour used for rain fed were medium when compared to irrigation. This shows high amount of labour needed for irrigation because making water way, ploughing, making fens in order to keep livestock from irrigated area, watering plants in program more in rain fed activities. For irrigation production more seeds were used (16.72qt/ha) than rain fed production (16.06 qt/ha). As respondents viewed their idea they think as narrowly sawing was slow water speed otherwise the irrigation water till out the plant since the land is watering with furrow irrigation.

Most of respondents use fertilizer and pesticide in rain fed season than irrigation. They have fewer tendencies to use fertilizer because they think irrigation land is relatively fertile for it is filled with soils that come from river at summer time and it is a means avoid the high price of inorganic fertilizer. Though Paraquat and propanil are the important herbicides used for weed control in potato (Walia, 2003), all producers in the study district didn't use herbicide because as potato cultivated more than twice there were no dangers of weeds especially in irrigation. Even if weeds appear they weeding by hand either for lack of herbicides adopted around study area and high cost to acquire from central market Addis Ababa. Most of them used pesticides for pre harvest diseases. It used highly on rain fed than irrigation.

Production Purpose

Potato producers use their product for different purposes. About 75% of Gudane variety users produce for sell and use the remainder for own consumption. Producers of Jalene and Menagesha sell 50% of their production whereas 100% of Belete variety users produce potato for market as seed.

5.7.4 Comparison of Preference for Improved and Local Planting Material

Almost all (98.3%) respondents mentioned that the productivity and disease tolerance of local variety was low when compared to improved varieties. The majority (93.6%) of respondents also mentioned that improved varieties have better market value than local verities. Further, improved varieties require less time to mature and give high yield.

5.8 Production Activities and Input Requirements for Potato Farming In the Area

5.8.1 Input Requirements

Bulkiness of potato planting material was the major bottleneck for propagation. Similarly, this made its dissemination expensive compared to other vegetables. In the study area, the analysis shows that sample producers use 16.06 quintals of potato tuber seed per hectare of land during rain fed production and 16.72 quintals in irrigation (Table 14).

The mean fertilizer rate applied by sample growers was 1.39 quintals per hectare for rain fed and 1 quintal for irrigation season. The average price (birr/qt) of potato seeds of Gudane, Jalene and Menagesha varieties was 625 birr while that Belete 1900 birr/qt. The price of fertilizer was 1400 (DAP) and 1355 (Urea) birr per quintal in the year 2014/15 (A/Berga District Cooperative Office 2014).

Not all the producers but most of them used pesticide for potato pre harvest disease. The average cost of this pesticide was 760 birr for one kilogram at Addis.

Knapsack (Herbicide Sprayer) was supplied by private traders and a small number of farmers bought it and they rent per amount of pesticide applied. This sprayer cost was 4000 birr in Addis in 2014/15.

Table: 14 Input requirements for potato farming in the area

S/N	Inputs used	Rain fed (main Season)		Irrigation	
		Amount /ha	Price(birr) per unit	Amount/ha	Price(birr) per unit
1	Seed (kg)	16.06	631.25	16.72	600.00
2	Fertilize (kg)	1.39	1400	1	1452
4	Pesticide(kg)	1	760		
6	Knapsack (Herbicide Sprayer) (number)	1	4000		

5.8.2 Major Problems in Potato Farming

The most important problems that hindered further potato production in the study district include high input cost (unaffordable price of clean newly released potato seed tubers), pre harvest disease, postharvest disease, problem of storage pests, lack of modern storage, problem of unavailability of transport means (in time and capacity) and shortage of seed supply that for the reason that of high input cost when compared to improved seed demand. The findings indicated that all of the respondents faced problems of pre harvest disease and unavailability of transport means.

Majority (61.1%) of the respondents have problems of storage pests and absence of modern storage of potato after harvesting, while 83.3% have a problem of high input costs whereas 88.8% and 33.3% of them faced pre harvest diseases and problem of postharvest spoilage due to ageing and mechanical damage respectively. Postharvest losses generally occur due to improper use of storing and transportation from farm area to storage and markets. Storage losses due to pests such as rodents and the potato tuber moth are most common. At low land (ranging from 2000masl up to 2880masl), the potato tuber moth prevents seed from being saved and used in subsequent production seasons. This leads to low market value from production in the season.

