STUDY ON THE COMBINED EFFECT OF NPSB FERTILIZER RATES AND VARIETIES ON GROWTH, YIELD AND YIELD COMPONENTS OF GARLIC (*Allium sativum* L.) IN GUMMER DISTRICT OF GURAGE ZONE, ETHIOPIA

MSc. THESIS

BY

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DEDICATION

This thesis is dedicated to my wife, Almaz Beharu, and my children, Betelihem Jadu and Abem Jadu, for their invaluable support throughout this work as well as all aspects of my life.

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
ATA	Agricultural Transformation Agency
CEC	Cation Exchange Capacity
CIMMYT	Center of International Maize and Wheat Improvement
CSA	Central Statistical Agency (Ethiopia)
DAP	Diammonium Phosphate
DMRT	Duncan Multiple Range Test
DZARC	Debrezeit Agricultural Research Center
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agricultural Organization of the United Nations
GWADO	Gummer Woreda Agricultural and Development Office
LSD	Least Significance Difference
m.a.s.l	Meter above sea level
NPSB	Nitrogen-Phosphorous-Sulfur-Boron
SAS	Statistical Analysis System

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ABSTRACT

Garlic (Allium sativum L.*) is one of the major horticultural crops known worldwide with respect to its production and economic value. It is also the main bulb crop produced in Ethiopia, including the southern region. However, farmers are producing garlic from locally available varieties without or with low rates of fertilizer input which results in low yield. Therefore, this experiment was conducted to evaluate the response of garlic varieties to different rates of NPSB. Three improved garlic varieties (Kuriftu, HL and Tseday) and one local cultivar (‘Tuma’’) and four levels of NPSB fertilizer rates (0, 144, 244, 344 kg NPSB ha^{-1}) were used. The experiment was arranged in a 4 X 4 factorial experiment under a Randomized Complete Block Design (RCBD) with three replications. Plant height (cm) and leaf number were significantly influenced by the interaction effect of varieties and NPSB fertilizer except leaf length (cm) that was significantly influenced only by the main effect of variety and NPSB. All yield and yield related traits were significantly influenced by the interaction effect of varieties and NPSB fertilizer rates except days to 50% emergence and bulb weight (g) that were significantly influenced only by the main effect of variety and NPSB. The highest total bulb yield was obtained from variety Kuriftu (8.81 t ha^{-1}) at the NPSB rate of 244 kg ha^{-1}, and the lowest recorded from the local cultivar (5.52 t ha^{-1}) without NPSB (0 kg) fertilizer application. The maximum plant height (74.17cm) was recorded from variety HL at 244 kg/ha NPSB and the highest number of garlic leaves (10.33) were obtained from variety Kuriftu that received the highest NPSB rate of 344 kg/ha. The longest leaf was recorded from variety Tsedey (34.875cm) which was followed by variety Kuriftu (34.154cm) and HL (32.596cm). The highest statistically significant bulb weight was recorded equally from variety Kuriftu, Tsedey and HL 43.42g, 42.77g and 41.92g respectively. Marketable bulb yield was very highly significant (P<0.001) and positively correlated with leaf number (r =0.68***), bulb weight (r =0.64***), bulb diameter (r =0.72***), and highly significant (P<0.01) and positively correlated with plant height (r =0.41**) and leaf length (r =0.46**). The cost benefit analysis indicated that variety Kuriftu with the application rate of 244 kg NPSB ha^{-1} gave the maximum MRR (1974.3%).*

Keywords: - Garlic, varieties, NPSB rates, growth, yield, yield components

1. INTRODUCTION

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). Garlic was originated in northwestern side of the Tien Shan Mountains and moved from there to Central Asia, Africa, Europe and America nearly 10,000 years ago (Etoh and Simon, 2002; Ipek *et al.*, 2008). At present, China is the main garlic producer and exporter country in the world with a production of 22,160,465 tones (FAO, 2017). It is one of the main Allium vegetable crops known worldwide with respect to its production and economic value. It is one of the oldest cultivated vegetables (Hamma *et al.*, 2013; Hassan, 2015). Garlic has been known since ancient Egypt and its cultivation is estimated to be known for 5000-6000 years (Ipek *et al.*, 2008). Currently, there are about 600 garlic varieties worldwide (Anonymous, 2018).

Garlic is propagated asexually by using cloves, but shows a high morphological diversity among cultivars. These cultivars have a wide range of adaptation to different environments.
Sexual propagation in garlic is expected to facilitate the exchange of genetic traits from one genotype to another and to improve garlic cultivars through classical breeding (Kamenetsky *et al.*, 2004). Garlic does not produce true seed but propagated asexually by planting cloves. Each bulb usually contains a dozen or more cloves and planted separately. Select only larger outer cloves of the best garlic bulbs for planting because larger cloves yield larger size and mature bulbs at harvest. Do not divide the bulb until ready to plant; early separation decreases yields. Select "seed bulbs" that are large, smooth, fresh, and free from disease. To plant garlic properly, dig a hole or trench, place the unpeeled clove gently into the hole with the pointed side up (the scar [stem] end down) and cover the clove with soil. Setting the cloves in an upright position ensures a straight neck (McLaurin, 2012).

Garlic is used as a seasoning in many foods worldwide; without garlic, many of our popular dishes would lack the flavor and character that make them favorites. It is a basic flavoring in many types of dishes ranging from vegetable soup, meat, salad, tomato combination, spaghetti, sausages and pickles (Brewster, 1994). Similar to green onions, it is also eaten as green and blenched tops in different ways as fresh and cooked. Immature bulb consumption is common especially in tropics (Rabinowitch and Brewster, 1990).

Garlic's volatile oil has many sulfur containing compounds that are responsible for the strong odor. It also has distinctive flavor and pungency known for its healthful benefits (Salomon, 2002).

Garlic contains considerable number of minerals like Ca, P and K, and leaves are rich sources of protein, vitamin A and C (Maly *et al.,* 1998). Garlic has higher nutritive value than other bulb crops (such as onion, shallot, leek, etc…) : 30–35% dry matter, 6–7% protein, 0.2% lipid, 23–28% carbohydrate, 0.7–0.9% fiber, 1.1–1.4% ash matter and vitamins, especially B1, B2, B6 and C. The bulb also contains antibiotics garlicin and allistatin, a number of enzymes, amino acids, universal substances, including trace elements (Maly *et al.,* 1998).

Garlic has also medicinal value which is well recognized in the control and treatment of hypertension, worms, germs, bacterial and fungal diseases, diabetes, cancer, ulcer, rheumatism etc. (Kilgori *et al.,* 2007; Samavatean *et al.,* 2011). Many people perceived and appreciated garlic for its many medicinal attributes (Rabinowitch and Currah, 2002).

The economic significance of garlic in Ethiopia is quite considerable. It is grown as a spice crop and is used for flavoring local dishes. It also contributes to the national economy as export commodity (Fekadu and Dandena, 2006). The production of such cash crops like garlic is proved to be a significant income generating activity for farmers, especially those who have limited cultivable land or small holder farmers (FAO, 2006). As an export crop, it is used to earn foreign currency by exporting it to Europe, the Middle East, Africa countries and USA (Kilgori *et al.,* 2007). At off season the same quantity of garlic is usually sold at twice or three times the value of onion (Getachew and Asfaw, 2000).

The total area under garlic cultivation in the world is 1,546,741 ha with a total production of 28,494,130 tones (FAO, 2018). In Ethiopia, the total area under garlic production has reached

15,381 ha with the total production estimated to be 138,664.3 tons and the average yield 9.02 t/ha (CSA, 2017).

However, the productivity and quality of garlic in Ethiopia is very low compared to the world average of 18.4 t/ha. Its production is spread throughout the country both under irrigation and rain fed conditions in different agro climatic regions (CACC, 2002). According to the Gurage Zone Agriculture and Development Office 2019/2020 survey report, about 148.2 ha of land was used for garlic production and 1778.4 tones produce were achieved. In the same production season, the total area covered by garlic and the total production in Gummer district was 17.5 ha and 210 tones, respectively (GWADO, 2019/20).

The low performance of garlic production both at the country level and in the study area can be accounted to the traditional production practices employed by smallholder farmers. One of these practices is poor knowledge on the application of fertilizers both in terms of rate and type (i.e lack of evidences on how much to apply for attaining economically optimum yield). Although most farmers are using synthetic (chemical) fertilizers, the rate of application is by far below the national blanket recommendation; which is about 150 kg urea ha^{-1} and 200 kg DAP ha^{-1} for garlic production (EIAR, 2007). The type and rate of fertilizer applications are among several agronomic practices, which influence most garlic yield. The fact that fertilizer types applied in the Ethiopian agricultural system were only urea and Di-ammonium Phosphate (DAP), which contain only nitrogen and phosphorous, that may not satisfy the nutritional requirements of garlic crop. Based on soil analysis map by ATA, (2012) Ethiopian soils in general showed deficiency of both macro and micro elements. Hence, to avert this situation, the Ministry of Agriculture of Ethiopia has recently introduced a new compound fertilizer that contains nitrogen, phosphorous, sulfur and boron with the ratio of 18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B (NPSB fertilizer), to solve macro and micro elements deficiency in Ethiopian agriculture.

Furthermore, in addition to in the use of inappropriate fertilizer application practices the continuing declining of soil fertility, and lacks of improved varieties are the most important factors that contribute to the productivity of garlic in Ethiopia (Teweldebrhan, 2009; Worku and Dejene, 2012). Although different blended fertilizers are currently being introduced to the farming system in Ethiopia, there are still no recommended application rates after farmers to use. Farmers in the study area are still using inadequate amount of such fertilizers resulting in low yield of garlic. Moreover, they are growing local garlic cultivars which are poor in their yield potential as compared to the newly released varieties by the EIAR and other research organizations. Therefore, this study was initiated with the general objective to evaluate and the response of garlic varieties to different rates of the recently introduced blended NPSB fertilizer at Gummer district, of Gurage zone.

