BAHIR DAR UNIVERSITY

COLLEGE OF AGRICUTLUR AND ENVIRONMENTAL SCIENCES

GRADUATE PROGRAM

ASSESSMENT OF GARLIC PRODUCTION PRACTICES AND EFFECTS OF DIFFERENT RATES OF NPS FERTILIZER ON YIELD AND YIELD COMPONENTS OF GARLIC (*ALLIUM SATIVUM* L) UNDER IRRIGATED FARMING SYSTEM IN YILMANA DENSA DISTRICT, AMHARA REGION, ETHIOPIA.

M.Sc. Thesis

By

Shege Getu Yayeh

October 2015

Bahir Dar, Ethiopia

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Shege Getu Yayeh

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (M.Sc.) IN HORTICULTURE

Major Supervisor: Dr. Melkamu Alemayehu

Co-Supervisor: Dr. Amare Haileslassie

October 2015

Bahir Dar, Ethiopia

THESIS APPROVAL SHEET

As a member of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by Mr. Shege Getu Yayeh entitled "Assessment of Garlic production practices and effects of different rates of NPS fertilizer on yield and yield components of garlic (*Allium sativum* L) under irrigated farming system in Yilmana Densa district, Amhara Region, Ethiopia". We here by certify that, the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M.Sc.) in Horticulture.

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DECLARATION

This is to certify that this thesis entitled "Assessment of garlic production practices and effects of different rates of NPS fertilizer on yield and yield components of Garlic (*Allium Sativum L)* under irrigated farming system in Yilmana Densa district, Amhara Region, Ethiopia" submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Horticulture to the Graduate Program of College of Agriculture and Environmental Sciences, Bahir Dar University by Mr. Shege Getu Yayeh (ID. No. BDU 0602061PR). The M.Sc. thesis is an authentic work carried out by him under our guidance. The matter embodied in this project work has not been submitted earlier for award of any degree or diploma to the best of our knowledge and belief.

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Name of the Supervisors

Name of Major Supervisor

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Name of Co-Supervisor

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DEDICATION

I would like to dedicate this thesis to my family who always support me and are eager to see my success.

ABBREVIATIONS AND ACRONYMS

CSA	Central Statistical Authority
DAP	Di-ammonium phosphate
EARO	Ethiopian Agricultural Research Organization
EIAR	Ethiopian Institute of Agricultural Research
ENAIA	Ethiopian National Agricultural Input Authority
FAO	Food and Agriculture Organization
HH	Household
LSD	Least Significance Difference
MoANRS	Ministry of Agriculture Natural Resource Sector
MoARD	Ministry of Agriculture and Rural Development
RCBD	Randomize Complete Block Design
SAS	Statistical Analysis system
SPSS	Statistical Package for Social Sciences
YDD-OoARD	Yilmana Densa District Office of Agriculture and Rural Development

ASSESSMENT OF FARMER`S PRODUCTION PRACTICES AND EFFECTS OF DIFFERENT RATES OF NPS FERTILIZER ON YIELD AND YIELD COMPONENTS OF GARLIC (*ALLIUM SATIVUM* L) UNDER IRRIGATED FARMING SYSTEM IN YILMANA DENSA DISTRICT, AMHARA REGION, ETHIOPIA.

By Shege Getu Yayeh

Advisors: Dr. Melkamu Alemayehu and Dr. Amare Haileslassie

ABSTRACT

The study was initiated with the objectives of assessing thegarlic production practices and the effects of different rates of NPS fertilizer on yield and yield components of garlic (Allium sativum l) under irrigated farming system in Yilmana Densa district, Amhara Region, Ethiopia. The work had two major components namely assesing garlic production practices were in three major garlic producing kebeles ofAdet Zuria, Goshaye and Ambesit and studing NPS fertilizer rate effects on garlic in Adet zuria kebele. The study was conducted in 2014/2015 cropping season. To assess production practices data were collected using semi-structured questionnaires from 30 garlic producing households where demographic structure and the whole value chain of garlic production system were recorded and analyzed using SPSS version 16. In the experimental part twelve different NPS fertilizer rate combinations were used. The experiment was laid down in a randomized complete block design (RCBD) with three replications. Data on growth and yield parameters were recorded and analyzed using SAS version 9.0. The assessment results showed that the agronomic and cultural practices currently employed by farmers contributed to the current low productivity of garlic in the study area. Use of low rate of fertilizers and low yielding local variety, low population of garlic plants per unit area and high incidence of diseases and insect pests characterize the garlic production system under farmer's practice. As a result the productivity of garlic under farmer`s management practices was low (8.65t/ha). Besides the average crop water productivity was 0.66 kg/m^3 which was relatively low compared to our finding. There was excess use of irrigation water which accounted about 9569.18-18811.7m^3/ha. Major constraints of garlic production in the study area include lack of suitable irrigated land, lack of quality planting material, shortage of irrigation water, fertilizers and pesticides, lack of money for input purchase, disease incidence (white rot).The results of the experiment reveled that most of the growth and yield parameters of garlic were significantly affected by NPS fertilizer. The highest significant plant heights (69.23cm), fresh (25.33g) and dry (5.05g) above ground biomass per plant were obtained from garlic plants supplied with NPS fertilizer at the rate of 105:122.6:22.6 N:P_2O_5:S kg ha^{-1} The highest leaf length (48.6 cm), leaf number (13.4), bulb diameter (4.27cm), marketable (17.42t/ha) and total (17.8 t/ha) bulb yield were recorded by the application of N:P_2O_5:S fertilizer at the rate of 140:122.6:22.6 kg/ha. However the mean values of these parameters were statistically similar with those which were recorded by the application of 140:92:17 N:P_2O_5:S kg ha^{-1}. Garlic plants treated without NPS fertilizer application were inferior in all growth and yield parameters . Correlation analysis revealed that there were strong positive ($P\leq 0.01$) correlations of total bulb yield with bulb diameter (0.62**), bulb length (0.61**), bulb weight (0.69**), dry weight of above ground biomass (0.73**), fresh above ground biomass/plant (0.50**), leaf length (0.74**), leaf number (0.44**), marketable bulb yield (0.99**) and plant height (0.74**). For enhancement of production and productivity of garlic in Yilmana Densa district and other similar environment, it is necessary to solve problems associated with the production of garlic like inappropriate cultural practices, lack of improved varieties, shortage of irrigable land, irrigation water and finance through extension activities. Application of NPS fertilizer at the rate of 140:92:17 N:P_2O_5:S kg ha^{-1} can be recommended for the production of garlic in the study area since it gave high marginal rate of return in this study. However is advised to repeat the experiment at the same or more level of NPS fertilizer to have forceful recommendation

Keywords*:* Bulb yield, households, garlic grower, productivity, water use efficiency

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CHAPTER 1. INTRODUCTION

1.1 Background and Justification

Garlic (*Allium sativum L*, 2n=16) belongs to the family Alliaceae and is the second most widely used *Allium* species next to onion (Rubatzky and Yamaguchi, 1997). According to Etoh and Simon (2002), it is originated on the northwestern side of the Tien-Shan Mountains of Kirgizia in the arid and semi arid areas of central Asia (Kazakhstan).

Garlic is among the most important bulb vegetable which is used as a spice and flavoring agent for foods (Velisek *et al.*, 1997). It is widely used around the world for its pungent flavor as a seasoning or condiment. It is a fundamental component in many or most dishes from various countries in the world including Ethiopia. Garlic adds a taste to foods as well as it helps to make them more palatable and digestible (Ahmad, 1996). In Ethiopia, garlic is used while preparing foods particularly some kinds of stew and in making dried foods for storage (Rubatzky and Yamaguchi, 1997).

Garlic contains different useful minerals, vitamins and many other substances used for the health of human beings. It contains more than 200 chemical compounds such as allicin, alliin, ajoene, allinase, peroxidase and myrosinase. Allicin is what gives garlic its antibiotic properties and is responsible for its strong odor. Ajoene contributes to the anticoagulant action of garlic. Thus, garlic can rightfully be called one of nature's wonders because it inhibits and kills bacteria, fungi and parasites as well as lowers blood pressure, blood cholesterol and blood sugar. It also prevents blood clotting. Besides, it protects the liver and exhibits anti-tumor properties (Sovova and Sova, 2004).

Garlic can be grown in a wide variety of soil types. However, it should be fertile, rich in organic matter, well drained, capable of holding adequate moisture during the growing period, and having a pH ranging from 6.8 to 7.2. Lower soil pH levels inhibit plant growth, and soil pH below 5.0 can actually lead to plant death (Janet, 2008). Garlic can also grows under a wide range of climatic conditions but prefers cool weather and grows best at higher elevation and within the geographic areas having a mean monthly growing temperature ranging from

12^{o}C to 24^{o}C (Libner, 1989). Relatively high temperatures up to 30^{o}C are required for optimum bulb development, but cooler conditions in the early stage favor vegetative growth (Tindall, 1983). In most areas, elevation from 500-2000 m provides suitable growing conditions, particularly during dry periods (Tindall, 1983). In Ethiopia, garlic grows probably throughout the cooler part of the country in the altitude ranges of 1800-2800m (Edwards *et al.*, 1997). It is cultivated in home gardens and in small irrigated fields by smallholder farmers and cooperatives.

The average annual world production of garlic is about 24,836,920 tones on 1,465,772 ha of land with the productivity of 16.9 t/ha (FAO, 2012). According to FAO (2012), China is the top garlic producer in the world and contributes about 80.8% of the total production, followed by India 4.6% (FAO, 2012). However, in terms of productivity, Uzbekistan is the first in the world followed by Egypt and China with the productivity of 24.8, 24.3 and 23.4 t/ha respectively (FAO, 2012).

In Ethiopia, the demand of garlic increasing and thus its production is increasing from year to year. The area under garlic cultivation is also increasing. The current annual production is estimated to be 222,548 tones on 21,258 ha of land with the productivity of 10.5 t/ha (CSA, 2013). However, productivity and quality of garlic produced in the country is very low compared to the world average as mentioned above. Amahara Region is one of the potential areas in Ethiopia for the production of garlic. The region contributes more than 50% (115,339 tones) of the national garlic production with the productivity of 11.13t/ha. Nearly 10% of garlic produced in the region is sourced from West Gojjam where the study was conducted with the productivity of 10.5t/ha (CSA, 2013) which is lower than the average garlic productivity of the Amhara Region.

The low production and productivity of garlic in Ethiopia in general and in Amhara region in particular are the results of various factors. Among which inappropriate agronomic practices, declining soil fertility, absence of proper diseases and insect pest managements and lack of improved varieties are the most important factors (Tesfaye and Habtu, 1986; Teweldebrhan, 2009; Worku and Dejene, 2012).

Garlic is a heavy feeder of soil plant nutrients and has a low nutrient extraction capacity because of its shallow and un-branched root systems. The fertilizer requirement of garlic is therefore relatively high compared to other horticultural crops (Brewster, 1997). Although the fertilizer requirement of the crop depends on the type of crop produced, the fertility status of the soil, and the environmental conditions of the area, garlic producers in Ethiopia including West Gojjam Zone use a blanket recommendation of 105 kg nitrogen and 92 kg phosphorus sourced from Urea and di-ammonium phosphate. Recently the Ministry of Agriculture has introduced a new fertilizer blend containing N, P, and S but its application rate for garlic is not yet known. Therefore, the aim of this study was assessing the constraints of farmer`s garlic production practices and evaluating the response of garlic to the newly introduced fertilizer blend NPS in the study area in order to contribute to horticultural development endeavors of the country in general and the Amhara Region in particular.

1.2 Objective of the Study

The main objective of this study was to assess farmer`s garlic production practices and evaluate the response of garlic to the different rates of NPS fertilizer. The specific objectives of the study were:

- To assess current farming practices and synthesize major potential and constraints in farmer`s garlic production practices
- To evaluate bulb yield and yield component of garlic at different rates of NPS fertilizer
- To determine the appropriate level of NPS fertilizer for an economically optimum bulb yield of garlic

CHAPTER 2. LITERATURE REVIEW

2.1 Brief Description of Garlic

Garlic has been extensively domesticated many thousands of years ago. No wild forms are found anywhere in nature which are related to the type of garlic currently in use. Thus a truly wild species of garlic is not yet known. But, *Allium longicuspis* which is endemic to central Asia is considered to be the most closely related species to the cultivated garlic and is considered to be the garlic's wild ancestor. Therefore, the center of origin of garlic is considered to be central Asia, including India, Afghanistan, West China, Russia (Preglove, 1972; Tindall, 1986; Edwards *et al.*, 1997).

Allium sativum L, commonly known as garlic is a species in the onion family Alliaceae. Botanically, it belongs to the genus *Allium*, family Alliaceae of plants that produce organosulfur compounds, such as allicin and diallyldisulfide (DADS), which account for their pungency, lachrymatory effects and spicy aroma. Its close relatives include vegetable crop such as onion (*Allium cepa*), leek (*Allium ampeloprasum*), shallots (*Allium ascalonicum*) and chive (*A. Schoenioprasum*) (Eric, 2010). Garlic is a diploid species with 2n = 2x = 16 of obligated apomixis. Therefore, it is a sterile species, produces sterile flowers and does not produce seeds and reproduces only by vegetative propagation through its bulbs or cloves (Mc-Collum, 1987; Figliuolo *et al.*, 2001; Ipek *et al.*, 2003 and 2005).

Garlic can be grown in different types of soil. However, sand, silt and clay loam is recommended for commercial production. The soil should be fertile, rich in organic matter, well drained, capable of holding adequate moisture during the growing period, and having a soil pH ranging from 6.8 to 7.2 (Janet, 2008). Garlic grows best within the warmer geographic areas having a mean monthly growing temperature ranging from 12^{o}C to 24^{o}C. Storage temperature of dormant cloves and temperatures before clove formation influenced the bulb formation and thus the yield of garlic (Libner, 1989). Long day favors the development of garlic, so it is preferable to plant during short periods to encourage maximum vegetative growth before the bulb occurs (Rice *et al.*, 1990). Excessive humidity and rainfall are

detrimental to both vegetative and bulb formation. The crop is therefore normally grown in low rainfall areas with irrigation during the early vegetable growth (Tindal, 1983).