The result indicated that, there were no problems in access to credit around sample kebeles. But the major problem on quality input was high cost. Sample households took credits from different credit institutions like Microfinance and cooperatives for various purposes. These institutions office were found at Incinni town and they have facilitators who join farmers at village with the institution. The results indicated that 6% sample farmers in the study district took credit from Cooperatives. Others deviated to took credit because of they didn't need not the problem of accessibility. Sample households, used the money for the purchase of farm inputs like improved seeds, fertilizers (Urea and DAP), chemicals (pesticides and herbicides) and farm implements for potato and other crop production, whereas others used to purchase livestock such as goats, sheep, and cow either for fattening or to increase the number of livestock to generate income from sell of the animals and their products.

In addition, data from Farmers' Focus Group Discussion (FGD) interview showed that the shortage of extension service there is no specialized extension services for potato growers except that potato is considered as just one of the vegetables. Application of knowledge of general agriculture is not sufficient for potato production especially kebele's that far from the district because kebele's that near to the district get advisory service from different supporting organizations.

5.8.3 Market for Potato

The results indicated that the common market where products sold around sample kebeles were Inchini and Mugher markets. The mean walking distance in to each market was 45 minutes one way walk with standard deviation of 11.08 to Inchini market and 60 minutes one way walk with standard deviation of 11.98 of Mugher market (table 15).

Table 15: Average producer price (Birr/qt), walking time (min) in different market and participants preferences to buyers and reasons in 2014/15

Market	Average Selling Price/ qt	SD	Walking time (min)	Stand. Deviation	Proportion of participants	Buyers at each market	Buyers Preference	Reasons to prefer buyers
Inchini	654.6	46.2	45	11.08	54%	Consumer, Retailers, Wholesalers	Retailers, Wholesalers	better price, paying in cash,
Mugher	625	36.9	60	11.98	46%	Consumer, Retailers, Wholesalers	Consumer, Retailers	Better price, sustainable relation in the business,

Source: Computed from producers' survey 2015

Prices of agricultural products have peculiar nature where the prices drastically drop at harvest time and increase substantially during planting time. For potato the price variability between harvest and planting is very high due to perishability of the product and shortage/lack of modern storage facilities. The potato price fluctuation is very high in the district. During 2014/15, the potato price at which the farmers sell ranged from Birr 500 per quintal at the peak harvest time to 800 birr per quintal during the slack season. The price is lower at Mugher, with an average of 625 birr per quintal compared to 654.6 birr per quintal at Inchini market. The price of seed potato is higher than the average ware potato price due to late harvest of the potato seed, period when the quantity of potato supplied to the market started to decrease and the price increases.

Farmer sells most of the ware potato starting from June to September and December to May months they sell seed. According to the respondents the reasons to sell in selected months were cash need from the product, post harvest disease and lack of storage for ware potato, lack of storage and others for seed.

5.8.4 Buyer Preferences

The result from survey indicated that sample farmers prefer firstly NGO to sell their products because of better price than the others, paying in cash, saving time and labour by coming to farm area, sell their products at one time, use their sacks for holding potato and giving training to the producers about production practices. Secondly they prefer wholesalers because of the reasons similar to NGO above except giving training where they do not get this service from cooperatives. Thirdly producers rank wholesalers besides the above reasons they get the benefit of durable relation in business but not get training from these particular buyers. Fourthly they rank retailers in terms of all criteria like wholesalers but durable relation in the business was considered lacking or unreliable from retailers' market relations. Finally they gave last rank position to consumers by all criteria listed above. Over all producers preferred to sell the product to retailers and wholesalers at both markets because others were not continuously coming to market place in the study area.

5.8.5 Reason/S to Prefer Specific Type of Buyer

Potato passes through different channels until it reaches the final consumer in the district. Consumers, retailers, whole sellers, Coop/unions and NGOs are the main potato buyers at this district. Producers' preferred one or more than one buyer/s to sell the product. The reason were better price, paying in cash, sustainable relation in the business, saving their time and labour by coming to farm location, give training, use their sacks and sell all at one time options.

