GROWTH, YIELD AND YIELD ATTRIBUTES OF GARLIC (*Allium sativum* L.) AS INFLUENCED BY THE INTERACTION OF VARIETIES AND RATES OF NPS BLENDED FERTILIZER IN METTU, SOUTHWESTERN ETHIOPIA

MSc THESIS

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JULY, 2020

JIMMA, ETHIOPIA

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A THESIS

Submitted to the School of Graduate Studies, Jimma University College of Agriculture and Veterinary Medicine, in Partial Fulfillment of the Requirements for the Degree of Master of Science in Horticulture

JULY, 2020

JIMMA, ETHIOPIA

DEDICATION

This thesis manuscript is dedicated to my beloved mother Liku Beyene, Sister, Aberash Jaleta and father, Jaleta Berkessa for their forbearance, encouragement, prayer and their extrovert support from the very beginning of my juvenile age up to this instant and during those difficult times with great affection and love and for their wholehearted partnership in the success of my life.

STATEMENT OF AUTHOR

First, I declare that this thesis is a result of my genuine work and that i have duly acknowledged all sources of materials used for writing it. This thesis has been submitted in partial fulfillment of the requirements of MSc degree in Horticulture at Jimma University, college of agriculture and veterinary medicine and is deposited at the university library to be made available to users under rules of the library. I seriously declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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Name: Abera Jaleta Berkessa Signature: ________

Place: Jimma University

Date of submission: 10/06/2020

BIOGRAPHICAL SKETCH

The author, Abera Jaleta Berkessa, was born in Kerkerro Homi Kebele, Alge-Sachi Disrict, Ilubabor Zone of Oromia Regional State in Ethiopia in 1991G.C. He attended his elementary education at Sodo Elementary School and secondary school education at Alge Secondary and Preparatory School. In 2011, he joined Jimma University, College of Agriculture and Veterinary Medicine and graduated in degree in Horticulture in June 2013.

After graduation, he was employed by 'ET HIGHLAND' flower company in Sebeta as junior agronomist in September 2014, and served for 5 months. In February 2014, he was employed by Oromia Agriculture Research Institute (OARI) and assigned to work as junior researcher in coffee agronomy at Mechara Agriculture Research Center, coffee research team where he served on different position including team leader of the coffee research team up to November 8, 2017. Then he was employed by Mettu University to work as graduate assistance in the department of Horticulture where he served up to September, 2018.

He joined the school of graduate studies of Jimma University, College of Agriculture and Veterinary Medicine in November 2018 to pursue a study leading to the degree of Master of Science in Horticulture.

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
CACC	Central Agricultural Census Commission
CSA	Central Statistical Agency of Ethiopia
CIMMYT	International Maize and Wheat Improvement Center
DzARC	Debrezeit Agricultural Research Centre
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	Food and Agricultural Organization Statistics
RCBD	Randomized Complete Block Design
MoANR	Ministry of Agriculture and Natural Resource
EthioSIS	Ethiopian Soil Information System

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ABSTRACT

Garlic productivity in Ethiopia (9.18 t ha^{-1}) is very low compared to the world average (18.4 t ha^{-1}), due to various factors, of which imbalanced fertilizers and lack of improved variety are the serious problems. Therefore, this experiment was conducted in 2019 at Mettu, Southwestern Ethiopia with the objective of investigating the effect of NPS blended fertilizer rate on growth, yield and yield attributes of garlic varieties. The experiment was laid out in a randomized complete block design in three replications using 20 treatments formed from factorially combined five garlic varieties (Tseday, Kuriftu, Chefe, Holeta and local) and four rates of NPS blended fertilizers (0, 181.5, 242 and 305.5 kg ha^{-1}). Data on different phenological, growth, yield and yield related variables were collected and analyzed using SAS, version 9.3. The analysis of variance showed that most of the studied parameters were significantly affected by the interaction of the two factors. The highest total (12.9 t ha^{-1}) and marketable bulb yield (12.9 t ha^{-1}) was recorded from Tseday variety at NPS blended fertilizer rate of 242 kg ha^{-1} but statistically alike with the same variety at NPS blended fertilizer rate of 305.5kg ha^{-1}, while the lowest was recorded from unfertilized plot of Chefe variety. Similarly, maximum total dry biomass weight (74.66 g plant $^{-1}$) and highest bulb dry matter content (60%) was recorded from Tseday variety produced at NPS blended fertilizer rate of 242 kg ha^{-1}. The highest net benefit (1,380,252.21ETB ha^{-1}) was recorded from Tseday variety supplied with 242 kg ha^{-1}NPS blended fertilizer. Thus, it can be concluded that the use of variety Tseday with the application of 242 kg ha^{-1} NPS blended fertilizer is economical. However, the results of the present study need to be validated and verified in different agro ecologies for different seasons in order to give a comprehensive recommendation.

Key words: Biomass, bulb, dry weight, net benefit, Tseday

1. INTRODUCTION

Garlic (*Allium sativum* L. 2n = 16) is the second most widely used cultivated bulb crops after onion in the World (Rubatzky and Yamaguchi, 1997; Yadav *et al*., 2017). It belongs to the family Alliaceae, genus Allium and originated in central Asia (Brewster, 1994). Garlic is widely used around the world for its pungent flavor as a seasoning or condiment. The production, total area under cultivation and productivity of the crop in 2018/19 in the world was 28,494,130 t, 1,546,741 ha and 18.4 t ha^{-1} respectively. The production of the crop in Ethiopia is estimated to be 178,221.9 t with area of production of 19,412.49 ha of land and productivity of 9.18 t ha^{-1} in 2018 (CSA, 2018). The productivity of the crop in Ilubabor Zone in 2018/19 is 2675 kg ha^{-1} which is quite low compared to national average (9950 kg ha^{-1}) (Lijalem, 2019, unpublished).

Despite the crop's high value and very important nature, presence of great potential for production and high market demand, productivity and production of garlic is very low compared to the world average in Ethiopia in general (DzARC, 2006) and Mettu district in particular. This low production and productivity of garlic in Ethiopia is due to various factors. Among which inappropriate agronomic practices, declining soil fertility, absence of proper diseases and insect pest managements and lack of improved varieties are the most important factors (DzARC, 2006; Yayeh, 2015). The major challenging problems in the district are lack of improved variety, use of traditional production practice, and disease and insect pests (Habtamu, 2019, unpublished). Due to lack of improved variety with required quality in sufficient quantity in the study area (Mettu), farmers are obliged to use their own or purchase local varieties from local market. Contrarily, improved varieties of garlic such as Bishoftu Nech, Qoricho, Chefe, Kuriftu, Holota local, Tseday and Chelenko-1 were released for mid to highland area of the country in the past years (MoANR, 2016), but are not available in this study area (Mettu). On the other hand, garlic varieties are proved to have great variation in growth performance, yield and different yield attributes (Rabinowitch and Currah, 2002; Tsega, 2006; Abadi, 2015; Ayalew *et al*., 2015; Ibrahim *et al*., 2018).

In addition to lack of improved varieties, use of imbalanced fertilizer (the sources of plant nutrients for Ethiopian agriculture over the past five decades have been limited to urea and Diammonium Phosphate (DAP) fertilizers which contain only nitrogen and phosphorus), lack of appropriate fertilizer recommendations and lower soil fertility are the major among the factors limiting the productivity and production of garlic that resulted in lower crop yields (Yayeh, 2015). Sulphur is absent in the fertilizer used for garlic production not only in Mettu area, but also in the country as a whole, despite the fact that sulphur is the 4th important nutrient for garlic.

However, Ethiopian soils lack most of the macro and micronutrients that are required to sustain optimal growth and development of crops (Geleta, 2014). Besides, a study done in Central Ethiopia elucidated that application of 92 kg N ha^{-1}, 40 kg P ha^{-1}, and 30 kg S ha^{-1} was suggested to be optimum for achieving good growth and highest bulb yield of garlic (Geleta, 2014). Another study done at Yilmana Densa District of Amhara Region by Yayeh (2015) indicated high marginal rate of return on garlic from application of NPS blended fertilizer at the rate of 140:92:17 N: P_2O_5: S kg ha^{-1}. This highlights the importance of developing an alternative means to meet the demand of nutrient in garlic plants by using balanced fertilizer that contains S and others in addition to the commonly used N and P fertilizers in one hand and area specific fertilizer recommendation owing the diverse soil background and fertility status.

An opportunity with this regard is that recently the Ministry of Agriculture of Ethiopia has been introduced a new compound fertilizer (NPS) containing Nitrogen, Phosphorous and Sulphur. This fertilizer has currently substituted DAP in Ethiopian crop production system as main source of Phosphorous (MoANR, 2013). EthioSIS map of Ethiopian soil recommends different types of blended fertilizer types for different area even for one zone and cannot be generalized to using one type of blended fertilizer type. But, application rate is not known yet for this area. Consequently, garlic growers in Mettu area are either using the general blanket recommendation or apply with local material without measuring.

The above mentioned researches and others done so far were done using single variety. But, crop nutrient requirement varies with species, variety, soil type and season (Yohannes, 1994). There is evidence that varieties may differ in their response to source and rate of applied fertilizers (Zhou *et al*., 2005; Kandil *et al*, 2010; Hassan *et al*., 2014; Abadi, 2015). Fertilizer response also varies with locations, hence demand location specific recommendation or development of recommendation for different varieties as they vary in maturity, the purpose for which they are grown and etc. But, little study has been done on response of garlic varieties to the rates of NPS blended fertilizer in the country in general and in study area in particular. Therefore, the current study was initiated with general objective of investigating the effect of NPS blended fertilizer rate on growth, yield and yield attributes of garlic varieties at Mettu, Southwestern Ethiopia.

Objectives:

1. To evaluate the influence of NPS blended fertilizer rate on growth, yield and yield attributes of garlic varieties at Mettu, Southwestern Ethiopia
2. To determine economically feasible rate of NPS blended fertilizer for garlic production at Mettu, Southwestern Ethiopia

2. LITERATURE REVIEW

2.1. Importance and Distribution of Garlic 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 the second most widely cultivated Allium species in Ethiopia next to onion (Yayeh, 2015). Among vegetable crops it ranks second in the number of landholders next to Ethiopian cabbage. In Ethiopia the Alliums group (onion, garlic, and shallot) are important bulb crops produced by small and commercial growers for both local use and export (Fekadu & Dandena, 2006). These crops are produced for home consumption and as a source of income to many peasant farmers in many parts of the country (Tabor & Zeleke, 2000). It is mainly used for flavoring and seasoning vegetables in different dishes. It is used as ingredient of local stew 'wot' and has also a tremendous use in the formulation of local medicines (Mulatu *et al*., 2014). It is not only produced for home consumption in the preparation of soup, pickle and other preservatives (Degwale, 2014) but also contributes to the national economy as export commodity (Fekadu & Dandena, 2006). Garlic is exported to Europe, Middle East and North America (DzARC, 2006).

2.2. Garlic Production and Productivity in Ethiopia

The best growing altitudes for garlic is between 700 and 1800 m.a.s.l. It is produced mainly in the mid and high lands of the country (Tabor & Zeleke, 2000). The bulk of garlic for domestic market is produced in homestead gardens of smallholder farmers in Ambo, Debrework, Adet, and Sinana and in many other areas of Ethiopian highlands (CSA, 2017). But, for export purpose it had been produced at Debre Zeit, Guder and Tsedey state farms. Identifying production problems and the potential of the crop, the Horticultural Crops Improvement Program of the Debrezeit Agriculture Research Center, in collaboration with other programs, has been engaged in the improvement of garlic cultivars and its production practices since 1987 (Tabor & Zeleke, 2000).

In Ethiopia garlic production is estimated to be 178,221.9 t from a production area of 19,412.49 ha of land and productivity is 9.18 t ha^{-1} in 2018 (CSA, 2018). The production and area of harvest of garlic increased in both area and volume of production in 2108 compared to 2017 but, the productivity was declined. In Ilubabor Zone in 2018/19 the productivity of the crop was 2 675 kg ha^{-1} which is very low compared to the national average of 9950 kg ha^{-1} (Lijalem 2019, unpublished). In Ilubabor Zone the crop is grown in the back yard under rain fed and irrigation as well. Majority of the garlic produced is used for home consumption. The rest is sold in the local market with only few farmers transporting it to Addis Ababa for sell (Lijalem 2019, unpublished).

Despite its importance, garlic productivity in Ethiopia is low due to genetic and environmental constraints affecting its yield and yield related traits (Geleta, 2014). Diverse crop management problems and the nature of propagation accounted for the low yield of garlic in Ethiopia; major production constraints include lack of proper improved varieties planting material, inappropriate agronomic practices, absence of proper pest and disease management practices and marketing facilities and lower soil fertility status in many soil types particularly N and P nutrients (Tabor & Zeleke, 2000).

2.3. Varietal Effect on Growth, Yield and Yield Attributes of Garlic

2.3. 1. Growth attributes of garlic

Today garlic is proved to have great variation for maturity date, bulb size, shape and color, flavor and pungency, clove number and size, number of whorls of cloves, bolting capacity, plant height, number and size of top sets and number of flowers and fertility (Rabinowitch and Currah, 2002). After evaluation of 120 garlic accessions collected from Central Asia, Kamenetsky *et al*. (2005) reported that garlic cloves vary in most vegetative characteristics like leaf number, bulb size and structure. Abadi (2015) indicated that plant height, leaf width and bulb neck diameter were significantly influenced by cultivar, nitrogen fertilizer and the interaction of the two. Ibrahim *et al*. (2018) have tested four garlic varieties and reported maximum stem diameter (13.5 mm) from the variety NARC-1 followed by variety Swat White (8.9 mm) and variety Garlic-1 (8.5 mm), while minimum stem diameter (8.2 mm) from Buner local variety. Ayalew *et al*. (2015) found significantly highest number of leaves from local variety than the rests.

Tsega (2006) and Islam *et al*. (2004) reported the presence of a wide range of variation in plant height, number of leaves, leaf diameter per plant, and leaf length across accessions. Brewster (1994) and Etoh and Simon (2002) also reported the presence of great variation of garlic in plant height and other morphological characters.

In general, none of above mentioned researches focused on varietal response to blended fertilizer rates on the growth performance, despite the fact that varieties differ in their response to levels of fertilizer and nutrients. In addition, even no any variety adaptation trial was done in study area, in spite of, availability of improved garlic varieties like Bishoftu Nech, Qoricho, Chefe, Kuriftu, Holota local, Tseday and Chelenko-1 in different regions of the country. That is why the current study was focused on varietal response to NPS blended fertilizer rates.

2.3.2. Yield and yield attributes

Garlic varieties may vary in different yield and yield related characters such as fresh and dry bulb weights, bulb diameter, bulb length, number of cloves per bulb, average clove weight, clove length and width, shoot dry weight, total biological yield, total bulb yield and marketable bulb yield (Abadi, 2015). Abadi (2015) also recorded highest fresh bulb and number of cloves per bulb weight from the variety Tsedey, highest bulb dry weight and highest bulb diameter from Felegdaero cultivar and widest clove diameter and highest clove length from cultivar Bora-1. Ibrahim *et al*. (2018) study revealed that maximum bulb diameter (56.0 mm) was noted in local variety Buner, while the minimum bulb diameter (51.8 mm) was recorded from variety NARC-1. They also reported maximum clove weight (13.6 g) from variety NARC-1 and minimum (4.5 g) in variety called Garlic-1. They further reported maximum yield (8.6 t ha^{-1}) from the local variety Buner while the minimum yield (1.7 t ha^{-1}) from variety NARC-1.

Abadi (2015) observed the highest shoot dry weight per plant (6.57 g) from cultivar Guahgot, the highest total dry biomass yields per plant from variety Tsedey (G-493) (18.91 g) and total bulb yield (12.61 t ha^{-1}) from Bora-1 cultivar. Abou El-Magd *et al*. (2012) also measured the highest and lowest shoot dry weight value of 5.95 g and 2.45 g from two different varieties. In addition, Hossein *et al*. (2014) reported relatively higher shoot dry weight of 6.38 g from Hamedan while the lowest shoot dry weight (4.03 g) was measured from the cultivar Violet.