Garlic is one of the most important bulb vegetables produced around the world for its pungent flavor and used as spice for seasoning and condiment of foods. It is a fundamental component in preparing many or most dishes around the world (Velisek *et al.*, 1997). In addition to adding taste for foods, garlic contains different useful minerals, vitamins and many other substances used for health of human beings. It is rich in sugar, protein, fat, calcium, potassium, phosphorous, sulfur, iodine fiber and silicon. In addition to sulfur, garlic also contains arginine, oligosaccharides, flavonoids, and selenium, all of which may be beneficial to the health of human being (Milner, 1996). It can inhibit and kill microorganisms, lower blood pressure, blood cholesterol and blood sugar, prevent blood clotting, protect the liver and contains antitumor properties (Davis *et al.*, 2003; McCann, 2003; Castleman, 2001; Schulz *et al.*, 2004; Sovova and Sova, 2004).

2.2 Farmers Production Practices and Major Garlic Production Constraints

2.2.1 Garlic production and its trend

Production of vegetables is largely practiced by smallholder farmers living near big cities in Ethiopia. Vegetables including garlic are cultivated as cash crop in small plots of land and help to improve the livelihood of subsistence farmers in mid and low lands of the country (FAO, 2006). Garlic is the second most widely cultivated *Allium* species in Ethiopia next to onion. The best growing altitudes for garlic is between 700 and 1800 m.a.s.l (Getachew and Asfaw, 2000). Adet, Ambo, Debre-Work, Sinana, Jimma and many other areas of the Ethiopian highlands are areas where a bulk of garlic is produced by small-scale farmers. In West Gojjam, north western Ethiopia, farmers produce garlic under rain fed conditions during both summer (June-October) and winter (November- February) irrgated cropping seasons for consumption and commercial purpose (Getachew and Asfaw, 2000). the recommended for the production of garlic and similar vegetables using irrigation water than during rainfall in tropical areas because of the incidence of destructive diseases (EIAR, 2007; Zeray Siyoum and Mohammed Yesuf , 2012)

Garlic production in Ethiopia is in increasing trend both in production and area coverage in the last five years. In 2006/07 cropping season for example 68,300 tons of garlic was produced on 9,266 hectares of land (MoARD, 2007). According to CSA (2013), the annual production of garlic reached to 222,548 tons and its area coverage increased to 21,258 hectares of land. It accounts 10.4% of the area covered by all vegetables and contributes 6.1% of the total vegetable produced in the country .Thus garlic is extremely important vegetable crop not only for local consumption, but also for export market and thus as source of foreign exchange earnings among the fruits and vegetables (EIAR,2007). However, its productivity is still very low which is accounted by various factors including use of low quality planting materials, imbalanced fertilizers, suboptimum irrigations, limited of improved varieties, lack of skills and means for proper disease and insect pest management and inappropriate agronomic practices (EIAR, 2007).

2.2.2 Garlic Production Practices

Varieties

Ethiopian Institute of Agricultural Research (EIAR) which operates at federal level and regional agricultural institutes are working on the improvement of crop varieties including garlic. However much of their work is concentrated on grain crops than horticultural crops. The budgets and human resource allocation for the development of the horticulture sector in general and improved planting material development in particular is often low. Nevertheless, Debre Zeit Agricultural Research Center is working on garlic planting material improvement. Therefore, improved varieties of garlic such as Bishoftu Nech (W-014), Qoricho and Tseday (G-493) are released from different research centers of the country in the last years. However their planting materials are not available for garlic producers which exerts problem in the production of garlic. Garlic growers use their own saved planting material or purchase local varieties from market through informal planting material system. Planting materials provided through this system has limitations in terms of productivity and quality (Amsalu *et al.*, 2014).

Planting material preparation and planting

The garlic bulb consists of numerous cloves, which is the main economic organ both for consumption and propagation. Fully matured and well-developed bulbs of medium to-large cloves are the best planting materials which should be free from disease and insect pest, and mechanical damages. A hectare of land will require about 800-1200 kg of planting materials depending on the size of the bulbs and planting distance (EIAR, 2007). Bulbs for planting should be stored at a temperature between 5^0C and 10^0C (Libner, 1989).

Cloves of bulbs are separated from one another and used for planting where the outer coves are the best planting material. In case of shortage however, the inner cloves can be also used for planting. The planting materials are then soaked in an insecticide-fungicide solution for at least two hours to get rid of seed-borne pests. Such cloves should be air-dried before planting (http://teca.fao.org).

Dried cloves are planted at spacing of 7-12 cm within rows which depends on the varieties of garlic used. Generally cloves of small-bulb strains are planted as close as 7 cm apart, while large-bulb strains will require as much as 12 cm between plants. Spacing between rows will depend on the method of planting and available equipment for cultivation. Single or multiple rows of plants are commonly used, with spacing between rows generally not less than 20 cm (Sims *et al.*, 1976). In Ethiopia recommended spacing for improved garlic varieties is 10x15x30 cm , where by 10 cm is the spacing between plants, 15 cm between rows and 30 cm the between double row (EIAR, 2007). Cloves are planted at depth of 3-5 cm: i.e. the distance from the soil surface to the top of the clove. In light or organic soils, they can be at 5 cm planting depth. In temperate climate, shallow planting may cause frost injury during winter and early spring. Garlic in the spring may be planted closer to the soil surface. Cloves are hand planted in Ethiopia. However, several imported home-made mechanical planters are also in use in various countries with moderate success (https://www.youtube.com/watch?v=IfBR8m9ew-U).

Irrigation

Garlic has a relatively shallow and limited root system. Thus garlic soil should be maintained near field capacity during most of the growing period. Both dry and too wet conditions easily

stressed garlic plants (Rubatzky and Yamaguci, 1997). Too wet soils may cause fungal diseases. Soil water deficit may causes reduction of leaf expansion, which reduces the amount of solar radiation intercepted as well as uptake of nutrients, because of reduced transpiration rates (Pereira and Chaves, 1993).

The annual rainfall requirement of garlic is about 900 -1400 mm, thus 9000-14000 m^3 /ha water (MoANRS, 2011). According to EIAR (2007) the garlic irrigation frequency differs with the developmental stages of plants, soil types and weather conditions. Accordingly they recommend to irrigate two times per week during sprouting (germination) and then after to irrigate garlic field every 5-10 days interval. During dry periods the crop should be irrigated at weekly intervals, but a longer interval may be necessary on heavy soils. In the interview made by Wale and Mengistu (2009) farmers in Libokemkem, Dembia and Fogera districts, the main garlic producing areas, said that they irrigate garlic field in seven days interval. Crop water productivity of garlic in Gumara watershed is about 0.9 kg/m^3 as reported by Haileslassie *et al.*, (2009). Irrigation should be stopped as soon as the leaves start to turn yellow (Fasika, 2012); otherwise the shelf life of the produce will be reduced.

Fertilizer application

Allium species including garlic have low nutrient extraction capacity than most crop plants because of their shallow and un-branched root system. Thus they require and often respond well to additional fertilizers with banding being a preferable application method (Brewster, 1994). N, P and K fertilizers are especially very important to obtain maximum yield of garlic. However the rate of fertilizer application should be determined based on the results of soil tests that can be influenced by soil type, the previous crop grown, the amount of organic matter present and the climatic conditions during the growing season. Generally the required P and K is broadcasted before garlic planting followed by shallow incorporation into the soil, while N from DAP can be applied at planting and the remaining in the form of urea should be applied by split applications, ½ of urea at 4 weeks after planting and ½ of urea 8 weeks after planting (Fasika, 2012).

The application of fertilizer for garlic production in Ethiopia is based on a blanket recommendation set by EIAR (2007) which is 92 kg phosphorous and 105 kg nitrogen sourced from DAP and urea. Such type of recommendation did not consider the type and fertility of the soil, environmental conditions and other factors that may influence the rate of fertilizer. Even though, the use of fertilizers in crop production has been generally increased in Ethiopia in the last years, garlic producers still use fertilizer below the blanket recommendation. Furthermore, they rely on fertilizers containing only N and P. There are no fertilizers which contain potassium, sulfur and micro nutrients that are important to increase production and productivity. As a result the nutrient level in the soil is steadily declined (Teklu and Teklewold, 2009). To tackle this problem, the government of Ethiopia introduced recently a fertilizer that contains nitrogen, phosphorous and sulfur (NPS).

Pest management

The most important constraint of garlic production and productivity are fungal disease and insect pest. Among the fungal diseases, white rot caused by *Sclerotium cepivorum and* rust caused by *Puccinia allii* and from the insect pest thrips are the major disease and insect pest in most garlic growing areas of Ethiopia (Agegnehu *et al.,* 2013; Bekele, 2006; Shibru, 2013; Wale and Mengistu, 2009)

The control method of White rot disease by farmer's use of proper irrigation interval and crop rotation are use to control soil inhibiting pathogens in Rib irrigation areas (Agegnehu *et al.*, 2013). Garlic rust control by Tilt chemical in Rib irrigation areas (Agegnehu *et al.*, 2013) and farmers of Libokemkem, Dembia and Fogera farmer's according to farmers garlic rust control by plant in off-season (Wale and Mengistu 2009). Thrips control methods Plant health adherence through removal of volunteer garlic plants and weeds around the cultivated fields and crop rotation would be useful in minimizing thrips populations in on garlic field (Waiganjo, 2005) and chemical sprays (Malathion 50%EC,Selicron) to control garlic thrips (Agegnehu *et al.*, 2013)

Harvesting and post harvest operations

Bulbs begin to mature 4-6 months in temperate (Libner, 1989) and 4 months on tropics (Rice *et al.*, 1990) after planting. Indices for maturity are softening of the main stem above the bulb, yellowing of 75% of the leaves and drying and collapse of the plant tops (Dickerson, 1999). Irrigation should be stopped 1-2 weeks before harvesting date, as it is easier to pull or dig out garlic from dry soil than mud and such produces will store better (ATTRA, 2001). After harvesting, the bulbs should be dried for about 8-10 days (Tindal, 1983) before marketing or storage to prevent deterioration in quality. Most of Ethiopian garlic producers however do not practice such curing activities, thus the quality of garlic produced in the country is very low. Cured garlic will keep for about 6 to 7 months if it is stored at a temperature of 32°F and 65-70% relative humidity. It is important to keep the temperature and humidity constant. Any variation in either of them will initiate sprouting. Good air circulation in the storage is also essential.

2.3 NPS Effects on Garlic Growth and Productivity

Garlic is a nutrient exhaustive crop and removes a good amount of nitrogen, phosphorus, and sulfur from the soil. Uptake of sufficient nutrient by the garlic crop is important to improve growth and marketable yield as well as quality of the crop (Nai-hua *et al.*, 1998). Besides the quality and intensity of flavor as well as nutritional and nutraceutical values of the crop depend upon the cultivars, agronomic practices, climate, soil fertility, and postharvest storage conditions of garlic. The availability of macro and micronutrients in vegetable production including garlic is the prime prerequisite for maximum yield and best possible quality of the crop which differs with fertility status of the soil and cropping seasons (Teklu *et al.*, 2004). Thus soil nutrient management plays a significant role in improving productivity and quality of the crop (Zhou *et al.*, 2005).

Nitrogen is an important for chlorophyll, enzymes and protein synthesis in plants. Its availability in soil is of prime importance for growing plants as it is a major and indispensible constituent of protein and nucleic acid molecules (Naruka and Dhaka, 2001; Yadav, 2003; Farooqui *et al.*, 2009). The availability of nitrogen in soil is associated with vigorous

vegetative growth where more carbohydrates are synthesized and thus increases the bulb weight and the total yield of garlic (Amin *et al.*, 1995).

The effects of nitrogen on growth and yield performance of garlic and similar vegetables have been discussed by various researches in different parts of the world. It affects mostly the vegetative growth such as plant height, leaf count and area, fresh and dry weight of garlic plants (Kakara *et al.,* 2002) thus also affects the yield of garlic. Zaman *et al.* (2011) for example reported that growth and yield of garlic were significantly influenced by nitrogen fertilizer. The maximum plant height (64.7 cm), number of leaves per plant (8.53), dry weight of leaves per plant (2.40 g), dry weight of single plant (4.33 g) were recorded with the application of 200 kg N/ha. The minimum mean values of all growth parameter of garlic were recorded in the control plots where no nitrogen fertilizer was applied. Further increase in the level of nitrogen (250 kg/ha) decreased most of the growth parameters of garlic. Generally plants grown with the application of 200 kg N/ha produced the maximum vegetative growth, possibly through enhancement of the photosynthetic activity and thus accumulation of dry matter in the garlic plants.

Bulb yield of garlic is a complex parameter that is resulted from the interaction of various yield components such as bulb length, bulb diameter, number of cloves and single bulb weight which are also affected by nitrogen fertilizer. In the study conducted by Zaman *et al.* (2011) all yield components of garlic were positively affected by the application of nitrogen up to 200 kg/ha. However the mean values of most yield components obtained from garlic plants supplied with 150 kg/ha and 200 kg/ha nitrogen were statistically similar. Similarly maximum bulb yield of garlic was obtained from plants which were supplied with 150 kg/ha nitrogen. Yield as well as yield components was at low level in garlic plants which were not supplied with nitrogen fertilizer.

In the study from Abreham *et al.* (2014), nitrogen fertilizer also affected significantly the bulb yield along with all growth as well as yield components of garlic Nitrogen fertilizer had a significant ($P \leq 0.001$) effect on days to maturity, plant height, shoot dry weight and mean leaf area per plant. Days to maturity was delayed by 13 days when 150 kg N ha^{-1} was applied compared with the control. Mean plant height of garlic at 100 and 150 kg N ha^{-1} was

significantly higher than the lower rate. The highest N rate (150 kg ha^{-1}) enhanced the shoot dry weight of plant as compared to the unfertilized plot and the highest mean leaf area per plant was achieved at 150 kg N $ha-^{1}$as compare to the unfertilized plots (Abrheham *et al.*, 2014).

Phosphorus is a constituent of nucleic acids, phospholipids, the coenzymes DNA and NADP, and most importantly ATP. It activates coenzymes for amino acid production used in protein synthesis; it decomposes carbohydrates produced in photosynthesis; and it is involved in many other metabolic processes required for normal growth, such as photosynthesis, glycolysis, respiration, and fatty acid synthesis. It enhances planting material germination and early growth, Phosphorus is essential for root growth, stimulates blooming, enhances bud set, aids in planting material formation, hastens maturity and provides winter hardiness to crops planted in late fall and early spring (Ray, 1999 and Nasiruddin *et al.*, 1993). According to Abreham *et al.* (2014) phosphorus had significant influence on the number of leaf per plant and the bulb yield of garlic. Its interaction with nitrogen also increased significantly the number of leaf per plant and bulb yield of garlic. The highest bulb yield was achieved at 100 kg N + 100 kg P_2O_5/ha at Mesqan districts, South Central Ethiopia. In onions, P deficiencies reduce root and leaf growth, bulb size and yield and can also delay maturation (Brewester, 1994). According to Betewulign *et al.* (2014) reporte the highest garlic plant height was recorded by the application of 100 kg N ha^{-1} + 120 kg P_2O_5 ha^{-1} and the highest leaf number and leaf length was obtained the application of 100 kg N ha^{-1}+ 130 P_2O_5 ha^{-1} in Jimma area .