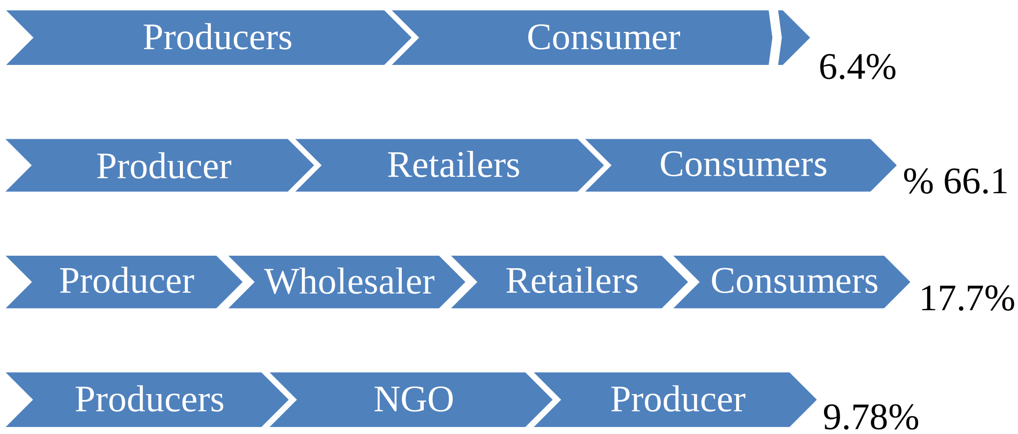

Fig: 2 Potato Supply chains

Source: Own sketch from survey result, 2015

5.9 Potato Seed and Fertilizer Supply Chain

Potato producing farmers in the study area get seed from different sources. For instance, in the district, the majority of the sample producers used their own-supplied seed. It was seen that district sample farmers are more experienced in using their own planting material (72%). This may be attributed to the high cost and unavailability of external sources timely and sufficiently specifically forimproved seeds which forcing farmers to preserve and maintain their own seed. Early in the main season all sample areas have sufficient seed from last season harvest that would be maintained under shade (under bed), local storage and maintain up to planting time to preserve the planting material for next season. Other farmers get seed from markets, exchange potato with other crops from their neighbors.

Survey indicated that around sample district there were no formal and informal potato seed Traders at allbased on information from Office of Trade and Industry. But potato producing farmers buy potato when the price drops drastically at harvest time and store in modern storage in addition to their product in storage.

The demographic and socioeconomic characteristics of the sample respondents (potato input supplying farmers) characterizing input supply chains of potato. The entire input supplier farmers handled during the study was 100 % male. This may indicate that the majority of potato input suppliers were male headed households taking part in input supply chains activities of potato in the district. These farmers do not only buy potato seed from other producers but also produce potato for seed by themselves.

The descriptive analysis indicated that the respondents were different in age, business experience, family size and educational level (Table 16). These producers had almost similar business experience (5.6 years).

Table: 16. Demographic & socioeconomic characteristics of input suppliers (seed potato (seed potato producers and retailers) (categorical variables)

Variables	**Attributes**	**Total (N=3)**		**χ2-test**
		N	%	
Sex	Female			0.36
	Male	3	100	
Education level	Illiterate	1	33.3	0.39
	Literate	2	66.6	
Marital status	Married	2	66.6	
	Unmarried	1	33.3	0.26

The average potato producing for seed head age was 43.3 years with an average family size of 3.2 (Table 17).

Table 17: Demographic & socioeconomic characteristics of input suppliers (seed potato producers and retailers) (continuous variables)

Variables	**Male respondents**		**Female respondents**		**t-test**
	Mean	SD	Mean	SD	
Age (years)	39.6	2.4	45	45	-2.01*
Family size (number)	3	1.2	2	2	-1.14*
Business Experience (years)	5.8	3.5	6.6	6.6	-2.03*

Note: ***** is statistically significant at 5% probability levels and SD is standard deviation.

Source: Own computation from survey result, 2015

As sample survey shows about 66.6 percent sample farmers have formal education (grade 4 up to 10). These retailers are characterized by more proportion in attending higher level formal education (grade 10) counterparts. These differences could affect their capacity and willingness prioritize adopt separate varieties, proper storing method, as it affects their communication skill and understanding of pertinent information flow, affects on their business value and technology.

These producers mostly buy from producers and sell to other producers and retailers by adding price to at the time of planting. These all potato seed supplier farmers were participated in local market. In 2014/15 production season 706 qt (97 qt Belete, 422qt Gudane and 187qt Jalene varieties) of potato seed supplied by these suppliers (figure.2) that take huge percent supply at the district (58%). The suppliers source was 75% own production and 25% others farmers. Locations of source (where they buy from) were B/Dimo and M/Chobotkebele farmers. The buyers (to whom the supplier sells) were Producers (62%), Holeta Research (11%) and Retailers (20%). Locations of these buyers were A/Berga District, M/Robi District, Ejere District and Holeta.