1.1 General objective

- To evaluate and the response of garlic varieties to different rates of the recently introduced blended NPSB fertilizer at Gummer district, of Gurage zone.

1.2 Specific objectives:-

- ✓ To identify the best performing variety that ensures the highest yield in the study area.
- ✓ To determine the optimum rate of NPSB fertilizer for an economically optimum yield of garlic in the study area.
- ✓ To evaluate and determine the best interaction of NPSB and varieties on growth, yield and yield components of garlic for the study area.

2. LITERATURE REVIEW

2.1. Botany and Origin of Garlic

Garlic *(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=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 (Figliuolo *et al*., 2001; Ipek *et al*., 2003 and 2005).

Garlic plants have thin tape shaped leaves about 30 cm long. Its roots reach up to 50 cm depth or little more. Heads or bulbs are white skinned, divided into sections called cloves. Each head could have from 6 to 12 cloves, which are covered with a white or reddish papery layer or "skin" (Hector *et al.*, 2012).

Sexual propagation in garlic is expected to facilitate the exchange of genetic traits from one genotype to another and to improve garlic cultivars through classical breeding (Kamenetsky *et al*., 2004). Garlic does not produce true seed but propagated asexually by planting cloves. Each bulb usually contains a dozen or more cloves and planted separately. Select only larger outer cloves of the best garlic bulbs for planting because larger cloves yield larger size and mature bulbs at harvest. Do not divide the bulb until ready to plant; early separation decreases yields. Select "seed bulbs" that are large, smooth, fresh, and free from disease. To plant garlic properly, dig a hole or trench, place the unpeeled clove gently into the hole with the pointed side up (the scar [stem] end down) and cover the clove with soil. Setting the cloves in an upright position ensures a straight neck (McLaurin, 2012).

Ethiopian Institute of Agricultural Research (EIAR) 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 (*Tseday, Kuriftu* and *HL*) are released from Debre Zeit Agricultural Research Center 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).

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°C and 10°C (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. In Ethiopia, garlic is planted with spacing of 30 cm inter-row and 10 cm intra-row using less than 11 mm diameter of clove (Lemma, 2001). 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.

Garlic is adapted to cool climates and should not generally be planted at altitude below 2000 m. a.s.l. (Nonnecke, 1989). Amount of rainfall during the growing period (4 to 6 months) should be 600 mm to 700 mm. Garlic withstands moderate frost on well-drained soils, rain fed crops may be planted on flat beds; but on heavy soils, which are poorly drained during the rains; it is advisable to plant on ridges as for irrigated crops. 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°C to 24°C. Storage temperature of dormant cloves and temperatures before clove formation influenced the bulb formation and thus the yield of garlic (Libner, 1989).

Yield and quality will vary with climate, region, altitude, soil and pH, cultural practices, and the variety of garlic. The term "biological elasticity" describes garlic's ability to acclimate to these factors over time. No one practice is best suited for every situation. It is advisable to conversation with local growers who have experience growing garlic and experiment with different cultural practices and varieties to discover the best combination for your operation (Siktberg *et al*., 2006). Lighter soils will need more frequent water applications, but less water applied per application. Water stress during the growing season can cause bulbs to be smaller and is thought to also cause a multiple stem disorder (Anonymous, 2004).

Garlic is used as a seasoning in many foods worldwide; without garlic, many of our popular dishes would lack the flavor and character that make them favorites. Garlic's volatile oil has many sulfur containing compounds that are responsible for the strong odor, it has distinctive flavor and pungency as well as for its healthful benefits (Salomon, 2002). It is a basic flavoring in many types of dishes ranging from vegetable soup, meat, salad, tomato combination, spaghetti, sausages and pickles (Brewster, 1994). Similar to green onions, it is eaten as green and blenched tops in different ways as fresh and cooked as well as immature bulb consumption is common especially in tropics (Rabinowitch and Brewster, 1990). Bread and butter obtained from garlic have many uses in homes and restaurant cooking and food preparations (Nonnecke, 1989). Moreover, it contains considerable amounts of minerals like Ca, P and K, and leaves are sources of protein, vitamin A and C (Maly *et al.*, 1998). Garlic has higher nutritive value than other bulb crops: 30–35% dry matter, 6–7% protein, 0.2% lipid, 23–28% carbohydrate, 0.7–0.9% fiber, 1.1–1.4% ash matter and vitamins, especially B1, B2, B6 and C. The bulb also contains antibiotics garlicin and allistatin, a number of enzymes, amino acids, universal substances, including trace elements (Maly *et al.,* 1998).

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Economic significance of garlic in Ethiopia is quite considerable; it is grown as spice and used for flavoring local dishes, and contributes to the national economy as export commodity (Fekadu and Dandena, 2006). Production of cash crops like garlic and other spices is proved to be income generating activity for farmers, especially for those who have limited cultivated land or small holder farmers (FAO, 2006). As a cash crop, it is used to earn foreign currency by exporting to Europe, the Middle East, Africa countries and USA (Kilgori *et al.*, 2007). At off season the same quantity of garlic is usually sold at twice or three times the value of onion (Getachew and Asfaw, 2000).

2.2. Garlic Production and Productivity in Ethiopia

In Ethiopia, garlic is one of the important bulb crops grown and used as a spice or a condiment throughout the country. It is mainly used for flavoring and seasoning vegetables in different dishes. It also has many medicinal properties (Abreham *et al.,* 2014). Total area under garlic cultivation in the world is 1,546,741 ha with total production of 28,494,130 tonnes (FAO, 2018). In Ethiopia, the total area under garlic production reached 15,381 ha and the production is estimated to 138,664.3 tons with an average yield of 9.02 t/ha (CSA, 2017). However, productivity and quality of garlic produced in the country is very low compared to the world average of 18.4 t/ha. One of the major problems affecting crop production in Africa including Ethiopia is the rapid depletion of nutrients in smallholder farms (Achieny *et al.,* 2010). In many garlic producing areas, low availability of nutrients is the major factor limiting garlic production next to soil moisture stress, which constrains liberation of nitrogen, phosphorus and sulfur from soil organic matter and their uptake by plant root (FAO, 2003). The production is spread throughout the country both under irrigation and rain fed conditions in different agro climatic regions (CACC, 2002). It has a wide range of climatic and soil adaptation (Lemma and Herath, 1994).

2.3. Garlic Varieties in Ethiopia

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), Kuriftu, HL, Chefe* and *Tseday* are released from Debre Zeit Agricultural Research Center and *Qoricho, Chelenko* and others varieties 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).

2.4. Fertilizer Requirement of Garlic

One of the major problems affecting crop production in Africa including Ethiopia is the rapid depletion of nutrients in smallholder farms (Badiane and Delgado, 1995; Achieng *et al.*, 2010). In many garlic-producing areas, low availability of nutrients is the major factor limiting garlic production next to soil moisture stress, which constrains liberation of nitrogen, phosphorus, sulphur and micro-nutrients from soil organic matter and their uptake by plant roots (FAO, 2003). To improve garlic production planting time, balanced fertilizer application, optimal plant population and other cultural practices should be considered (Brewster and Butler, 1989; Potgieter, 2006). According to Luo *et al.* (2000) report, both yield and quality of garlic can also be improved through nitrogen and sulphur fertilization.

In Ethiopia and elsewhere in Sub-Saharan Africa smallholder farmers generally apply low amounts of mineral fertilizers to crops (Morris *et al.,* 2007. Consequently, most of the soils on which farmers produce their crops are deficient in nitrogen and phosphorus (Asnakew and Tekalign, 1991). Garlic growers in the central highlands of Ethiopia often rely on fertilizer sources that contain only N and P (Urea and Diammonium phosphate), resulting in steadily declining available soil S and K levels (FAO, 2003). Potassium and S uptake imbalance relative to N can predispose the crop to serious disease and insect damages. Under such conditions, the plants will have reduced shoot growth and low yields and quality, consequently reducing the viability of this alternative cash crop.

The quantity of nutrients to be applied depends on the yield potential of the cultivar, the level of available nutrients in the soil, and growing conditions (Marschner, 1995). Similarly, Selections of the best variety with their proper rate of fertilizer are very important factors to increase productivity and marketability of garlic (Abreham *et al*., 2014; Shaheen *et al*., 2007).

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).

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 is no fertilizers recommendation which contain potassium, sulfur and micro nutrients that are important to increase production, productivity and quality. 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, sulfur and boron (NPSB).

2.4.1. NPSB fertilizer effects on garlic growth and productivity

Garlic is a nutrient exhaustive crop and removes a good amount of nitrogen, phosphorus, sulfur and boron from the soil. Uptake of sufficient nutrient by the 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 values of the crop depend upon the cultivars, agronomic practices, climate, soil fertility, and post-harvest 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).

2.4.1.1 Role of nitrogen on growth and bulb yield of garlic

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).

Nitrogen has been identified as being the most limiting nutrient in plant growth. Plants absorb nitrogen in the cation form ($NH4^{+}$) or the anionic form ($NO3^{-}$). Plants obtain readily available N forms from different sources. The major forms include: biological nitrogen fixation by soil microorganisms, mineralization of organic N, industrial fixation of nitrogen gas and fixation as oxides of nitrogen by atmospheric electrical discharge. Similarly, mineralization of organic nitrogen to inorganic forms depends on temperature, level of soil moisture and supply of oxygen (Tisdale *et al.,* 1995; Miller and Donanue, 1995). Nitrogen is necessary and important element for increasing the yield and quality of vegetables such as garlic (Gulser, 2005). As increased the level of N, increased the growth trend of the number of leaves, leaf length and plant body that garlic has a high nitrogen requirement, particularly in the early stages of growth.

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^{-1}. However the mean values of most yield components obtained from garlic plants supplied with 150 kg ha^{-1} and 200 kg ha^{-1} nitrogen were statistically similar. Similarly maximum bulb yield of garlic was obtained from plants which were supplied with 150 kg ha^{-1} 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).