Sulfur has an important role of in plant protein synthesis and some hormones formation. It is also necessary for enzymatic action, chlorophyll formation, synthesis of certain amino acids and vitamins, hence it help to have a good vegetative growth leading to get high yield (El-Shafie and El-Gamaily, 2002).

Application of sulfur increased plant height, number of leaves, bulb diameter, bulb weight and total bulb yield (Balasubramonium*et al.*, 1979). Zaman *et al.* (2011) reported that garlic bulb yield increased with successive increase in the level of sulfur up to 45 kg/ ha and there after decreased. On the other hand Lancaster *et al*. (2001) and Hariyappa (2003) reported

significant increased yield and yield attributes (bulb diameter and bulb length) of garlic at higher rates of sulfur application. The increment of garlic bulb yields was associated with the increment in root growth for nutrient absorption and photosynthesis activities that increased the production of assimilates to fill the sinks resulted the increased bulb yield (Zaman *et al.*, 2011). Similar results like the increased average bulb weight, size and total bulb yields of onion with sulfur fertilizer application were reported by various researchers (Attia, 2001; Dabhi *et al.,* 2004; Jaggi, 2005; Nasreen *et al.,* 2007). They also suggested that sulfur deficiency in the soil would adversely affect the growth and yield performance of onion.

Combination of sulfur with nitrogen also affects the growth and yield performance of garlic. According to the findings of Faraooqui *et al. (*2009) the combined application of 200 kg ha^{-1} nitrogen and 60 kg ha^{-1} sulfur significantly increased the plant height, number of leaves per plant, bulb diameter, bulb fresh weight, and total bulb yield of garlic. However, the application of N at 150 kg ha^{-1} + S at 60 kg ha^{-1} gave the best cost benefit ratio.

The availability of balanced macro and micronutrients in the soil is essential for optimum growth and development of crops which differ with soil and nutrient types and cropping season (Teklu *et al.,* 2004). Improved management of nitrogen, phosphorus, potassium and other inputs in the soil could improve yields and quality of vegetables and other crops (Nai-hua et al., 1998). According to these authors, fertilizer management practices should balance the supply of N, P and K as well as other nutrients based on results of soil analysis and requirements of plants. On the other hand application of only N and P containing fertilizers causes reduction of the quantity of K and S in most of the soils as there is also evidence of fixation of potassium and leaching of sulfur in different types of soils in addition to mining by different crops as result of continues cultivation of land (Murashkina *et al.*, 2006). Therefore the application of K and S and other micronutrients to soils having even fair amounts of K and S contents may still show its effect on plants. Matthew *et al.* (2000) and Havlin *et al.* (2007) stated that Zinc mineral showed high sensitivity in onion production.

However farmers in Ethiopia rely on fertilizer sources that contain only nitrogen (N) and phosphorus (P) that resulted in steady decline in other nutrients in the soil. Besides smaller

potassium and sulfur uptake relative to N can predispose the crop to serious disease and insect damage (ENAIA, 2003).

Deficiencies of S are likely to be a major constraint to crop production including garlic in Ethiopia. However as Luo *et al.* (2000) indicated the quantity and quality of garlic was significantly influenced by the application of nitrogen and sulfur fertilizers. An increased in alliin content of leaves and bulbs of garlic was also observed with increased sulfur supply, whereas nitrogen fertilization was necessary for ensuring successful vegetative growth of garlic (Kakara *et al.*, 2002). Stork *et al.* (2004) reported that the application of nitrogen along sulfur at an early vegetative (sprouting) stage is useful for the promotion of strong vegetative growth before cold winter months.

CHAPTER 3. MATERIALS AND METHODES

3.1 Description of the Study Area

Yilmana Densa is one of the 15 districts of West Gojjam Administrative Zone, bordered by Bahir Dar Zuriya and South Gonder in the north, Quarit and Sekela in the south, Gonj-kollela in the east and Mecha districts in the west. Adet is the district administrative town. The district has 33 rural and 3 town *kebeles* and the total population of the district in 2007 was 214,852, of which 195,683 were living in rural and 19,169 in different towns (CSA, 2007).

Geomorphologically, the district is 12% lowland, 64% midland and 24% highland, while its topograpic features are 56% undulating, 20% mountainous, 8% gorge, and 16% plateau. Total land size is estimated to be 99,180 hectare, out of which 46,097 hectare (ha) is used for annual and 109.09 ha for perennial crops production. Grazing land, forest land, bush and water bodies constitute 4,367.83, 3,697.69, 3,066.69 and 1,572.43 ha, respectively. About 1,397.95 ha are under constructions, 2,302.08 ha is potentially cultivable land, 36,299.27ha is non-cultivable and 269.97ha land is others. The soil of the district is red, black and brown with the proportion of 65%, 20% and 15%, respectively (YDD-OoARD, 2009).

Altitude ranges from 1800 to 3200 m.a.s.l. The average rainfall of the district is between 1051.8 and 1488.2 mm. The mean annual temperature ranges from 8.8-25.2^{o}C. Major crops grown in the districts are teff (*Eragrostis tef),* wheat *(Triticum aestivum* L), maize *(Zea mays* L), barley *(Hordeum vulgare),* potato *(Solanum tuberosum),* field pea *(Pisum sativum),* faba bean *(Vicia Faba),* finger millet (*Eleusine coracana)* and the like (YDD-OoARD, 2009).

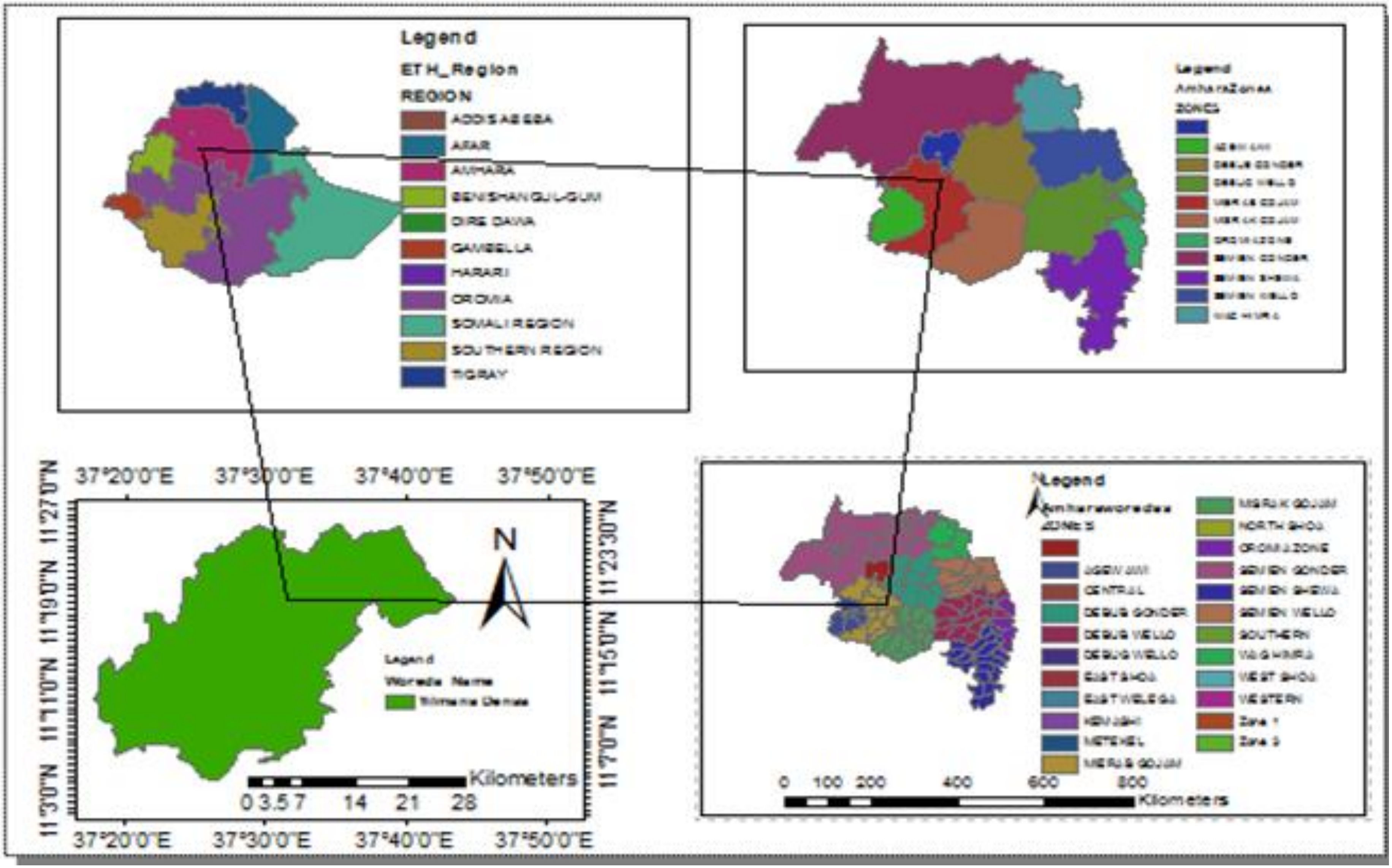

Figure 3.1:Map of the study area

3.2. Assessment of Farmer's Production Practices of Garlic

3.2.1 Sampling procedures

The farmer`s garlic production practices were assessed in three major garlic producing *kebeles* of Yilmana Densa District (Adet Zuria, Goshiye and Ambesit) which are selected purposefully. The list of garlic producing households of the *kebeles* was obtained from *kebele* agriculture offices. From these garlic producing households, ten household head from each *kebeles* were randomly selected and interviewed using semi-structured questionnaires. When the head of the household was unable to give information, then the household head was replaced by one of the family members whose age was greater than 18 years. In the case of whose age was greater than 18 years participants in the household, lottery method was used to select only one. For whose age was greater than 18 years, participants who were not found at home, the interviewers were revisiting the HH two times at different time intervals. If the interviewers failed to get whose age was greater than 18 years participant or if the head of the household was unable to give information, then the household was replaced by another household.

Table 3. 1:Total , garlic producing and intriviews households

Kebele	Adet Zuria	Goshaye	Ambesit	Total
Households	1882	2063	1601	5546
Garlic producing households	103	99	96	298
Interviwes households	10	10	10	300

3.2.2 Irrigation water measurement procedure

The amount of the irrigation water used by the farmers was assessed by float method. The amount of water used in all ten selected farmers in the selected *kebele* was measured and the mean value was taken for analysis. The irrigation water measurement was carried out on 20 meter straight canal where irrigation water flowed. To find the velocity (m/s) of water tennis

ball was used and time (s) required for traveling the 20 meter canal was measured. The measurement was carried out three times and the mean velocity was then multiplied with 0.85 (correction factor) to estimate the average water velocity of the irrigation water.

To measure the water flow (m^3), the width and depth of the water surface in the canal was measured. The width was measured ten times within the twenty meter canal and the average width was taken for calculation. The depth of the stream was measured at left and right edges, center of the canal which was repeated four times within the canal distance and the mean depth of the canal was taken to calculate the amount of water flowed. This was combined with the number of application and duration of application for each irrigation event to estimate the total applied water. Finally the water flow (m^3), total irrigation water used and its productivity were calculated using the formulas below.

Water flow (m^3) = water velocity (m/s) x width x depth……………………………. .(1)

The total irrigation water used by farmers was then calculated by using the formula:

Total irrigation water used (m^3) = time (in second) required to irrigate the land x water flow (m3) x number of irrigation multiplied………………………………………………… (2)

Crop water productivity (kg/m^3) = yield (kg)/total water used yield (m^3) ……………. (3)

3.2.3 Data collection and analysis

Data were collected using semi-structured questionnaires having two parts. The first part deal with the socio - demographic structure of the participants. The second part covered the whole value chain of garlic production system such as cropping system, cultivar used, time of planting, land preparation, planting method, fertilizer used, disease control methods employed, harvesting methods, postharvest handling and marketing. Interviewers were proceeding from house to house. They introduced them self and explained the purpose of the interview and asked the questions using specific statements in a standard procedure. Consent to participate were obtained from each interviewee.

All sets of data were subjected to SPSS computer software and descriptive statistics such as mean, standard deviation, frequency, etc. were used to analyze the collected data.

3.3 Responces of Yield and Yield Components of Garlic under Different NPS Fertilizer application Rates

3.3.1 Treatments and experimental design

In this study healthy and uniform medium-sized cloves of local variety garlic was used. DAP and urea was used to full fil the required amount of NPS. The experiment was consisted of ten NPS fertilizer rates, one farmer`s practice one and control (without fertilizer), a total of twelve fertilizer rates (Table 3.1). The treatments were arranged in randomized complete block design (RCBD) by using lotory method randomization with three replications (Table 3.2). Each plot was 1.5 meter wide and 2 meter long. The space between plots and replications was 0.5 and 1 m respectively. Healthy and uniform medium-sized local variety garlic cloves were planted in double row arrangement of 30 cm between double rows, 15 cm between rows and 10 cm between plants in the row. Number of rows per plot was 10 (5 double rows) where each rows contained 15 plants, thus a total of 150 plants per plot.