The result of Ayalew *et al*. (2015) experiment indicated highest fresh bulb weight of 16.56 t ha^{-1} from the local variety and lowest (5.57 t· ha^{-1}) from Tseday 92. They observed the highest mean bulb diameter from local variety and Kuriftu. They also measured the highest number of cloves per bulb (20.45) and highest bulb dry matter of 25.83% from the local variety and MM-98, respectively. Additionally, Mahmood *et al*. (2002) reported that the average bulb yield in cultivar "Chinese" was 3.4, 2.3, 1.6 times higher than G-S-1, 'Lehson' and 'Ghulati', respectively.

Regrettably, none of above mentioned and researches others done so far concentrated on varietal response to blended fertilizer rates on yield attribute's and yield response, despite the fact that varieties differ in their response to levels of fertilizer and nutrients. In addition, no any variety was adapted in the condition of the study area, in spite of, availability of improved garlic varieties in different regions of the country. Therefore, the current study was focused on varietal response to NPS blended fertilizer rates.

2.4. The Effect of Nitrogen on Growth, Yield and Yield Aspects of Garlic

2.4.1. Effect of Nitrogen on growth attributes

Nitrogen is necessary and important element for increasing the yield and quality of vegetables including garlic (Gulser, 2005). Adequate application of N during sprouting stage and application of different sources and rates of N play an important role in the production of vigorous vegetative and optimum leaf expansion of crops and influences bulb size produced (Stork *et al*., 2004).

Different research outputs indicated that N application improved growth performance of garlic. Increasing N level from 50 to 200 kg ha^{-1} increased the growth trend of garlic for the number of leaves, leaf length, plant height, leaf area, leaf count, neck thickness, fresh and dry plant mass (Farooqui *et al*., 2009; Geleta, 2014; Ayalew *et al*, 2015; Kenea and Gedamu, 2018; Sebnie *et al*., 2018). Usman *et al*. (2016) reported that increasing Nitrogen rates to 100 kg N ha^{-1} resulted in longer leaves and greater number of leaves per plant. Abadi (2015) recorded taller plant height of 81.58 cm and longer leaf length of 54.41cm from the improved variety Bishoftu Nech at the application of 123 kg ha^{-1} Nitrogen fertilizer. A study by Yayeh (2015) indicated that 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 N kg ha^{-1}.

Unfortunately, none of above mentioned researches and others done so far concentrated on varietal response to blended fertilizer rates on growth response of garlic, despite the fact that varieties differ in their response to levels of fertilizer and nutrients. They used single variety in their study, except Abadi (2015). These previous researches used only nitrogen as a source of nutrient for the crop in spite of the fact that, "balanced application of nutrients can improve soil fertility and eliminate the effect of nutrient deficiencies beyond improving of garlic productivity and quality". Thus nitrogen by its lone cannot meet the nutrient demand of the crop for optimum growth performance. In addition, fertilizer response varies with locations, which opens a door to look for location specific recommendation. Therefore, in order to ensure balanced use of nutrient for this crop, to search out for exact fertilizer requirement for the varieties and to come with site specific recommendation, the current study was done using different varieties and NPS blended fertilizer rate.

2.4.2. Effect of nitrogen on yield and yield attributes

Nitrogen is necessary and important element for increasing the yield and quality of vegetables such as garlic (Gulser, 2005). With this regard Sebnie *et al*. (2018) observed maximum bulb yield (7.11 t ha^{-1}) from plots fertilized with Nitrogen at the rate of 92 N kg ha^{-1}. In contrast, Kilgori *et al*. (2007) reported that increasing levels of Nitrogen up to 120 kg ha^{-1} resulted in significant increase in bulb yield while further increase to 240 kg N ha^{-1} reduced the yield. Others still reported that higher rate of N application (200 kg N ha^{-1}) was also significantly increased bulb diameter, neck thickness, number of cloves per bulb, fresh weight of cloves, dry weight of cloves, fresh weight of bulb, dry weight of bulb and bulb yield of garlic (Gaviola and Lipinski, 2008; Farooqui *et al.*, 2009; Hore *et al.*, 2014). Abadi (2015) reported highest fresh bulb weight of 43.39 g per plant from variety Tsedey (G-493) at the highest rate of N (123 kg N ha^{-1}), while highest bulb dry weight of 14.81 g from Felegdaero cultivar at the same level of N. They also identified that N rate of 82 kg N gave the highest total yield of 12.61 t ha^{-1} for Bora-1. Moreover, maximum bulb diameter, shoot dry weights and bulb yield, the highest mean clove weight, highest fresh bulb, highest bulb dry matter weight was recorded from plants grown from the application 100 to 150 kg N ha^{-1} (Getaneh, 2011; Zaman *et al*., 2011; Hossein *et al*., 2014; Mulatu *et al*., 2014, Kenea and Gedamu, 2018).

Geleta (2014) identified N rate of 138 kg N ha^{-1} on Vertisols increased the mean clove weight by 29.51% and 9.22% as compared to control and 92 kg N ha^{-1}, respectively. They also reported highest bulb yield and diameter from the application of 138 kg N on Vertisols. Further, they explained that significantly higher garlic bulb weights and bulb yield were obtained from the Andosols in response to the application of 92 kg N ha^{-1}, but the highest bulb diameter was obtained from 138 kg N ha^{-1}.

In general, none of above mentioned researches and others concerted on varietal response to blended fertilizer rates on yield attribute's and yield response, despite the fact that varieties differ in their response to levels of fertilizer and nutrients. They used single variety in their study, except Abadi (2015). In addition, except Geleta (2014), they used only nitrogen as a source of nutrient for the crop in spite of the fact that, "balanced application of nutrients can improve soil fertility and eliminate the effect of nutrient deficiencies beyond improving of garlic productivity and quality". Thus nitrogen by its lone cannot meet the nutrient demand of the crop for optimum yield. Furthermore, fertilizer response varies with locations, which opens a door to look for location specific recommendation. Therefore, to fill these methodologic gabs, the current study was done using different varieties and blended fertilizer rate.

2.5. Effect of Phosphorous on Growth, Yield and Yield Attributes of Garlic

2.5.1. Effect of phosphorus on growth attributes

Teklemariam (2007) and Arif *et al*. (2016) found significant increase of number of leaves $plant^{-1}$ of garlic by application of phosphorus. The maximum leaf number, the highest plant height and leaf area of garlic leaves was recorded at the rate of 69 P_2O_5 kg ha^{-1} (Tibebu *et al*., 2014) and 40 P_2O_5 kg ha^{-1} (Geleta, 2014). Degwale (2014) figured out that the maximum plant height, leaf number and leaf area index of garlic was recorded at the application rate of 92 P kg ha^{-1}.

Adem and Tadesse (2014) reported highest garlic plant height from the application of 100 N kg ha^{-1} + 120 P_2O_5 kg ha^{-1} and highest leaf number and leaf length was obtained from the application of 100 N kg ha $^{-1}$ + 130 P_2O_5 ha^{-1} in Jimma area.

Fatefully, none of above mentioned researches and others done previously focused on varietal response to blended fertilizer rates on growth response of garlic, despite the fact that varieties differ in their response to levels of fertilizer and nutrients. They used single variety and only phosphorus as a source of nutrient for the crop in spite of the fact that, “balanced application of nutrients can improve soil fertility and eliminate the effect of nutrient deficiencies beyond improving of garlic productivity and quality”. Thus phosphorus by its lone cannot meet the nutrient demand of the crop for optimum growth performance. In addition, fertilizer response varies with locations, which needs to look for location specific recommendation. Therefore, the current study was done using different varieties and blended fertilizer rate to fill these information gabs.

2.5.2. Effect of phosphorus on yield attributes

The effect of different rates of phosphorus application on garlic yield is reported by many researchers. For instance, Sims *et al*. (2003) stated that application of P from 29 to 48 kg ha^{-1} is adequate for better garlic production while in the desert areas rates of up to 96 P kg ha^{-1} might be needed. Phosphorus fertilization at the rate of 50 kg ha^{-1} in irrigated shallot and 25 kg P ha^{-1} in rain fed with supplemental irrigation of shallot showed increased bulb yield and mean bulb weight (Woldetsadik, 2003). In contrast, Kilgori *et al*. (2007) reported that increase in P levels from 0 to 44 kg P ha^{-1} had no significant effect on yield of garlic.

Degwale (2014) indicated that the maximum clove numbers, fresh biomass yield and total bulb yield of garlic were recorded at the combined application of N and Phosphorus at the rates of 23 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} respectively. They further explained that the application of 46 kg and 92 kg P_2O_5 ha^{-1} significantly increased mean clove weight by 20.49% and 20.7% over the control, respectively. The highest dried bulb yield was recorded from 69 kg P_2O_5 ha^{-1} according to Tibebu *et al*. (2014) and from 122.6 kg ha^{-1} P_2O_5 according to Yayeh (2015) while, lower was from 0 kg P_2O_5 ha^{-1}. The study by Geleta (2014) showed that phosphorus application on both Andosols and Vertisols at the rate of 40 kg P ha^{-1} led to the production of heavier cloves, highest bulb diameter, highest bulb weight and highest bulb yield.

In general, none of above mentioned researches and others done formerly were done using different varieties and rates of blended fertilizer on yield attribute’s and yield response, despite the fact that varieties differ in their response to levels of fertilizer and nutrients. They used single variety in their study. In addition, except few studies, the nutrient used was only phosphorus as a source of nutrient for the crop in spite of the fact that, “balanced application of nutrients can improve soil fertility and eliminate the effect of nutrient deficiencies beyond improving of garlic productivity and quality”. Thus phosphorus by its lone cannot meet the nutrient demand of the crop for optimum yield. Furthermore, fertilizer response varies with locations, which opens a door to look for location specific recommendation. Therefore, to fill these methodologic gabs, the current study was done using different varieties and blended fertilizer rate.

2.6. Effect of Sulphur on Growth, Yield and Yield Aspects of Garlic

2.6.1. Effect of sulphur on growth attributes

Being sulphur loving crop, sulphur response in garlic is natural and expected. Consequently, significantly increased garlic growth, bulb and foliage yields and other yield and quality attributes of the plant following sulphur application within the range of 20 to 60 kg ha^{-1} was reported (Losak and Wisniowska-kielian, 2006). Plant height, number of leaves, leaf length, fresh weight of leaf and leaf width significantly increased by application sulphur at the range of 30 to 40 kg S ha^{-1} in onion (Hariyappa, 2003; Nasreen, 2007; Tripathy *et al.*, 2013; Geleta, 2014). Jaggi (2005) recorded maximum plant height (44.6 and 35.3 cm) and leaves per plant (6.9 and 6.7) with application of sulphur at 80 kg ha^{-1} in onion. Farooqui *et al.* (2009) recorded highest plant height, number of leaves per plant and fresh weight of leaves at treatment combination of 200 kg N ha^{-1} + 60 kg S ha^{-1}. Hore *et al.* (2014) found maximum plant height (76.16 cm) and number of leaves (11.96) with treatment combination S at 60 kg ha^{-1} and N at 50 kg ha^{-1}.

All most all of the above experiments were done using single variety and only sulphur as a source of nutrient for the crop in spite of the fact that, “balanced application of nutrients can improve soil fertility and eliminate the effect of nutrient deficiencies beyond improving of garlic productivity and quality”. Thus sulphur by its lone cannot meet the nutrient demand of the crop for optimum growth performance. In addition, fertilizer response varies with locations, thus researching for location specific recommendation is paramount important. Therefore, the current study was done using different varieties and blended fertilizer rate to fill these information gabs.

2.6.2. Effect of sulphur on yield attributes

Many research results done so far indicated that the yield and yield components in bulb crops including garlic increased by the application of sulphur. For instance, Sharma *et al.* (2000), Lancaster *et al.* (2001) and Hariyappa (2003) reported a significant increase in onion and Jaggi (2005), Jaggi and Raina (2008) and Geleta (2014) in garlic bulb yield and yield attributes following sulphur application at 30 kg ha^{-1}.

Srinidhi (2000) and Harendra *et al*. (2005) noticed maximum dry matter production of leaves and bulb and bulb yield (33.78 t ha^{-1}) at 40 kg S ha^{-1}. They also concluded that garlic produced maximum dry matter of leaves and bulb and bulb yield (5.75 t ha^{-1}) garlic at 60 kg S ha^{-1}. Farooqui *et al*. (2009), Jilani *et al*. (2009) and Hore *et al*. (2014) have also reported increased bulb and foliage yields and other yield attributes (number of cloves/bulb, yield $plant^{-1}$ and percent dry weight of bulb) in garlic from application of sulphur ranging from 20 to 60 kg ha^{-1} over no sulphur.

Verma *et al*. (2012) reported that application of 90 kg ha^{-1} S produced neck thickness, number of cloves per bulb, weight of bulb, bulb diameter and bulb yield, whereas the combined application of 5.0 t ha^{-1} vermi compost along with 60 kg ha^{-1} S was found to be significantly superior with respect to bulb weight (34.55 g), bulb yield (19.9.2 t ha^{-1}) and net returns of garlic. A study done in central Ethiopia by Geleta (2014) displayed that significantly higher garlic bulb weights and highest bulb yield were obtained from both Andosols and Vertisols in response to the application of 60 kg S ha^{-1} and 30 kg S ha^{-1}, respectively. Additionally, they indicated that the highest bulb diameter was obtained from 30 kg S ha^{-1} on Andosols, and 60 kg S ha^{-1} on Vertisols.

In general, none of above mentioned and others formerly done researches were done using different varieties and rates of blended fertilizer on yield attribute's and yield response of the crop, despite the fact that varieties differ in their response to levels of fertilizer and nutrients. They used single variety in their study. In addition, except few studies, the nutrient used was only sulphur as a source of nutrient for the crop in spite of the fact that, "balanced application of nutrients can improve soil fertility and eliminate the effect of nutrient deficiencies beyond improving of garlic productivity and quality". Unless combined with other essential nutrients, sulphur by its lone cannot meet the nutrient demand of the crop for optimum yield. Furthermore, fertilizer response varies with locations, which opens a door to look for location specific recommendation. Therefore, to fill these methodologic gabs, the current study was done using different varieties and blended fertilizer rate.

2.7. Effect of NPS Blended Fertilizer on Growth, Yield and Yield Component of Garlic

2.7.1. Effect of NPS blended fertilizer on growth attributes

Application of different rates of NPS blended fertilizer directly or indirectly affects the growth performances of garlic. Geleta (2014) reported that morphological characters like plant height, neck diameter and leaf area index and the concentrations of N, P, K and S nutrients, and their uptake by garlic plant were significantly influenced by the applications of different compound fertilizers, season and soil types at different growth stages.

Research done by Nigatu *et al*. (2018) on onion indicated that the longest onion plants (60.07 cm) were observed from the application of NPS fertilizer at the rate of 73.5:92:16.95 kg ha^{-1} N: P_2O_5: S, while shortest from nil application. On the other hand, they confirmed that the longest (51.07 cm) and the widest (1.44 cm) onion leaves were observed from onion plants fertilized with 136.5:119.6:22 kg ha^{-1}, while the shortest (44.33 cm) and narrowest (1.33 cm) leaves were observed from onion planted on the control plot. Yayeh (2015) obtained the highest mean plant height of garlic (69.2 cm) by the application of 105:122.6: 22.6 kg ha^{-1} N: P_2O_5: S fertilizer. They also identified that the highest number of garlic leaves (12.1) and longest leaf (48.6 cm) was observed at 140:122.6: 22.6 kg ha^{-1} rate of N: P_2O_5: S). Plants that didn't receive N: P_2O_5: S fertilizer had the lowest leaf number as well as the shortest leaves.