2.4.1.2. Role of phosphorus on growth and bulb yield of garlic

Phosphorus acts as a structural component of membrane system of cells, chloroplasts and mitochondria. It is a constituent of energy phosphates like ADP and ATP, nucleic acid, nucleo proteins, purines, pyrimidine, nucleotides and several coenzymes. It involved in the basic reaction of photosynthesis and plays an important role in cell division; break down of carbohydrate, transfer of inherited characteristics and hastening the maturity of plants. It is also an essential constituent of majority of enzymes which are important in the transformation of energy in carbohydrate and fat metabolism and also in respiration of plants. About 93-99 per cent of the total phosphorus is insoluble and hence directly not available to plants. Only about a quarter of water soluble phosphate is taken up by plants in the season of the application and the remaining is converted into insoluble (unavailable) forms (Verma, 1993).

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).

Limited phosphorus in bulb crops reduced root growth, leaf growth, bulb size, yield and delayed maturation (Stone *et al.,* 2001). Phosphorus had shown a strong response of bulb when applied on loamy sandy soils (Ladebusch, 1999). Phosphorus has a primary importance for root enlargement. The movement of phosphorus in the soil is very slow and its uptake is usually depend on the concentration gradient and diffusion in the soil close to the roots, so sufficient amount of phosphorus should be available in the soil for optimal yield (Robertson, 1999). 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^{-1} 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) report 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

2.4.1.3. Role of sulfur on growth and bulb yield of garlic

Sulfur is the fourth major essential nutrient particularly in garlic. 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 (ElShafie and El-Gamaily, 2002). Its role in balanced fertilization and consequently in yield and quality enhancement of garlic is being increasingly appreciated. Sulfur performs many physiological functions like synthesis of sulfur and methionine (Singh *et al.,* 1995). The level of this element in soil is depleting regularly and this condition has arised due to the continuous use of sulfur free fertilizers and intensive cropping of high sulfur requiring crops. Sulfur plays an important role in plant's growth and development. It is involved in the synthesis of amino acids like cystine, cysteine, methionine etc. It is also responsible for characteristic taste and smell of garlic like onion and mustard (Tisdale *et al.,* 1985).

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^{-1} and thereafter 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.

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.

2.4.1.4. Role of boron on growth and bulb yield of garlic

Boron is one of the most widely applied micro-nutrient although it is required in very small quantity. It has different role in plant metabolic activities. Cell division, carbohydrates metabolism and water relation in plants are controlled by boron. Sugar translocation within the plant body is controlled by boron. In deficient condition of boron, growing plants become dead and ultimately the lateral shoots, buds and flowers dies. Chlorosis, thickening and curling of leaves are also observed. Boron also found to increase bulb yield up to 1kg B/ha (Francois, 1991). Boron deficiency in garlic caused a marked reduction in yields. Jermsiri *et al.* (1995) reported that applying borax to garlic increased the yield by 24-40%. The addition of other micronutrients as well as borax tended to improve bulb quality.

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 (Naihua *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).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted under field condition at Gumer district (*Jenboro Kebele*), Gurage zone, Ethiopia. It was carried out under rain-fed condition in 2020/21. The district capital town, Arekite, is found 62km of Wolkite, town (capital of the Gurage zone) and 220 km from Addis Ababa on the South West direction. The agro climatic zonation of the district is characterized as Dega with altitude ranges from 2400-3100 m.a.s.l. It is geographically located at 8^0 3' 30"N of latitude and 37^0 59' 30"E of longitude. The mean annual temperature ranges from 10 to 19^oC with an average of 16^0C. The area receives annual rainfall of 1400mm and 1800mm minimum and maximum respectively. The soil type of the area is characterized as black to brown in color, clay loam with slightly acidic. The rainfall pattern is bimodal in which 85% of rainfall is in the main season (summer period of June to September) where as the 15% is received in the Belg period (March to May); (GWADO, 2016).

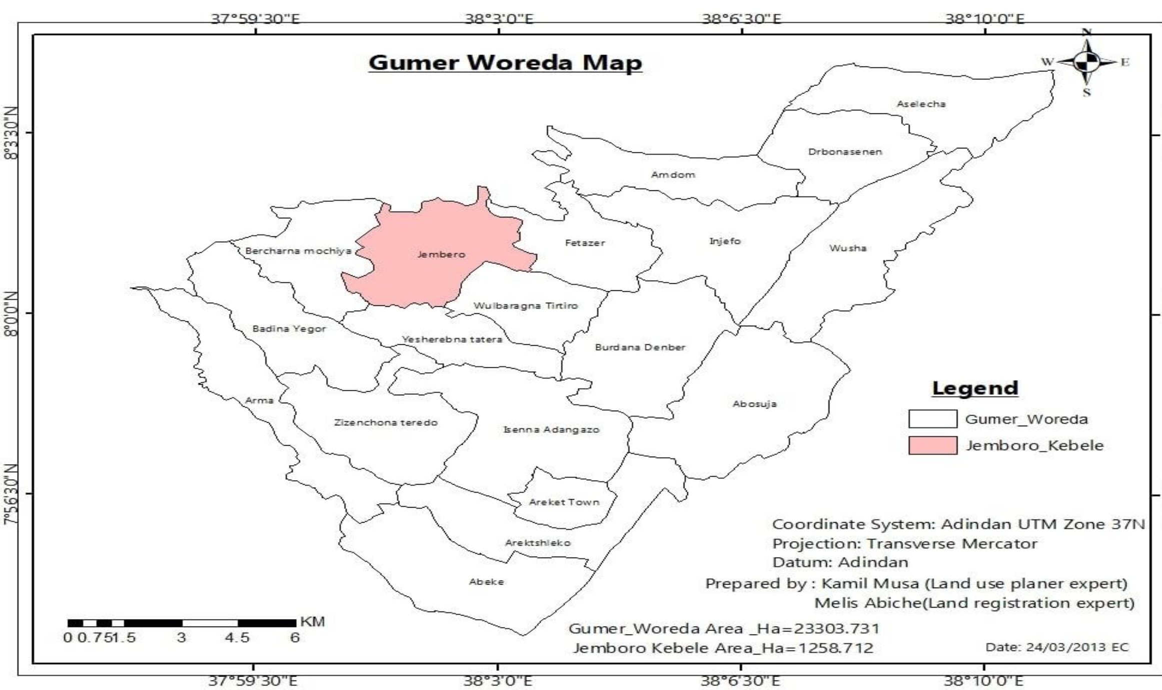

Figure 1: Map of the study area

3.2. Experimental Materials

As shown under table/ below, three improved garlic varieties (*Tseday*, *Kuriftu* and *HL*) released by DebreZeit Agricultural Research Center (DARC) and one local cultivar (“*Tuma”*) which is produced locally/traditionally around the experimental site. The improved garlic varieties were selected based on their adaptability, yield potential and relative tolerance to disease and pest as compared to other locally used varieties. The description of the planting materials is presented in Table 1.

Table 1: Description of garlic varieties used for the experiment

Variety/ cultivar	Year of release	Breeder / Maintainer	Altitude(m)	Days to maturity	Yield (t/ha)
Tseday	1999/00	DZARC/EIAR	1900-2600	138	>8.5
Kuriftu	2010	DZARC/EIAR	1900-2600	140	8
HL	2016	DZARC/EIAR	1900-2600	128	7
local cultivar ('Tuma')	-	-	-	-	-

Source: Debrezeit Agriculture Research Center /EIAR, 2019 and local market for the three released varieties and for the local cultivar respectively.

3.3. Treatments and Experimental Design

The experimental treatments were consisted of NPSB (18.9-37.7-6.95-0.1) fertilizer at four levels (0 kg/ha, 144 kg/ha, 244 kg/ha, 344 kg/ha) and four garlic varieties (*Tseday*, *Kuriftu*, *HL* and “*Tuma”*). Therefore, there were sixteen treatment combinations in the experiment laid out in 4*4 factorial arrangements under Randomized Complete Blocked Design (RCBD) with three replications. The gross plot size of each experimental plot was 2.1m x 1.1m (2.31m^2) accommodating 7 rows with 11 plants per row. The gross experimental area was 10.3m x 27.1m (279.13m^2). Space of 30cm and 10cm was maintained between rows and plants, respectively. Spacing of 30cm x10cm was confirmed to be optimal for better production of garlic (Mengesha and Tesfaye, 2015). Medium sized (less than 11 mm diameter of clove); healthy cloves were used for planting (Lemma, 2001). The space between blocks and plots was 1m and 0.5m, respectively. Each of the experimental treatments was randomized in each replication.

Since NPSB fertilizer is new for the study area, there is lack of baseline information about the levels of NPSB fertilizer to be applied. Due to that, the phosphorus and nitrogen contained in the formerly recommended and used fertilizers of DAP and Urea was used as a basis for determining the NPSB fertilizer treatment levels. Based on this, three levels (144 kg/ha, 244 kg/ha, and 344 kg/ha) of NPSB (Nitrogen, Phosphorus, Sulfur and Boron) fertilizer and the control (0 kg/ha NPSB) were used as treatments. The national blanket recommended rate of urea was applied uniformly to fulfill the nitrogen requirement of the crop not covered by the NPSB blended fertilizer.