Table 3. 2: Level of NPS fertilizer used for the study

Treatments	Fertilizer rate		
	N kg ha^{-1}	P_2O_5 kg ha^{-1}	S kg ha^{-1}
T1	0	0	0
T2 (farmer's practice*)	75.69	61.18	0
T3(blanket recommendation**)	105	92	0
T4	105	92	17
T5	105	61.4	11.3
T6	105	122.6	22.6
T7	70	92	17
T8	70	61.4	11.3
T9	70	122.6	22.6
T10	140	92	17
T11	140	61.4	11.3
T12	140	122.6	22.6

* based on interview during proposal development

**Recommendation of EIAR, 2007.

Table 3. 3: Field layout of the experiment

Block I		Block II		Block III	
Plot 1.1	T 11	Plot 2.1	T 5	Plot 3.1	T 4
Plot 1.2	T 7	Plot 2.2	T 2	Plot 3.2	T 12
Plot 1.3	T 10	Plot 2.3	T 8	Plot 3.3	T 5
Plot 1.4	T 6	Plot 2.4	T 4	Plot 3.4	T 8
Plot 1.5	T 3	Plot 2.5	T 10	Plot 3.5	T 2
Plot 1.6	T 4	Plot 2.6	T 7	Plot 3.6	T 6
Plot 1.7	T 9	Plot 2.7	T 12	Plot 3.7	T 11
Plot 1.8	T 2	Plot 2.8	T 1	Plot 3.8	T 10
Plot 1.9	T 5	Plot 2.9	T 9	Plot 3.9	T 3
Plot 1.10	T 1	Plot 2.10	T 3	Plot 3.10	T 9
Plot 1.11	T 8	Plot 2.11	T 6	Plot 3.11	T 1
Plot 1.12	T 12	Plot 2.12	T 11	Plot 3.12	T 7

3.3.2 Management of the experimental plots

The experiment site was plowed 4 times at 20 cm depth. Soil sample was taken randomly from 9 spots diagonally from the experiment area at the depth of 20 cm before planting and mixed to make a composite. Some physical and chemical properties of the composite soil, namely pH, organic matter content and NPS contents were determined in Amhara Design and Supervision Works Enterprise soil laboratory. Required quantity of phosphorus in the form of DAP and NPS fertilizers was applied at the time of planting, whereas urea as a main source of nitrogen was applied in two splits of 4 and 8 weeks after planting (Fasika, 2012). Other

management activities like weeding, irrigation, cultivation and plant protection measures were done uniformly for all plots as recommended for garlic.

Table 3. 4: Physical and chemical property of the experimental site soil

pH	EC	Texture				CEC	OC	OMC	TN	Av.P
	ds/m	% Sand	%Clay	% Silt	Class	cmol(+)kg	%			ppm
6.2	0.215	12	69	19	Heavy clay	61.8	1.87	3.23	0.16	9.20

3.3.3 Method of data collection and analysis

Both the growth and yield parameters were collected from 1.8 m^2 the net plot area

Growth parameters

Plant height (cm):- Plant height from the soil surface to the top of the longest leaf of 10 randomly selected plants was measured using a ruler at physiological maturity and the mean values were computed for further analysis.

Leaf length (cm):- The longest leaf of ten randomly selected plants at physiological maturity was measured at the attachement of pseudo-stem using ruler and expressed as a mean value in centimeter (cm) and used for further analysis.

Number of leaves/plan: - Number of leaves of randomly selected ten plants per plot was counted at physiological maturity and the mean values were computed.

Above ground biomass/plant (g):- Fresh weight of ten randomly selected plants from each plot was measured at harvesting and the mean value per plant was computed.

Dry weight of above ground biomass (g):- Dry weight of ten randomly selected plants at harvest was measured using sensitive balance after drying them in oven for 24 hours at 70^0C and the mean values per plant was computed and used for further analysis.

Maturity date: - the number of days elapsed from the time of planting up to the time when 75% of plants in the plot became dry and collapsed at the neck was counted and the mean values were computed.

Yield parameter

Bulb weight (g):- The mean bulb weight in gram was computed by weighting ten randomly selected bulbs at harvest.

Bulb length (cm):- The length of ten randomly selected bulbs was measured from the bottom to the top using caliper and the mean values were computed.

Bulb diameter (cm):- The mean size of the bulb was computed by measuring the diameter at the middle of ten randomly selected bulbs using caliper.

Marketable bulb yield (t ha^{-1}): - Bulbs which were free of mechanical, disease and insect pest damages, uniform in color and medium to large in size were considered as marketable. The weight of such bulbs obtained from each plots was measured in kilogram using scaled balance and expressed as ton per hectare.

Unmarketable bulb yield (t ha^{-1}): Harvested bulbs which are damaged, undersized, misshaped, and decayed were sorted and considered as unmarketable. The weight of such bulbs obtained from each plots was measured in kilogram using scaled balance and expressed as ton per hectare.

Total bulb yield: Total yield was obtained by adding marketable and unmarketable yields.

The data collected was subjected to the analysis of variance (ANOVA) by using SAS (Statistical Analysis System) version 9.0.

Least significant difference (LSD) test at 5% probability was used for mean separation when the analysis of variance indicated the presence of significant differences..

Correlation analysis was performed to determine simple relationship between yield and yiled components as affected by rate of NPS fertilizer application.

Economic analysis was made following CIMMYT methodology (CIMMYT, 1988). The cost of fertilizer and labour cost as variable cost . Marginal rate of return was calculated as change of net benefit divided by change of cost.

CHAPTER 4. RESULTS AND DISCUSSION

4.1 Assessment of Farmer's Production Practices of Garlic

4.1.1 Demographic information

According to the results of the assessment, participation of female headed households in the production of garlic was very low. Their participation was about 3.3% only (Table 4.1). 96.7% of the interviewed garlic producers were male headed households. The result showed generally the participation of female headed household in the production of garlic is not common in the study area. Garlic production is dominated by male headed households in the area because in Ethiopia patriarchal households including in the study area. Adet Zuria and Goshaye have 100 % male whereas Ambesit 90% male and 10% female household head. Family size of households have Four and above four 50%, 80% and 90%, and less than four 50%, 20%, and 10% Adet Zurian, Goshaye and Ambesit respectively (Table 4.1).

Among the sampled household heads, 33.3%, 23.3% and 26.7% are illiterate, read and write and have attended 1-7 grades respectively for all the study *kebeles*. Farmer household heads who attend 8-10 grades were about 15.7%. No farmer was attained a grade above 10 (0%). Hence, the majority of the sampled household head are literate (66%). From the sample household of individual *kebele* education status illiterate 20 %, 20 %, 60 %, read and write 10%, 30%, 30%, 1-7 grades 30%, 40%, 10% and 8-10 grades 40%, 10%, 0% Adet Zuria, Goshaye and Ambesit respectively.

The average ages of the sampled household heads were 33.9, 45 and 44 years in Adet Zuria, Goshaye and Ambesit, respectively. The average age of the household head for all the study areas was 41.2 years (Figure 4.2).

Table 4. 1: Sex and family size of household in the study area

Descriptions	Adet Zuria (N=10)	Goshaye (N=10)	Ambesit (N=10)	Total (N= 30)
Sex of household head	Percent (%)	Percent (%)	Percent (%)	Percent (%)
Male	100	100	90	96.7
Female	00	00	10	3.3
Family size of household				
≥4	50	80	90	73.3
< 4	50	20	10	26.7

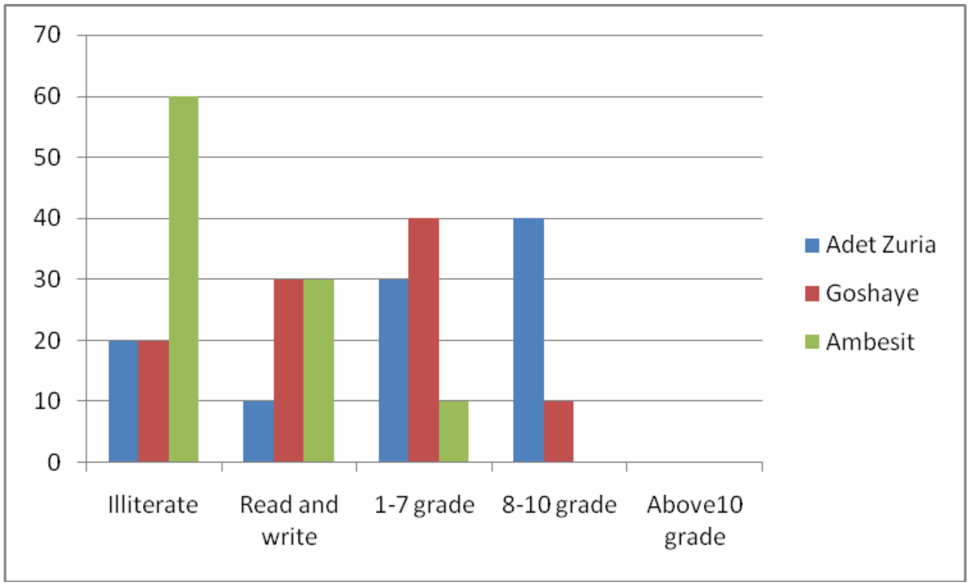

Figure 4.1: Educational level of household heads in the study *kebeles*

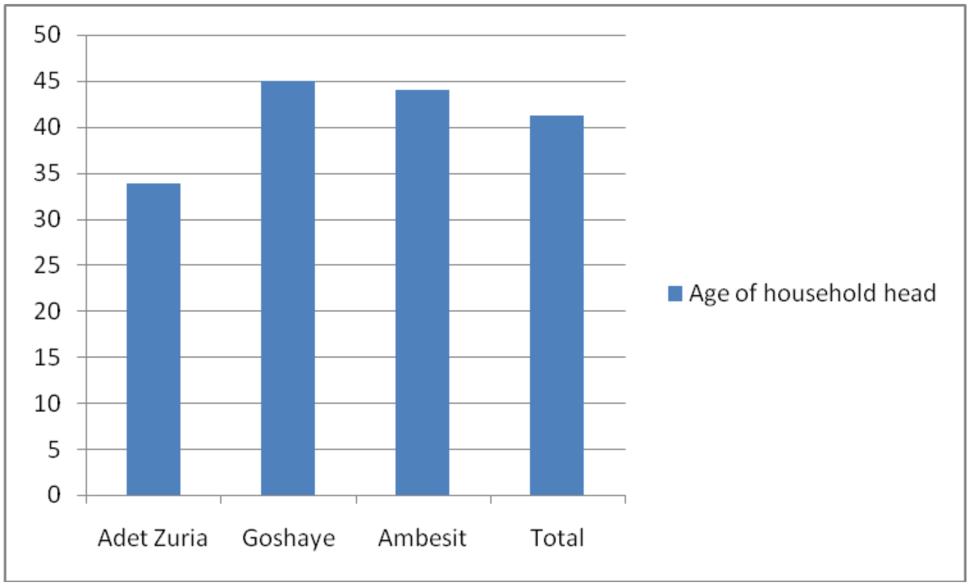

Figure 4.2: Age of house hold head in the study *kebeles*

4.1.2 Farming practices

Owned cultivated land and garlic land

The Total Landholding (hectare) land size of sample respondents varied from 0.5 to 1.5 hectares with an average holding of 0.883 hectares. The average size of land used for garlic production was 0.181 hectares. Among the three sample *kebeles*, Household heads in Adet Zuria has small total land holding for the production of crops as compared to Goshaye and Ambest. However, the average cultivated land allocated for garlic production in Adet Zuria (0.24 ha) was larger than in Goshaye (0.23 ha) and Ambesit (0.07 ha). This could be associated with the educational status, and the ages of household heads, distance to road, market and water avilablity , because they were more educated ,near to road and market , relatively young as indicated above, young farmers are more market oriented than old farmers so that they knew the economic importance of garlic.

Table 4. 2: Total landholding and land allocated for garlic production in the study kebeles

Descriptions	Adet Zuria (N=10)	Goshaye (N=10)	Ambesit (N=10)	Total (N= 30)
	Mean	Mean	Mean	Mean
Total land holding (ha)	0.75	1	0.90	0.9
Garlic production area (ha)	0.24	0.23	0.07	0.18
%age of area allocated for garlic	32	23	7.8	20

Garlic production system

Farmers in the study *kebeles* have different experiences in the production of garlic (Appendix Table 1). Most of the farmers, about 66.7%, have less than 5 years experience. 13.3, 6.5, and 13.3% of the farmers have 5-10, 10-15 and more than 15 years experience respectively, in the production of garlic. Most of the sample garlic producers in Adet Zuria, (90%) and Ambesit (70%) were less experienced (less than 5 years) than those in Goshaye which were about 40%. Thus about 60% of garlic producers in Goshaye have more than five years experience in the production of garlic. As indicated above most of garlic producing household heads in Adet Zuria were young, therefore they will not have much experience in garlic production which is in agreement with this result.

According to the assessment results, garlic is produced in main cropping season and during off season using irrigation water. However 93.3% of the sample farmers produced garlic once during off season using irrigation water where garlic was mostly planted in November and harvested in March and April. Only 6.7% of the sample farmers produced garlic twice a year during main cropping, and off seasons. Although irrigated farming requires high investment expense in water pump, fuel and labor, farmers preferred to produce garlic during off season

using irrigation water. Because as the interviewed farmers said, during irrigation season the incidence of white rot and garlic rust diseases is very low and thus yields produced in this system are much more compared to those produced in the rainy season. This result is in confirmation with the results of EIAR, (2007) and Zeray Siyoum and Mohammed Yesuf (2012) that recommended the production of garlic and similar vegetables using irrigation water than during rainfall in tropical areas because of the incidence of destructive diseases.

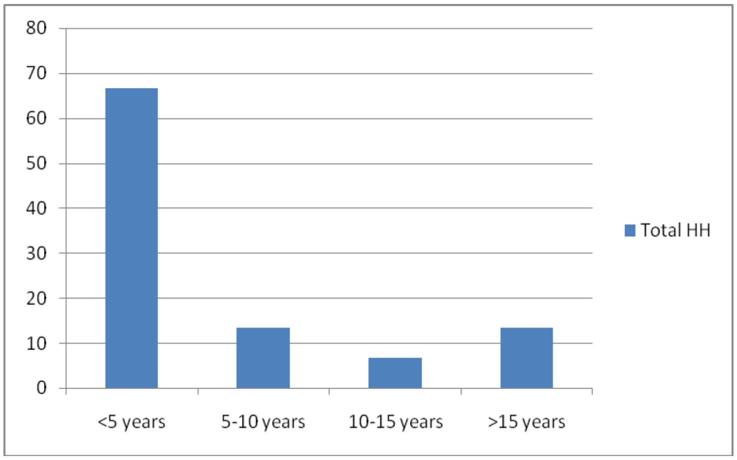

Figure 4.3: Experience of farmer’s garlic production in study *kebeles*

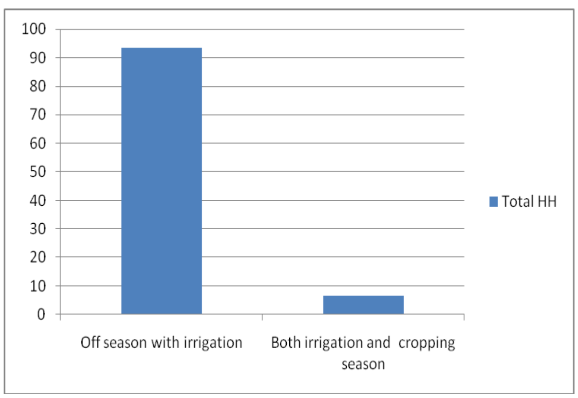

Figure 4.4:Garlic production systems in study *kebeles*

Varieties used and their sources

According to the assessment results the farmers in the study area used only local garlic varieties (Appendix Table 2). There is no improved planting material producing companies in the study area. They used either their own saved planting materials or buy planting materials from local market. 66.7 % of interviewed farmers purchased their planting materials from

local market and 30 % of them used their own saved planting materials for the production of garlic. 3.3% of the farmers used their own saved planting materials and purchase from local market to satisfy their needs.