The above experiments and others were done using single variety, despite the fact that varieties vary in their fertilizer requirements. Currently, in Ethiopia only urea and Diammonium Phosphate (DAP) fertilizers is being used for garlic production in spite of the fact that, "balanced application of nutrients can improve soil fertility and eliminate the effect of nutrient deficiencies beyond improving of garlic productivity and quality". But, even if there is recent introduction of some new blended fertilizer, no research result was reported on optimum level of these fertilizers. In addition, fertilizer response varies with locations, thus researching for location specific recommendation is paramount important. Therefore, the current study was done using different varieties and blended fertilizer rate to fill these information gabs.

2.7.2. Effect of NPS blended fertilizer on yield and yield attributes

Yayeh (2015) observed highest fresh (25.33 g) and dry (5.05 g) above ground biomass per plant at the rate of 105:122.6:22.6 N: P_2O_5: S while the lowest values were observed at nil application. They indicated that plants supplied with the highest NPS fertilizer rate of 140:122.6:22.60 N: P_2O_5: S kg ha^{-1} produced the longest mean bulb length (3.75 cm), the biggest bulb diameter (4.27 cm), the highest marketable yield (17.42 t ha^{-1}) and the highest total bulb yield of garlic (17.80 t ha^{-1}).

Research done by Nigatu *et al*. (2018) indicated that the highest fresh (51.83 g) and dry (5.20 g) weights of the aboveground biomass of onion plants were recorded from treatment combination of 136.5:64.4:11.86 kg ha^{-1} N: P_2O_5: S fertilizer. They additionally noticed that maximum bulb weight (198.83 g), highest marketable bulb yield (20.9 t ha^{-1}) and higher total bulb yields (21.4 t ha^{-1}) was obtained from onion plants supplied with 105:119.6:22 kg ha^{-1} N: P_2O_5: S fertilizer rate. Ababulgu (2018) reported that the highest total tuber yield (40.23 t ha^{-1}) and highest marketable tuber yield (39.79 t ha^{-1}) was obtained with combined application of 150 kg NPS blended fertilizer ha^{-1} + 30 t Cattle Manure ha^{-1}, while lowest was from nil treatment.

Generally, none of above mentioned researches and others done so far concentrated on varietal response to blended fertilizer rates on yield attribute's and yield response, despite the fact that varieties differ in their response to levels of fertilizer and nutrients. They used single variety in their study despite the fact that varieties vary in their fertilizer requirements. Regarding the current situation in Ethiopia, only urea and Diammonium Phosphate (DAP) fertilizers is being used for garlic production in spite of the fact that, "balanced application of nutrients can improve soil fertility and eliminate the effect of nutrient deficiencies beyond improving of garlic productivity and quality". But, even if there is recent introduction of some new blended fertilizer, no research result was reported on optimum level of these fertilizers on yield and yield components. Furthermore, fertilizer response varies with locations, which opens a door to look for location specific recommendation for attainment of optimum yield. Therefore, to fill these methodologic gabs, the current study was done using different varieties and blended fertilizer rate.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted at Mettu, Ilubabor zone penitentiary farm specifically at Horticulture site in 2019 main cropping season under rain-fed condition. The site is located in Ilubabor Zone and located 600 km in the south- west of Addis Ababa, the capital of Ethiopia. It is located at longitude of 35^{o}35'E and latitude of 8^{o}8'N (Philips and Carillet, 2006; Ilubabor Zone Agriculture Office 2019, unpublished data) (Figure 1). The area has an average annual rainfall of 1829 mm during the main growing season and average minimum and maximum temperatures of 12.7^{0}C and 28.9^{0}C, respectively. It is also situated at an altitude of 1870 m.a.s.l. The soil type of the site is Nitosol with a pH of 5.5-6 (Ilubabor Zone Agriculture Office, 2019, unpublished data).

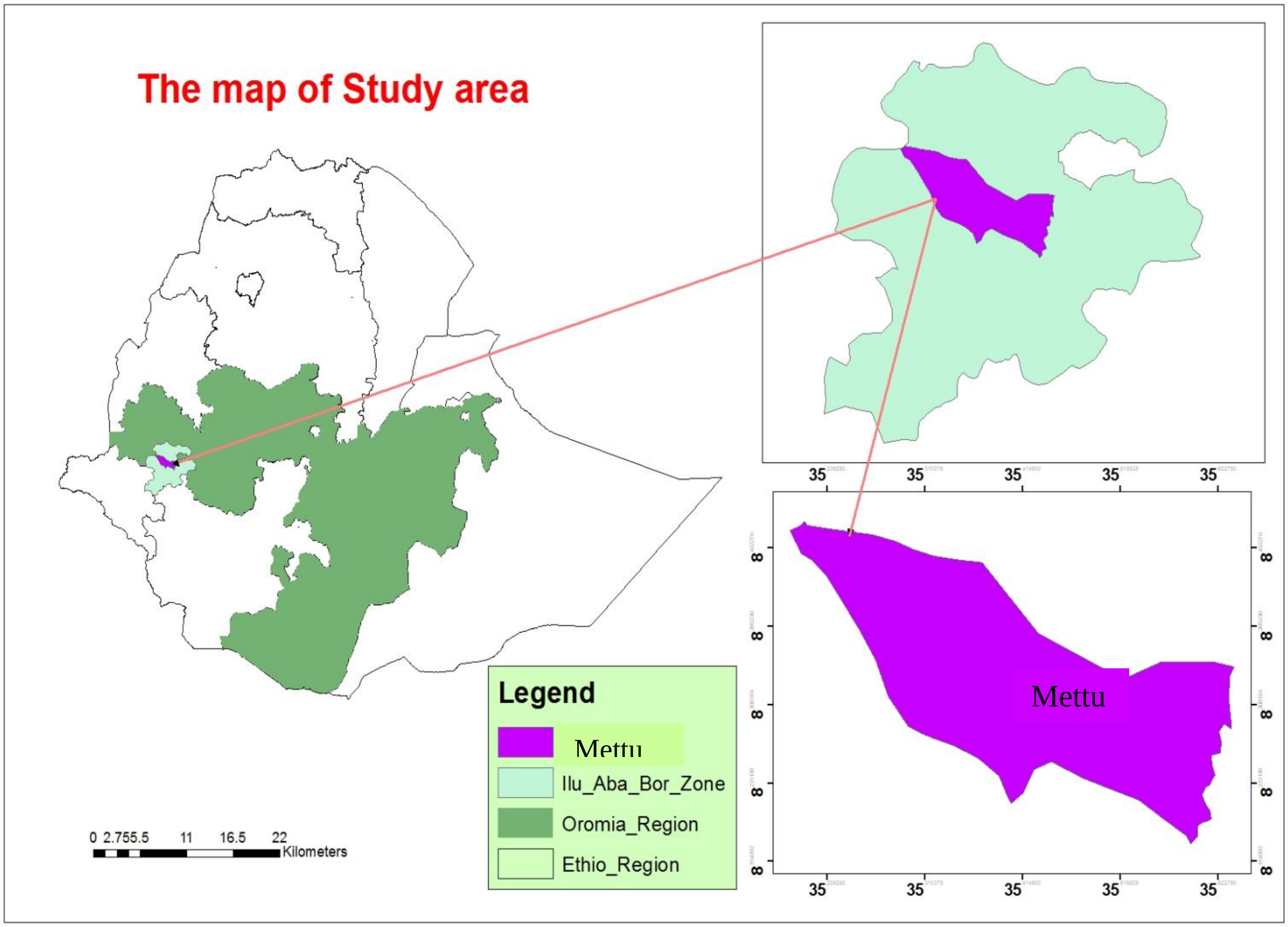

Figure 1: Map of the study area

3.2. Experimental Materials

Five garlic varieties, 4 improved (Tseday, Kuriftu, Chefe, Holeta) and one local, were used for this experiment. The planting material or cloves of the 4 improved varieties was collected from Debrezeit Agricultural Research Center (DzARC) and local cultivar was bought from local market. Cloves of medium size (2 - 2.5 g) were used as a planting material. The description of the planting materials is presented in Table 1.

Table 1: Description of the varieties used

S. No-	Varieties	Year of release	Maturity	Breeder/Maintainer
1	Tseday	1990	133	DzARC/EIAR
2	Kuriftu	2010	128	DzARC/EIAR
3	Chefe	2015	119	DzARC/EIAR
4	Holeta	2015	126	DzARC/EIAR
5	Local	-	130	Farmers around Mettu

Source: MoANR (2016)

3.3. Treatments and Experimental Design

The experiment consisted of four rates of NPS blended fertilizer (0, 181.5, 242 and 305.5 kg ha^{-1}), and five garlic varieties (Tseday, Kuriftu, Chefe, Holeta and one local) that are factorially combined and formed a total of 20 treatment combination. The rates of NPS blended fertilizer was derived on bases of national blanket recommendation of DAP (200 kg ha^{-1}) (Tewodros *et al*., 2014; Zeleke and Derso, 2015). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

The gross plot size was 2.0 x 1.5 m (3.0 m^2). The spacing between blocks and plots was 0.75 and 0.5 m, respectively. In each plot, there were 5 rows with 20 plants per row which comprised a total of 100 plants per plot; the clove was planted at a space of 30 cm x 10 cm between rows and plants, respectively. The spacing between rows and plants which was used in this experiment was adopted from the previous national recommendation. Thus, total gross area of the experiment field was 6 m x 49.5 m = 297 m^2. The outer most one row on each side of a plot and 20 cm at both ends of each row were considered as border. Thus, the net plot size was 0.9 x 1.8 m = 1.62 m2.

3.4. Experimental Procedure

The experimental field was plough with oxen. Large clods were broken down in order to make the land fine tilth and then the required plots were measured and laid out. The plots were leveled very well and ridges of about 20 cm high were prepared.

Each NPS fertilizer rate used in this study was calculated from the national blanket recommendation of 200 kg DAP ha^{-1} (Zeleke and Derso, 2015). First the amount of P_2O_5 in the recommended rate (200kg ha^{-1}DAP) was calculated. Then the calculated amount (92 kg ha^{-1}) was converted to NPS blended fertilizer equivalence and that calculated amount (242 kg ha^{-1}) was used as baseline. Finally, about 25% of NPS equivalence (242 kg ha^{-1}) up and down used to form the treatment rates (0,181.5, 242 and 305.5 kg ha^{-1}).

At planting time, cloves were separated from the bulb and sorted (i.e. diseased, damaged and very small size clove were separated). The planting materials (cloves) were planted with the tip in upright position and the basal part of the clove down. The full dose of NPS fertilizer was applied at sowing time as per the specified or selected levels. The fertilizer was applied 5 cm to the side of a clove. All other non-experimental agronomic practices were applied uniformly to the entire plots throughout the experiment time (Tabor & Zeleke, 2000).

Harvesting was done when 70% of the leaves felled over by digging up or pulling the individual plants by hand and sun dried for ten days.

3.5. Data collected

3.5. 1. Soil Sampling and Analysis

Soil sampling was done before the commencement of the experiments to determine initial fertility status of the soils (before treatment application) and at the end of the experiment to check the improvement made to the soil. The soil samples were taken from 0-30 cm depth (Geleta, 2014). It was taken randomly using an auger in a zigzag pattern from the entire experimental field. Before the experiment, about 30 soil samples were taken and composited in a bucket to represent the site. After the experiment (after harvest) soil samples were taken from each replication and composited as per treatments. The soil samples were broken into small crumbs and then thoroughly mixed. From this mixture, a composite sample weighing 1 kg was filled into a plastic bag. The sample was duplicated and prepared for determining the physico-chemical properties. The soil was air-dried and sieved through a 2 mm sieve.

The soil samples were analyzed for pH, textural class, total nitrogen, available phosphorus, electrical conductivity (EC), cation exchange capacity (CEC), organic matter and organic carbon.

The pH of the soils was measured potentiometrically by means of pH-meter using combined glass-calomel combination electrode in the supernatant suspension of 1:2.5 soil to water ration (Jackson, 1967; Van Reeuwijk, 1992). Ten (10) g of air-dried soil which is < 2mm was used for pH test. The liquid used was water. Texture of the soil was determined by hydrometer method (Standard Bouyoucos hydrometer, ASTM No. 152H graduated in $gliter^{-1}$ or percent) (Hazelton and Murphy, 2007). The reagent used was Amyl alcohol and 50 g of soil with < 2 mm size was used for textural class identification. After analysis, results were corrected to a temperature of 20^0C before doing computations. For temperature readings above 20^0C correction values were added to the hydrometer reading and for temperature readings below 20^0C correction values are subtracted from the hydrometer reading.

Total nitrogen content was determined using the modified micro Kjeldhal method (Cottenie *et al*., 1982). The Kjeldahl procedure was based on the principle that the organic matter is oxidized by treating soil with concentrated sulfuric acid, nitrogen in the organic nitrogenous compounds being converted into ammonium sulfate during the oxidation. Potassium sulfate was added to raise the boiling point of the mixture during digestion and copper sulfate and selenium powder mixture was added as a catalyst. 1 g of soil sample (< 0.5 mm sieve) was used for identification of total nitrogen. Concentrated sulfuric acid Sp. gr. 1.84 (96%) was used as reagent. Available phosphorus was analyzed by using Bray method as described by Bray and Kurz (1945). Ammonium fluoride (1 M) was used as reagent. 2 g of air-dry soil (< 2 mm) was used. The electrical conductivity (EC) of soils was measured from a soil water ratio of 1:2.5 socked for one hour by electrical conductivity method as described by Sahlemedhin and Taye (2000).

The soil organic carbon was measured under standard conditions with potassium dichromate in sulfuric acid solution. As a reagent, $K_2Cr_2O_7$ (Potassium dichromate solution) was used in excess of that needed to destroy the organic matter and the excess was determined by titration with ferrous sulfate solution, using diphenylamine indicator to detect the first appearance of un-oxidized ferrous iron (Walkley and Black, 1934). 2 g of air-dry soil was used. Soil organic matter contains 58% C. Conversion of % carbon to % organic matter was, therefore, done with the empirical factor of 1.724, which was obtained by dividing 100 by 58 (100/58).

% Organic matter = 1.724 x % carbon

In order to determine CEC, the ammonium acetate method was applied. First the soil sample was leached with neutral 1M ammonium acetate at pH 7 washed with ethanol and then, the adsorbed ammonium was replaced by sodium (Na). Thus, the CEC was determined titrimetrically by distillation of ammonia that may be displaced by Na (Sahlemedhin and Taye, 2000). 5 g of soil was used for measurement of CEC.

3.5.2. Agronomic data

3.5. 2. 1. Crop phenology

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

Days to harvest maturity: was recorded as the number of days from date of planting to the time when 70% of plants' foliage of each plot starts drying up and when plants show neck fall

3.5.2. 2. Growth data

Leaf length: The length of three leaves per plant (from upper, medium and lower plant parts) was measured at physiological maturity by using a ruler and the average leaf length was taken from ten randomly tagged plants at physiological maturity.

Leaf diameter: the average diameter of leaves was recorded from ten randomly taken plants in the three central rows. Three leaves from each stratum of the sample plants (from upper, medium and lower parts of plants) were measured at the widest part of each leaf at the time of physiological maturity.

Leaf number per plant: was determined by counting total number of leaves produced by 10 randomly selected plants per plot at physiological maturity and their averaged number per plot was recorded.

Plant height: was measured from ten randomly sampled plants per plot as the distance from the soil surface to the tip of the longest mature leaf at physiological maturity.

3.5.2.3. Yield and yield related traits data

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

Dry weight of above ground biomass per plant: - Dry weight of ten randomly selected plants from each plot at harvest was measured using sensitive balance after drying in oven for 24 hours at 70^0C and the mean values per plant was computed.

Bulb diameter: was measured from randomly taken bulbs of ten plants at the widest point in the middle portion of the bulb using graduated caliper.

Fresh bulb biomass weight per plant: the average fresh bulb weight per plant was recorded weighing middle bulbs of ten plants at harvesting.

Dry bulb biomass weight per plant: average dry matter weight (g) of bulbs was measured after drying ten randomly sampled bulbs from each replication in an oven with a forced hot air circulation at 70°C until a constant weight is obtained.

Total fresh biomass weight per plant: was the summation of fresh bulb biomass and fresh above ground biomass.