Table 2: Treatment combination and treatments

No.	Variety	Fertilizer rates (kg ha^{-1})	Treatment combination
1	V1 (Tseday)	0 (NPSB0) 144 (NPSB1) 244 (NPSB2) 344 (NPSB3)	V1NPSB0 V1 NPSB1 V1 NPSB2 V1 NPSB3
2	V2 (Kuriftu)	0 (NPSB0) 144 (NPSB1) 244 (NPSB2) 344 (NPSB3)	V2NPSB0 V2 NPSB1 V2 NPSB2 V2 NPSB3
3	V3 (HL)	0 (NPSB0) 144 (NPSB1) 244 (NPSB2) 344 (NPSB3)	V3NPSB0 V3 NPSB1 V3 NPSB2 V3 NPSB3
4	V4 (Tuma)	0 (NPSB0) 144 (NPSB1) 244 (NPSB2) 344 (NPSB3)	V4NPSB0 V4 NPSB1 V4 NPSB2 V4 NPSB3

Where: V= variety, T= treatment, NPSB = (Nitrogen, Phosphorous, Sulfur and Boron)

3.4. Soil Analysis

Soil samples were collected randomly from the entire experimental field in a zigzag manner at a depth of 20 cm before planting. The soil samples that were organized in to one kg composite sample size in order to determine the soil physicochemical properties. The composite soil sample was air dried, crushed with wooden pestle and mortar to pass through a 2 mm sieve size for the analysis of physical and chemical properties. Total nitrogen, available phosphorus, organic matter, soil pH, Cation Exchange Capacity (CEC), organic carbon and soil texture were determined at Wolkite town soil laboratory and available sulfur (mg/kg (ppm)) and available boron (mg/kg (ppm)) were determined at Hawasa town soil laboratory. The soil pH was measured in 1:2.5 soils to water ratios using an electrode pH meter. Organic carbon content of the soil was determined using the Walkley and Black method (Walkley and Black, 1934) while available phosphorus was estimated following the standard procedure of Olsen *et al.*, (1954); and total nitrogen was estimated using the Kjeldahl method (Jackson, 1958). Available sulphur was determined using the mono-calcium phosphate extraction method (Hoeft *et al*., 1973) and available boron determined using the hot water method (Havlin *et al*., 1999).

3.5. Experimental Procedure and Field Management

The experimental land was prepared well in accordance with the standard practices used. The land was ploughed and leveled properly before planting. Field layout was designed and prepared and each treatment was assigned randomly to the experimental plots within each replication independently.

Medium sized and healthy garlic cloves were planted at 5cm depth in well prepared raised beds at a spacing of 10cm between plants and 30cm between rows. The planting materials (cloves) were planted with the tip in upright position and the basal part of the clove down. Based on the treatments, the total quantity (full dose) of NPSB fertilizer was applied at time of planting. Urea was applied constantly using the blanket recommendation (150 kg ha^{-1}) in split applications, ½ of urea at 4 weeks after planting and ½ of urea was applied 8 weeks after planting. All the other variables other than the experimental treatments (like cultivation and weeding) were kept constant and applied as per the national recommendation for garlic crop production. According to EIAR (2007), 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. However, No disease and insect pest occur on the experimental field. So, no chemical or other control method was applied for the control of pests and diseases.

3.6. Data Collection

Crop phenology data, growth, yield and yield component parameters were collected and recorded from the central five rows either on the basis of sample plants or plot basis as described below.

3.6.1. Phenological parameters

Days to 50% emergence: this was recorded when 50% of the planted cloves sprouted and emerged out of the soil in each plot.

Days to physiological maturity: physiological maturity was recorded when 75% of the leaves of the plants in each plot become yellow, dry and/or shown senescence.

3.6.2. Growth parameters

Plant height (cm): the average length of the plant was measured from the soil surface to the tip of 20 randomly taken plants in each plot at physiological maturity.

Leaf length (cm): Averages of length from 20 randomly taken plants were measured at physiological maturity using ruler from the attachment of pseudo-stem to the tip growth point.

Leaf number per plant: average of the total number of healthy leaves was counted from the 20 randomly taken plants from middle five central rows at physiological maturity.

3.6.3. Yield and yield components

Average bulb weight per plant (g): the average mature bulb weight per plant was recorded after weighting 20 plants bulb weight produced in the five central rows and dividing by the number of plants (20).

Average bulb diameter (cm): bulb diameter was measured from randomly taken 20 bulbs at the widest point in the middle portion of the bulb using graduated caliper and then divided to 20.

Marketable bulb yield per hectare (t ha^{-1}): Bulbs which were free of mechanical damage, disease and insect pest attack, uniform in color and medium to large in size were taken from 5 central rows of each plot considered as marketable. The weight of such bulbs obtained from each net plot was measured in kilogram using a weighing balance and then expressed as ton per hectare.

Unmarketable yield per hectare (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 net plot was measured in kilogram using a weighing balance and expressed as ton per hectare.

Total yield per hectare (t ha^{-1}): Total yield was obtained by adding up both the marketable and unmarketable yields.

3.7. Data Analysis

The data were subjected to analysis of variance (ANOVA) using SAS statistical software of version 9.3 (SAS, 2007). DMRT test at 5% level of probability was used to delineate the significances between and/or among the treatment means. Correlation analysis was conducted for yield and yield components of garlic.

3.8. Partial Budget Analysis

Partial budget analysis was employed for economic analysis of the fertilizer application and it was carried out for the combined bulb yield data. The potential response of crop towards the added fertilizer and price of fertilizers during planting ultimately determine the economic feasibility of fertilizer application (CIMMYT, 1988). To estimate the total costs, the current prices of NPSB were collected at the time of planting and market price of garlic bulbs was taken at harvest. The economic analysis was based on the formula developed by CIMMYT (1988) and given as follows:

Gross average bulb yield (kg ha^{-1}) (AvY): was an average yield of each treatment.

Adjusted yield (AjY): was the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers. **AjY = AvY- (AvY-0.1)**.

Gross field benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield. **GFB = AjY*field/farm gate price**

Total cost: was the cost of NPSB, fertilizer application cost and garlic bulb yield transport cost of the experiment. NPSB fertilizer cost was based on 2021 price during planting. The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, crop protection and harvesting were assumed to remain the same or were insignificant among treatments.

Net benefit (NB): was calculated by subtracting the total costs from gross field benefits for each treatment. **NB = GFB – total cost**

Marginal rate of return (MRR %): was calculated by dividing change in net benefit by change in cost which was the measure of increasing in return by increasing input.

$$\text{Marginal rate of return (\%)} = \frac{\text{Change in net benefit}}{\text{Change in total cost}} \times 100$$

4. RESULTS AND DISCUSSION

4.1. Soil Sample Analysis

Composite soil sample of the experimental site was analyzed for soil physical and chemical properties before planting. According to textural classification system of USDA (1987), the soil was classified as silt loam soil texture (Table 3). Goronski *et al.* (2010) categorized the texture of Gloucester and surrounding areas based on the size of the soil particles. Sandy soils have very large particles, silt and clay (very fine). Water, air and plant roots can move freely in sandy soil but not in very fine clay.

The total nitrogen content of the soil in the study area is medium 0.25 % (Table 3). Goronski *et al.* (2010) described that N content of soils between 0.15-0.25 percent is medium and greater than 0.25 % is high. The available phosphorus of the soil in the study area was categorized within very low (3.34 ppm) which was based on the ranges rated by Egel *et al.* (2014). Most vegetables will benefit from P fertilization if the soil is less than 35-40 ppm (P content using the Bray-Kurtz P1 extraction method). The available potassium contents of the soil of the study area was considered as high (115.6 ppm), according to Egel *et al.* (2014), who stated the soil with greater than 85 ppm K is categorized under high potassium content. According to the rating of Tekalgn Tadesse (1991), the experimental site soil has high organic matter (5%) and high organic carbon (2.9%).

According to the rating of Hazelton and Murphy (2007), soil of the experimental field is slightly acidic in pH (6.02), and high in cation exchange capacity (31.22 meq $100g^{-1}$). Available sulfur (7.57 ppm) and available Boron (0.083 ppm) are low according to the rating of EthioSIS (2014). From the results of soil analysis, it can be depicted that all sulfur, nitrogen, phosphorus and boron may be yield limiting factor for garlic production in the area.

Table 3: Soil Physical and Chemical Properties of the Study Site

1. Physical Properties	**Value**	**Rating**
Sand (%)	30	-
Silt (%)	51	-
Clay (%)	19	-
Textural Class	Silt loam	-
2. Chemical properties		
pH (1: 2.5 H_2O)	6.02	Slightly acidic
CEC (meq/100 g soil)	31.22	High
Total Nitrogen (%)	0.25	Medium
Available Phosphorus (ppm)	3.34	Very low
Available Potassium (ppm)	115.6	High
Organic Matter /OM/ (%)	5	High
Organic Carbon /OC/ (%)	2.9	High
Available Sulfur (ppm)	7.57	Low
Available Boron (ppm)	0.083	Low
Exchangeable Cations (meq/100g soil)		
- EA-exchangeable acids	0.72	-
- EAl-exchangeable Al	0.33	-
- ECa-exchangeable Ca	6.7	-
- EMg- exchangeable Mg	2.25	-
- EK- exchangeable K	3.85	-
Moisture content (%)	4.5	-
Moisture correction factor	1.044	-

4.2. Phenological parameters

4.2.1. Days to 50% emergence

The analysis of variance showed that the main effects of variety and NPSB showed very highly significant effect ($P < 0.001$) and significant effect ($P < 0.05$) on days to emergence respectively. However, the interaction of varieties and NPSB rate showed statistically non-significant difference (Appendix Table-2).

The shortest days to emergence (11.91) was recorded from variety *Tsedey*. However, all the other varieties are in statistical parity. Therefore, variety *Tsedey* was emerged earlier by 1.76, 1.25 and 1.67 days than variety *Kuriftu*, *HL* and local, respectively (Table-4). The difference in the response of varieties for days to emergence among the different varieties may be due to their genetic makeup. Therefore, garlic varieties like *Tsedey* can be regarded as early emerging compared to the other tested varieties. This result is similar with the report of Dickerson and Wall (1993) who also observed significant differences among nine varieties of garlic in emergence success in New Mexico.

Application of NPSB at the highest rate of 344 kg/ha resulted in significantly shortest days to emergence (12.33). However, all the rest fertilizer treatments are in statistical parity. The earliest emergence at the highest NPSB fertilizer application may be due to the increased amount of Phosphorus added to the soil which have increased role on the emergence of garlic. This result agree with the report of Sebnie *et al.,* (2018) who observed the earliest days to emergence at optimum phosphorus level.