The availability of improved varieties in sufficient quantity and quality is very important for the production of high yield of crops including garlic. However, although different improved garlic varieties such as Qoricho, Bishoftu Netch and Tseday92 were released in Ethiopia (EIAR, 2007) farmers used only local garlic varieties sourced from their own saving and local market. planting materials sourced with this chain, informal planting material system, have limitations in terms of quality as the interviewed farmers mentioned which is in agreement with Amsalu *et al.* (2014). Generally the above mentioned scenario is a very limiting factor for the development of garlic production in the study area.

Land preparation and planting

Average frequency of garlic land preparation for all the study *kebeles* is about 3.8 times plowing. Among the study *kebeles*, farmers in Adet zuria, Goshaye, and Ambesit plowed their garlic field on average 3.6, 4.6, and 3.1 times, respectively (Appendix Table 3), before planting of their garlic.

Appropriate planting system enables farmers to keep optimum plant population density in their fields. Hence, both over, and less population in a given plot of land has negative effect on crop yields including garlic.

In the study area, sample farmers planted garlic cloves in double row planting arrangement of 34.8 cm between double rows, 26.8 cm between rows and 11.8 cm between plants in the row (Appendix Table 3) which is not in line with research recommendation. According to EIAR (2007), the recommended spacing for improved garlic production is 30 cm between double rows, 15 cm between rows and 10 cm between plants in the row. Thus garlic plant population in the farm of sample farmers in the study area was low (86.5 qt/ha), which in turn results low bulb yield (Yemane *et al.*, 2013). Therefore, farmers in the area should keep the optimum garlic plant density to improve the productivity of their land.

Irrigation

In the study area, garlic production is practiced under irrigated conditions as the result of this study indicated above. About 97% of the sample farmers used rivers as a source of water (Appendix Table 4) which is in line with the finding of (Tlahun *et al.*, 2010) where they found that rivers are the main sources of water for irrigated vegetable production including garlic. The river water is diverted with canls and from here water is pumped to the farm with motor pump.

Most sample farmers, about 93%, irrigated their garlic field using furrow irrigation method and about 7% of them apply water to their garlic using traditional sprayer which is also in agreement with (Tlahun and Mulugeta, 2015) who showed furrow irrigation as a method mostly implemented by farmers to supply water to irrigated crops including vegetables.

With regard to irrigation frequency about 70% of the interviewed farmers irrigated their farms every week (7 days) while 30% of them supply their garlic with water every five days interval without considering the developmental stages of garlic and the prevailing environmental conditions in the area. These results are not in agreement with the recommendations made by EIAR (2007). According to the recommendation garlic should be irrigated two times per week at early stage of development (emergence and germination stages) and then after in 5-10 days interval depending on the type of soils and environmental conditions of the areas.

Types, rates, times, and methods of fertilizers application in the study *kebeles*

The Application of fertilizers is an important cultural practice in vegetable production which helps to satisfy the nutrient needs of crops required for the production of high yield. About 83, and 97 percent of the interviewed sample farmers used DAP and urea (Appendix Table 5), respectively, for the production of garlic. However, only 6.6% of them used organic fertilizer which will have a negative effect on the yield of garlic. Among the *kebeles*, all the interviewed farmers in Adet zuria used DAP and urea whereas 90% and 100% of them in Goshaye used DAP and urea fertilizers, respectively for the production of garlic. Farmers in Ambesit were less users of DAP and urea compared to those in other *kebeles* with the mean

value of 60 and 90% respectively, which may have its negative impact in the productivity of garlic in this *kebele*.

The average rates of DAP and urea applied by sample household heads were about 125 and 155 kg/ha which is low compared to the recommendation of EIAR (2007). According to them the blanket recommendation of DAP and urea for the production of garlic is 200 and 150 kg/ha. Farmers in the study area perceive that their soil is fertile enough for the production of garlic so that it is not necessary to follow the recommendation made by the research institutes.

Fertilizer application time should coincide with the developmental stages and thus the need of the crop plants including garlic. The assessment results of time and method of fertilizer application is presented in Appendix Table 6. About 72% of the interviewed farmers applied half of the quantity of DAP one month, and the remaining quantity two months after planting of garlic. Only 8% of the farmers applied DAP at planting time while 20% of them applied one month after garlic planting. Common DAP application methods employed by interviewed farmers were spot application (54%) side dressing (44%).

75.9% of the interview farmers applied half of the quantity of urea one month, and the remaining quantity two month after planting of garlic. 24.1 % of farmers applied urea only one time after one month of garlic planting. Common Urea application methods employed by interviewed farmers were spot application (58.6%), side dressing (37.9 %) and broadcasting (3.4%).but the research recommended application time of DAP is broadcasted before garlic planting followed by shallow incorporation into the soil, while urea should be applied by split applications half of urea at 4 weeks after planting and the remaining half of urea 8 weeks after planting (Fasika, 2012).

Pests and their control methods

Diseases and insect pests are serious concern in the production of garlic in Ethiopia including the study area. Among others white rot (*Sclerotium cepivorum*) and garlic rust (*Puccinia allii*) were the serious diseases observed in the study area. While White rot of garlic was observed in 10%, 80% and 10% of the sample household in Adet Zuria, Goshaye and Ambesit,

respectively, garlic rust was found in 40% (Adet Zuria), 20% (Goshaye) and 10% (Ambesit) of the sample households (Appendix Table 7). Generally 33% and 23% of the farms of the sample households were infested by white rot and rust of garlic respectively. The result is in line with the results of Bekele (2006), Wale & Mengistu (2009), Agegnehu *et al. (*2013), and Shibru (2013) that found the common garlic diseases of garlic in Ethiopia are white rot and garlic rust.

Farmers in the study area used chemicals such as Bayleton_25 WP and Ridomil 68 WG to control diseases of garlic. 30% of the sample household used chemicals to control garlic rust (Appendix Table 7). According to the respondents no chemicals are available to control white rot of garlic. According to Agegnehu *et al.* (2013) indicated that White rot disease can be controlled by use of proper irrigation intervals and crop rotation.

Insect pests like thrips are common in Ethiopian onion and garlic fields including in the study area. All garlic fields of the sample households were attacked by thrips (*Thrips tabaci* L.). As reported by Wale and Mengistu (2009) and Agegnehu *et al.* (2013), thrips is one of the constraints of garlic production in most of garlic growing areas of Ethiopia, which is in agreement with this study. Although thrips was found in all farms of the sample households, it was easily controlled by spraying Profit 72 % EC in two weeks interval as reported by respondents (Appendix Table7).

Cultivation and weeding are cultural operations frequently practiced by garlic growers to loosen the compacted soil around the plant root and to avoid nutrient competition with garlic plants, respectively. Thus timely cultivation of garlic field is one of the important practices in improved garlic production package. According to the survey results, majority of the sample farmers performed cultivation more than three times (70 %), while 23% of them cultivated their field three times in garlic production process (Appendix Table 8). This result is in agreement with the recommendation given by EIRA (2007) which indicate that onion and garlic production fields should be cultivated for about 2-3 times in one growing season to loosen the soil around the root zone.

4.1.3 Harvesting and postharvest operations

According to the informants, garlic was harvested 5-6 months after planting (Appendix Table 9) which is in line with Libner (1989) and Rice *et al.,* (1990) which said that garlic bulbs begin to mature 4-6 months after planting. The maturity indices of garlic were well known by farmers in the study area. About 77% of the households said that garlic is ready for harvest when 75% of its leaves are died. The results are in agreement with Dickerson (1999) and ATTRA (2001) who indicated that the garlic plants are ready for harvest when the main stem above the bulb soften, 75% of the leaves become yellow and the tops begin to dry out and collapse.

Garlic was harvested by digging and uprooting. Bulbs should be cured or dried for some days before either marketing or storage to prevent deterioration. Accordingly, 76.7% of the sample households practiced curing/drying by spreading garlic bulbs in shady places. However, 60% of the sample farmers in Adet Zuria *kebele* did not dry their garlic after harvesting because they sale their produces immediately after harvesting. Such practices reduce the storability of garlic and increase postharvest loss as indicated by Tindal (1983).

Harvested garlic bulbs should be stored in clean and well ventilated storage either in container or spread in floor or any other structure. Farmers in the study area store their garlic in bags or spread loose on above ground structure (*kot*) or ground/floor. They store garlic generally for short period of time ranging from two weeks to two months. While bags were used to store garlic for short period of time, spreading of garlic on above ground structure or ground floor helped them to store garlic for relatively long period of time (up to two months). Generally garlic can be stored for a long period of time when cured properly and stored in well ventilated and cold storage (Tindal 1983). However, the garlic storage practice in the study area is not as such suitable for long term storage, since it lacks proper curing process and lacks appropriate storage structures like cold storage. Moreover farmers produce garlic for immediate sale to improve their income.

Garlic and crop water productivity

The average garlic production of the sample households was 2.56, 1.8 and 0.49 tons in Adet Zuria, Goshaye and Ambesit, respectively. The average productivity of the sample households in the study *kebeles* was about 8.7 t/ha. There was productivity difference among sampled *kebeles*. The productivity of garlic in Adet Zuria was relatively higher (11.0 t/ha) compared to Ambesit (7.2 t/ha). However, garlic productivity in the study *kebeles* was generally low, even lower than the average garlic productivity in West Gojam Zone (10.5 t/ha) as well as in Amhara Region (11.13 t/ha). This low productivity of garlic may be attributed inappropriate agronomy practice, absence of proper disease and insect pest management practices, absence of improved variety, and other which is in conformity with results of Tesfaye and Habtu (1986); Teweldebrhan (2009); Worku and Dejene; (2012).

The average crop water productivity in the study *kebeles* was about 0.66 kg/m^3 which are very low compared to the finding of Haileslassie *et al.* (2009). They found that crop water productivity of garlic in Gumara watershed (Blue Nile Basin) was about 0.9 kg/m^3. The low crop water productivity of garlic in the study area may be attributed due to low crop productivity (8.65 t/ha) and over irrigation (9,569-18811m^3/ha). According to MoANRS (2011) the recommended irrigation water for one session of garlic production is estimated between 9000-14,000m^3/ha.

Table 4. 3: Garlic and crop water productivity

Descriptions	Adet Zuria (N=10)	Goshaye (N=10)	Ambesit (N=10)	Total (N= 30)
	Mean	Mean	Mean	Mean
Area of garlic land in ha	0.24	0.23	0.074	0.18
Bulb yield in ton	2.575	1.8	0.49	1.62
Garlic production t /ha	11.04	7.77	7.146	8.65
Total water used (m^3)	3459.4	2935.8	1014.8	2470
Total water used (m^3 /ha)	14421	12738	12908	13355
Crop water productivity kg/ m^3	0.76	0.63	0.58	0.66

4.1.4 Major constraints and opportunities of garlic production

Major constraints of garlic production

According to the respondents the major constraints of garlic production in the study *kebeles* were limitation of irrigable land, shorteage of money for input purchase, disease and insect pests, limitation of improved and high yielder varieties, shortage of irrigation water and shortage of chemicals (fertilizers, pesticides). However their degree of importance differed with sample *kebeles*. limitation of irrigable land followed by shortage of money for input purchase were the biggest problem in Adet Zuria, while in Goshaye *kebele* the prevalence of white rot followed by limitation of quality planting materials were the major constraints of garlic production. In Ambesit *kebele* the major constraints of garlic production were shortage of irrigation water followed by limitation of irrigable land, shortage of money for input purchase and shortage of chemicals (fertilizer, pesticides, etc). Unavailable fertilizer it was followed by shortage of money

Garlic Production Opportunities

- There are improved garlic varieties released by research institutes which have by far high yielding potential than the local once. Hence there is opportunity to have these varieties and increase the productivity of garlic.

- There is a possibility of controlling thrips, serious insect pest of garlic, by application of insecticides like Profit 72 % EC;

- Farmers are aware in suitability of garlic for double cropping

- There is a possibility of exporting garlic to regional market like Djibouti, Somalia, South Sudan and Sudan
- Growing commercial crops like garlic helps to satisfy the livelihood of ever increasing population and decreasing the agricultural land size.
- Market price
- Expansion of irrigation infrastructure policy

4.2 Responces of Yield and Yield Components of Garlic at Different NPS Fertilizer Rates

4.2.1 Growth parameters of garlic as influenced by NPS fertilizers

Plant height

The height of garlic plants was highly significantly ($P<0.01$) affected by the different rates of NPS fertilizer. The highest mean plant height (69.2cm) was recorded by the application of 105:122.6: 22.6 kg/ha $N:P_2O_5:S$ fertilizer (T6) followed by 140:122.6: 22.6 kg/ha $N:P_2O_5:S$ fertilizer (T12) with the mean value of 68.5cm. However no significant difference in plant height was observed between the two treatments. The lowest mean plant height of 55.27 cm was recorded from the control plants that were not applied with $N:P_2O_5:S$ fertilizer.

The results of this study clearly showed that the incorporation of sulfur in nitrogen and phosphorus fertilizers enhances the plant height of garlic. The highest plant height of garlic was recorded at the ratio of 105:122.6:22.6 $N:P_2O_5:S$ kg ha^{-1} applications of $N:P_2O_5:S$

fertilizer below and above this ratio reduced or have no significant positive effect on the plant height of garlic. The highest phosphorous and sulfur given in this treatment (T6) may contribute in the metabolic process such as formation of nucleic acids, Phospholipids, co-enzymes, and chlorophyll which intern enhance the growth and development of garlic plants as described by El-Shafie and El-Gamaily (2002), Ray (1999) and Nasiruddin *et al.* (1993). the results are in conformity with the findings of Balasubramonium *et al.* (1979) application of sulfur increased plant height, Betewulign *et al.* (2014) reported that the highest garlic plant height was the application of 100 kg N ha $^{-1}$ + 120 kg P_2O_5 ha^{-1},faraooqui *et al*. (2009) the combined application of 200 kg ha^{-1} nitrogen and 60 kg ha^{-1} sulfur significantly increased the plant height and Zaman *et al.* (2011) reported that Plant height increased gradually with increasing the levels of sulfur up to 45 kg/ha beyond which it decreased

Leaf number and length

Leaf number ($P \leq 0.05$) as well as length ($P < 0.01$) of garlic leaves were influenced by different rates of NPS fertilizers. The highest number of garlic leaves (12.1) was observed on plants that received the highest nitrogen rate (T12 with 140:122.6: 22.6 kg ha^{-1} N:P_2O_5:S). However the mean value was significantly similar with the leaf number mean values of plants treated with all N:P_2O_5:S fertilizer rates except T1 and T3. The longest leaf was also observed on garlic plants treated with T12 (48.6 cm) followed by T6 (48.2cm) which received 105:122.6:22.6 kg ha^{-1} N:P_2O_5:S fertilizer. Plants that didn’t receive N:P_2O_5:S fertilizer had the lowest leaf number as well as the shortest leaves.