Total dry biomass weight per plant: was the summation of dry bulb biomass and dry above ground biomass.

Average bulb weight per plant: the average dry bulb weight per plant was recorded weighting middle bulbs ten plants of each replication after curing randomly.

Number of cloves per bulb: The number of cloves was counted from 10 bulbs and their mean was taken as clove number per bulb.

Average clove weight: This was recorded as average of the weight of ten randomly taken cloves after curing.

Clove diameter: was measured at the widest point in the middle portion of ten randomly selected cloves using graduated caliper in cm.

Total bulb yield per ha: was recorded by weighing the total yield of the net area after curing for 10 days in sunlight and the yield was converted to t ha^{-1}.

Bulb dry matter content: average dry matter weight of bulbs after curing was measured by drying 10 randomly sampled bulbs of each plot in an oven with a forced hot air circulation at 70°C until a constant weight was obtained. The percent of bulb dry matter was calculated by taking the ratio of the dry weight to the fresh weight of the sampled bulbs and multiplying it by 100.

$$BDMC (\%) = \frac{\text{Weight of bulb dry matter}}{\text{Bulb fresh weight}} \times 100$$ where, BDMC-Bulb dry matter content

Marketable bulb yield per ha: marketable bulbs was determined by size end healthiness. Then, the sorted bulbs were weighed and converted to tons per hectare as marketable yield.

Unmarketable yield: the amount of unhealthy bulbs (defected, diseased, immature, badly stained skins, damaged) and under sized that may not acceptable by the market was weighted and converted to tons per hectare as unmarketable bulbs. Under sized bulb was categorized using the standard, marketable clove if >2.0g, acceptable marketable clove if 1.5-1.99g, scarcely marketable clove if 1.0-1.49g and unmarketable clove if <1.0g (Gedamu, 2005).

Harvest index: was determined as the ratio of the dry matter yield of total bulb per ha and dry matter yield of total biomass per ha and multiplied by100.

$$HI (\%) = \frac{\text{Total dry matter yield of bulb}}{\text{Total dry matter yield of biomass}} \times 100$$ Where, HI-Harvest Index

3.5. Data Analysis

The collected data was subjected to analysis of variance (ANOVA) using the general linear model of SAS, version 9.3. All significant pairs of treatment means were compared using the Least Significant Difference (LSD) test at 5% level of probability. Simple linear correlation was employed for determination of associations between yield and yield related traits. In addition, normality test was done for all the studied characters.

3.6. Partial budget Analysis

To estimate the total costs, the current prices of NPS blended fertilizer (16 Birr $kg^{-1)}$ was collected at the time of planting and market price of garlic bulbs (120 Birr kg^{-1}) was taken at harvest. The economic analysis was based on the formula developed by (CIMMYT, 1988) as follows:

Gross/unadjusted average bulb yield (AvY): was an average yield of each treatment. **Adjusted bulb yield (AGY):** was the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers

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 = AGY*field/farm gate price

Total/variable cost: was the cost of NPS and its application. The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, crop protection and harvesting was assumed to remain the same or was 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 will be the measure of increasing in return by increasing input.

4. RESULTS AND DISCUSSION

4. 1. Soil Physico-Chemical Properties of the Experimental Site

The soil texture of the experimental site before experiment was 16% sand, 28% silt and 56 % clay (Table 2). It has been unchanged by application of the fertilizer. The texture of the soil of the experimental site before and after experiment was clay based on the soil textural triangle of the International Society of Soil Science System (Rowell, 1994); even if there were numerical improvement in the textural classes. The clay texture indicates the high degree of weathering that took place in geological times and the high nutrient and water holding capacity of the soil.

The pH of the soil after harvest was ranged from 5.2 to 6.3, which, had no much difference with the pH of the soil before planting (5.7) (Table 2) which was moderately acidic (EthioSIS, 2013). The reason behind the acidity nature of the Mettu soil is due to high rainfall coverage. Even if it was not in a continuous trend, there was a reduction in pH as level of the fertilizer increased. According to Landon (1991) soils having pH value in the range 5.5 to 7.5 are considered suitable for most agricultural crops. Besides, Bachmann (2001) indicated that pH in the range of 5 to 7.5 is favorable for garlic production. Thus, the pH of the experimental soil before and after the experiment was within the range optimum for productive soil.

Soil organic carbon content of before planting was 1.46 % (Table 2), which is medium according to EthioSIS (2013). After the experiment, organic carbon varied from 3.15 to 3.61% (very high) were obtained from all the varieties fertilized with 305.5kg ha^{-1} NPS blended fertilizer while the entire control plot gave very low value of organic carbon according to EthioSIS (2013) classification (Table 2). A similar trend was seen on organic matter content (Table 2). There was a much improvement of both parameters due to applied fertilizer when compared with pre-planting results and this shows that the soil was responded to the applied NPS blended fertilizer.

Table 2: Selected physico-chemical properties of the soil of the experimental site before planting and after harvest

		pH	Rating	% OC	Rating	AV.P	Rating	% OM	Rating	CEC	Rating	%TN	Rating	% Sand	% clay	% silt	T/class
Before planting		5.7	Moderately acidic	1.46	Medium	36.54	Medium	2.52	Low	34.21	High	0. 148	Low	16	56	28	Clay
After harvest																	
Varieties	NPS(kgha-1)																
Chefe	0	5.62	Moderately acid	0.46	very low	18	Low	0.8	v.low	34.21	High	0.13	Low	16	56	28	Clay
Chefe	181.5	5.78	Moderately acid	2.52	High	43.68	High	4.34	Medium	33.19	High	0.22	Medium	22	48	30	Clay
Chefe	242	5.24	Highly acidic	2.73	High	50.83	High	4.7	Medium	35.31	High	0.24	Medium	23	49	26	Clay
Chefe	305.5	5.42	Highly acidic	3.15	V. high	53.2	High	5.41	High	37.42	High	0.27	High	24	50	26	Clay
Holeta	0	5.74	Moderately acid	0.42	very low	16	Low	0.72	v. low	34.21	High	0.12	Low	16	56	28	Clay
Holeta	181.5	6.26	Moderately acid	2.55	High	45.11	High	4.39	Medium	31.4	High	0.22	Medium	28	44	28	Clay
Holeta	242	5.24	Highly acidic	2.84	High	51.54	High	4.88	Medium	37.24	High	0.24	Medium	19	53	28	Clay
Holeta	305.5	6.06	Moderately acid	3.35	V. high	53.45	High	5.77	High	43.07	High	0.29	High	10	62	28	Clay
Kuriftu	0	5.74	Moderately acid	0.29	very low	16	Low	0.5	v.low	34.21	High	0.08	Low	16	56	28	Clay
Kuriftu	181.5	5.61	Moderately acid	2.58	High	47.73	High	4.43	Medium	38.68	High	0.22	Medium	12	60	28	Clay
Kuriftu	242	5.24	Highly acidic	3.01	V. high	51.78	High	5.18	High	38.27	High	0.26	High	15	59	26	Clay
Kuriftu	305.5	5.32	Highly acidic	3.45	V. high	56.06	High	5.94	High	37.86	High	0.3	High	18	58	24	Clay
Local	0	6.00	Moderately acid	0.27	very low	13	Low	0.47	v.low	34.21	High	0.07	Low	16	56	28	Clay
Local	181.5	5.52	Highly acidic	2.67	High	48.9	High	4.6	Medium	32.72	High	0.23	Medium	28	46	26	Clay
Local	242	5.24	Highly acidic	3.12	V. high	52.49	High	5.37	High	33.3	High	0.27	High	27	45	28	Clay
Local	305.5	5.57	Highly acidic	3.51	V. high	57.49	High	6.04	High	33.88	High	0.3	High	26	44	30	Clay
Tseday	0	6.30	Moderately acid	0.25	very low	12	Low	0.43	v.low	34.21	High	0.07	Low	16	56	28	Clay
Tseday	181.5	5.55	Highly acidic	2.67	High	50.35	High	4.6	Medium	34.54	High	0.23	Medium	27	47	26	Clay
Tseday	242	5.24	Highly acidic	3.14	V. high	53.2	High	5.41	High	36.37	High	0.27	High	23	52	24	Clay
Tseday	305.5	5.87	Moderately acid	3.61	V. high	59.4	V. high	6.21	High	38.2	High	0.31	High	20	58	22	Clay
Reference		EthioSIS, (2013)		EthioSIS, (2013)		Bray and Kurz, (1945)		Olsen *et al*., (1954)		Hazeton and Murphy, (2007)		Hazeton and Murphy, (2007)					

Where: pH= power of hydrogen, %OC = organic carbon (%), %OM = Organic matter (%), %TN= total Nitrogen (%), AV. P (ppm) = available phosphorous (ppm), CEC (meq/100g) = Cation exarches capacity (meq/100g), T/class= Textural class, v.low= very low, v.high=very high

Total nitrogen of the experimental soil before experiment was 0.148 (%) (Table 2). According to EthioSIS (2013) this value is low. After harvest, highest total nitrogen (ranged from 0.27% - 0.31% among varieties) which is high according to rating of Hazeton and Murphy (2007) was observed from experimental plot that received 305.5 kg ha^{-1} NPS blended fertilizer. The lowest values, which ranged from 0.07% to 0.13% among varieties were observed for control treatments (Table 2). The soil analysis result of before experiment indicated that the need to apply N for garlic crop to get optimum yield and quality and was confirmed by the final soil result because the crop responded to the applied fertilizer due to increased soil fertility with application of the NPS blended fertilizers.

The cation exchange capacity (CEC) of the soil before planting and after harvest was ranged from 31.4 to 43.07 meq/100g, respectively (Table 2). It is almost similar and both of it is high according to rating of Hazelton and Murphy (2007). Cation exchange capacity indicates that the soil has the capacity to hold nutrient cations and supply to the crop. Soils high in CEC contents are considered as agriculturally fertile.

The soil analysis result of before experiment revealed that the available P of the soil was 36.54 ppm (Table 2). This is medium according to Bray and Kurz (1945) and is unsatisfactory for optimum garlic growth and yield. After harvest highest amount of available phosphorus content (59.4 ppm) which is very high according to Bray and Kurz (1945) classification was obtained from 305.5kg ha^{-1} NPS blended fertilizers application on Tseday variety (Table 2). Likewise, all the rest of the applied fertilizer level gave high available phosphorus. But, control plots of all the varieties gave low available phosphorus according to Bray and Kurz (1945) rating. There was a much improvement in available P due to applied NPS blended fertilizer when compared with pre-planting results and this shows that the soil responded well to the applied NPS blended fertilizer.

4.2. Crop Phenological data

4.2.1. Days to 50 % emergence

Both main and interaction effect of variety and NPS blended fertilizer did not show significant effect on days to 50 % emergency (Appendix Table 1). The non-significance difference among different varieties of garlic at different rates of NPS fertilizer may be due to very low nutrient uptake capacity of the crop at the initial stage because of small growth of roots. It may also be due to the fact that the movement of P in soil is very low and its uptake generally depends on the concentration gradient and diffusion in the soil near roots.

4.2.2. Days to harvest maturity

The analysis of variance revealed that, days to maturity was significantly influenced by both main ($P = 0.0001$) and interaction effect ($P = 0.0005$) of variety and NPS blended fertilizer (Appendix Table 1). Accordingly, the earliest (101.67) days to maturity was recorded by Chefe variety at zero NPS fertilizer application (Table 3). The delayed days to maturity (136.67) was recorded by Tseday variety at higher application rate of NPS (305.5 kg ha^{-1}) and is different from all the treatment combinations except the same variety at 242 kg ha^{-1} NPS application rate (Table 3). Across all the varieties as the amount of the fertilizer increased, the maturity date also increased except the highest rate (305.5 kg ha^{-1}) which is non-significant from near lower rate (242 kg ha^{-1}). This means plants that were supplied with the fertilizers matured far latter than those in the control treatments.

Prolonged maturity in response to increasing rate of NPS blended fertilizer may be attributed to the availability of optimum nutrients contained in NPS blended fertilizer that may have led to prolonged maturity through enhanced leaf growth and photosynthetic activities thereby increasing partition of assimilate to the storage organ. The application of nitrogen fertilizer enhances vegetative growth and delays flowering and fruit set. But, there is a report indicating that application of phosphorus (Brady and Weil, 2002) and sulfur (Naeem and MacRitchie, 2003) fertilizer enhances early growth and hastens maturity. Therefore, delayed maturity date due to increasing rates of NPS blended fertilizer might be due to the effect of the nitrogen that offset the effect of the two (phosphorus and sulfur fertilizers) on crop maturity. Genetic makeup of the varieties also played a role, because the varieties were varied in the days to maturity.

The earliest day of maturity at the control treatment may be due to the insufficient supply of nutrients that enhance the vegetative growth of the crop. When plants are N-deficit they mature quickly, which is one of the escape mechanism of plants from non-conducive or stress condition for normal growth (Jasso *et al*., 2005). The result is in harmony with the findings of Abadi

(2015) who identified significant influence of interaction effects of cultivars and nitrogen rates on the plant maturity. Islam *et al*. (2004) and Getaneh (2011) also observed that plants grown with the highest level of nitrogen took the longest period to complete the vegetative growth.

Table 3: Interaction effect of variety and NPS blended fertilizer rate on days to maturity of garlic at Mettu in 2019

Variety	NPS	Days to maturity
Chefe	0.00	101.67^{j}
	181.50	112.00^{h}
	242.00	119.00^{def}
	305.50	119.67^{cdef}
Holeta	0.00	106.30^{i}
	181.50	115.67^{fgh}
	242.00	121.67^{cde}
	305.50	122.67^{cd}
Kuriftu	0.00	112.00^{h}
	181.50	116.33^{fg}
	242.00	123.33^{c}
	305.50	122.33^{cd}
Local	0.00	113.33^{gh}
	181.50	118.00^{ef}
	242.00	130.00^{b}
	305.50	129.67^{b}
Tseday	0.00	113^{gh}
	181.50	118.67^{def}
	242.00	136.33^{a}
	305.50	136.67^{a}
LSD (0.05)		4.08
CV (%)		2.07

Means followed by the same letter within a column are not significantly different at 5% level of significance; CV =Coefficient of Variation; LSD =Least Significant Difference

4.3. Growth Parameters

4.3. 1. Leaf diameter

As observed from analysis of variance, the main effect of variety and NPS blended fertilizers showed significant ($P<0.01$) effect on leaf diameter as well their interaction showed significant ($P<0.05$) effect on leaf diameter (Appendix Table 1).

The widest leaf (1.85 cm) (Table 4) was observed from Tseday variety at NPS blended fertilizer rate of 242 kg ha^{-1} and 305.5 kg ha^{-1}. The narrowest leaf (1.1 cm) was observed in unfertilized Chefe variety (Table 4).

Table 4: Interaction effect of variety and NPS blended fertilizer rate on leaf diameter of garlic at Mettu in 2019

Variety	NPS	Leaf diameter (cm)
Chefe	0.00	1.10^{j}
	181.50	1.24^{h}
	242.00	1.38^{d-g}
	305.50	1.34^{d-h}
Holeta	0.00	1.19^{ij}
	181.50	1.31^{e-i}
	242.00	1.53^{cb}
	305.50	1.37^{d-h}
Kuriftu	0.00	1.27^{f-i}
	181.50	1.42^{b-e}
	242.00	1.53^{cb}
	305.50	1.53^{cb}
Local	0.00	1.31^{e-i}
	181.50	1.41^{c-f}
	242.00	1.50^{cb}
	305.50	1.55^{b}
Tseday	0.00	1.26^{g-i}
	181.50	1.46^{b-d}
	242.00	1.85^{a}
	305.50	1.75^{a}
LSD (0.05)		0.14
CV (%)		6.14

Means followed by the same letter within a column are not significantly different at 5% level of significance; CV =Coefficient of Variation; LSD =Least Significant Difference

This significant difference may be due to the genetic difference of the varieties in their growth performance. Application of NPS blended fertilizer also played an important role in the production of vigorous vegetative growth and optimum leaf expansion of garlic. The nutrients in NPS blended fertilizer especially nitrogen improves the vegetative growth of the garlic which leads to increasing in leaf diameter (Appendix Table 4) through the increased photosynthetic area in response to nitrogen fertilization that enhanced assimilates production and partitioning to the plants.