Table 4: The main effects of variety and NPSB for days to 50% emergence

Varieties	Days to 50% Emergence	NPSB kg/ha	Days to 50% emergence
HL	13.16[a]	0	13.33[a]
Kuriftu	13.67[a]	144	13.41[a]
Local	13.58[a]	244	13.25[a]
Tsedey	11.91[b]	344	12.33[b]
S.E. (±)	0.3	S.E. (±)	0.3
LSD (0.05)	0.85	LSD (0.05)	0.85
CV (%)	7.8	CV (%)	7.8

Where: Means followed with same letter(s) are not significantly different with each other. S.E. (±) = standard error, CV (%) = coefficient of variation and LSD (5%) = least significant difference at P<0.05

4.2.2. Days to 75% Maturity

Both variety and NPSB fertilizer were interacted to significantly influence days to 75% physiological maturity similarly, main effect of variety showed very highly significant difference. However, the main effect of NPSB fertilizer did not showed significant difference for the parameter days to 75% maturity (Appendix table-1). Variety *Tsedey* exhibited the shortest days to physiological maturity (127.67 and 127.33) days at NPSB fertilizer rates of 244 kg/ha and 344 kg/ha, respectively, which were not statistically different with NPSB rate of 144 Kg/ha (Table 5). This showed that variety *Tsedey* took the shortest days to physiological maturity than the other varieties in the interaction with NPSB fertilizer. This is due to the genetic difference among the varieties when interact with high and small amounts of fertilizer make them to mature early or late.

The current result is in conformity with the report of Abraham *et al*. (2014) who stated that *Tsedey* variety matured earlier (126 day) than the local cultivar.

Table 5: The interaction effect of varieties and NPSB on days to 75% maturity

Days to 75% physiological maturity				
Varieties	**NPSB kg ha $^{-1}$**			
	0	144	244	344
HL	134.67^{abc}	132.33^{abcd}	134^{abc}	134.67^{abc}
Kuriftu	134.33^{abc}	134.33^{abc}	134^{abc}	131.67^{bcd}
Local	135^{ab}	135.33^{ab}	136^{ab}	137^{a}
Tsedey	132.33^{abcd}	129.67^{cd}	127.67^{d}	127.33^{d}
S.E. (±)	0.2341			
LSD (0.05)	1.35			
CV (%)	1.22			

Where: Means followed with same letter(s) are not significantly different with each other. S.E. (±) = standard error, CV (%) = coefficient of variation and LSD (5%) = least significant difference at P<0.05

4.3. Growth parameters

4.3.1 Average plant height (cm)

The analysis of variance revealed that plant height was significantly influenced by the interaction of the garlic varieties and NPSB fertilizer rates. Similarly, the main effects of variety and NPSB fertilizer were highly significantly (p<0.001) influence this parameter (Appendix table-1).

The maximum plant height (74.17cm) was recorded from *HL* variety at 244 kg/ha NPSB rate, which was not significantly different from the values (71.62cm and 69.08cm) recorded from the same variety at 344 kg/ha and 144 kg/ha NPSB, and from *Kuriftu* variety at 244 kg/ha NPSB respectively (Table 6). The minimum plant height (60.8cm) was recorded from variety *Kuriftu* at the unfertilized treatment (0 kg/ha NPSB), which was not significantly different from the local cultivar and *Tsedey* variety at all rates of NPSB, and *HL* variety at zero level of NPSB.

The results of this study clearly showed that incorporation of boron, sulfur, nitrogen and phosphorus fertilizers enhances the plant height of garlic varieties. The highest plant height of garlic *HL* variety was recorded at fertilizer application ratio of 46.12 N- 92 P_2O_5-16.96 S and 0.244 B. Therefore, applications of fertilizer below and above ratio reduced or have no significant positive effect on the plant height of garlic varieties. The highest phosphorous and sulfur given in this treatment combinations may contributed in the metabolic process such as formation of nucleic acids, phospholipids, coenzymes, and chlorophyll which intern enhance the growth and development of garlic plants (El-Shafie and El-Gamaily, 2002; Ray, 1999 and Nasiruddin *et al.*, 1993). Besides a significantly different result of plant height were reported by Abou El-Magd, *et al.,* (2012); Panse *et al.,* (2013) based on their perspective garlic varieties trials.

4.3.2 Average leaf number/plant

The analysis of variance showed that leaf number was significantly ($P< 0.05$) affected by the interaction of the garlic varieties and NPSB fertilizer rates. Similarly the main effect of variety and NPSB fertilizer showed highly significant difference (Appendix table-1). Significantly highest number of garlic leaf per plant (10.33) was obtained from variety *kuriftu* that received the highest NPSB rate of 344 kg/ha, which was not significantly different from the leaf number (9.15) recorded from the same variety at 244 kg/ha NPSB (Table-6). It was significant difference with among the other treatments.

The possible reasons for observed highest number of leave per plant could be due to the availability of enough plant nutrients through the application of NPSB fertilizer that positively influenced the vegetative growth of the plants. These nutrients contained the synthesis of the different components of protein required for leaf development, photosynthesis and metabolic processes required for plant growth. Phosphorus and nitrogen have attribute to production of more leaves by boosting the photosynthetic area.

These findings are in consistence with the work done by Blay *et al*. (2002) and Gebremichael Yohannes *et al*. (2017) who reported the increase leaf number per plant due to supply of nitrogen. Uzma *et al*. (2016) reported that low level of phosphorus fertilizer application results in reduction in leaf expansion and leaf surface area, as well as number of leaves in garlic. 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 result observed in this study is in agreement with the findings of Abreham *et al.* (2014), who reported significant influence of phosphorus on the number of leaf per plant in garlic, Balasubramonium *et al.* (1979), which stated application of sulfur increased, the number of leaves in garlic. Betewulign *et al.* (2014) reported that the highest garlic leaf number was obtained by the application of 100 kg N ha^{-1} + 130 kg P_2O_5 ha^{-1}. Faraooqui *et al.* (2009) reported that the combined application of 200 kg ha^{-1} nitrogen and 60 kg ha^{-1} sulfur significantly increased the number of leaves per plant in garlic, and Zaman *et al.* (2011) reported that , number of leaves/plant in garlic, increased gradually with increasing the levels of sulfur up to 45 kg ha^{-1} beyond which it decreased.

Table 6: Interaction effect of varieties and NPSB on plant height and leaf number per plant of garlic crop

	Plant height				**Leaf number**			
	NPSB kg ha^{-1}				**NPSB kg ha^{-1}**			
Varietie	0	144	244	344	0	144	244	344
HL	65.167^{bcd}	69.08^{abc}	74.17^{a}	71.62^{ab}	7.6^{c}	7.92^{bc}	7.99^{bc}	8.367^{bc}
Kuriftu	60.08^{d}	65.48^{bcd}	69.83^{abc}	62.67^{cd}	7.7^{bc}	8.32^{bc}	9.15^{ab}	10.33^{a}
Local	60.1^{d}	62.25^{cd}	61.67^{cd}	63^{cd}	7.15^{c}	7.98^{bc}	7.95^{bc}	7.95^{bc}
Tsedey	64.416^{bcd}	62.917^{cd}	64.33^{bcd}	61.416^{cd}	7.167^{c}	7.783^{bc}	8.1^{bc}	8.33^{bc}
S.E. (±)	0.38				S.E. (±)			0.068
LSD (0.05)	2.2				LSD (0.05)			0.4
CV (%)	4.04				CV (%)			5.79

Where: Means followed with same letter(s) are not significantly different with each other. S.E. (±) = standard error, CV (%) = coefficient of variation and LSD (5%) = least significant difference at P<0.05

4.3.3 Average leaf length (cm)

The analysis of variance showed that leaf length was significantly ($P < 0.05$) and highly significantly ($P < 0.01$) influenced by the main effect of varieties and NPSB, respectively. However, varieties and NPSB did not interact to significantly influence leaf length (Appendix table-2).

The longest leaf was recorded from variety *tsedey* (34.875 cm) which was statistically not different from the leaf length recorded from varieties *kuriftu* (34.154 cm) and *HL* (32.596 cm). However, the shortest leaf length was recorded from the local cultivar (30.729 cm) (Table-7).

Regarding NPSB blended fertilizer treatment, the highest leaf length was recorded at 244 kg/ha NPSB fertilizer application rate which was significantly different compared with the other fertilizer rates. Even though the shortest leaf length was recorded from the unfertilized treatment, it was in statistical parity with the rest fertilizer treatments. This showed that addition of NPSB fertilizer more or less than 244kg/ha will not have significant positive effect on the leaf length of garlic (Table-7).

The increased leaf length at the 244 kg/ha of fertilizer application is due to the fact that the addition of optimum amount of NPSB may be attributed to more availability of nutrients, especially N, which enhances the length of garlic leaves by its simulative effect on cell division and cell enlargement that in turn may increase 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 current results are in conformity with the findings of Balasubramonium *et al.* (1979) who reported application of sulfur increased garlic leaf length.

Table 7: The main effects of varieties and NPSB for leaf length of garlic

Varieties	**Leaf length (cm)**	**NPSB kg/ha**	**Leaf length (cm)**
HL	32.596[ab]	0	30.633[b]
Kuriftu	34.154[a]	144	32.638[b]
Local	30.729[b]	244	36.125[a]
Tsedey	34.875[a]	344	32.958[b]
S.E. (±)	1	S.E. (±)	1
LSD (0.05)	2.9	LSD (0.05)	2.9
CV (%)	10.47	CV (%)	10.47

Where: Means followed with same letter(s) are not significantly different with each other. S.E. (±) = standard error, CV (%) = coefficient of variation and LSD (5%) = least significant difference at $P<0.05$

4.4 Yield and Yield Components

4.4.1 Average bulb weight (g)

The analysis of variance showed that main effect varieties and NPSB are significant ($P < 0.05$) and highly significant differences ($P < 0.01$) respectively on bulb weight. However, interaction effect of variety and NPSB on bulb weight was not significantly different (Appendix table-2). The highest bulb weight was recorded from varieties *Kuriftu*, *Tsedey* and *HL* (43.42 g, 42.78 g and 41.92 g, respectively) which were not statistically different (Table-8). Whereas, the lowest bulb weight was produced by the local variety (40.48 g), the existence of significant variation among garlic varieties for bulb weight was reported (Youssef, 2013; Tibebu, *et al.*, 2014).