Next Producers buy the seed from these suppliers as they offer according to variety requirement and producing power of the producers. In addition these producers transported their seed potato to the nearby local market and sell it to rural producers and others sell from storage to other producers (figure 4). Producer usually buy seed potatoes a few days before planting. So they didn’t need storage for seed. Traders, Wholesalers and Retailers are key actors in potato seed supply chain in Ethiopia (Hirpa*et al*., 2010). Traders supply different amount and types of inputs to the producers depending on different demographic and socioeconomic characteristics of the household.

Table: 18 Potato seed supplied by district farmers in 2015

Input Supplier	Market participation	Input Type	Unit	Amount supplied for last season	Suppliers (source of the input)
Farmers	Local Market	Seed	Qt	706	-Own Production, -Other Farmers production

The scope of these farmers were getting income from this product by adding cost and change the sack, means they buy ware potato with big sack then store it three to four months in modern storage and sell it with small sacks at time of planting. These sample suppliers supply totally 706 qt of potato seed for different suppliers like producers, GO, NGO and retailers different amount.

There were also input supply actors who are involved in agricultural input supply in the study area (table 19). Currently, primary cooperatives/ union, farmers, NGOs and Government are the main source of input suppliers. They supply inputs for other productions not only specifically for potato.

Non Governmental Organizations like World Vision Ethiopia (WV), Oromo Self Reliance Association (OSRA), Livestock and Irrigation Value-Chains for Ethiopian Smallholders (LIVES) and Governmental Organizations like Holeta Agricultural Centers (HARC) were also participated in such activity (Table 19). All such actors are responsible to supply agricultural inputs like improved seed varieties and fertilizers which are essential inputs at the production stage for potato.

Table: 19. Potato seed and fertilizer supply from different organizations for irrigation and main season to selected kebeles 2015

Name of Organization	Supply for irrigation					Supply for main season				
	Seed (qt)	Variety Type	Source	Fertilizer (qt)	Source	Seed (qt)	Variety Type	Source	Fertilizer (qt)	Source
OSRA	150	Gudane	B/Dimo farmer	1.5	Primary Coop.of A/Berga	148.5	Gudane	B/Dimo farmer	6.5	Primary Coop.of A/Berga
Holeta Research Center						8	Belet	Holeta		
						10	Gudane			
LIVES	10.5	Gudane	B/Dimo farmer	3.5			-			Primary Coop.of A/Berga
World Vision	93	Gudane	Jeldu	4		91	Gudane	B/Dimo farmer	150	Primary Coop.of A/Berga
Total	253.5			9		257.5			156.5	

Source: AdeaBergaworeda Agriculture office 2014/15

Holetta Agricultural Research Centre was the only formal institution that supplied seed potato to farmers in the district. Improved varieties are the backbone of the formal seed industry. The national agricultural research system (NARS) is responsible for variety development and generation of appropriate technologies that can maximize the yield potential of new varieties (EIAR, 2011).

The scope of this Organisation was supplied a small amount of seed potato free of charge to demonstrate and popularize improved potato varieties with its agronomic practice. Therefore, there were no actual prices for institutional seed potato and prices of seed potato obtained from specialized seed potato growers were used as proxies for institution-seed potato prices. After a season this Organisation takes that amount of seed from first farmer and disseminate to other farmers in that district. Research Institution seed is seed potato produced and supplied by a formal institution (EARO, 2004).

AlemuChala, the B/Dimo seed potato grower is one shining example working with this Institution how an innovative grower can adopt new technology and demonstrate his success to other farmers. He produces improved variety like Gudane, Jalene and Belete for seed which was supplied from Holetta Agricultural Research Centre. He has modern storage for storing his product until planting time and sells this product 373qt for different buyers (producers 34.3%, Holeta Research 28.3%, World Vision 12.9% and Retailers 16%).

LIVES project was starts in 2013 in this district for the resource poor households in the target areas being supported to produce high value livestock and irrigated crop commodities. Thescope of this project is to improve competitiveness, sustainability and equity in value chains for selected high value irrigated crop (like potato) commodities in target areas by Supplying of (irrigated) agricultural inputs/services, agro chemicals, fertilizers, seeds, seedlings, grafting materials, Crop spraying services and Storage facilities.