The current finding is parallel with the study of Abadi (2015) who reported that the interaction effect of varieties and nitrogen rates showed significant differences of leaf width. As a report of Smriti *et al*. (2002), Nasreen (2007) and Geleta (2014) the highest leaf diameter was observed at the higher rates of sulphur. Nigatu *et al*. (2018) also observed the widest onion leaves on onion plants which were fertilized with 136.5 N:119.6 P_2O_5:22 S kg ha^{-1} and narrowest leaves from the control onion plants. On the other hand, the present finding disagrees with report of Teklemariam (2007) who indicated that neither main, nor interaction effects of N and P fertilizers application significantly affected leaf diameter of garlic.

4.3.2. Leaf length

Output from the analysis of variance indicated that the main effect of Variety and NPS blended fertilizer showed significant effect (p = 0.0001) on leaf length but their interaction did not (Appendix Table 1). The longest leaf (39.05 cm) was observed from Tseday variety but, at par with local cultivar (38.8 cm) (Table 5). The shortest leaf (30.09 cm) was observed from plot planted with Chefe variety (Table 5). Regarding the main effect of blended NPS blended fertilizer, the longest (40.51 cm) and the shortest leave (28.95 cm) was recorded for NPS blended fertilizer rate of 242 kg ha^{-1} and control, respectively. The leaf length increased as the NPS rate increased up to 242 kg ha^{-1}, but further increasing up to 305.5 kg ha^{-1} decreased the leaf length to 37.83cm (Table 5). This convince that the elongation of leaf length only continues up to optimum level of the NPS blended fertilizer and further increasing beyond the optimum level may bring about reduction in leaf length.

This significant difference in leaf length of garlic varieties may be due to the difference of the varieties genotypic characteristics. The higher leaf length at the higher NPS blended fertilizer rate may be due to the positive effect of nutrients in NPS blended fertilizer especially N on vegetative growth and leaf expansion as is also suggested by Halvin *et al*. (2003). Similarly, it may be associated with the fact that nutrients in NPS blended fertilizer is important for plant cell division, elongation, synthesis of chlorophyll, enzymes and proteins which are important for plant growth. It might also be attributed to an adequate amount of phosphorus to form good root system and strong stem particularly in crops with restricted root system like garlic, thereby, enhance the ability of the plant to explore nutrients vital for leaf growth.

This result is in agreement with the findings of Danna *et al*. (2000) and Ahmed *et al*. (2007) who reported that availability nutrients that allowed young garlic plants to be more vigorous in their growth and development. There is highly significant difference between garlic germplasm on leaf (Tewodros *et al*., 2014; Getahun, 2016; Yeshiwas *et al*., 2018). The present result is parallel with that of Yayeh (2015) who reported the recording of longest leaf length of garlic at NPS rate of 105:122.6:22.6 kg $ha^{-1}$and shortest at nil application. Nigatu *et al*. (2018) also observed the longest onion leaves from onion plants which were fertilized with 136.5 N: 119.6 P_2O_5:22 S kg ha^{-1}, and shortest leaves from the control onion plants. In contrast to the current finding, Teklemariam (2007) indicated that neither the main, nor the interaction effects of N and P fertilizers application significantly affected leaf length.

4.3.3. Leaf number per plant

Results of analysis of variance of this study indicated that the main effect of Variety and NPS blended fertilizer showed significant difference ($p = 0.0001$) on leaf number $plant^{-1}$ but their interaction was non-significant (Appendix Table 1). The highest leaf number (10.9) was observed on the plot with the variety Tseday and followed by local cultivar (9.85) (Table 5). On the other hand, the lowest leaf number (8.44) was observed in plot planted with the variety Chefe (Table 5). Concerning the main effect of NPS blended fertilizer, the highest leaf number (10.34) which is non-significant from treatment 242 kg ha^{-1} and the lowest leaf number (7.94) was recorded from NPS rate of 305.5 kg ha^{-1} (10.34) and nil application, respectively (Table 5). There was increasing trend of leaf number as the NPS rate increased from 0 up to 242 kg ha^{-1}, but further increasing up to 305.5 kg ha^{-1} decreased the leaf number.

This significant difference between varieties may be due to the genetic difference of the varieties in their growth performance. Kamenetsky *et al*. (2005) and Tsega (2006) reported that garlic cloves vary in most vegetative characteristics like leaf number, bulb size and structure. The positive effect of NPS blended fertilizer on leaf number per plant of garlic could be attributed to the enhancing effect of P on root development, which might have led to effective nutrient uptake and water. Phosphorus is the second major nutrient being essential constituent of cellular protein and nucleic acid that might have encouraged meristematic activity of plants resulting in increased plant height, number of leaves per plant and leaf area. It might also be attribute to the role of N on plant growth and development and that of S on enhancing availability of nutrients.

The present experimental result is in line with that of Yayeh (2015) who recorded higher leaf number at 105:122.6: 22.6 kg ha^{-1} N: P_2O_5: S fertilizer. Geleta (2014) reported higher leaf number per plant at the rates of 92 kg N, 40 kg P and 30 kg S ha^{-1}. The maximum leaf number of garlic leaves was recorded at the rate of 92 kg P_2O_5 ha^{-1} (Degwale, 2014), at 69 kg P_2O_5 (Tibebu *et al*., 2014). This study result disagrees with that of Nigatu *et al*. (2018) who identified that application of NPS fertilizer didn't significantly influenced the number of onion leaves per plant.

Table 5: The main effects of variety and NPS blended fertilizer rate on plant height (cm), leaf length (cm) and leaf number per plant of garlic at Mettu in 2019

Variety	Plant height (cm)	Leaf number $plant^{-1}$	Leaf length (cm)
Chefe	37.28^{d}	8.44^{d}	30.09^{d}
Holeta	44.79^{c}	9.05^{c}	32.69^{c}
Kuriftu	46.40^{c}	9.05^{c}	35.67^{b}
Local	50.44^{b}	9.85^{b}	38.80^{a}
Tseday	55.84^{a}	10.91^{a}	39.05^{a}
LSD (5%)	1.80	0.44	1.79
NPS			
0.00	37.72^{c}	7.94^{c}	28.95^{d}
181.50	45.20^{b}	9.18^{b}	33.74^{c}
242.00	52.31^{a}	10.34^{a}	40.51^{a}
305.50	52.55^{a}	10.38^{a}	37.83^{b}
LSD (5%)	1.60	0.39	1.60
CV (%)	4.65	5.58	6.14

Means followed by the same letter within a column are not significantly different at 5% level of significance; CV =Coefficient of Variation; LSD =Least Significant Difference

4.3.4. Plant height

Analysis of variance indicated that the main effect of Variety and NPS blended fertilizers showed high significant differences ($p = 0.0001$) on plant height but their interaction was non-significant (Appendix Table 1). The tallest plant height (55.84 cm) was observed from variety Tseday followed by local cultivar (50.44 cm). On the other hand, the shortest plant height (37.28 cm) was observed from the variety Chefe (Table 5). The tallest plant height (52.55 cm and 52.31 cm) was recorded from NPS blended fertilizer rate of 242 kg ha^{-1} and 305.5 kg ha^{-1} while the shortest plant height (37.72 cm) was recorded from zero NPS application (Table 5). There was increasing trend in plant height as the NPS rate increased from 0 up to 242 kg ha^{-1}, but further increasing up to 305.5 kg ha^{-1} decreased the plant height. This assure that the increment of plant height only continues up to optimum level of the NPS blended fertilizer and further increasing beyond the optimum level may bring about reduction in plant height.

The difference in plant height might be due to the genetic differences of the cultivars. The increased plant height at the higher level of blended NPS fertilizer could be attributed to the increasing adequate supply of nitrogen, phosphorus and sulfur nutrients, which helped, in high vegetative growth and development. Sulfur plays an essential role in chlorophyll formation and many reactions of living cells (Tisdale *et al*., 1995). Phosphorus is required in large quantities in shoot and root tips where metabolism is high and cell division is rapid. According to Bungard *et al*., (1999), nitrogen is an important building block of amino acids and a crucial element in the formation of proteins required for growth and development of plants including garlic. This result is in agreement with the findings of Tsega (2006), Panse *et al*. (2013), Mulatu *et al*. (2014) and Getahun (2016), who reported a wide range of variation in plant height and other morphological characters among different garlic varieties. There is also conformity between this result and the work of Adem and Tadesse (2014), Faraooqui *et al*. (2009) and Zaman *et al*. (2011) who recorded higher plant height of garlic at 100 kg N ha^{-1} + 120 kg P_2O_5 ha^{-1}, 200 kg ha^{-1} nitrogen and 60 kg ha^{-1} and 45 kg^{-1} sulfur respectively. In opposite to the current finding Degwale (2014) found significant difference in plant height due to interaction of N and P.

4.4. Yield and Yield Related Parameters

4.4. 1. Fresh and dry above ground biomass weight per plant

The main and interaction effect of variety and NPS blended fertilizer had significant (p=0.0001) and significant (p=0.004) influence respectively on both fresh and dry above ground biomass as observed from analysis of variance (Appendix Table 2). The highest fresh and dry above ground biomass per plant was recorded from variety Tseday at higher NPS blended fertilizer (305.5 and 242 kg ha^{-1}) (Table 6). For dry above ground biomass per plant the local variety at 305.5 kg ha^{-1} NPS application also produced the highest value. However, the lowest fresh and dry above ground biomass per plant was registered from Chefe and Holeta varieties with zero application (Table 6). Across all the varieties the higher rates of NPS (305.5 and 242 kg ha^{-1}) produced the highest fresh and dry above ground biomass per plant.

The increment in the aboveground fresh and dry biomass yield due to added fertilizer might be due to the fact that phosphorus and sulphur is essential in most metabolic processes that happen above the ground. These processes include: energy generation, nucleic acid synthesis, photosynthesis, respiration, glycolysis, membrane synthesis and integrity, enzymatic activation or inactivation, redox reactions, signaling and carbohydrate metabolism leading to the enhancement of dry biomass yield (Tisdale *et al*., 1995). Also it could be attributed to genetic difference of the varieties and increased photosynthetic area in response to NPS blended fertilization that enhanced assimilates production and partitioning to the plants. Moreover, it might be due to improved root growth and increased uptake of nutrients favoring better growth and delayed senescence of leaves of the crop due to synergetic effect of the nutrients (NPS).

This finding is in agreement with the finding of Abadi (2015) who demonstrated significant influence of the interaction of cultivar and nitrogen fertilizer on shoot dry weight due to increased plant height and leave size. It is also similar with the study result of Yayeh (2015) who reported the highest fresh and dry above ground biomass per plant at the rate of 105:122.6:22.6 N: P_2O_5: S kg ha^{-1}. Garlic varieties are different in fresh and dry above ground biomass per plant due to genetic difference (Abou El-Magd *et al*., 2012; Hossein *et al*., 2014). In contrary to the current finding, Nigatu *et al*. (2018) indicated NPS fertilizer shown non-significant effect on fresh and dry weight of the aboveground biomass of onion.

4.4.2. Fresh and dry bulb biomass weight per plant

The main (p=0.0001) and interaction effect of cultivar and NPS blended fertilizer (p=0.004) had significant influence on total fresh and dry biomass per plant as observed from analysis of variance (Appendix Table 2). Even if, it was statistically at par with 242 kg ha^{-1} NPS and local cultivar at 305.5 kg ha^{-1}, the highest fresh bulb biomass weight per plant (93.36 g) was recorded from variety Tseday at 305.5 kg ha^{-1} NPS blended fertilizer application (Table 6). The lowest (13.92 g) was recorded from unfertilized Chefe variety but, statistically similar with all level of the same variety except at 305.5 kg ha^{-1}, Holeta and Kuriftu at control (Table 6). The lowest dry (5.5 g) bulb biomass weight per plant was recorded from unfertilized Chefe variety but, was statistically similar with all NPS level of the same variety and all variety at control except Tseday (Table 6). The highest dry bulb biomass weight per plant of 56.41 g and 55.86 g was obtained from Tseday at 305.5 and 242 kg ha^{-1} NPS, respectively without significant difference between them statistically (Table 5). Across all the varieties the higher rates (305.5 and 242 kgha^{-1}) were statistically similar on fresh and dry bulb biomass weight per plant. However, there is increasing trend of these parameters from control to 242 kg ha^{-1} across all the varieties except Chefe.

The difference on fresh and dry bulb biomass weight per plant could be due the effect of genetically differences of the varieties and the fact that nutrient in NPS blended fertilizer act as an integral component of many essential plant compounds like chlorophyll, proteins and it is a major part of all amino acids. This in turn increases the vegetative growth and promotes carbohydrate synthesis through photosynthesis and ultimately increased fresh and dry bulb biomass weight per plant (Appendix Table 4). Increased bulb dry weight at higher rates of sulphur is probably due to sulphur role in synthesis of sulphur containing amino acids, proteins, energy transformation and activation of enzymes which in turn enhances carbohydrate metabolism and photosynthetic activity of the plants with increased chlorophyll synthesis. Similarly, as the study of Ayalew (2015) significantly highest fresh bulb weight per plant was recorded from the local variety than Kuriftu, Bishoftu Nech, Tseday 92 and MM-98.

4.4.3. Total fresh and dry biomass weight per plant

The main (p=0.0001) and interaction effect of cultivar and NPS blended fertilizer(p=0.004) had significant influence on total fresh and dry biomass per plant as observed from analysis of variance (Appendix Table 2). The highest total fresh biomass weight per plant (142.5 g) was recorded by cultivar Tseday at 305.5 kg ha^{-1} NPS fertilizer (Table 6). The highest total dry biomass weight per plant of 74.66 g, 73.93 g and 63.61 g was obtained from Tseday at 305.5, 242 kg ha^{-1} and local at 305.5 kg ha^{-1} NPS fertilizer, respectively without significant statistical difference between them (Table 6). The lowest total fresh weight (21.25 g) was recorded by unfertilized Chefe variety but it was statistically similar with all level of the same variety except 305.5 kg ha^{-1}, Holeta and Kuriftu at control. Similarly, the lowest total dry (8.26 g) biomass weight per plant which was statistically similar with all level of the same variety except 305.5kg ha^{-1} and all variety at control except Tseday was recorded by unfertilized Chefe variety (Table 6). Across all the varieties the higher rates (305.5 and 242 kg ha^{-1}) were statistically similar on total fresh and dry biomass weight per plant. However, there is increasing trend of these parameters as one moves from the control to 242 kg ha^{-1} across all the varieties except Chefe.

The higher total fresh and dry biomass per plant at higher rates of NPS blended fertilizer might be due to nutrients in NPS such as nitrogen which is an integral component of many essential plant compounds like chlorophyll, proteins and it is a major part of all amino acids (Brady and Weil, 2002) and P which play an important role on photosynthetic productivity and final leaf area. This in turn increases the vegetative growth and produces good quality foliage and that can promote carbohydrate synthesis through photosynthesis and ultimately increases total biomass yield of plants. Proportional vegetative growth especially plant height might also have played a role in increasing of total biomass yields. This is confirmed by the correlation analysis, which indicated that total fresh biomass weight showed strong and positive correlation with plant height (r=0.95), leaf length (r=0.85), leaf diameter (r=0.84) and number of leaf per plant (r=0.85) (Appendix Table 4). Total dry biomass weight also showed strong and positive correlation with plant height (r=0.94), leaf length (r=0.84), leaf diameter (r=0.85) and number of leaf per plant (r=0.85) (Appendix Table 4). Furthermore, it might also due to the genetics difference of the varieties.