Bulb weight of garlic was also significantly influenced by the application of NPSB fertilizer. As compared to the unfertilized treatments, all treatments with NPSB fertilizer showed significantly ($P< 0.05$) higher weight of garlic bulbs, but there is no significant difference among them. The lowest bulb weight (39.94 g) was obtained from the unfertilized treatment. Highest bulb weight of garlic was recorded at the rate of 244 kg ha^{-1} NPSB. Applications of fertilizer above this ratio reduced or have no significant positive effect on the bulb weight of garlic varieties.

The results of the present study are generally in line with the findings of other researchers where application of blended fertilizers like NPKS or single nutrients like phosphorous and sulphur improved bulb weight (Aliyu`s *et al.,* 2008; Aster Kora, 2009; Mahala, 2015). The significant differences among garlic varieties bulb weight due to the application of fertilizers was reported by many authors (Yudhvir and Ramesh, 2003; Hector *et al.,* 2012 and Abedi *et al.,* 2013).

Table 8: The main effects of varieties and NPSB for bulb weight of garlic

Varieties	**Bulb Weight (g)**	**NPSB kg/ha**	**Bulb Weight (g)**
HL	41.92^{ab}	0	39.94^{b}
Kuriftu	43.42^{a}	144	41.96^{a}
Local	40.48^{b}	244	43.75^{a}
Tsedey	42.78^{a}	344	42.94^{a}
S.E. (±)	0.653	S.E. (±)	0.653
LSD (0.05)	1.9	LSD (0.05)	1.9
CV (%)	5.36	CV (%)	5.36

Where: Means followed with same letter(s) are not significantly different with each other. S.E. (±) = standard error, CV (%) = coefficient of variation and LSD (5%) = least significant difference at $P<0.05$

4.4.2 Average bulb diameter (cm)

Bulb diameter was significantly ($P < 0.01$) influenced by the interaction effects of garlic variety and NPSB fertilizer. Similarly, the main effects of variety and NPSB fertilizer were highly significantly influenced the same parameter (Appendix table-3). The biggest bulb diameter (5.87 cm) was recorded from variety *kuriftu* at fertilizer rate of 244 kg ha^{-1} NPSB followed by the value (5.53 cm) recorded from the same variety at an application rates 344 kg/ha NPSB. However, bulb diameters obtained from these treatments interactions were statistically similar. Applications of fertilizer below and above 244 kg ha^{-1} reduced or have no significant positive effect on the bulb diameter of garlic varieties. On the other hand, the smallest bulb diameter (3.87 cm) was recorded from local variety interacted with the unfertilized treatment (Table 9).

The increase in bulb diameter is obviously associated with increased in dry matter production and allocation of assimilates to the bulb through increased number of leaves, plant height and leaf length and thus higher photo assimilate concentration in the bulbs that ensure large bulb diameter. The results of the present study revealed that bulb diameter of garlic varieties were influenced with the different rates of NPSB fertilizer, which may be due to influence of different nutrients on metabolic activity of the crop. The combined positive effects of phosphorous and sulfur on metabolic processes such as amino acids, vitamins, lipids, and some hormones formations was reported (Nasiruddin *et al.,* 1993). Moreover, it was reported that, sulfur and nitrogen stimulate the enzymatic actions and chlorophyll formation of garlic (El-Shafie and El-Gamaily, 2002).

The results obtained in this study was in conformity with the findings of Nasiruddin *et al.* (1993) and Hariyappa (2003) who reported that the application of sulfur increased bulb diameter of garlic. Yudhvir and Ramesh (2003) reported the biggest bulb diameter of 5.53 cm, while Singh *et al.* (2012) reported 4.84 cm. Abraha Gebrekiros *et al*. (2015) and Uzma *et al*. (2016) reported the increased diameter of garlic and onion due to the combined application of phosphorous and sulfur, which is in line with the present study.

Table 9: Bulb diameter of garlic varieties as influenced by NPSB fertilizer

	Bulb diameter (cm)			
	NPSB kg ha $^{-1}$			
Varieties	0	144	244	344
HL	4.75^{cd}	5.03^{cd}	5.15^{bc}	5.09^{bcd}
Kuriftu	4.85^{cd}	5.14^{bc}	5.87^{a}	5.53^{ab}
Local	3.87^{f}	4.15^{ef}	4.18^{ef}	4.18^{ef}
Tsedey	4.61^{de}	4.99^{cd}	5.22^{bc}	4.95^{cd}
S.E. (±)	0.0214			
LSD (0.05)	0.1224			
CV (%)	3.027			

Where: Means followed with same letter(s) are not significantly different with each other. S.E. (±) = standard error, CV (%) = coefficient of variation and LSD (5%) = least significant difference at P<0.05

4.4.3. Marketable Bulb Yield (t ha^{-1})

Analysis of variance showed that the interaction effect of varieties and NPSB fertilizer were highly significant (P< 0.01) influenced marketable bulb yield of garlic. The main effects of variety and NPSB fertilizer were highly significantly influenced this parameter (Appendix Table-3). The highest marketable bulb yield (8.14 t ha^{-1}) was recorded from variety *kuriftu* at 244 kg/ha NPSB, which was statistically similar with the value (7.36 t ha^{-1}) recorded from the same variety at fertilizer rate of 344 kg/ha NPSB. While the lowest marketable bulb yields (4.76 t ha^{-1}) was recorded from the local cultivar from unfertilized treatment. Therefore, increasing rates of fertilizer from 0 kg to 244 kg/ha was found to increase the marketable yield of garlic. However, garlic varieties exhibited reduced yield of marketable bulbs at 0 kg/ha and 144 kg/ha rates.

According to Tadese, (2009) investigation of the average marketable bulb yield per hectare of garlic varieties differed significantly. Zaman *et al.* (2011) reported that marketable bulb yield of garlic was increased with increasing sulfur level up to 45 kg ha $^{-1}$ and thereafter decreased. In the current experiment the highest marketable bulb yield was obtained from variety *Kuriftu* at NPSB fertilizer treatments of 244 kg/ha and 344 kg/ha which do have sulfur content of 16.96 and 23.91, respectively, by excluding the residual sulfur content of the soil. Hariyappa (2003) also recorded a significant increased marketable bulb yield of garlic with the application of sulfur. 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 into higher productivity of crops (Naruka and Dhaka, 2001; Yadav, 2003; Farooqui *et al.*, 2009).

4.4.4. Unmarketable Bulb Yield (t ha^{-1})

Analysis of variance showed that the interaction effect of varieties and NPSB fertilizer were significantly different ($P < 0.05$) on unmarketable bulb yield of garlic. The main effects of variety and NPSB fertilizer were highly significantly influenced this parameter (Appendix Table-3). The highest unmarketable bulb yield was obtained from *HL* variety (0.92 t ha^{-1}) at unfertilized treatment, which was statistically similar with values (0.85 and 0.84 t ha^{-1}) recorded from *HL* variety at fertilizer rates of 144 kg ha^{-1} NPSB and variety *kuriftu* at unfertilized treatment respectively. Statistically lower unmarketable bulb yield was obtained from all varieties when interacted with at fertilizer rate of 344 kg/ha NPSB (Table-10).

Khan *et al.*, (2002) indicated that application of fertilizer not only improve average bulb weight but also enhance marketable bulbs and significantly reduce the production of unmarketable bulbs by preventing culling or wastage of too much bulbs. Availability of excess soil nutrients for sub-optimal growth led to over size or weight of bulbs, split bulbs, physiologically disordered, doubles, rotten, off-color and discolor and consequently higher unmarketable yield (Moray *et al.*, 2012). Similar to the present finding, Tibebu *et al.*, 2014 reported unmarketable yield showed no significant differences among varieties and similarly nitrogen fertilizer also had no significant effect on unmarketable yield.

4.4.5. Total Bulb Yield (t ha^{-1})

Variety and NPSB were interacted to significantly influence the parameter total bulb yield of garlic. The main effect of variety and NPSB were found to influence this parameter highly significantly (Appendix Table-3). The highest total bulb yield was recorded from variety *kuriftu* (8.81 t ha^{-1}) at 244 kg ha^{-1} NPSB, which was statistically similar with the value (8 t ha^{-1}) recorded from the same variety at the rate of 344 kg ha^{-1} NPSB. However, the lowest total bulb yield of garlic (5.52 t ha^{-1}**)** was recorded from local cultivar and at 0 kg ha^{-1} and which was not significantly different from the value (6.15 t ha^{-1}) recorded from the same variety at 144 kg ha^{-1} NPSB (Table-10).

This is because both 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 in to 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) who reported the application of sulfur increased the growth 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^{-1} and thereafter decreased. Hariyappa (2003) also recorded a significantly increased yield of garlic with the application of sulfur. It was reported that the significant differences among garlic varieties in total bulb yield in the range between 10.24 to 7.76 t ha^{-1} (Hossein *et al.,* 2014; Youssef, 2013). Relatively low yield was reported by Kilgori *et al.* (2007) in the range between 5.84 to 8.02 t ha^{-1}.