WVE in A/Berga district supports rural resource poor smallholder female headed farmers in case of agriculture. The main scope of WVE supplying input for rural resource poor smallholder females headed farmers.

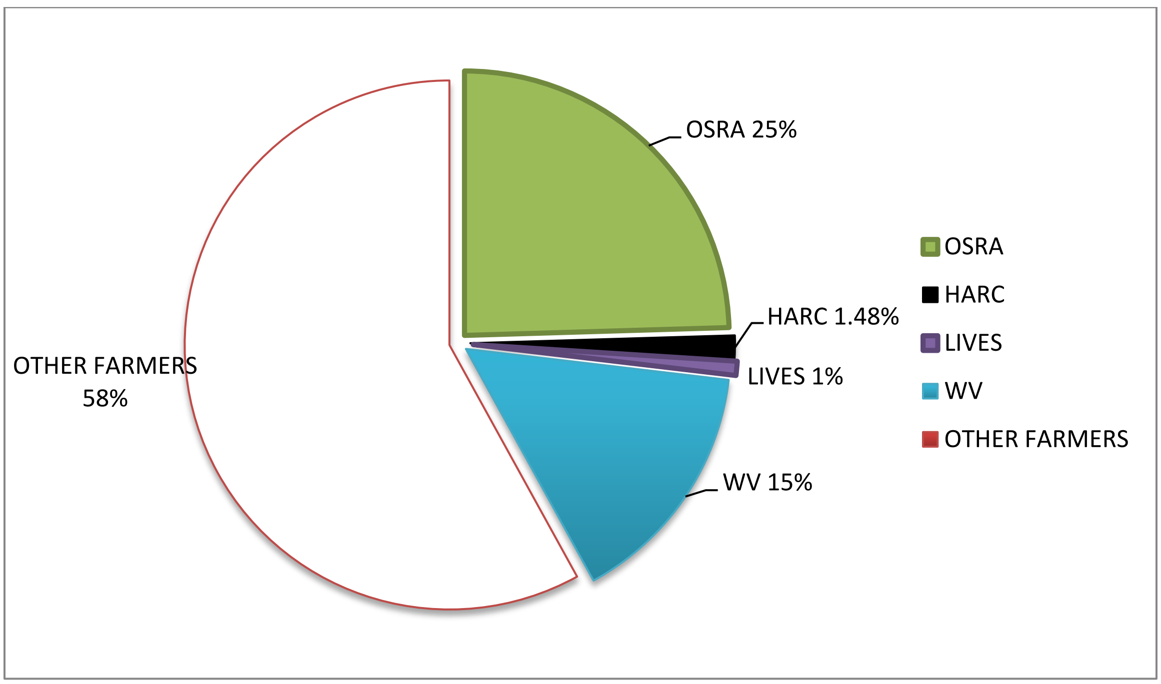

Figure 3. Proportion of potato seed supplied by different sources in the study areas 2014/15
Source: Own sketch from survey result, 2015