The increment of garlic plant leaf number and length with the addition of higher level of NPS may be attributed to more availability of nutrients, especially N, which enhances the number of leaves and length by its simulative effect on cell division and cell enlargement that in turn may increase number of leaves and leaf length.Also enhances protein synthesis leading to an increase in building up carbohydrates and this in turn resulted in increases in plant growth characters. Phosphorus plays a pivotal role in metabolic processes and it is a main constituent of energy compounds, nucleic acids,phospholipids and co-enzymes. Also it may be attributed to favorable effects of phosphorus on root development and formation of carbohydrates. The application of sulphur helps in the availability of other nutrients resulting in better growth and

increased uptake of all the nutrients at higher levels of sulphur (El-Shafie and El-Gamaily ,2002; Ray , 1999; Nasiruddin *et al.*, 1993). The obtained results are in conformity with the findings of Abrheham *et al.* (2014) phosphorus had significant influence on the number of leaf per plant, Balasubramonium *et al.* (1979 application of sulfur increased , number of leaves and length increased, Betewulign *et al.* (2014) reported that the highest garlic leaf number and leaf length was the application of 100 kg N ha $^{-1}$+ 130 kg P_2O_5 ha^{-1} ,faraooqui *et al*. (2009) the combined application of 200 kg ha^{-1} nitrogen and 60 kg ha^{-1} sulfur significantly increased the number of leaves per plant, and Zaman *et al.* (2011) reported that , number of leaves/plant, highest leaf length, increased gradually with increasing the levels of sulfur up to 45 kg/ha beyond which it decreased.

Above ground biomass

The fresh weight of the above ground biomass of garlic was highly significantly ($P<0.01$) affected by NPS fertilizer rates (Table 4.20). The highest fresh above ground biomass per plant (25.33 g) was recorded at the rate of 105:122.6:22.6 N:P_2O_5:S followed (22.67 g) by 140:122.6:22.6 N:P_2O_5:S kg ha^{-1} where the mean values were not significantly different when compared each other. The lowest above ground biomass fresh weight per plant (13.3g) was recorded from plants which were not supplied with N:P_2O_5:S fertilizer (control). Similarly, the highest above ground dry weight per plant (5.05g) was recorded at the rate of 105:122.6:22.6 N:P_2O_5:S followed by 140:122.6:22.6 N:P_2O_5:S kg ha^{-1} (4.51g) which was statistically similar to the former one. Similar to the above ground fresh biomass, the lowest significant dry weight was observed from control plants which were not applied with N:P_2O_5:S fertilizer.

The results of this study clearly showed that the incorporation of sulfur in nitrogen and phosphorus fertilizers an effect on promoting vigorous plant growth. Also the improvement of fresh and dry weight of whole garlic plant could be attributed to an increased photosynthetic area in response to NPS fertilization that enhanced assimilates production and partitioning to the plants. The obtained results are in conformity with the findings of Abrheham *et al.* (2014) ; Balasubramonium *et al.* (1979) Betewulign *et al.* (2014); faraooqui *et al*. (2009) and Zaman *et al.* (2011) on garlic. NPS fertilization positively affected all vegetative characters of garlic

plant. Abrheham *et al.* (2014) phosphorus had significant influence on the number of leaf per plant, Balasubramonium *et al.* (1979 application of sulfur increased plant height, number of leaves, bulb diameter, bulb weight and total bulb yield, Betewulign *et al.* (2014) reported that the highest garlic plant height was the application of 100 kg N ha $^{-1}$ + 120 kg P_2O_5 ha^{-1} and the highest leaf number and leaf length was the application of 100 kg N ha $^{-1}$+ 130 kg P_2O_5 ha^{-1} ,faraooqui *et al*. (2009) the combined application of 200 kg ha^{-1} nitrogen and 60 kg ha^{-1} sulfur significantly increased the plant height, number of leaves per plant, bulb diameter, bulb fresh weight and Zaman *et al.* (2011) reported that Plant height, number of leaves/plant highest leaf weight, increased gradually with increasing the levels of sulfur up to 45 kg/ha beyond which it decreased.

Table 4. 4: Garlic growth parameters as affected by NPS fertilizer rates in Adet Zuria Kebele

$N:P_2O_5:S$ application rate kg ha^{-1}	Parameters					
	PHT	LL	LNO	MD	FWB	DWB
T1(0:0:0)	55.27^{d}	38.23^{d}	12.13^{c}	135.0	13.3^{d}	2.76^{d}
T2(75.69:61.18)	64.13^{bc}	44.13^{bc}	13.10^{ab}	135.00	18.1^{bcd}	3.70^{bcd}
T3(105:92:0)	62.17^{c}	43.20^{c}	12.63^{bc}	135.0	16.67^{cd}	3.32^{cd}
T4(105:92:17)	64.13^{bc}	44.17^{bc}	12.87^{ab}	136.00	22.50^{ab}	4.23^{abc}
T5(105:61.4:11.3)	66^{abc}	46.10^{abc}	13.13^{ab}	136.00	18.67^{bc}	3.83^{bc}
T6(105:122.6:22.6)	69.23^{a}	48.17^{a}	12.97^{ab}	135.33	25.33^{a}	5.05^{a}
T7 (70:92:17)	66^{abc}	46.43^{abc}	13.27^{ab}	136.00	18.17^{bcd}	3.57^{bcd}
T8(70:61.4:11.3)	64.17^{bc}	44.47^{bc}	13.07^{ab}	134.00	18.50^{bc}	3.68^{bcd}
T9(70:122.6:22.6)	66.6^{ab}	46.43^{abc}	13.10^{ab}	134.33	17.33^{cd}	4.12^{abc}
T10(140:92:17)	65.63^{abc}	47.07^{ab}	13.27^{ab}	135.3	19.17^{bc}	3.79^{bc}
T11(140:61.4:11.3)	63.17^{bc}	44.17^{bc}	13.23^{ab}	135.33	17.17^{cd}	3.31^{cd}
T12(140:122.6:22.6)	68.5^{a}	48.6^{a}	13.40^{a}	136.00	22.67^{ab}	4.51^{ab}
Mean	64.58	45.09	13.01	135.28	18.97	3.82
CV	3.67	4.69	3.04	0.99	15.95	14.98
Significant difference	**	**	*	NS	**	**

PHT= Plant height (cm) LL= Leaf length (cm) LNO= Leaf number MD= Maturity date FWB= Fresh above ground biomass/plant (g) DWB= Dry weight of above ground biomass (g), T1 –T12= Treatments 1 to 12,CV=coefficient of variation ,NS=non significant, *= significant ($P < 0.05$), **= highly significant ($P<0.01$)

4.2.2 Yield related traits of garlic as affected by NPS

Bulb size

Plants supplied with the highest NPS fertilizer rate of 140:122.6:22.60 N:P_2O_5:S kg ha^{-1} produced the longest mean bulb length (3.75cm) which was statistically significant compared to those from the control plants (3.22cm). However, compared to the bulbs obtained from other treatments, the mean bulb length obtained from the highest NPS fertilizer rate (140:122.6:22.60 N:P_2O_5:S kg ha^{-1}) was not statistically significant. Similarly, the biggest bulb diameter of garlic (4.27 cm) was achieved by application of the highest NPS fertilizer rate (140:122.6:22.60 N:P_2O_5:S kg ha^{-1}) which was however statistically similar with diameters of bulbs obtained from other treatments except those from the control plants (3.48 cm), which was significantly ($P<0.05$) less compared to those from other treatments.

The results of the present study revealed that bulb length and bulb diameter parameters of garlic were influenced with the different rates of NPS fertilizer. The highest bulb length and diameter of garlic were generally obtained from the application of highest rates of phosphorous and sulfur. This is due the combined positive effects of phosphorous and sulfur in metabolic processes such as amino acids, vitamins, lipids, and some hormones formations (Nasiruddin *et al.*, 1993). Furthermore sulfur and nitrogen stimulate the enzymatic actions and chlorophyll formation which increased bulb size of garlic (El-Shafie and El-Gamaily, 2002).

The results obtained in this study is in conformity with the findings of Nasiruddin *et al*. (1993) that reported the application of sulfur increased bulb diameter and bulb length of garlic. It is also in agreement with the findings of Hariyappa (2003) where the bulb diameter of garlic was increased with increasing sulfur level.

Bulb weight

Bulb weights of garlic were statistically not significantly influenced by the application of NPS fertilizer. Compared to the control, most NPS fertilizer rates increased the weights of garlic bulbs. The highest Bulb weight (46.50g) was achieved by the application of 105:122.6:22.60 $N:P_2O_5:S$ kg ha^{-1} folloewd140:92:17 NPS $N:P_2O_5:S$ ha^{-1} (43.8 g). However weights of bulbs obtained from these treatments were statistically similar when compared to each other.

The highest bulb weight of garlic was recorded at the ratio of 105:122.6:22.6 $N:P_2O_5:S$ kg ha^{-1} applications of $N:P_2O_5:S$ fertilizer below and above this ratio reduced or have no significant positive effect on the bulb weight of garlic. The highest phosphorous and sulfur given in this treatment (T6) may contribute in the metabolic process such as formation of nucleic acids, Phospholipids, co-enzymes, and chlorophyll which intern enhance the bulb weight of garlic plants as described by El-Shafie and El-Gamaily (2002), Ray (1999) and Nasiruddin *et al.* (1993).

Bulb yield

The highest marketable yield of garlic was obtained from T12 (140:122.6:22.60 $N:P_2O_5:S$ kg ha^{-1}) followed by T10 (140:92:17 $N:P_2O_5:S$ kg ha^{-1}) and T6 (105:122.6:22.6 $N:P_2O_5:S$ kg $ha^{-1)}$ with the mean values of 17.42, 16.16 and 15.81 t ha^{-1} respectively, whereby the mean values were similar ($P<0.05$) when compared to each other. The lowest significant ($P<0.05$) marketable bulb yield (9.97t ha^{-1}) was recorded from the control treatment where no NPS fertilizer was applied. Similar trend in total bulb yield of garlic was also observed in T12, T10 and T6 with the mean values of 17.80, 16.74, and 16.42t ha^{-1}, respectively, which were not statistically different when compared each other. The total bulb yield of garlic in control treatment was also significantly ($P<0.05$) the lowest yield (10.82t ha^{-1}) obtained in this study. In case of unmarketable yield, the highest unmarketable yield was obtained from T5 followed by T1 and T2 with the mean values of 1.08, 0.85 and 0.713 t ha^{-1}, respectively.

The results of the present study revealed that yield and yield parameters of garlic were influenced with the different rates of NPS fertilizer. The highest bulb weight, diameter and

length of garlic were generally obtained from the application of highest rates of phosphorous and sulfur. This is due the combined positive effects of phosphorous and sulfur in metabolic processes such as amino acids, vitamins, lipids, and some hormones formations (Nasiruddin *et al.*, 1993). Furthermore sulfur and nitrogen stimulate the enzymatic actions and chlorophyll formation which promote the growth and development leading to high yielding performance of plants (El-Shafie and El-Gamaily, 2002). Thus an adequate supply of nutrients to plants is associated with vigorous vegetative growth resulting higher productivity of crops (Naruka and Dhaka, 2001; Yadav, 2003; Farooqui *et al.*, 2009).

The results obtained in this study is in conformity with the findings of Nasiruddin *et al*. (1993) that reported the application of sulfur increased plant height, number of leaves, bulb diameter, and bulb yield of garlic. It is also in agreement with the findings of Zaman *et al.* (2011) where the bulb yield of garlic was increased with increasing sulfur level up to 45 kg/ha and there after decreased. Hariyappa (2003) also recorded a significant increased yield and bulb diameter of garlic with the application of sulfur.

Table 4. 5: Garlic yield parameters as affected by NPS fertilizer rates in Adet Zuria Kebele

$N:P_2O_5:S$ application rate kg ha^{-1}	Parameters					
	BW	BL	BD	MYT	UMYT	TYT
T1(0:0:0)	32.83	3.22	3.48^{b}	9.97^{f}	0.85	10.82^{e}
T2(75.69:61.18)	40.33	3.60	4.01^{a}	13.60^{cde}	0.713	14.31^{cd}
T3(105:92:0)	43.50	3.71	4.16^{a}	14.81^{bcde}	0.34	15.16^{bcd}
T4(105:92:17)	41.33	3.77	4.20^{a}	15.03^{bcd}	0.65	15.67^{abc}
T5(105:61.4:11.3)	39.83	3.57	3.93a	13.08^{de}	1.08	14.17^{cd}
T6(105:122.6:22.6)	46.50	3.71	4.22^{a}	15.81^{abc}	0.61	16.42^{abc}
T7 (70:92:17)	40.17	3.72	4.10^{a}	13.68^{cde}	0.53	14.21^{cd}
T8(70:61.4:11.3)	39.17	3.47	3.95^{a}	12.49^{e}	0.59	13.08^{de}
T9(70:122.6:22.6)	39.33	3.68	4.17^{a}	14.36^{bcde}	0.45	14.81^{bcd}
T10(140:92:17)	43.83	3.84	4.1917^{a}	16.16^{ab}	0.57	16.74^{ab}
T11(140:61.4:11.3)	42.17	3.53	4.06^{a}	14.24^{bcde}	0.66	14.90^{bcd}
T12(140:122.6:22.6)	43.67	3.75	4.27^{a}	17.42^{a}	0.38	17.80^{a}
Mean	41.05	3.63	4.06	14.22	0.619	14.84
CV	11.40	6.51	5.38	9.89	39.90	9.38
Significant difference	NS	NS	*	**	NS	**

BW = Bulb weight (g) BL= Bulb length (cm) BD = Bulb diameter (cm) MYT = Marketable bulb yield (ton ha^{-1}) UMYT= Unmarketable bulb yield (ton ha^{-1}) TYT=Total bulb yield (ton ha^{-1}) CV=coefficient of variation, T1 –T12= Treatments 1 to 12 ,NS=non significant *= significant ($P < 0.05$), **= highly significant ($P<0.01$)

4.2.4 Correlations between growth and yield parameters as influenced by NPS

Correlation between growth and yield components of garlic as influenced by application of NPS fertilizer was computed and its results are presented below in Tables 4.6 Correlation coefficient was used for measuring the relationship of any two parameters as explained by Gomez and Gomez (1984). The correlation analysis showed that total bulb yield of garlic was strongly and positively ($P \leq 0.01$) related with leaf length (0.74^{**}), leaf number (0.44^{**}), plant height (0.74^{**}), fresh above ground biomass (0.50^{**}), dry weight of above ground biomass (0.73^{**}), bulb diameter (0.62^{**}), bulb length (0.61^{**}), bulb weight (0.69^{**}), and marketable bulb yield (0.99^{**}) except with unmarketable bulb yieled (-0.25^{ns}).