There is similarity between this investigation and that of Degwale (2014) who indicated that the application of 46 N kg ha^{-1} increased fresh biomass yield by 14.67% compared to the control treatment. The study is also comparable to the report of Abadi (2015) who indicated that the highest and significant total dry biomass yields per plant were produced from variety Tseday at an application of 123 N kg ha^{-1}. On the other hand, Kilgori *et al*. (2007) reported that application of varying rates of P had no significant impact on fresh biomass yield in opposite to the current.

Table 6: Biomasses and bulb characters as affected by interaction of variety and NPS blended fertilizer rate at Mettu in 2019

Variety	NPS (kgh^{-1})	FABM (gplant^{-1})	DABM (gplant^{-1})	TFBM (gplant^{-1})	TDBM (gplant^{-1})	BL (cm)	BD (cm)	Av.BW (gplant^{-1})	FBBM (gplant^{-1})	DBBM (gplant^{-1})
Chefe	0.00	7.33^{j}	2.74^{i}	21.25^{j}	8.26^{j}	2.27^{l}	2.11^{j}	5.21^{i}	13.92^{j}	5.51^{k}
	181.50	11.70^{h-j}	4.283^{hi}	33.91^{h-j}	13.25^{ij}	2.69^{jkl}	2.50^{hij}	8.13^{hi}	22.22^{hij}	8.96^{jk}
	242.00	14.34^{g-j}	5.32^{g-i}	41.59^{g-j}	17.58^{h-j}	2.90^{i-k}	2.71^{f-i}	10.10^{hgi}	27.25^{g-j}	12.26^{ijk}
	305.50	16.19^{f-h}	5.67^{f-h}	46.97^{f-i}	19.53^{ghi}	3.03^{g-j}	2.82^{fgh}	10.76^{fgh}	30.77^{f-i}	13.86^{h-k}
Holeta	0.00	9.93^{ij}	3.70^{hi}	28.80^{ij}	11.80^{ij}	2.37^{kl}	2.20^{ij}	7.50^{hi}	18.87^{ij}	8.10^{jk}
	181.50	17.38^{f-h}	5.99^{f-h}	50.40^{f-h}	21.29^{ghi}	3.13^{g-j}	2.91^{fgh}	11.38^{fgh}	33.02^{fgh}	15.30^{hij}
	242.00	25.23^{de}	9.15^{de}	73.17^{de}	34.07^{def}	3.72^{ef}	3.47^{cde}	17.39^{de}	47.94^{de}	24.92^{efg}
	305.50	27.42^{cd}	10.18^{cd}	79.52^{cd}	37.33^{cde}	3.87^{de}	3.60^{bcd}	19.34^{cd}	52.10^{cd}	27.15^{def}
Kuriftu	0.00	12.02^{h-j}	4.38^{hi}	34.86^{h-j}	14.24^{hij}	2.75^{i-k}	2.56^{g-j}	8.33^{hi}	22.84^{hij}	9.86^{ijk}
	181.50	20.18^{e-g}	7.31^{e-g}	58.52^{e-g}	25.46^{fgh}	3.27^{f-i}	3.05^{efg}	13.89^{efg}	38.34^{efg}	18.15^{ghi}
	242.00	29.53^{cd}	10.67^{cd}	85.62^{cd}	40.82^{cd}	3.94^{de}	3.67^{bcd}	20.27^{cd}	56.10^{cd}	30.16^{de}
	305.50	28.62^{cd}	10.05^{c-e}	82.99^{cd}	39.21^{cde}	3.88^{de}	3.61^{bcd}	19.08^{cde}	54.37^{cd}	29.17^{edf}
Local	0.00	14.64^{g-i}	5.33^{g-i}	42.44^{g-i}	17.75^{hij}	2.97^{g-j}	2.76^{fgh}	10.13^{ghi}	27.81^{ghi}	12.41^{ijk}
	181.50	22.51^{d-f}	8.07^{d-g}	65.27^{d-f}	29.31^{efg}	3.46^{efg}	3.22^{def}	15.32^{d-g}	42.76^{def}	21.25^{fgh}
	242.00	40.96^{b}	15.10^{b}	118.77^{b}	59.23^{b}	4.73^{bc}	4.08^{b}	28.68^{b}	77.82^{b}	44.14^{c}
	305.50	44.31^{ab}	16.02^{ab}	128.49^{ab}	63.61^{ab}	5.09^{ab}	4.74^{a}	30.44^{ab}	84.19^{ab}	47.59b^{c}
Tseday	0.00	22.44^{d-f}	8.30^{d-f}	65.07^{d-f}	29.61^{d-g}	3.42^{e-h}	3.18^{def}	15.76^{def}	42.63^{def}	21.32^{fgh}
	181.50	33.06^{c}	12.04^{c}	95.89^{c}	46.83^{c}	4.29^{cd}	3.99^{bc}	22.88^{c}	62.83^{c}	34.78^{d}
	242.00	48.89^{a}	18.86^{a}	141.80^{a}	74.66^{a}	5.26^{ab}	4.90^{a}	35.74^{a}	92.90^{a}	55.86^{ab}
	305.50	49.14^{a}	17.52^{ab}	142.50^{a}	73.93^{a}	5.51^{a}	5.13^{a}	33.29^{ab}	93.36^{a}	56.41^{a}
LSD (5%)		7.17	2.79	20.81	11.20	0.55	0.54	5.31	13.60	8.53
CV (%)		17.51	18.7	17.51	20.03	9.13	9.64	18.71	17.51	20.76

Means followed by the same letter within a column are not significantly different at 5% level of significance; CV =coefficient of variation; LSD =least significant difference; FABM (gplt^{-1}) =Fresh Above ground biomass (g); DABM (gplt^{-1}) =Dry weight of above ground biomass (g); BD (cm) = Bulb diameter (cm); FBBM (gplt^{-1})=Fresh bulb biomass (gplt^{-1}); DBBM (gplt^{-1})= Dry bulb biomass (gplt^{-1}); TFBM (gpt^{-1})=Total fresh biomass (gplt^{-1}); TDBM (gpt^{-1})=Total Dry biomass (gplt^{-1}); Av.BW (gplt^{-1})= Average bulb weight (g)

4.4.4. Bulb diameter

The bulb diameter was significantly influenced (p=0.0001) by the main effect of variety and NPS blended fertilizer. Similarly, both factors interacted to significantly (p=0.0410) influence bulb diameter of garlic as analysis of variance indicated (Appendix Table 2). The widest bulb diameter (5.1 cm) was recorded from the variety Tseday at the fertilizer treatment level of 305.5 kg ha^{-1} NPS fertilizer significant difference from 242 kg ha^{-1} NPS and the local cultivar at 305.5 kg ha^{-1} (Table 6). The narrowest bulb diameter (2.11 cm) was recorded from the unfertilized Chefe variety which is statistically similar with Holeta and Kuriftu at control and same variety at 181.5 kg ha^{-1} NPS (Table 6). An increasing trend in the diameter of garlic bulbs was observed with increasing NPS concentrations from the control to 242 kg ha^{-1} across all the varieties except Chefe.

This significant difference on garlic bulb diameter might have ascribed to the synergistic role played by the three nutrients in providing balanced supply of nutrients to the crop. It might also be attributed to high level of phosphorus throughout the growth period of the plant in the root zone which is essential for the cell enlargement, rapid root development and good utilization of water that resulted indirectly in increased bulb diameter. Furthermore, sulfur and nitrogen stimulate the enzymatic actions and chlorophyll formation which might increase bulb size of garlic. Corresponding vegetative growth may also be the reason because there is strong and positive correlation between bulb diameter and growth parameters such as plant height (r=0.94), leaf length (r=0.82), leaf diameter (0.84) and number of leaf per plant (0.86) (Appendix Table 4).

In agreement with this finding, Geleta (2014) recorded the widest bulb diameter from plot treated with the combined rates of 138 kg N ha^{-1} + 40 kg P ha^{-1} + 30 kg S ha^{-1} on Andosols, and with the combined rates of 138 kg N ha^{-1} + 40 kg P ha^{-1} + 60 kg S ha^{-1} on Vertisols. Besides, there is parity between the current and Teklemariam's (2007) study which identified that nitrogen and phosphorous application significantly influenced bulb diameter and the maximum was produced at 120 kg N ha^{-1} along with 60 kg P ha^{-1}. Yayeh (2015) reported longest mean bulb length and maximum bulb diameter of garlic from NPS fertilizer rate of 140:122.6:22.60 N: P_2O_5: S kg ha^{-1}. Contrary with the current result, Tibebu *et al*. (2014) reported that all interaction effects among variety, N and P on mean bulb diameter were non-significant. Similarly, Nigatu *et al*. (2018) reported non-significant effect of NPS on onion diameter.

4.4.5. Mean bulb weight

Both main (p= 0.0001) and interaction (p=0.0045) effects of varieties and NPS blended fertilizer rate had significant effect on average bulb weight (Appendix Table 2). Variety Tseday with produced significantly highest average bulb weight of 35.74 g at the rate of 242 kg ha^{-1} NPS blended fertilizer, which was statistically similar with the application of 305.5 kg ha^{-1} NPS from the same variety and local cultivar. On the other hand, variety Chefe with 0 $kgha^{-1}$ NPS rate gave the lowest average bulb weight of 5.22 g (Table 6). This may have been attributed to the synergistic role played by the supply of balanced nutrients to the crop. The nitrogen, phosphorous and sulfur components in the treatments may contributed in the metabolic process such as formation of nucleic acids, phospholipids, co-enzymes, and chlorophyll which intern enhance the bulb weight of garlic plants as described by Nasiruddin *et al*. (1993). It could also be attributed to the increase in number and length of leaf, bulb diameter and extended physiological maturity in response to fertilization, all of which may have led to increased assimilate production and allocation to the bulbs. This is confirmed by the strong and positive correlation of bulb weight with number (r=0.85) and length (r=0.82) of leaf and bulb diameter (r=0.97) (Appendix Table 4) in addition to the genotypic differences of varieties in their bulb weight.

In agreement with the current experimental result, Geleta (2014) reported significantly higher garlic bulb weights from the combined application of 92 kg N ha^{-1} + 40 kg P ha^{-1} + 60 kg S ha^{-1} on Andosols. This corroborates with the results of Nigatu *et al*. (2018) who also reported maximum bulb weight from onion plants supplied with 105:119.6:22 kg ha^{-1} N: P_2O_5: S fertilizer rate. However, the current finding is in contrast with the finding of Yayeh (2015) who reported non-significant influence of NPS fertilizer on bulb weights of garlic. More contrastingly, increased application of P did not significantly influence mean bulb weight (Teklemariam, 2007; Kilgori *et al*., 2007).

4.4.6. Number of cloves per bulb

Main effect of varieties had significant (p= 0.0001) effect on number of cloves per bulb of the crop (Appendix Table 2). But, the main effect of NPS blended fertilizer rate and the interaction effect of both factors had no significant effect on cloves per bulb of garlic (Appendix Table 2). The highest number of cloves per bulb (13.33) was recorded from Tseday variety, whereas the lowest (10.67) was recorded from Chefe variety (Table 7). The rest of the varieties are statistically similar in number of cloves per bulb. The difference in number of cloves per bulb of garlic variety might be attributed to genetic difference among the varieties.

In line with this, Teklemariam (2007) indicated that N and P applications had no significant effect on number of cloves per bulb. The result also agrees with the study of Ayalew (2015) who observed significantly, highest number of cloves per bulb from the local variety. Similarly, Getahun (2016), Yeshiwas *et al*. (2017) and Ibrahim *et al*. (2018) confirmed that there is a varietal variation in number of cloves bulb^{-1}. However, this study result has disparity with the work of Hossein *et al*. (2014) and Kenea and Gedamu (2018) in which clove number per bulb was maximum at higher rates. Besides, it has inconsistency with result of Abadi (2015) who reported significant interaction effect of fertilizer and cultivar on number of cloves per bulb.

Table 7: The main effect of variety on clove number per plant of garlic at Mettu in 2019

Variety	Clove number per plant
Chefe	10.67^{c}
Holeta	12.08^{b}
Kuriftu	12.08^{b}
Local	12.25^{b}
Tseday	13.33^{a}
LSD (5%)	0.85
CV (%)	8.5

Means followed by the same letter within a column are not significantly different at 5% level of significance; CV =Coefficient of Variation; LSD =Least Significant Difference

4.4.7. Average clove weight

Analysis of variance revealed that the main (p=0.0001) and interaction (p=0.0046) effects of varieties and NPS blended fertilizer rates had significant effect on average clove weight (Appendix Table 2). Though, it has statistical parity with 305.5 kg ha^{-1} and local cultivar at 305.5 kg ha^{-1} NPS, the highest average clove weight (2.98 g) was recorded by cultivar Tseday at 242 kg ha^{-1} NPS (Table 8). On the other hand, the lowest average clove weight of 0.44 g was recorded from unfertilized Chefe variety but, was statistically similar with all level of the same variety except fertilizer levels of 305.5 kg ha^{-1}, all varieties at control except Tseday (Table 8).

The increase in mean clove weights in response to increasing rate of NPS blended fertilizer may be attributed to the availability of balanced optimum nutrients availability that led to high mean clove weight through facilitating improved leaf growth and photosynthetic activities thereby increasing partitioning of assimilate to the storage organ. This can also be noticed from the strong and positive correlation between clove weight and leaf length (r=0.85) and diameter (r=0.84) (Appendix Table 4). The significant difference observed between germplasm for average clove weight might also be due to genetic difference between the varieties. In line with this Teklemariam (2007) reported the presence of significant variation on average clove weight of garlic due to application of N and P. Likewise, the study report of Degwale (2014) confirmed that both N and P_2O_5 at 46 kg ha^{-1} gave highest clove weight, while minimum weight from the control treatment.

Table 8: Some clove characters of garlic as affected by interaction of variety and NPS blended fertilizer rate at Mettu in 2019

Variety	NPS	Average clove weight (g)	Clove diameter (cm)
	0.00	0.44^{i}	1.10^{k}
	181.50	0.68^{hi}	1.26^{ijk}
Chefe	242.00	0.84^{ghi}	1.34^{g-j}
	305.50	0.90^{fgh}	1.38^{ghi}
	0.00	0.59^{hi}	1.14^{jk}
Holeta	181.50	0.95^{fgh}	1.42^{ghi}
	242.00	1.45^{de}	1.63^{def}
	305.50	1.61^{cd}	1.68^{de}
	0.00	0.69^{hi}	1.28^{h-k}
Kuriftu	181.50	1.16^{efg}	1.47^{fgh}
	242.00	1.69^{cd}	1.71^{de}
	305.50	1.59^{cde}	1.68^{de}
	0.00	0.84^{ghi}	1.36^{ghi}
Local	181.50	1.27^{d-g}	1.53^{efg}
	242.00	2.39^{b}	1.99^{bc}
	305.50	2.54^{ab}	2.12^{ab}
	0.00	1.31^{def}	1.52^{efg}
	181.50	1.91^{c}	1.83^{cd}
Tseday	242.00	2.98^{a}	2.18^{ab}
	305.50	2.78^{ab}	2.27^{a}
LSD (5%)		0.44	0.21
CV (%)		18.76	9.57

Means followed by the same letter within a column are not significantly different at 5% level of significance; CV =Coefficient of Variation; LSD =Least Significant Difference

4.4.8. Clove diameter

The analysis of variance revealed that the main (P=0.0001) and interaction (p=0.0283) of varieties and NPS blended fertilizer had significant effect on clove diameter (Appendix Table 2). The widest clove diameter (2.270 cm) was recorded by Tseday variety at 305.5 kgha^{-1} NPS but have statistical parity with 242 kg ha^{-1} NPS and local cultivar at 305.5 kg ha^{-1}(Table 8). On the other hand, the narrowest clove diameter (1.11 cm) was recorded from Chefe variety at zero application but statistically similar with the same variety at 181.5 kg ha^{-1}, Holeta and Kuriftu at control (Table 8). This significant difference on garlic clove diameter might be attributed to the synergistic role of the three nutrients in providing balanced nutrients to the crop and genotypic difference of varieties in producing different sized clove. It is due to the combined positive effects of phosphorous and sulfur in metabolic processes such as amino acids, vitamins, lipids, and some hormones formations. This in turn increases the vegetative growth and produces good quality foliage and promotes carbohydrate synthesis through photosynthesis and ultimately increased clove size of plants. This research report is similar with the report of Abadi (2015) who recorded significant and widest clove diameter from local cultivar at application of 82 kg ha^{-1} N.