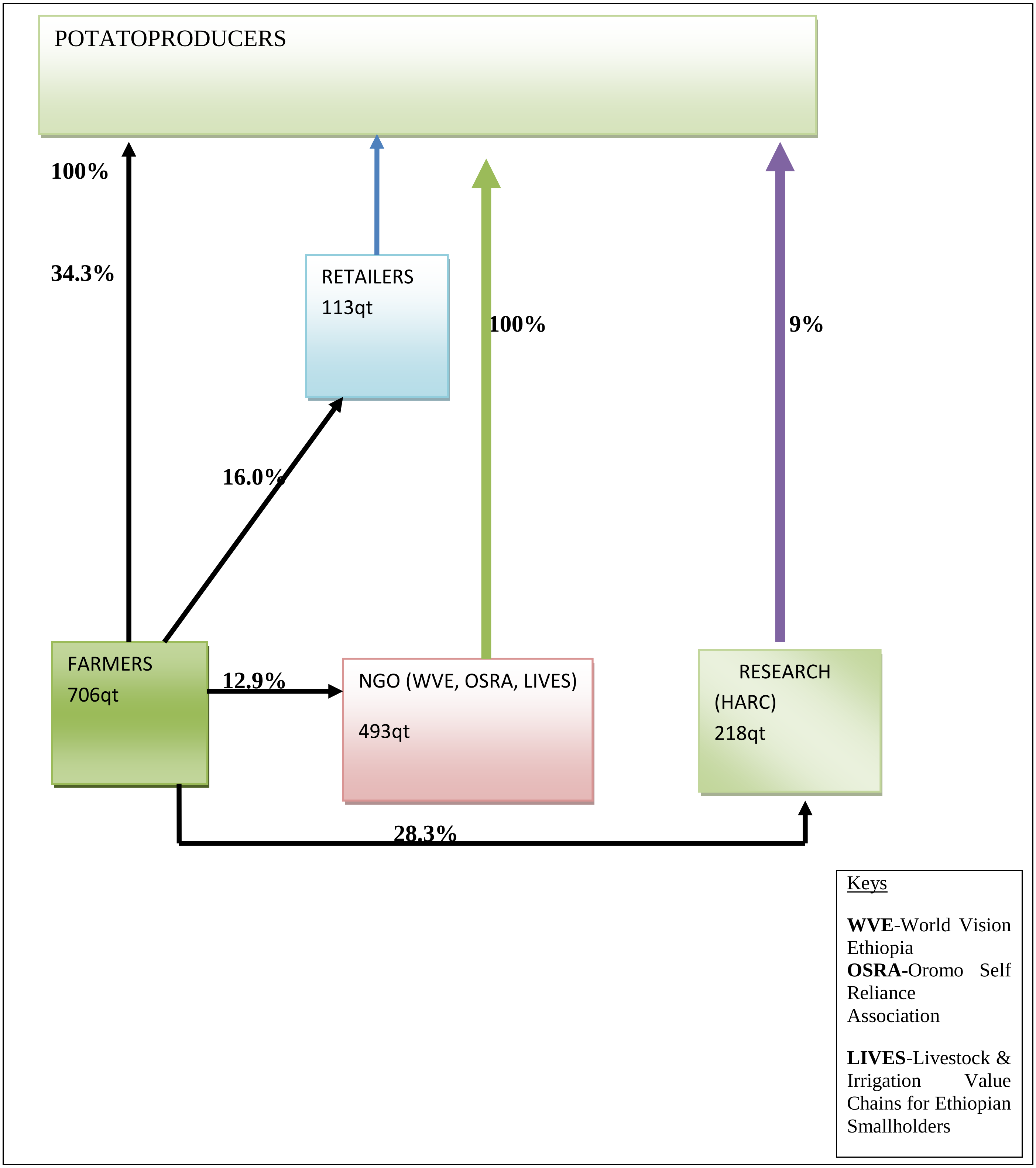

Figure 4: Potato Seed supply chain at the District 2014/15

Source: Own sketch from survey result, 2015

Potato seed supplier farmers were supplied 91.5% for different suppliers (potato producers, retailers, NGOs, Govern Organization) that take huge percent supply at the district (58%). Next to them different NGOs 40.5%, GO (HARC) 1.48 % supply respectively. This shows that these suppliers not fulfill the producer's want.

Regarding fertilizers, some farmers (61%) used only organic fertilizer (manure and compost) while some (13%) farmers used both inorganic and organic fertilizers on rain fed season depending on capacity to buy inorganic fertilizer, distance to homestead, variety type used and the soil fertility status as perceived by the sample farmers. Inorganic fertilizer was supplied by cooperative union directly to the potato producers and middlemen with NGOs. The data taken from District Irrigation Office shows 4,516 quintals of fertilizer (2495qt for rain fed and 2021qt for irrigation) supplied for district farmers. The data taken from vegetable production officer shows 4516 quintals of fertilizer (2495qt for rain fed and 2021qt for irrigation) supplied for district farmers. From this quantity, sample NGO bought only 3.75% and supplied to the producers. Others (96.3%) supplied directly to the producers. This shows that majority of producers bought cash this inorganic fertilizer directly from primary cooperative of the district. In that year Holeta Agricultural Research Center supplied only improved seeds. As a result this Organization advices producer about fertilizer rate and application method not supplying fertilizer with seeds. Pesticides are supplied mostly by private traders. But they didn't supply specific herbicide for potato disease and even if they supply its cost is high. Because of these reasons potato producers buy pesticide from Addis.