The increment in bulb yield was a result of increase in plant height, number of leaves per plant,leaf length and leaf diameter, which led to relatively giant plant morphology.Plant height showed a positive and significant correlation with number of leaves per plant, leaf length, total bulb weight, bulb yield per hectare, bulb diameter. In harmony with this study, Korla et al. (1981) reported that plant height was positively and significantly correlated with weight of bulb and bulb diameter. Plant height also showed a positive and significant relationship with number of leaves per plant and it was positively and significantly correlated with leaf length that obviously led to increment in photosynthetic area that might have partly contributed to increment in yield of bulb per plant. Number of leaves per plant indicated positive and significant correlation with leaf diameter, total bulb weight, bulb yield per hectare, bulb diameter and marketable yield. The positive and significant correlation of number of leaves per plant with such parameters indicated the paramount contribution for bulb yield in garlic. This is in agreement with the work of Badshah and Umar (1999), who have reported positive correlation between leaf number and yield in garlic. Leaf length was positively and significantly correlated with leaf diameter, bulb yield per hectare and bulb diameter, it was correlated with number of leaves per plant, total bulb weight, and marketable bulb yield.

Table 4. 6: Correlations between growth and yield parameter

Parameters	BD	BL	BW	DWB	FWB	LL	LNO	MD	MYT	PHT	TYT	UMYT
BD												
BL	0.88^{**}											
BW	0.50^{**}	0.43^{**}										
DWB	0.53^{**}	0.50^{**}	0.40^{*}									
FWB	0.44^{**}	0.41^{*}	0.35^{*}	0.91^{**}								
LL	0.65^{**}	0.63^{**}	0.58^{**}	0.60^{**}	0.46^{**}							
LNO	0.26^{NS}	0.21^{NS}	0.30^{NS}	0.32^{ns}	0.27^{ns}	0.53^{**}						
MD	0.32^{ns}	0.40^{*}	0.07^{ns}	0.44^{**}	0.47^{**}	0.15^{ns}	-0.11^{ns}					
MYT	0.67^{**}	0.66^{**}	0.68^{**}	0.54^{**}	0.50^{**}	0.74^{**}	0.43^{**}	0.09^{ns}				
PHT	0.63^{**}	0.61^{**}	0.56^{**}	0.73^{**}	0.60^{**}	0.91^{**}	0.54^{**}	0.20^{ns}	0.74^{**}			
TYT	0.62^{**}	0.62^{**}	0.69^{**}	0.54^{**}	0.50^{**}	0.74^{**}	0.44^{**}	0.08^{ns}	0.99^{**}	0.74^{**}		
UMYT	-0.57^{**}	-0.52^{**}	-0.10^{ns}	-0.22^{ns}	-0.15^{ns}	-0.28^{ns}	-0.03^{ns}	-0.15^{ns}	-0.37^{*}	-0.20^{ns}	-0.25^{ns}	

4.2.5 Marginal rate of return of garlic as affected by NPS

Marginal rate of return was analyzed using the technique described by CIMMT (1988) to assess the costs and benefits of the treatments. Based on this technique, the highest marginal rate of return was obtained from 140:92:17 kg/ha N:P_2O_5:S (Table 4.8). The marginal rate of return indicated that 140:92:17 kg/ha N:P_2O_5:S resulted in maximum marginal rate of return (10,386.4) followed by 105:92:0kg/ha N:P_2O_5:S with (6530.414) marginal rate of return. The least relative marginal rate of return was recorded in the application of 70:92:17 kg/ha N:P_2O_5:S with (182.9478) marginal rate of return. The variable labor cost indicates in (table 4.7) due to the application of fertilizer.

Table 4. 7: Total variable cost and gross income benefit

$N:P_2O_5:S$ application rate kg ha^{-1}	Variable cost per ha					Income per ha		
	Fertilizer cost (Eth-Birr)			LC-ETHBirr	TVC-ETH Birr	MY (t)	GI-Eth Birr	GI-TVC Birr (net benefit)
	DAP	NPS	Urea					
T1 (0:0:0)	0	0	0	0	0	9.97	299100	299100
T2 (75.7:61.2:0)	1862	0	1264.5	2400	5526.5	13.6	408000	402473.5
T3 (105:92:0)	2800	0	1686	2400	6886	14.81	444300	437414
T4 (105:92:17)	0	3388	1442.092	2400	7230.09	15.03	450900	443669.9
T5 (105:61.4:11.3)	0	2261	1815.822	2400	6476.82	13.08	392400	385923.2
T6 (105:122.6:22.6)	0	4516.4	1067.8	2400	7984.2	15.81	474300	466315.8
T7 (70:92:17)	0	3388	586.728	2400	6374.72	13.68	410400	404025.3
T8 (70:61.4:11.3)	0	2261	960.5704	2400	5621.57	12.49	374700	369078.4
T9 (70:122.6:22.6)	0	4516.4	212.436	2400	7128.83	14.36	430800	423671.2
T10 (140:92:17)	0	3388	2296.332	2400	8084.33	16.16	484800	476715.7
T11 (140:61.4:11.3)	0	2261	2670.624	2400	7331.62	14.24	427200	419868.4
T12 (140:122.6:22.6)	0	4516.4	1922.04	2400	8838.44	17.42	522600	513761.6

Assumptions: Price of garlic = 30 Birr/kg; labor cost = 50 Birr/person; NPS price = 14 Birr/kg; DAP price= 14 Birr/kg; Price of Urea=11.24 Birr/kg; LC=labor cost; TVC=total variable cost; MY=marketable yield, t=ton; GI=Gross income

Table 4. 8: Marginal rate of return

Treatment	Cost	Net benefit	MRR %	Rank
T1	0	299100	-	-
T2	5526.5	402474	1870.506	5
T7	6374.72	404025	182.9478	7
T3	6886	437414	6530.414	2
T4	7230.09	443670	1818.1	6
T6	7984.2	466316	3002.997	4
T10	8084.33	476716	10386.4	1
T12	8838.44	513762	4912.533	3

MRR (Marginal rate of return) = Change in net benefit/ change in cost ×100

CHAPTER 5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Garlic is an important cash crop in Ethiopia including Amhara Region. However production and productivity is by far lower compared to other countries. Intervention on the production of garlic therefore requires information about the production practices employed by farmers and thus identification of the major constraints and opportunities of garlic production including in the study *kebele*. On the other hand Bureau of Agriculture introduced a new fertilizer in crop production system which contains nitrogen, phosphorous and sulfur where its optimum rate of application is no yet identified. Therefore, the main aim of this study is to assess the farmer`s garlic production practices and to investigate the effects of NPS fertilizer on growth and yield performance of garlic in the study area.

Garlic is produced during the main cropping season and during off season using irrigation in the study *kebeles*. During the main cropping season, farmers plant garlic at the onset of rainfall (June) and they harvest it October/November. The garlic irrigation season in the study *kebeles* is November to April. Farmers in the study *kebeles* used totally local garlic varieties sourced from local market and own save. No improved garlic varieties were available in the study *kebeles*.

Farmers in the study *kebeles* plowed their garlic field about 3.8 times before planting which is relatively well. They planted their garlic cloves in double row arrangement of 34.8 cm between double rows, 26.8 cm between rows and 11.8 cm between plants in the row which is relatively wide the thus reduced the population that leads to reduced yield. Furrow irrigation was the dominant method used in the study *kebeles* to apply irrigation water to garlic field which was mostly sourced from rivers. Most of the farmers in the study *kebeles* used mineral fertilizers such as DAP and urea to improve soil fertility and thus to increase production and productivity of garlic. However the rate of application is by far below the blanket recommendation for garlic production in the area which resulted unsatisfactory yield performance of garlic in the *kebeles* as indicated in T2.

Pests were one of the major in the production of garlic in the study *kebeles*. According to the farmer`s observation white rot (*Sclerotium cepivorum)* and garlic rust (*Puccinia allii*) were the major diseases occurred in the area. They used fungicides such as Ridomil 68 % WG and Bayleton 25 % WP to control garlic rust while no chemical was available to control white rot of garlic. Although thrips were common in all garlic farms, they were easily controlled by spraying of insecticides like Profit 72 EC chemical in two weeks interval. The common way of weed control in garlic farms was by cultivation using hoe and hand weeding. No herbicides were used for the control of weeds in garlic production.

According to farmers, garlic was ready for harvest five to six months after planting when 75% of the leaves were died, which is relatively comparable with the research finding in this study (about 4.5 months). Although most farmers sale their garlic immediately after harvesting, some farmers store it in sacks and/or spread open in above ground structure (*kot*) or on floor for their own consumption which may facilitate postharvest losses. Most farmers transported their produces using pack animals and cart and sold it for whole sellers.

The average production, productivity and crop water productivity is low due to inappropriate agronomy practice, absence of proper disease and insect pest management and use of low yieldig local Varity.

Lack of land and lack of money are among others the main constraints of garlic production in the study area. Nevertheless, the study area has also huge opportunities for the improvement of garlic production including long year experiences of farmers, due attention given by the governmental offices to irrigation farming and availability of relatively cheap labor force.

Application of mineral fertilizer like NPS is necessary to improve the production and productivity of garlic in the study area. Thus, results of this study revealed that almost all yield and yield parameters were significantly affected by different rates of NPS fertilizer. Most of the growth parameters of garlic were significantly highest at NPS fertilizer rate (T6) of 105:122.6:22.6 $N:P_2O_5:S$ ha^{-1}. Highest yield also obtained from plants treated with $N:P_2O_5:S$ fertilizer rate of 140:122.6:22.6 (T12) which was statistically similar with the yield obtained from those plots treated with 140:92:17 kg/ha (T10) and 105:122.6:22.6 (T6). The highest

marginal rate of return was however obtained from plants treated with $N:P_2O_5:S$ fertilizer rate of 140:92:17 kg/ha (T10)

5.2 Recommendations

The above findings indicated that Yilmana Densa district has a huge potential in the production of garlic production. However, its production is facing a lot of constraints which require various intervention activities such as:

- Upgrading the skills, knowledge and attitudes of the producers in the production of garlic
- Improving the availability of inputs such as improved garlic varieties, fertilizers, pesticides, irrigation equipments
- Developing the availability of water bodies through intensive soil and water conservation activities, rain water harvesting technologies and spring water development measures.

In addition the yield of garlic at Yilmana Densa district can be statistically improved by using $N:P_2O_5:S$ fertilizer at the rate of 140:92:17 kg ha^{-1}. To develop forceful recommendation however, it will be good to repeat the experiment on soils of different characteristics and agro-ecological conditions using different improved garlic varieties. Moreover it is also recommended to repeat the experiment with higher level of NPS fertilizer rates.

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APPENDIX

Appendix Table 1: Experience of farmers and production systems of garlic in study *kebeles*

Descriptions	Adet Zuria (N=10)	Goshaye (N=10)	Ambesit (N=10)	Total (N= 30)
Experience in garlic production	Percent (%)	Percent (%)	Percent (%)	Percent (%)
<5 years	90	40	70	66.7
5-10 years	10	20	10	13.3
10-15 years	0	20	0	6.7
>15 years	0	20	20	13.3
Garlic production system				
Off season with irrigation	90	100	90	93.3
Both irrigation and cropping season	10	0	10	6.7

Appendix Table 2: Garlic varieties used and their sources in the study area

Descriptions	Adet Zuria (N=10)	Goshaye (N=10)	Ambesit (N=10)	Total (N= 30)
Varieties used and sources	Percent (%)	Percent (%)	Percent (%)	Percent (%)
Improved varieties	0	0	0	0
Local planting materials	100	100	100	100
Source of planting material s				
Saved planting material	10	50	30	30
Local market	80	50	70	66.7
Market and own planting material	10	0	0	3.3

Appendix Table 3: Frequency of plowing and planting system

Discretions	Adet Zuria (N=10)	Goshaye (N=10)	Ambesit (N=10)	Total (N= 30)
Plow	Mean	Mean	Mean	Mean
Plow frequency	3.6	4.6	3.1	3.8
Planting system				
Between double row	35.5	34.5	34.37	34.82
Between single row	26	25	30	26.78
Between plant in the row	12.5	11.5	11.25	11.78

Appendix Table 4: Sources of irrigation water, methods and frequency of irrigation for garlic production in the study area

Descriptions	Adet Zuria (N=10)	Goshaye (N=10)	Ambesit (N=10)	Total (N= 30)
Source of water for irrigation	Percent (%)	Percent (%)	Percent (%)	Percent (%)
River	100	100	90	96.7
Harvested water	0	0	10	3.3
Irrigation methods used				
Furrow irrigation	100	10	80	93.3
Tradition spraying	0	0	20	6.7
Irrigation frequency				
Every week	70	70	70	70
5 days interval	30	30	30	30

Appendix Table 5: Types, and mean fertilizers rates applied for garlic production in the study area

Description	Adet Zuria (N=10)		Goshaye (N=10)		Ambesit (N=10)		Total (N=30)	
	Percentage of farmers	Rates (kg/ha)	Percentage of farmers	Rates (kg/ha)	Percentage of farmers	Rates (kg/ha)	Percentage of farmers	Rates (kg/ha)
DAP	100	195	90	135	60	46	83.3	125
Urea	100	200	100	180	90	85	96.7	155
Compost/manure	0	-	0	-	20	-	6.6	-

Appendix Table 6: DAP and urea application time and method

Descriptions	Adet Zuria (N=10)	Goshaye (N=10)	Ambesit (N=9)	Total (N= 29)
DAP application time	Percent (%)	Percent (%)	Percent (%)	Percent (%)
At planting	0	11.1	16.7	8
One months after planting	10	0	66.7	20
Half one month, and the remaining half two months after planting	90	88.9	16.7	72
Urea application time				
One month after planting	0	0	77.8	24.1
Half one month, and the remaining half two months after planting	100	100	22.2	75.9
DAP application method				
Spot	70	22.2	83.3	56
Side dressing	30	77.8	16.7	44
Urea application method				
Spot	70	30	77.8	58.6
Side dressing	30	70	11.1	37.9
Broadcasting	0	0	11.1	3.4