4.4.9. Total bulb yield

Analysis of variance indicated that the main effects of varieties and NPS blended fertilizer rate had significant (p=0.0001) effect on total bulb yield while, the two factors significantly (p= 0.003) interacted to influence the yield (Appendix Table 3). The highest total bulb yield of 12.9 t ha^{-1} was recorded from the variety Tseday at 242 kg ha^{-1} NPS blended fertilizer treatment level followed by the same variety (11.97 t ha^{-1}) at 305.5 kg ha^{-1} NPS without significant difference between them (Table 9). On the other hand, the lowest yield (1.87 t ha^{-1}) was accrued from unfertilized Chefe variety, but has statistical likeness with same variety at 242 and 181.5 kg ha^{-1} NPS blended fertilizer treatment level and all varieties at nil application except Tseday (Table 9). Increasing NPS application rates up to 242 kg ha^{-1} in all varieties generally increased total bulb yields of the garlic varieties. But further increasing reduced total bulb yield.

The significant yield difference may be due to the varied yield potential of the varieties caused by the difference in their genetic architecture in nutrient uptake by garlic plants, resulting in an increased diameter and weight of cloves that cumulatively increased the total bulb yield. According to Marschner (1995) application of sulfur containing blended fertilizer like in NPS modifies soil pH, improves soil-water relation and increases the availability of plant nutrients like N, P, Fe, Mn and Zn, which may increase the bulb yield of garlic. Furthermore, sulfur and nitrogen stimulate the enzymatic actions as well as chlorophyll formation, both of which promote the growth and development of plants and improve the yield performance of garlic plants. Corresponding vegetative growth and other yield component may also the reason of improvement in total bulb yield as the correlation analysis indicated that total bulb yield showed strong and positive correlation with most of the growth parameters and yield components (r=0.47-0.99) (Appendix Table 4).

Similar to the present result, Jilani *et al*. (2009), Getahun (2016) and Getahun and Getaneh (2019) reported that garlic varieties could have different yield potential in different agro-ecologies due to their genetic potential and genotype x environment interaction effect. A significant total bulb yield differences which ranged between 10.24 to 7.76 t ha^{-1} was reported among garlic cultivars by Youssef (2013), Hossein *et al*. (2014), and Mulatu *et al.* (2014). This result is analogous to the result of Geleta (2014) who reported highest yield at 92 kg N + 40 kg P + 60 kg S ha^{-1} on Andosols and at 138 kg N + 40 kg P + 60 kg S ha^{-1} on Vertisols. Nigatu *et al.* (2018) recorded highest marketable bulb yield of 21.4 t ha^{-1} with NPS fertilizer rate at the concentration of 105:119.6:22 kg ha-1 N: P_2O_5: S and lower at control. Similarly, the combined application of 120 kg N + 22 kg P ha^{-1} resulted in good yield of garlic (Kilgori *et al*., 2007). Higher rates of fertilizers were reported to significantly increase total bulb yield of garlic (Teklemariam, 2007; Degwale, 2014; Bhagwan *et al*., 2012; Tibebu *et al*., 2014; Yayeh, 2015).

4.4.10. Marketable bulb yield

Marketable bulb yield per hectare was significantly influenced by varieties, NPS blended fertilizer rate (p=0.0001) and their interactions (p=0.0006) (Appendix Table 3). The variety Tseday with produced the significantly highest marketable bulb yield of 12.9 t ha^{-1} from application of 242 kg ha^{-1} NPS blended fertilizer which was equal from the same variety at 305.5 kg ha^{-1} NPS (Table 9). The lowest (1.02 t ha^{-1}) was observed from unfertilized Chefe variety but statistically at par with the same variety at 181.5 kg blended NPS ha^{-1} and Holeta and Kuriftu variety at nil application (Table 9). Across all cultivars, the marketable yield increased with increasing rates of NPS from 0 to 242 kg ha^{-1}, beyond which is either decreased or have non-significant variation from near lower level in the varieties.

This may be due to genetic variability of the varieties. Application of sulfur containing blended fertilizers like NPS improves availability of micronutrients by amending the soil pH that may in turn increase yields of vegetable crops including garlic. The availability, balance and synergistic effect of these nutrients increased the clove size of the garlic, which might increase the number of marketable cloves and this might in turn increased the marketable yield of the crop. This result is covenant with report of Degwale (2014) who reported highest marketable yield at the combined application of N and P fertilizers at 46 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}. Moreover, Yayeh (2015) recorded highest marketable yield of garlic (17.42t ha^{-1}) from 140:122.6:22.60 N:

P_2O_5: S kg ha^{-1}. The current result contrasts the result of Teklemariam (2007) who claimed non-significant main effect of P and its interaction with N on marketable yield of garlic

Table 9: Interaction effect of variety and NPS blended fertilizer rate on total bulb yield, marketable bulb yield, unmarketable bulb yield and dry biomass yield of garlic at Mettu in 2019

Variety	NPS	Total bulb yield (t ha^{-1})	Marketable bulb yield (t ha^{-1})	Unmarketable bulb yield (t ha^{-1})	Bulb dry matter content (%)
Chefe	0.00	1.87^{j}	1.02^{j}	0.85^{a}	39.67^{j}
	181.50	2.92^{ij}	2.12^{ij}	0.80^{ab}	40.33^{j}
	242.00	3.63^{hij}	3.00^{ghi}	0.63^{d}	45.00^{g}
	305.50	3.87^{ghi}	3.27^{f-i}	0.60^{d}	45.00^{g}
Holeta	0.00	2.53^{ij}	1.68^{ij}	0.85^{a}	42.83^{i}
	181.50	4.09^{f-i}	3.33^{f-i}	0.77^{b}	46.33^{fg}
	242.00	6.25^{de}	5.79^{cde}	0.47^{e}	52.00^{d}
	305.50	6.95^{cd}	6.49^{cd}	0.47^{e}	52.00^{d}
Kuriftu	0.00	2.99^{ij}	2.19^{ij}	0.80^{ab}	43.17^{hi}
	181.50	5.00^{e-h}	4.20^{e-h}	0.80^{ab}	47.33^{f}
	242.00	7.28^{cd}	6.95^{c}	0.33^{f}	53.83^{c}
	305.50	6.86^{cd}	6.53^{cd}	0.33^{f}	53.67^{cd}
Local	0.00	3.64^{hij}	2.88^{hi}	0.77^{b}	44.67^{gh}
	181.50	5.50^{d-g}	4.77^{d-g}	0.73^{bc}	49.67^{e}
	242.00	10.31^{b}	10.24^{b}	0.07^{g}	56.67^{b}
	305.50	10.48^{b}	10.48^{b}	0.00^{g}	56.47^{b}
Tseday	0.00	5.67^{def}	4.87^{def}	0.80^{ab}	50.00^{e}
	181.50	8.23^{c}	7.56^{c}	0.67^{cd}	55.33^{bc}
	242.00	12.90^{a}	12.90^{a}	0.00^{g}	60.00^{a}
	305.50	11.97^{ab}	11.97^{ab}	0.00^{g}	60.00^{a}
LSD (5%)		1.8	1.81	0.08	1.67
CV (%)		17.68	19.51	8.88	2.03

Means followed by the same letter within a column are not significantly different at 5% level of significance; CV =Coefficient of Variation; LSD =Least Significant Difference

4.4.11. Unmarketable bulb yield

As analysis if variance indicated that the main effects of varieties and NPS blended fertilizer rate and their interaction had significant (p= 0.0001) effect on unmarketable bulb yield per hectare (Appendix Table 3). There was no unmarketable bulb from Tseday variety at 305.5 kg ha^{-1} NPS, 242 kg ha^{-1} NPS and local cultivar at 305.5 kg ha^{-1} with statistically non-significant difference from the local cultivar at 242 kg ha^{-1} NPS. On the other hand, the highest unmarketable yield (0.85 t ha^{-1}) was obtained from unfertilized plot of Chefe variety that have statistical parity with all unfertilized varieties and Chefe and Kuriftu varieties at 181.5 kg ha^{-1} (Table 9). Decreasing trend in unmarketable bulb yield was observed moving from zero to 242 kg ha^{-1} NPS but further increasing didn't.

This could be attributed to the less partitioning of photosynthates towards cloves due to reduced growth of photosynthetic leaves in unfertilized plants. At lower fertilizer rates the lack of nutrients for sub-optimal growth, that resulted in less availability of soil nutrients might lead to under sized and irregular shaped bulbs, consequently higher unmarketable bulb yield. Alike this, Yayeh (2015) reported lowest unmarketable bulb yield of garlic at 140:122.6:22.60 N: P_2O_5: S kg ha^{-1}. Correspondingly, minimum and significant unmarketable bulb yield of garlic was reported by Degwale (2014) at a combination rate of 23 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}. However, unlike the present study result, Abadi (2015) did not report significant difference neither from the main nor from the interaction effect of varieties and NPS blended fertilizer rates. Besides, Teklemariam (2007) reported non-significant interaction effect of N and P on garlic unmarketable bulb yield.

4.4. 12. Bulb dry matter content

Analysis of variance showed that the main of varieties and NPS blended fertilizer rate and their interaction effects had significant ($p= 0.0001$) difference on bulb dry matter content statistically (Appendix Table 3). Variety Tseday with application of 242 and 305.5 kg ha^{-1} NPS blended fertilizer had the highest bulb dry matter content (60%). The lowest bulb dry matter content of 39.67% was recorded from the unfertilized Chefe variety but statistically at par with the same variety at 181.5 kg NPS (Table 9). Across all cultivars, the bulb dry matter content increased significantly with increasing rates of NPS from 0 to 242 kg ha^{-1}, beyond which it is either decreased or have non-significant effect.

The observed difference in dry matter content might be due to the natural difference of varieties in their genetic potential dry matter accumulation. The increase of bulb dry matter content with increasing NPS application rates observed in the present study is probably the results of accumulation and partitioning of more assimilates into the storage organ bulb. Increase of plant growth that contribute to bulb dry weight by increasing N level might be due to its role in photosynthesis, protein synthesis, cell division and enlargement which are the basic steps of plant growth as can be noticed from the strong and positive correlation ($r=0.92$) of bulb dry matter with bulb dry weight (Appendix Table 4).

Analogous to this result, Geleta (2014) reported that combined applications of 92 kg N + 40 kg P + 30 kg S ha^{-1} and 138 kg N + 40 kg P + 60 kg S ha^{-1} led to the attainment of optimum bulb dry content on Andosols and Vertisols, respectively. Getahun (2016) reported maximum percent dry matter yields from plants grown in plots that received 150 kg ha^{-1} N. Teklemariam (2007) also reported that application of N at the rate of 120 kg ha^{-1} along with 60 kg P ha^{-1} resulted in highest dry matter (18.20 g) per bulb. Divergent to this finding, Degwale (2014) documented that bulb dry matter percent was not significantly affected by interaction effects of N and P.

4.4.13. Harvest index

Analysis of variance indicated that the main effect of Variety and NPS blended fertilizers showed significant differences (p = 0.0001) on harvest index but their interaction did not (Appendix Table 3). The highest harvest index (74.34%) was observed from Tseday variety, while the lowest (68.74%) was from a plot that received Chefe variety (Figure.2). Concerning the main effect of NPS blended fertilizers, the highest harvest index (73.81%) was observed on plot that received NPS blended fertilizers of 305.5 kg ha^{-1} rate, while the lowest (69.29%) was from unfertilized plot (Figure.3).

The reason behind the observed improvement in harvest index at higher rates of NPS blended fertilizers could be due to enhanced production and greater partitioning of the photosynthate to the bulbs in leaves that have increased leaf size. It could also be attributed to the strong movement of assimilates from the leaves to the bulbs during the growing period and increased bulb weight at higher NPS rates. This is confirmed by the strong and positive correlation of harvest index with bulb weight (r=0.83) (Appendix Table 4). The synergistic role played by the three nutrients in providing balanced supply of nutrients to the crop might also be the reason. N and P may also have cumulative effect on the growth and dry matter production, which is also report by Teklemariam (2007). This result is comparable to research report of Degwale (2014) who recorded maximum harvest index from a combination of 46 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}. Besides, Kenea and Gedamu (2018) observed significantly highest harvest index (60.52%) from application of 130 kg N ha^{-1} N. In correspondence with the present result, Geleta (2014) also reported highest harvest index at the combined application of 138 kg N + 40 kg P + 30 kg S ha^{-1} on Andosols and 138 kg N + 80 kg P + 0 kg S ha^{-1} on Vertisols.

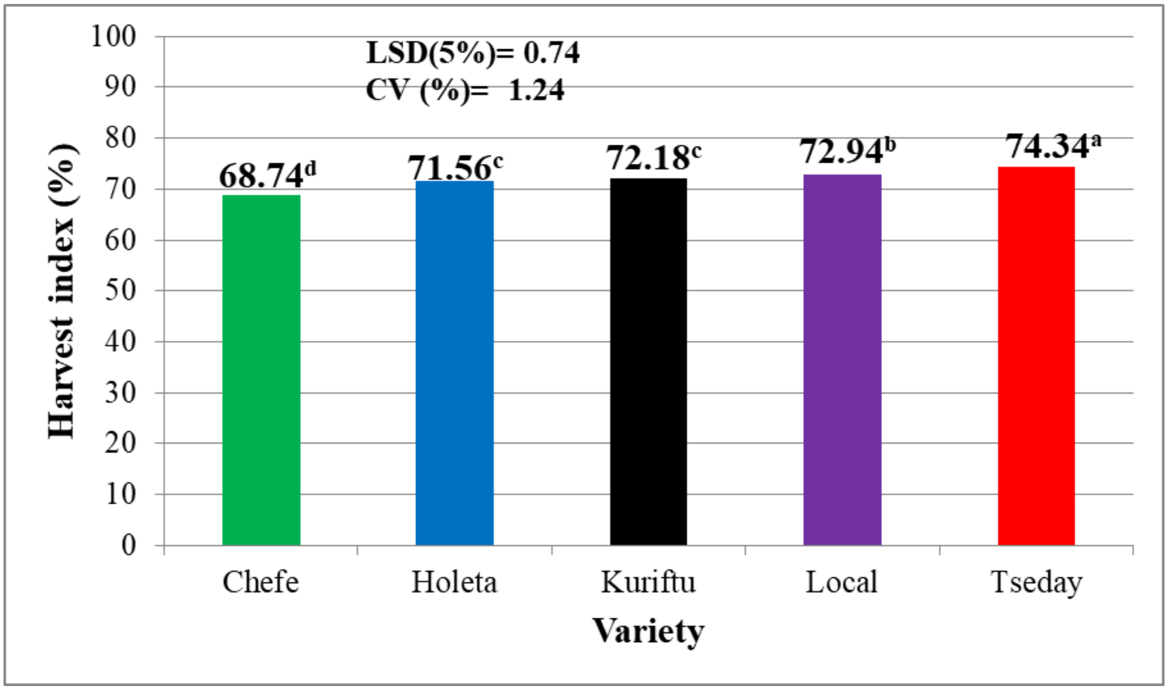

Figure 2: The main effect of variety on harvest index (%) of garlic at Mettu in 2019