Table 10: Interaction effect of varieties and NPSB fertilizer on marketable, unmarketable and total bulb yield of garlic

	Marketable bulb yield (t ha $^{-1}$)				**Unmarketable bulb yield (t ha^{-1})**				**Total bulb yield (t ha $^{-1}$)**			
	NPSB kg ha^{-1}				**NPSB kg ha^{-1}**				**NPSB kg ha^{-1}**			
Varieties	0	144	244	344	0	144	244	344	0	144	244	344
HL	5.83^{cde}	6.34^{bcde}	6.68^{bcd}	6.71^{bc}	0.92^{a}	0.85^{ab}	0.76^{bcd}	0.67^{cdef}	6.75^{cdef}	7.19^{cdef}	7.44^{bcd}	7.38^{bcde}
Kuriftu	5.88^{cde}	6.44^{bcde}	8.14^{a}	7.36^{ab}	0.84^{abc}	0.69^{cdef}	0.67^{cdef}	0.64^{def}	6.72^{cdef}	7.13^{cdef}	8.81^{a}	8^{ab}
Local	4.76^{f}	5.44^{ef}	6.2^{cde}	6.47^{bcde}	0.76^{bcd}	0.71^{bcde}	0.7^{bcdef}	0.69^{cdef}	5.52^{g}	6.15^{fg}	6.9^{cdef}	7.16^{cdef}
Tsedey	5.65^{def}	6.1^{cde}	6.4^{bcde}	6.5^{bcde}	0.64^{cdef}	0.57^{ef}	0.57^{ef}	0.55^{f}	6.29^{efg}	6.67^{cdef}	6.97^{cdef}	7.05^{cdef}
S.E. (±)	0.011				0.002				0.01			
LSD (0.05)	0.062				0.0093				0.061			
CV (%)	5.122				7.13				4.5			

Where: Means followed with same letter(s) are not significantly different with each other. S.E. (±) = standard error, CV (%) = coefficient of variation and LSD (5%) = least significant difference at P<0.05

4.5 Correlation Analysis on Growth, Yield Components and Yield

The analysis of correlation between phenology, growth, and yield related and yield parameters are indicated in Table 11. Marketable bulb yield was very highly significantly ($P<0.001$) and positively correlated with leaf number ($r = 0.68^{***}$), bulb weight ($r = 0.64^{***}$), bulb diameter ($r = 0.72^{***}$), and highly significant ($P<0.01$) and positively correlated with plant height ($r = 0.41^{**}$) and leaf length ($r = 0.46^{**}$) (Table 11).

Total bulb yield was very highly significant ($P<0.001$) and positively correlated with leaf number ($r = 0.7^{***}$), bulb weight ($r = 0.63^{***}$), bulb diameter ($r = 0.7^{***}$), marketable bulb yield ($r = 0.99^{***}$), unmarketable bulb yield ($r = 0.55^{***}$) and highly significantly ($P<0.01$) positively correlated with plant height ($r = 0.46^{**}$), leaf length ($r = 0.43^{**}$) (Table 11).

Plant height showed a positive and very highly significant ($P<0.001$) correlation with bulb diameter ($r = 0.48^{***}$), unmarketable bulb yield ($r = 0.53^{***}$) and positively and highly significantly ($P<0.01$) correlate with marketable bulb yield ($r = 0.41^{**}$), total bulb yield ($r = 0.46^{**}$). In harmony with this study, Korla *et al.* (1981) reported that plant height was positively and significantly correlated with bulb diameter.

The increment in total bulb yield was a result of increase in plant height, number of leaves per plant, leaf length which led to relatively giant plant morphology and 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 bulb diameter, bulb weight, marketable bulb yield, unmarketable bulb yield and total bulb 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 bulb weight, bulb diameter, marketable bulb yield and total bulb yield

Table 11: Simple correlation coefficient among growth and yield variables of garlic

	PH	LN	LL	DTE	DTM	BW	BD	MBY	UMBY	TBY
PH	1									
LN	0.2 ^{ns}	1								
LL	0.17 ^{ns}	0.15 ^{ns}	1							
DTE	0.19 ^{ns}	-0.01 ^{ns}	-0.2^{ns}	1						
DTM	0.12 ^{ns}	-0.2 ^{ns}	-0.4**	0.5***	1					
BW	0.21 ^{ns}	0.41**	0.45**	-0.07 ^{ns}	-0.3*	1				
BD	0.48***	0.6***	0.5***	-0.1 ^{ns}	-0.4**	0.6***	1			
MBY	0.41**	0.68***	0.46**	0.03 ^{ns}	-0.2 ^{ns}	0.64***	0.72***	1		
UMBY	0.53***	0.44**	0.004^{ns}	0.04 ^{ns}	0.16 ^{ns}	0.3 ^{ns}	0.24 ^{ns}	0.4**	1	
TBY	0.46**	0.7***	0.43**	0.032 ^{ns}	-0.1 ^{ns}	0.63***	0.7***	0.99***	0.55***	1

Where; *** = Correlation is very highly significant at (P<0.001); ** = highly significant at (P<0.01); * = significant at (P<0.05); ns = non-significant at (P>0.05) ; PH = Plant height; LN = Leaf number; LL = Leaf length; DTE = Days to emergence; DTM = Days to maturity; BW = Bulb weight; BD = Bulb diameter; MBY = Marketable bulb yield; UMBY = Unmarketable bulb yield; TBY = Total bulb yield

4.6 Partial Budget Analysis

The economic analysis was done to evaluate the benefits of each treatment where the costs of blended NPSB fertilizer (17.80 birr/kg), Application cost of blended NPSB fertilizers 18 persons 144 kg ha^{-1}, each 175 ETB day^{-1} and cost of garlic bulb yield transportation to the nearest market (250 Birr ton^{-1}) were considered as total variable costs. The price of the adjusted marketable garlic bulb yield during the time of harvesting was Birr 105 kg^{-1}, which was used in the present study.

Partial budget analysis was shown a significance differences by ranking the treatments in order to increasing of the total variable cost. The highest total bulb yields 6.5, 8.14, 6.71 and 6.47 t ha $^{-1}$ were recorded from *tsedey, kuriftu, HL* and local varieties at 344 NPSB kg ha $^{-1}$ fertilizer application but *kuriftu* at 244 NPSB kg ha $^{-1}$ fertilizer application, respectively.

Similarly, the highest adjusted marketable bulb yield were increased the same order with the above mentioned treatment orders (Table 12). However, *kuriftu* had the highest net benefit of 758,049.3 birr at 244 NPSB kg ha $^{-1}$ fertilizer application. This was followed by *kuriftu* and *HL* varieties that exhibited net benefit of 680,215.8 and 619,041.8 birr at 344 NPSB kg ha $^{-1}$ fertilizer application.

The highest marginal rate of return was recorded from *kuriftu* variety which was exhibited 1974.3 at 244 NPSB kg ha $^{-1}$ fertilizer application. This was followed by local variety that exhibited marginal rate of return 1252.4 and 1023.14 at 244 and 344 NPSB kg ha $^{-1}$ fertilizer application, respectively. While the lowest marginal rate of return was recorded by *tsedey* variety which gave 480.41 at 344 NPSB kg ha $^{-1}$ fertilizer application, followed by *HL* variety which gave 499.1 at 344 NPSB kg ha $^{-1}$ fertilizer application. On the other hand, application of 244 NPSB kg ha $^{-1}$ recorded the highest marginal rate of return for *kuriftu* variety as compared to all combination treatments. Therefore, this could be recommended for the study area.

Table 12: Partial budget and marginal rate of return analysis for the response of garlic varieties to blended NPSB fertilizer rates

Trt No	Varieties	Blended NPSB (kg ha^{-1})	AMB Y (t ha^{-1})	ADMB Y (t ha^{-1})	TVC (ETB)	GFB (ETB)	Net Benefit (ETB)	MRR (%)
1	Tsedey	0	5.65	5.085	1271.25	533925	532653.75	-
2	Tsedey	144	6.1	5.49	7085.7	576450	569364.3	631.4
3	Tsedey	244	6.4	5.76	11208.2	604800	593591.8	613.25
4	Tsedey	344	6.5	5.85	15110.7	614250	599139.3	480.41
5	Kuriftu	0	5.88	5.3	1325	556500	555175	-
6	Kuriftu	144	6.44	5.8	7163.2	609000	601836.8	799.25
7	Kuriftu	244	8.14	7.33	11600.7	769650	758049.3	1974.3
8	Kuriftu	344	7.36	6.624	15304.2	695520	680215.8	894.5
9	HL	0	5.83	5.25	1312.5	551250	549937.5	-
10	HL	144	6.34	5.71	7140.7	599550	592409.3	728.73
11	HL	244	6.68	6	11268.2	630000	618731.8	691
12	HL	344	6.71	6.04	15158.2	634200	619041.8	499.1
13	Local	0	4.76	4.3	1075	451500	450425	-
14	Local	144	5.44	4.9	6938.2	514500	507561.8	974.5
15	Local	244	6.2	5.6	11168.2	588000	576831.8	1252.4
16	Local	344	6.47	5.8	15098.2	609000	593901.8	1023.14

Where: - AMBY = Actual marketable bulb yield; ADMBY= Adjusted marketable bulb yield; TVC= Total variable cost; GFB= Gross field benefit; MRR (%) =Marginal rate of return

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Garlic is an important cash crop in Ethiopia including SNNP Region and the study area. However, the production and productivity of the crop is by far low as compared to other countries. Intervention on the production of garlic therefore requires adequate information about the production practices employed by farmers' as well as identification of the major constraints and opportunities.

Due to the deficiency of Ethiopian soils in both macro and micro elements, blended fertilizers have recently been introduced into the agriculture system. One of these fertilizers is NPSB, which consist four elements very mandatory for plant growth and development. However, the fertilizer was introduced without blanket recommendation, so that site specific fertilizer trials are very important in order to ensure optimum yield of garlic due to the heterogeneous character of soil. On the other hand, farmers in the study area are using local garlic varieties sourced from nearby local markets and their own saving. No improved garlic varieties have been introduced as yet to the study area. This is addition to their use of inadequate amount of fertilizers that results in much lower yield of garlic. Cognizant of these, the current study was initiated with the aim to evaluate and determine the response of garlic varieties to different NPSB fertilizer rates in the study area.

The treatments were consisted of NPSB fertilizer at four rates (0 Kg/ha, 144 Kg/ha, 244 Kg/ha, 344 Kg/ha) and four garlic varieties (*Tseday*, *Kuriftu*, *HL* and a local check "*Tuma"*). A total of sixteen treatment combinations were used. The experiment was laid out using RCBD with 4*4 factorial arrangements and three replications. Soil samples were collected randomly from the entire experimental field in a zigzag manner at a depth of 20 cm before planting. The soil samples that were then organized in one kg composite sample, which were used analysis and determine the soil physicochemical properties. Crop phenological data, growth, yield and yield component parameters were also collected and recorded.