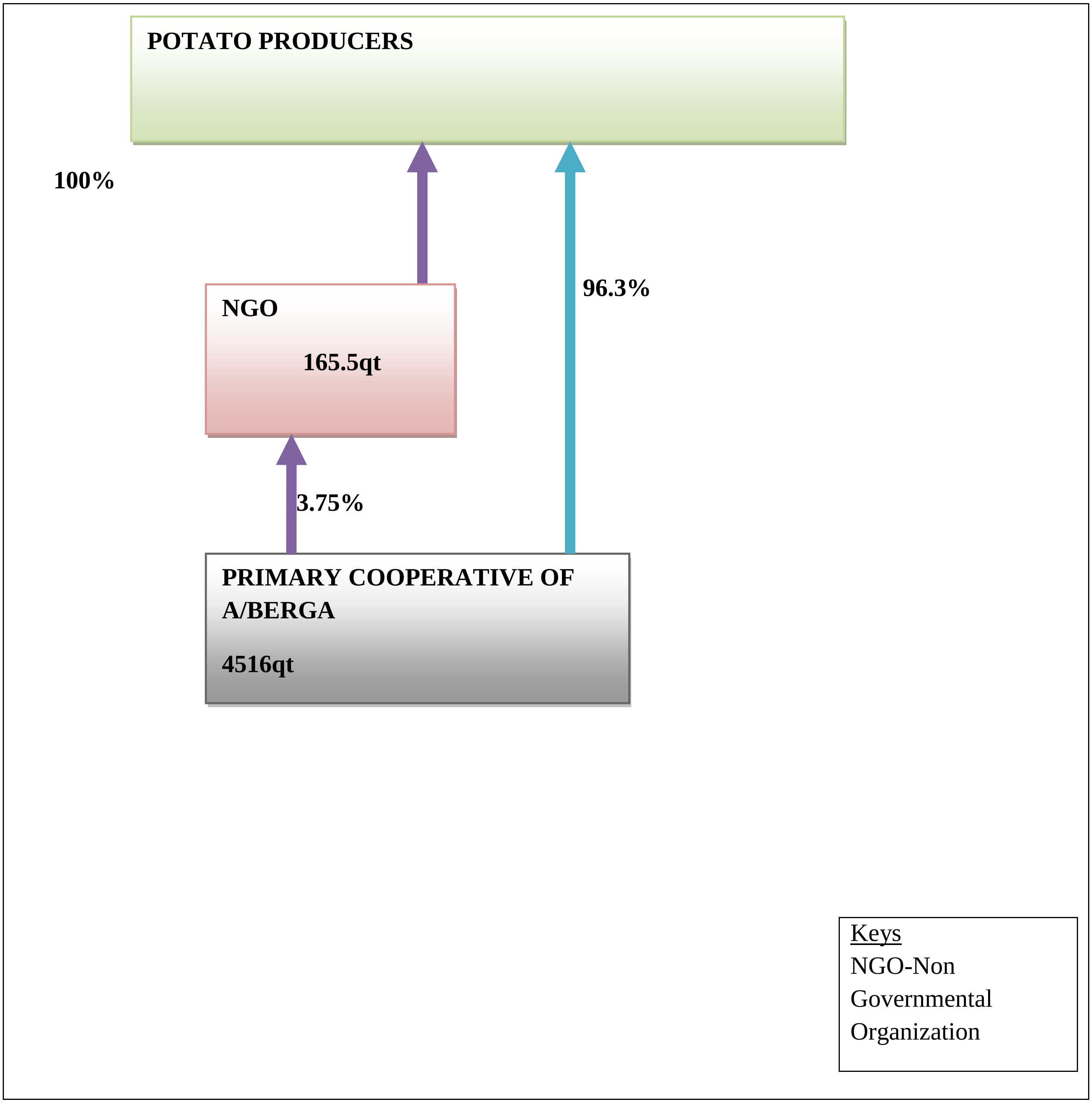

Figure 5: Fertilizer used for potato supply chain at the District 2014/15

Source: Own sketch from survey result, 2015

5.10 The Major Problems of Potato Input Suppliers in the District

The major problem of sample potato seed suppliers around the area mentioned by potato seed supplying farmers were related to the problems in increase price of improved seed, fertilizer and Pesticide, high seed production costs, which leads to potato supplying producers adding price on seed, lack of producers awareness about improved seed to buy and used instead of local variety (knowledge gap regarding improved potato and labour problems), lack of trained workforce. There is a shortage of training program on use if improved variety seeds and production activity specially farmers that are far from the district. There is also problem of transporting material or shortage of farm machineries(basket) that avoids damage of haulm at time of planting. When potato is stored in storage for seeding purpose the haulm appears. At this time it needs care, otherwise it breaks. The sampled suppliers used cartoon to minimize this risk. Postharvest spoilage due to aging and mechanical damages happens from harvest time. Post harvest disease, storage pest like insect pest (red ants), rodents are also other problems.Postharvest losses generally occur due to improper use of storing and transportation from farm area to storage and storage to farm area, markets and other place for production purpose. The mentioned problems are some of the major constraints hindering input supply chains of potato seed of the district.