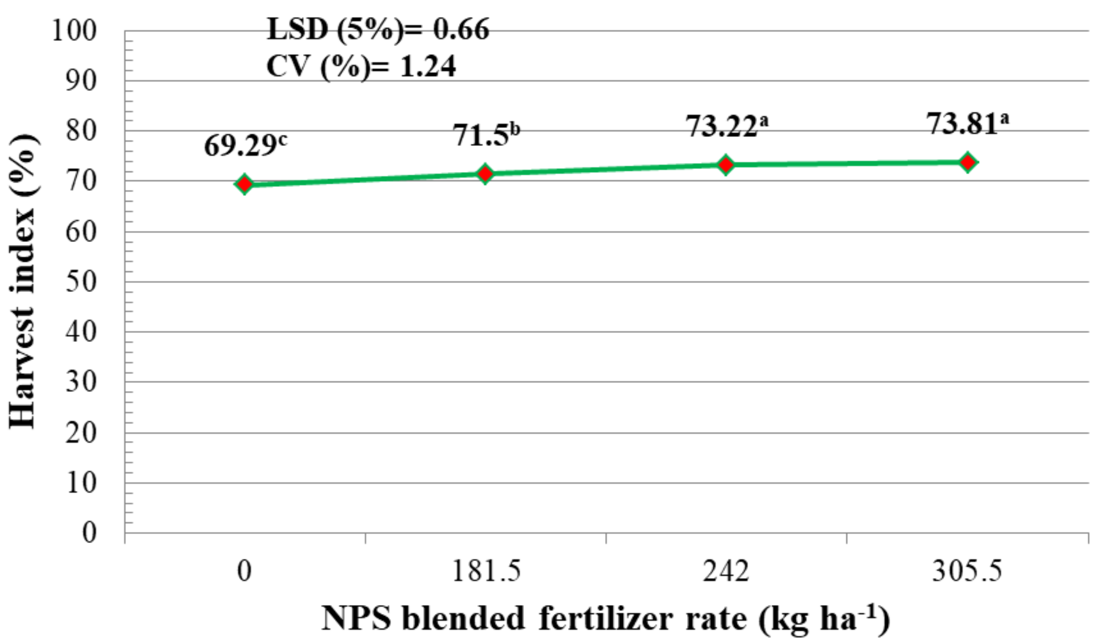

Figure 3: Main effect of NPS blended fertilizer rate on harvest index (%) of garlic at Mettu, in 2019

Means followed by the same letter are not significantly different at 5% level of significance; CV =Coefficient of Variation; LSD =Least Significant Difference

4.5. Partial Budget Analysis

The partial budget analysis showed that variety Tseday with application of 242 kg ha^{-1} NPS blended fertilizer gave the maximum net economic benefit (1,380,252.21ETB), whereas the lowest net benefit (110,040.60 Birr ha^{-1}) was obtained from unfertilized Chefe variety (Table 10). As fertilizer rate increased from 0 to 242 kg NPS blended fertilizer ha^{-1} both net benefit and margin rate of return increased along all varieties, but further increasing resulted in reduced net benefit and margin rate of return due to increased total variable cost at higher rates. Therefore, Tseday variety with application of 242 kg NPS blended fertilizer ha^{-1} was economical. In line to this Geleta (2014) concluded that application of nitrogen, phosphorus, and sulphur at the rates of 92 kg N, 40 kg P, and 30 kg S ha^{-1} led to enhanced production of garlic. Besides as reported by Yayeh (2015) application of NPS fertilizer at the rate of 140:92:17 N: P_2O_5: S kg ha^{-1} resulted in higher net benefit. Harmony with the present economic analysis result, highest net benefit in onion was reported from NPS fertilizer at the rate of 105:119.6:22 N: P_2O_5: S kg ha^{-1} by Nigatu *et al*. (2018).

Table 10: Summary of partial budget analysis of the effects of NPS blended fertilizer application on Garlic varieties at Mettu, in 2019

Var	NPS(kg ha^{-1})	UAMBY(kg ha^{-1})	AMBY(kg ha^{-1})	GB	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	MRR (%)
Chefe	0.00	1024.87	922.39	110040.60	0	110040.60	-
Chefe	181.50	2124.15	1911.73	228069.63	3811.5	224258.13	2996.66
Chefe	242.00	2999.70	2699.73	322078.03	5082	316996.03	7299.32
Chefe	305.50	3268.69	2941.82	350959.55	6408	344551.55	2078.09
Holeta	0.00	1683.32	1514.98	180737.55	0	180737.55	-
Holeta	181.50	3324.58	2992.12	356960.42	3811.5	353148.92	4523.45
Holeta	242.00	5785.04	5206.54	621139.74	5082	616057.74	20693.34
Holeta	305.50	6486.62	5837.96	696468.33	6408	690060.33	5580.89
Kuriftu	0.00	2193.81	1974.42	235548.88	0	235548.88	-
Kuriftu	181.50	4192.34	3773.10	450131.38	3811.5	446319.88	5529.87
Kuriftu	242.00	6951.59	6256.43	746392.26	5082	741310.26	23218.45
Kuriftu	305.50	6526.69	5874.02	700770.54	6408	694362.54 D	-
Local	0.00	2875.64	2588.07	308756.98	0	308756.98	-
Local	181.50	4772.90	4295.61	512466.02	3811.5	508654.52	5244.59
Local	242.00	10242.90	9218.61	1099779.92	5082	1094697.92	46126.99
Local	305.50	10477.95	9430.16	1125017.71	6408	1118609.71	1803.30
Tseday	0.00	4866.56	4379.90	522522.30	0	522522.30	-
Tseday	181.50	7558.97	6803.07	811606.48	3811.5	807794.98	7484.53
Tseday	242.00	12902.43	11612.19	1385334.21	5082	1380252.21	45057.63
Tseday	305.50	11968.59	10771.73	1285067.63	6408	1278659.63 D	-

Cost of NPS=16Birr kg^{-1}; Fertilizer application=500 Birr/100kg/ha; cost of harvesting=0.2birr kg^{-1}; transportation cost= 0.1-birr kg^{-1} bagging cost=0.2-birr kg^{-1}; sorting cost=0.2-birr kg^{-1} and market price of garlic at the time of dispatch =120birr kg^{-1} Field price of garlic= 120birr-(0.2+0.1+0.2+0.2birr) = 119.5birr kg^{-1}. Yield was adjusted by 10% reduction to compromise with the yield produced by farmers UAMBY-Unadjusted marketable bulb yield, AMBY-Adjusted marketable bulb yield, GB-Gross benefit, TVC- Total variable cost, NB-Net benefit, MRR-Marginal rate of return, D-Dominated.

5. SUMMARY AND CONCLUSION

Garlic is a high value crop. Regardless of this and great potential for production and high market demand of the crop in Ethiopia in general and the study area in particular, it's productivity and production is very low compared to the world average.

Based on this fact, the current study was done during 2019 to investigate the effect of NPS blended fertilizer rate on growth, yield and yield attributes of garlic varieties at Mettu, South Western Ethiopia. Twenty treatments formed from a factorial combination of five garlic varieties (Tseday, Kuriftu, Chefe, Holeta and one local) and four rates of NPS blended fertilizers (0, 181.5, 242 and 305.5 kg ha^{-1}) were laid out in randomized complete block design with three replications.

The analysis of variance showed that most of the studied parameters were significantly affected by the main treatment effects varieties and NPS blended fertilizer rates and their interaction. Tseday had better growth performance while, Chefe variety showed low growth performance. The maximum total dry biomass weight (74.66 g $plant^{-1}$) was obtained from Tseday variety at NPS blended fertilizer rate of 242 kg ha^{-1}, while the lower were observed at plot planted with the variety Chefe and received zero application. The earliest (101.67) and prolonged (136.67) days to maturity was recorded from Chefe variety at nil application and Tseday variety at rate of 305.5 kg ha^{-1} NPS blended fertilizer application, respectively.

Furthermore, widest leaf diameter (1.85 cm), highest total (12.9 t ha^{-1}) and marketable bulb yield (12.9tha^{-1}), and higher bulb dry matter content (60%) was recorded from application of NPS blended fertilizer at the rate of 242 kg ha^{-1} on Tseday variety, while the lower were recorded from unfertilized Chefe variety. The highest (74.34%) and lowest harvest index (68.74%) was observed from Tseday and Chefe variety, respectively. On the other hand, the highest harvest index (73.81%) was observed on plot that received NPS blended fertilizers at 305.5 kg ha^{-1} rate, while the lowest (69.29%) was in unfertilized plot. Likewise, total bulb yield was positively and significantly correlated with all growth, yield and yield attributes except days to emergence and unmarketable yield. The economic analysis also indicated that the highest net benefit/return (1,380,252.21 ETB ha^{-1}) was recorded from the variety Tseday with application of 242 kg ha^{-1} NPS blended fertilizer and the lowest (110,040.6 ETB ha^{-1}) from variety Chefe at 0 kg ha^{-1} NPS blended fertilizer.

In conclusion, production of Tseday variety with application of 242 kg ha^{-1} NPS blended fertilizer is economical and increased the productivity of garlic in the study area. However, the results of the present study need to be validated and verified in different agro ecologies and seasons in order to give a comprehensive recommendation.

6. REFERENCE

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7. APPENDIX

Appendix Table 1: Analysis of variance (ANOVA) for phenology and growth parameters of garlic as affected by varieties and NPS blended fertilizer rate in 2019 at Mettu, Southwestern Ethiopia.

Mean square							
Source of variation	DF	DE	DM	PH	LN	LL	LD
Variety (A)	4	0.86NS	316.96***	568.94***	10.95***	181.1***	0.17***
Fertilizer (B)	3	0.42NS	1020.19***	742.08***	19.93***	381.2***	0.34***
Replication	2	0.52NS	14.87	2.82NS	0.33NS	2.1NS	0.00NS
A x B	12	0.49NS	24.57***	7.07NS	0.13NS	4.0NS	0.02*
Error	38	0.74	6.09	4.77	0.28	4.69	0.01
CV (%)		8.6	2.07	4.6	5.6	6.14	5.70

Key:

*, ** and ***, significant at P<5%, P<1% and 0.1 respectively, NS- Non-significant, DF- degree of freedom, A x B = interaction of factor variety (A) and factor fertilizer (NPS) (B), and CV (%) = coefficient of variation, DE- days to emergency, DM- days to maturity, PH- plant height, LN- leaf number per plant, LL-leaf length, LD-leaf diameter.

Appendix Table 2: Analysis of variance (ANOVA) for Yield components of garlic as affected by varieties and NPS blended fertilizer rate in 2019 at Mettu

Source of variation	DF	FABW	DABW	FBBW	DBBW	TFBW	TDBW	BD	Av.BW	CN	Av. CW	CD
Variety (A)	4	1200.76***	165.81***	4334.63***	1801.52***	10097.95***	3060.34***	5.41***	598.87***	10.79***	4.15***	0.82***
Fertilizer (B)	3	1329.79***	176.17***	4800.73***	1902.58***	11183.61***	3235.06***	6.18***	635.73***	0.55NS	4.42***	0.95***
Replication	2	60.93NS	7.75NS	220.06NS	99.81NS	512.73NS	163.19NS	0.43*	27.95NS	2.62NS	0.19NS	0.02NS
A x B	12	57.84**	8.66**	208.81**	105.10***	486.42**	172.73***	0.22*	31.28**	0.87NS	0.22**	0.03*
Error	38	18.84	2.85	68.02	26.63	158.47	46.094	0.10	10.30	1.06	0.07	0.02
CV (%)		17.51	1.69	17.51	20.76	17.51	20.03	9.64	18.71	8.5	18.76	9.57

Key:

*, ** and ***, Significant at P<5%, P<1% and 0.1 respectively, NS- Non-Significant, DF- Degree of Freedom, A x B = interaction of factor variety (A) and factor fertilizer (NPS) (B), and CV (%) = Coefficient of Variation, FABW –Fresh Above Ground Weight per plant, DABW-Dry Above Ground Biomass weight per plant, FBBW –Fresh Bulb Biomass Weight per plant, DBBW-Dry Bulb Biomass Weight per plant, TFBW –Total Fresh Biomass Weight per plant, TDBW-Total Dry Biomass Weight per plant, BD-Bulb Diameter (cm), Av.BW – Average Bulb Weight (g plant-1), CN-Clove Number per bulb, Av.CW – Average Clove Weight (g plant-1), CD-Clove Diameter (cm)

Appendix Table 3: Analysis of variance (ANOVA) for Yield, Bulb dry matter content and Harvest index of garlic as affected by varieties and NPS blended fertilizer rate in 2019 at Mettu, Southwestern Ethiopia

Source of variation	DF	TBY(t ha^{-1}**)**	MBY(t ha^{-1})	UMBY(t ha^{-1})	BDMC (%)	HI
Variety (A)	4	76.76***	86.05***	0.285***	307.68***	51.62***
Fertilizer (B)	3	80.61***	101.16***	1.227***	318.36***	61.65***
Replication	2	3.03NS	3.06NS	0.000NS	0.37NS	0.19NS
A x B	12	3.79**	4.68***	0.055***	4.45***	1.03NS
Error	38	1.18	1.20	0.002	1.02	0.80
CV (%)		17.68	19.52	8.88	2.03	1.24

Key:

*, ** and ***, Significant at P<5%, P<1% and 0.1 respectively, NS- Non-Significant, DF-Degree of Freedom, A x B = interaction of factor variety (A) and factor fertilizer(NPS) (B), and CV (%) = Coefficient of Variation, TBY-Total Bulb Yield in tone per hectare, MBY-Marketable Bulb Yield in tone per hectare, UMBY- Unmarketable Bulb Yield in tone per hectare, BDMC-Bulb Dry Matter Content (%.) and HI-Harvest Index

Appendix Table 4: Pearson correlations analysis result between growth, yield and yield components of garlic as affected by varieties and NPS blended fertilizer rate

	Dm	De	PH	LN	LL	LD	Tfbmy	Tdbmy	BD	AvBW	NC	ACW	TBY	MBY	UMBY	BDM	HI
Dm		0.08ns	0.91***	0.87***	0.87***	0.88***	0.91***	0.91***	0.91***	0.91***	0.4**	0.91***	0.91***	0.92***	-0.9***	0.87***	0.83***
De			0.11ns	-0.03ns	0.08ns	0.15ns	0.079ns	0.07ns	0.07ns	0.07ns	-0.19ns	0.07ns	0.08ns	0.08ns	-0.08ns	0.028ns	0.057ns
PH				0.90***	0.8***	0.85***	0.95***	0.94***	0.94***	0.94***	0.51***	0.94***	0.95***	0.95***	-0.83***	0.96***	0.92***
LN					0.88***	0.86***	0.85***	0.85***	0.86***	0.85***	0.48***	0.85***	0.85***	0.86***	-0.78***	0.88***	0.85***
LL						0.92***	0.85***	0.84***	0.82***	0.85***	0.45***	0.85***	0.85***	0.86***	-0.84***	0.88***	0.83***
LD							0.84***	0.85***	0.84***	0.85***	0.49***	0.84***	0.85***	0.86***	-0.81***	0.85***	0.78***
tfbmy								0.99***	0.98***	0.99***	0.46***	0.99***	0.99***	0.99***	-0.88***	0.93***	0.86***
tdbmy									0.98***	0.99***	0.46***	0.99***	0.99***	0.99***	-0.88***	0.92***	0.84***
BD										0.97***	0.47***	0.97***	0.97***	0.97***	-0.84***	0.92***	0.86***
AveBW											0.45***	0.99***	0.99***	0.99***	-0.87***	0.92***	0.83***
NC												0.45***	0.47***	0.46***	-0.3***	0.52***	0.52***
ACW													0.99***	0.99***	-0.87***	0.92***	0.83***
TBY														0.99***	-0.87***	0.92***	0.84***
MBY															-0.89***	0.93***	0.84***
UMBY																-0.85***	-0.77***
BDM																	0.94***
HI																	

Ns=non-significant, *, **and *** indicate significant difference at 5%, 1% and 0.1% respectively. DM =Days to 50 % emergence DE =Days to maturity, PH= Plant height, LN =Leaf number per plant, LL= Leaf length, LW= Leaf width, TFBMY=Total fresh biomass, TDBMY=Total Dry biomass, BD = Bulb diameter, Av.BW= Average bulb weight, NC= Number of cloves per bulb, ACW= Average clove weight, TBY=Total bulb yield, MBY=Marketable bulb yield per hectare, UMBY=Unmarketable yield per hectare, BDM=Bulb dry matter , HI=Harvest index