Appendix Table 7: Disease and insect pest occurrence and their measurement

Descriptions	Adet Zuria (N=10)	Goshaye (N=10)	Ambesit (N=10)	Total (N= 30)
Disease occurrence	Percent (%)	Percent (%)	Percent (%)	Percent (%)
White rot	10	80	10	33.3
Garlic rust	40	20	10	23.3
No observed	50	0	80	43.3
Measurement of disease control				
Chemical	40	50	0	30
Not used	60	50	100	70
Insects that are serious problems in garlic field				
Thrips	100	100	100	100
Measurement of insect pest control				
Chemical	100	100	70	90
Not used	0	0	30	10

Appendix Table 8: Frequncy of garlic cultivation in the study *kebeles*

Descriptions	Adet Zuria (N=10)	Goshaye (N=10)	Ambesit (N=10)	Total (N= 30)
Cultivation	Percent (%)	Percent (%)	Percent (%)	Percent (%)
Twice	0	0	20	6.7
Trice	10	20	40	23.3
>Three times	90	80	40	70

Appendix Table 9: Harvesting indicators and harvesting method of garlic

Descriptions	Adet Zuria (N=10)	Goshaye (N=10)	Ambesit (N=10)	Total (N= 30)
Garlic taking months for harvesting	Percent (%)	Percent (%)	Percent (%)	Percent (%)
5months	80	10	10	33.3
6months	20	90	90	66.7
Indicators ready for harvesting				
50%leaves have died off	20	10	10	13.3
75%leaves have died off	80	70	80	76.7
100%leaves have died off	0	20	10	10
Methods of harvesting				
Uprooting	100	100	100	100

Appendix Table 10: Practice of curing after harvesting, method of garlic curing, method of storing garlic and duration of store garlic

Descriptions	Adet Zuria (N=10)	Goshaye (N=10)	Ambesit (N=10)	Total (N= 30)
Practice of curing after harvesting	Percent (%)	Percent (%)	Percent (%)	Percent (%)
Yes	40	100	90	76.7
No	60	0	10	23.3
Method of garlic curing				
A shady place with dry air	40	100	90	76.7
Not used	60	0	10	23.3
Method of storing garlic				
Bag	80	40	10	43.3
On kot	10	30	70	36.7
Spread on floor	10	30	20	20
Duration of store garlic				
1week	70	10	10	30
2week	0	0	10	3.3
3week	0	0	10	3.3
1month	10	60	30	33.3
2 months	0	10	40	16.7
>2months	20	20	0	13.3

Appendix Table 11: Major constraints of garlic production in the study *kebeles*

Descriptions	Adet Zuria (N=10)	Goshaye (N=10)	Ambesit (N=10)	Total (N= 30)
Major constraint	Percent (%)	Percent (%)	Percent (%)	Percent (%)
Lack of land	60	0	10	23.3
Lack of money	40	0	10	16.7
white rot	0	60	0	20
Lack of quality planting material	0	20	0	6.7
Shortage of irrigation water	0	0	70	23.3
Unavailable fertilizer	0	20	10	10

Appendix Table 12: Analysis of variance for plant height

Source of variation	Df	SS	MS	F value	Pr>value
Trt	11	424.12	38.56	6.85	<.0001
Rep	2	11.07	5.53	0.98	0.3898
Error	22	123.80	5.63		
Total	35	558.99			
CV (%)	3.67				
Mean	64.58				
LSD	4.02				

Appendix Table 13: Analysis of variance for leaf length.

Source of variation	Df	SS	MS	F value	Pr>value
Trt	11	251.75	22.89	5.11	0.0006
Rep	2	0.60	0.30	0.07	0.9350
Error	22	98.52	4.48		
Total	35	350.87			
CV (%)	4.69				
Mean	45.09				
LSD	3.58				

Appendix Table 14: Analysis of variance for leaf number.

source of variation	Df	SS	MS	F value	pr>value
Trt	11	3.90	0.35	2.26	0.05
Rep	2	0.90	0.45	2.86	0.078
Error	22	3.46	0.16		
Total	35	8.26			
CV (%)	3.05				
Mean	13.01				
LSD	0.6715				

Appendix Table 15: Analysis of variance for maturity date

Source of variation	Df	SS	MS	F value	Pr>value
Trt	11	14.55	1.32	0.73	0.69
Rep	2	10.89	5.44	3.01	0.069
Error	22	39.78	1.80		
Total	35	65.22			
CV (%)	0.99				
Mean	135.28				
LSD	2.28				

Appendix Table 16: Analysis of variance for above ground biomass/plant

Source of variation	Df	SS	Ms	F value	pr>value
Trt	11	333.80	30.34	3.31	0.0081
Rep	2	65.18	32.59	3.56	0.0458
Error	22	201.49	9.16		
Total	35	600.47			
CV (%)	15.95				
Mean	18.97				
LSD	5.12				

Appendix Table 17: Analysis of variance for Dry weight of above ground biomass

Source of variation	Df	SS	MS	F value	Pr>value
Trt	11	11.95	1.09	3.31	0.0081
Rep	2	0.63	0.32	0.97	0.3954
Error	22	7.22	0.33		
Total	35	19.80			
CV (%)	14.98				
Mean	3.82				
LSD	0.97				

Appendix Table 18: Analysis of variance for Bulb weight

Source of variation	Df	SS	Ms	F value	Pr>value
Trt	11	385.22	35.02	1.60	0.1683
Rep	2	41.43	20.71	0.95	0.4039
Error	22	482.24	21.92		
Total	35	908.89			
CV (%)	11.40				
Mean	41.05				
LSD	7.9278				

Appendix Table 19: Analysis of variance for Bulb length

Source of variation	Df	SS	Ms	F value	Pr>value
Trt	11	0.94	0.08	1.53	0.19
Rep	2	0.00024	0.00012	0.00	0.9978
Error	22	1.23	0.05		
Total	35	2.17			
CV (%)	6.514082				
Mean	3.63				
LSD	0.40				

Appendix Table 20: Analysis of variance for bulb diameter

Source of variation	Df	SS	MS	F value	Pr>value
Trt	11	1.470	0.133	2.80	0.0190
Rep	2	0.113	0.057	1.19	0.32
Error	22	1.049	0.048		
Total	35	2.63			
CV (%)	5.38				
Mean	4.06				
LSD	0.37				

Appendix Table 21: Analysis of variance for Marketable bulb yield

Source of variation	Df	SS	MS	F value	Pr>value
Trt	11	121.74	11.07	5.59	0.0003
Rep	2	3.64	1.82	0.92	0.4133
Error	22	43.54	1.98		
Total	35	168.92			
CV (%)	9.89				
Mean	14.22				
LSD	2.38				

Appendix Table 22: Analysis of variance for Unmarketable bulb yield

Source of variation	Df	SS	MS	F value	Pr>value
Trt	11	1.36	0.12	2.03	0.0757
Rep	2	0.097	0.048	0.80	0.4639
Error	22	1.34	0.060		
Total	35	2.80			
CV (%)	39.90				
Mean	0.62				
LSD	0.42				

Appendix Table 23: Analysis of variance for Total bulb yield

Source of variation	Df	SS	MS	F value	Pr>value
Trt	11	107.93	9.81	5.07	0.0006
Rep	2	4.92	2.46	1.27	0.3002
Error	22	42.60	1.94		
Total	35	155.46			
CV (%)	9.38				
Mean	14.84				
LSD	2.36				

Questionnaires for assessment of production of Garlic

Part I. Demographic information

1. Name of farmer/Code: ___________
2. Sex of Household head a). Female b). Male
3. Age of Household head in Years a). <18 b). 19-33 c). 33-48 d). >48
4. Family size a). >4 family member b). <4 family member
5. Educational status of Household head

   a). Literate b). Illiterate c). 1-6 grade d). 8-10 grade d). Others----------
6. District ______________*Kebele*/PA _____________

Part II. Farm practices

1. What is your total land holding? a). <0.50ha b). 0.50-1.0ha c). 1.0-1.50ha d). >1.50ha

2. What size of your land is dedicated to Garlic production?

   a). <0.25ha b). 0.25-0.50ha c).0.50-0.75ha d).1.0ha e).>1.0ha

3. How long is your experience in Garlic production?

   a. <5 years b. 5-10 years c.10-15 years d. > 15 years

4. Where do you get your planting materials from?

   a. Farmers' shop b. BoA c. Own planting material d. Colleague e. others----

5. Have you ever produced planting materials of vegetables/Garlic before?

   a. Yes b. No

6. Which variety of garlic do you grow?

   a). Qoricho b). Bishoftu Netch c). Tseday92 d). Others --------------

7. When do you grow Garlic?

   a. Cropping season b. off season with irrigation c. Both

8. How many times in a year do you produce Garlic?

   a. Once b. Twice c. Trice

9. If you are producing Garlic with irrigation, what is your source of water for cultivation?

   a. Rain b. River c. Borehole d. Rain and River e. Others---------

10. If you are using irrigation, which method do you use?

    a. Watering can b. Furrow Irrigation c. Flooding d. Others---------

11. How frequently do you irrigate your Garlic?

    a. Every day b. Every week c. Every two weeks d. Others-----

12. Who is irrigating your Garlic plants?

    a. Women b. children c. household head d. hired labour e. other----

13. What time in the day do you planting garlic clove?

    a. Early morning b. noon time c. late evening d. Others -----

14. What is the spacing do you use by planting onion in the field?

a). 10 x 20cm b). 20 x 20cm c).20x30cm d).10x15x30cm
e).Others---------------

15. Who does planting garlic clove?

a. Women b. children c. household head d. hired labour e. other----

16. Please provide details on the types of fertilizers, method and rate of their application

	Urea (kg/ha)	DAP (kg/ha)	Compost (kg/ha)	Manure (kg/ha)
How much do you apply?				
When do you apply?				
How do you apply?				
Who does apply fertilizers?				

17. Do you grow garlic on the same piece of land every year?

a. Yes b. No

18. What kinds of diseases did you observe on your garlic plants?

a. Black leg b. club rot c. leaf spots d. Others---------

19. What measures did you take?

20. Which insect pest are causing serious problem at garlic production field?

a. Cut worm b. Beetles c. Thrips d. Others-----

21. What measures did you take?

----

22. Which kinds of weeds are common in your garlic plot?

----

23. How do you control those weeds?

----

24. How often do you remove weeds from the garlic plot?

a. Once b. twice c. trice d. >three times

25. Who is involved in weeding?

a) Women b. children c. household head d. hired labour e. other----

26. From the following, what are the biggest problems in garlic farming? You may choose Several:

a. Lack of irrigation / dependence of rainfall
b. Lack of information about good farming practices
c. Poor-quality planting material Garlic
d. Suitable land for Garlic
e. Money for investment / rural credit
f. Availability of cold storage units
g. Application of poor technology
h. Lack of proper chemicals
i. Unreliable cash flow for the farmer
j. No unified scales or measurements
k. road network

27. What should be done to solve these problems?

For this question you have to list the probable solutions and let the farmer prioritize

Part III. Harvest and postharvest operation

1. How long does garlic take to reach harvesting?

a. 3months b. 4months c. 5Months d. >5months

2. How do you know when your garlic is ready for harvesting?
    a. Number of day's b. 50% leaves have died off c. 75% leaves have died off d. 100% leaves have died off e. Others ----
3. How do you harvest your garlic?
    a. Cutlass b. sickle c. uprooting d. Others------
4. What time of the day are you harvesting your garlic?
    a. Early morning b. Mid Noon c. Late evening d.Others--
5. Who is involved in harvesting?
    a. Women b. children c. household head d. hired labor e. other----
6. Do you practice curing of garlic after harvesting?
    a. Yes b. No
7. If Yes, How do you cure?
    a. Shady place with dry air b. exposed to direct sunlight c. by smoking d. others
8. How much do you produce in a given area? ....
9. What is the purpose of your garlic production?
    a. Home consumption b. Sale c. Home consumption and sale
10. What proportion of garlic is consumed sold?
    a.All b. 3/4th c. ½ d. 1/4th
11. Whom do you sell your garlic to?
    a.Consumers b. Hotels/restaurants c. Brokers d. Whole sellers e. Retailers
12. What is the price of garlic in good days and bad days? ------- and ---------
13. If you have to sale you garlic, how far do you travel?
    a.1 hour b. 2hours c. 3 hours d. 4 hours e. others -----
14. How do you take your garlic to the market?
    a.On foot b. by Pack animals c. By Vehicle d. Others----
15. Who does take garlic to the market?
    a.Women b. Children c. Head of household d. Hired labour e. others—
16. How do you store your garlic?
    a.Boxes b. bag c. cellar d. Basket e. others------
17. If there is no good price for your garlic, what do you do with them?
18. For how long can you store your garlic?

    a). 1week b). 2 weeks c).3weeks d).1month e).2months f).others----

Part IV. Institutional Support

19. In the last 3 years, did you receive any kind of training on garlic production?
    a.Yes b. No
20. If yes, from whom?
    a.University b. Research Center c. NGO d. BoA e. Others---

21. Have you ever received any credit service for your garlic production?

    a.Yes b. No

22. If yes, from whom?

    a.University b. Research Center c. NGO d. BoA e. others---

23. Did your household receive any planting material from ARDO or an agricultural Extension agent? a. Yes b. No.

24. If yes, from whom?

    a.University b. Research Center c. NGO d. BoA e. Others-----

25. Did you have any advice on marketing of garlic?

    a.Yes b. No

26. If yes, from whom?

    a.University b. Research Center c. NGO d. BoA e. Others------

BIOGRAPHY OF THE AUTHOR

The author, Mr Shege Getu Yayeh was born in 1986 in Yilmana Densa district, West Gojjam Zone of Amhara National, Regional State from his father Mr. Getu Yayeh and his mother Yambel Zeleke. He attends from 1994 – 2000 Abika Elementary schools, from 2000-2002 Adet Junior school, from2002- 2004 Adet High School, from 2004-2006 in Mecha district at Merawi preparatory and he joined in 2006 in Jimma University College of Agriculture and Veterinary Medicine. He graduated from Jimma University in the Year 2009 Bachelor of Science degree /BSc/ in Horticulture. After graduating, he was worked in Yilmana Densa district agricultural office. Finally, he joined the school of graduate studies of Bahir Dar University 2013 to pursue a study leading to MSc degree in Horticulture.