The suppliers of inputs prefer to buy on farm to avoid or minimize the possibility mixing of varieties and to get advantage of packing in bulk in large sacks for later resell it in smaller sacks. However major problem they encounter is that the road is not conducive for use the accessible transportation means (carts). Other means available include back of donkey and horse but not suitable to transport in bulk. This was in line with the study that found means of transportation in Ethiopia varies among producers depending on the amount of area of production but predominately on pack of animals (donkey) (Mulatu, E et al 2005a).

6 CONCLUSION AND RECOMMENDATION

Firstly the present study showed that optimum plant density positively increased potato tuber yield. This study verified that planting potato using recommended plant density for Gudane 47619plants/ha (30 cm x 70 cm) produced the highest tuber yield due to the high number of tubers initiated and maintained and marketable yield. While increasing plant density beyond the optimum level decreases tuber yield. Furthermore, using local variety followed by planting using similar population as Gudane produced the least potato tuber yield. The differences in yield of demonstration could also be explained by varietal performance differences.

Therefore integration of using improved variety (Gudane) and proper plant density 47619plant/ha (30cmX70cm) can enhance overall potato tuber yield and yield components. This might be due to integration of using improved varieties with recommended plant density encouraged more vegetative growth and development at the expense of reproductive growth of tuber number and potato yield.

Low yield per hectare is one of the most hampering factors that affect potato production. In order to increase crop yield, first, the farmers must be properly trained about improved farming operations usage of improved varieties with recommended packages. This study indicated that farmers were not applying potato production packages particularly plant density, even though they were convinced by production advantages and benefits of applying recommended plant density during the field visit organized and group discussion.
Therefore, to obtain adequate potato tuber yield, potato producing farmers in AdeaBerga district need to be properly trained in order to adopt proper plant population of improved varieties with recommended agronomic practices.

Secondly,study was aimed at analyzing input supply chain of potato. Wholesalers purchase potato from farmers and sell to retailers and consumers. Retailers purchase potato from producers and wholesalers and sell to consumers. As this founding indicated there were no potato input suppliers of Retailers and Wholesalers at all in the district. At this stage Potato input supply chain actors of the study areas are potato producing farmers, Governmental and NGOs.

There are also governmental and nongovernmental supportive actors who support seed potato input supply chain directly or indirectly. Input supply chain supporters provide facilitation tasks like creating awareness, facilitating seed source, credit services. The main supporters of the potato supply chain in the study areas are Governmental and Non Governmental Organizations.

Major problems of the development of potato supply chain are found in all the stages of the chain. At the farm-level, potato producers are faced with high postharvest losses, pre harvest diseases, high input costs like fertilizer, shortage of input and newly improved released seeds. On supplier's side high input costs, low price of product, lack of storage, lack of transport means, post harvest disease, Problem of transporting material (basket), post harvest disease, post harvest spoilage and storage pests are major problems.

The input system is mainly based on informal system where farmer saved seeds are used for own production and supply to other producers. The situation in potato showed that seed supply system heavily relied on farmers' supply that produce both ware potato and seed potato. Public institutes like research centers supplied an insignificant proportion of seed in the district during the study period. Hence, farmers used seed variety which they get access from unreliable sources without alternatives. This input supply chain analysis pinpointed number of opportunities and constraints influencing the development of the subsector in the district. Based on field study in selected study kebeles and reviewing existing literature, in order to fully exploit the opportunities and minimize the outstanding challenges, the following recommendation is drawn.

- Develop capacity and capability of seed producing farmers in seed multiplication, marketing and distribution in order to meet the demand for quality and accessible seed of the study area and beyond;
- Build the capacity of farmers' cooperatives for fertilizer and other chemicals supply and also to engage on potato seed production and marketing.

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