The analysis of variance revealed that most parameters were significantly influenced by the interaction of variety and NPSB fertilizer except some parameters like days to emergence, leaf length and bulb weight which were significantly influence by the main effects of variety and NPSB fertilizer.

The maximum plant height (74.17cm) was recorded from variety *HL* at 244 kg/ha NPSB, and the highest number of garlic leaf (10.33) was obtained from variety *kuriftu* that received the highest NPSB rate of 344 kg/ha. The longest leaf was recorded from variety *Tsedey* (34.875cm) which was followed by variety *Kuriftu* (34.154cm) and *HL* (32.596cm). Statistically equal highest bulb weight was recorded from variety *Kuriftu*, *Tsedey* and *HL* (43.42g, 42.77g and 41.92g) respectively, which was not statistically significantly different.

The highest total bulb yield was obtained from *kuriftu* variety treated with 244 kg/ha NPSB which was statistically similar with the yield obtained from *kuriftu* variety treated with 344 kg/ha NPSB.

Marketable bulb yield was very highly significantly ($P<0.001$) and positively correlated with leaf number ($r = 0.68^{***}$), bulb weight ($r = 0.64^{***}$), bulb diameter ($r = 0.72^{***}$), and highly significant ($P<0.01$) and positively correlated with plant height ($r = 0.41^{**}$) and leaf length ($r = 0.46^{**}$) and total bulb yield was very highly significant ($P<0.001$) and positively correlated with leaf number ($r = 0.7^{***}$), bulb weight ($r = 0.63^{***}$), bulb diameter ($r = 0.7^{***}$), marketable bulb yield ($r = 0.99^{***}$), unmarketable bulb yield ($r = 0.55^{***}$) and highly significantly ($P<0.01$) positively correlated with plant height ($r = 0.46^{**}$), leaf length ($r = 0.43^{**}$) (Table 11).

The highest Marginal Rate of Return (MRR) was recorded from *kuriftu* variety which was exhibited 1974.3 at 244 NPSB kg ha $^{-1}$ fertilizer application. While the lowest marginal rate of return was recorded by *tsedey* variety which gave 480.41 at 344 NPSB kg ha $^{-1}$ fertilizer application, followed by *HL* variety which gave 499.1 at 344 NPSB kg ha $^{-1}$ fertilizer application.

5.2 Recommendations

In the current study variety *Kuriftu* gave the highest yield and highest Marginal Rate of Return (MRR) when interacted with NPSB rate of 244 kg/ha. Hence this combination is recommended for the study area and areas with similar agro-ecological conditions. However, since the experiment was conducted for one season and in only one location, so it is difficult to say that this is conclusive recommendation. Therefore, it is also recommended that the experiment be repeated more locations and seasons. Preferably, it is also recommended to study the response on more garlic varieties using this and other types of blended fertilizers.

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7. APPENDIXES

APPENDIX TABLES

Appendix Table 2: Mean squares from analysis of variance (ANOVA) for days to 75% maturity, plant height and number of leaves as influenced by garlic varieties and blended NPSB fertilizer rate.

		Mean of squares		
Source of variation	DF	DTM	PH	NL
Rep	2	9.083*	2.42^{ns}	0.193^{ns}
Var	3	92.743***	154.75***	3.197***
NPSB	3	4.85^{ns}	51.1***	3.796***
Var*NPSB	9	7.32*	18.56*	0.552*
Error	30	2.639	6.875	0.221

Where: DF = degrees of freedom, NS, *, ** and *** implies non-significant, Significant and highly significance and very highly significance differences at 5% level of probability, respectively.

Appendix Table 2: Mean squares from analysis of variance (ANOVA) for days to 50% emergence, leaf length and bulb weight on main effects of garlic varieties and blended NPSB fertilizer rate.

		Mean of squares		
Source of variation	DF	DTE	LL	BW
Rep	2	2.021^{ns}	35.16^{ns}	18.095*
Var	3	7.833***	40.55*	19.344*
NPSB	3	3.055*	61.87**	32.448**
Var*NPSB	9	2.185^{ns}	16.013^{ns}	5.521^{ns}
Error	30	1.043	12.003	5.108

Where: DF = degrees of freedom, NS, *, ** and *** implies non-significant, Significant and highly significance and very highly significance differences at 5% level of probability, respectively.

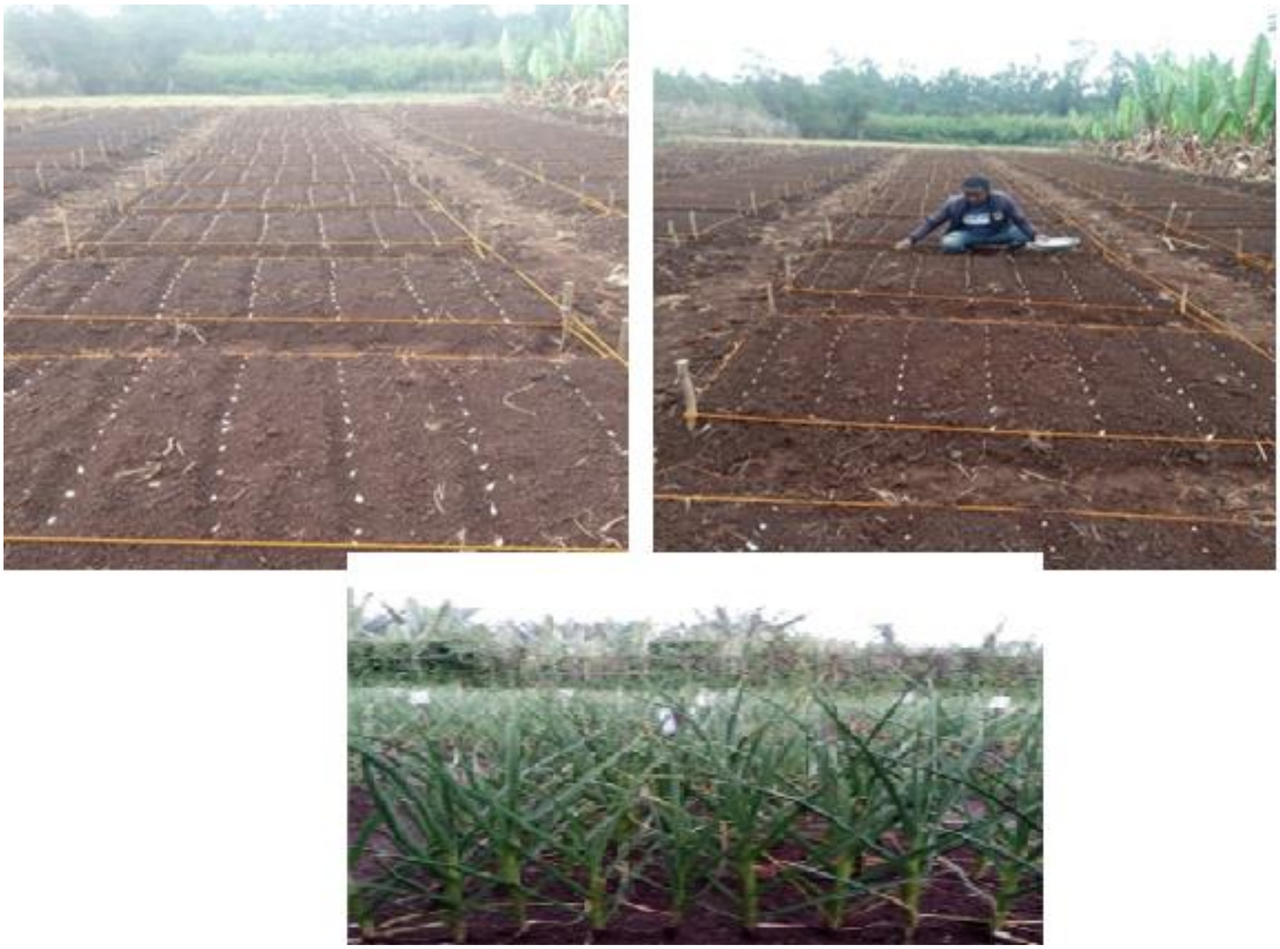
Appendix Table 3: Mean squares from analysis of variance (ANOVA) for bulb diameter, marketable bulb yield, unmarketable bulb yield and total bulb yield as influenced by garlic varieties and blended NPSB fertilizer rate.

		Mean of squares			
Source of variation	DF	BD	MBY	UMBY	TBY
Rep	2	0.0032^{ns}	0.042**	0.0004^{ns}	0.0497***
Var	3	3.4***	0.17***	0.00452***	0.181***
NPSB	3	0.73***	0.245***	0.00537***	0.311***
Var*NPSB	9	0.073**	0.0195**	0.000342*	0.021**
Error	30	0.0215	0.0056	0.000126	0.0053

Where: DF = degrees of freedom, NS, *, ** and *** implies non-significant, Significant and highly significance and very highly significance differences at 5% level of probability, respectively.

APPENDIX FIGURES

Appendix Figure 1: The land preparation, planting bed preparation and planting material preparation



Appendix Figure 2: Planting and vegetative growth

Appendix Figure 3: Growth parameters data collection

Appendix Figure 4: Harvesting and yield data collection

8. BIOGRAPHIC SKETCH

The author was born on June 25, 1983 in Gummer district, Gurage zone, and Southern regional state. He attended his primary school education in Gummer at Zizencho Junior School from 1993 to 1998. He then attended Junior Secondary school and high school at Arekite senior secondary school from 1999 to 2002. In 2003, he joined Wolaita ATVET College of agriculture and graduated on July 06, 2005 with Diploma in plant science. After his graduation, he was employed by Gurage zone, Getta and Gummer Woreda bureau of agriculture and rural development as an extension agent and supervisor from 2006 to 2016.

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