RESPONSE OF GARLIC (*Allium sativum* L.) VARIETIES TO TYPES OF BLENDED FERTILIZERS IN MIHUR-AKLIL DISTRICT OF GURAGE ZONE, ETHIOPIA

Msc. Thesis

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This is to certify that the thesis entitled "**Response of Garlic *(allium sativum* l.*)* Varieties to Different Types of Blended Fertilizers in Mihur-Aklil District of Gurage Zone, Ethiopia"** submitted in partial fulfillment of the requirements for the degree of **Master's** with specialization in **Horticulture,** the Graduate Program of the **Department/School of Horticulture,** and has been carried out by Mr. Habtemariam Fikadu Bereka Id. No 013/13, under our supervision. Therefore we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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We, the undersigned, members of the Board of Examiners of the final open defense by **Habtemariam Fikadu Bereka** have read and evaluated his thesis entitled "**Response of Garlic *(Allium sativum* L.*)* Varieties to Different Types of Blended Fertilizers in Mihur-Aklil District of Gurage Zone, Ethiopia"**, and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of master science

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DEDICATION

I would like to dedicate this piece of work to my beloved wife, Mrs. Kibrinesh Tigistu, for her boundless contribution towards the successful completion of this study and beyond.

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LIST OF ABBREVIATIONS AND ACRONYMS

AFAP	African Fertilizer and Agribusiness Partnership
AGRA	Alliance for a Green Revolution in Africa
AjY	Adjusted Yield
ANOVA	Analysis of Variance
ATA	Agricultural Transformation Agency
AvY	Gross Average Bulb Yield
Birr	Ethiopian Birr
CRV	Crop Variety Register
CIMMYT	Center of International Maize and Wheat Improvement
CSA	Central Statistical Agency (Ethiopia)
CV	Coefficient of Variance
DABPI	Department of the Agricultural Bureau of Plant Industry
DAIS	Directorate for Agricultural Information Service
DZARC	Deberziet Agricultural Research Center (EIAR, Ethiopia)
EMA	Ethiopia Mapping Agency
EIAR	Ethiopian Institute of Agricultural Research
EthioSIS	Ethiopian Soil Information System
FAO	Food and Agriculture Organization of United Nations
FAOSTAT	Food and Agricultural Organization Statistics
FDRECSA	Federal Democratic Republic of Ethiopia Central Statistics Agency
GFB	Gross Field Benefit

IFDC	International Fertilizer Development Center
LAI	Leaf Area Index
LSD	Least Significance Difference
MAWAO	Mihur Aklil Woreda Agricultural Office
MRR	Marginal Rate of Return
NB	Net Benefit
NPS	Nitrogen-Phosphorus-Sulphur
NPSB	Nitrogen-Phosphrous-Sulphur-Boron
NPSZn	Nitrogen-Phosphrous-Sulphur-Zinc
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
SNNPR	Southern Nation Nationalities People Region
WKU	Wolkite University

RESPONSE OF GARLIC *(Allium sativum* L.*)* VARIETIES TO DIFFERENT TYPES OF BLENDED FERTILIZERS IN MIHUR-AKLIL WOREDA OF GURAGE ZONE, ETHIOPIA

ABSTRACT

Garlic (Allium sativum L.) is one of the major vegetable and cash crops cultivated throughout the world including Ethiopia. Garlic productivity in Ethiopia (9.18t ha^{-1}) is very low compared to the world average (18.4t ha^{-1}. Its production is constrained by several factors including lack of productive varieties, improved agronomic practices, diseases and insect pests. Among these, inappropriate type of fertilizer and lack of improved varieties are the major ones. Hence, this experiment was conducted in 2023 at Mihur-Aklil District of Gurage zone, Ethiopia with the objective of investigating the effect of blended fertilizer type 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 (Tsedey, Kuriftu, Chefe, Holeta and local) and four types of blended fertilizers (0, NPS, NPSB and NPSZn). 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 bulb yield (17.08t ha^{-1}), marketable bulb yield (14.94 ha^{-1}), bulb weight (37.27g), bulb diameter (24.27mm), plant height (77.8cm), leaf length (52.33) and leaf area (38.80cm^2) was recorded from Tsedey variety at NPSB blended fertilizer type while the widest leaf width (1.04cm) was recorded from Tsedey variety treated with NPSZn blended fertilizer type and the highest clove weight (2.70g) was recorded from Kuriftu variety treated with NPSZn blended fertilizer type. The partial budget analysis result showed that the highest net benefit of 963881.281Eth-Birr ha^{-1} was obtained from variety Tsedey and NPSB fertilizer. Thus, from the present study, the variety Tsedey and NPSB fertilizer are recommended for economic production in the study area and areas with similar agro-ecological settings. However, since the study was carried out only for one cropping season and in single location, it is as well recommended that to be repeated across seasons and locations.

Keywords: Garlic**, v**arieties, blended fertilizers, yield components, yield

1. INTRODUCTION

Garlic *(Allium sativum L.)* that belongs to the *alliaceae* family is among the most important bulb vegetable crops and the second most widely used allium next to onion is used as spice due to its pungent flavor (Mohammed *et al.*, 2021). It has been originated in Central Asia and spread to all other parts of the world through trade and colonization (Muluken, 2020). Garlic produces unique flavors savored by most of the world's culture (Weldemariam *et al*. 2017). Its volatile oil has many Sulphur containing compounds that are responsible for its strong odor, its distinctive flavor and pungency as well as for its healthful benefits (Yayeh *et al.*, 2019). It has high nutritive value and used for households throughout the year (Dessie and Mulat 2019). The chemical constituents of garlic have been reported to treat cardiovascular diseases, cancer, diabetes, blood pressure, atherosclerosis, and hyperlipidemia (Vincent, 2019).

Garlic is one of the most important bulb vegetables, produced by small and commercial growers for the local or export market (Gizachew *et al.*, 2021). In Ethiopia, the total area under garlic production during 2019/20 was reported to be 18,344.47 ha with total production of 1,525,946.34 Q (Zewdu, 2022) and the average 10.04 tons/ha. Which is very low compared to world average productivity of 18.4 tons/ha (Bizuayehu *et al.*, 2021) and some the neighboring country like Egypt 24.34 t/ha (Mohammed *et al*., 2021). Ethiopia is ranked 13th in the world's garlic production (Muluken, 2020) but it is the third in Africa in the area of production (19,412.49 ha) next to Egypt and Algeria (Weldemariam *et al*. 2017).

Besides its importance, in many parts of the world its productivity is low mainly due to genetic and environmental factors affecting its yield and yield related traits .But in Ethiopia, productivity of garlic is less than half of the world average because of lack of productive varieties, improved agronomic practices that clean planting material (PM) as well as diseases and insect pests are the major causes for the low productivity (Getachew *et at.*, 2022).

However to overcome such production problems great effort should be made in the selection and breeding of high-yielding cultivars and the development of cultural techniques (Gizachew *et al.*, 2021) and correspondingly selections of variety with proper rate and fertilizer types are very important factors to increase the productivity and marketability of garlic (Abraham *et al.*, 2014). Similarly (Tadesse, 2015) stated that selections based on morphological and agronomical characteristics of varieties that respond to fertilizer rates are essential to produce high yield, adaptable and high market acceptance.

N, P and K fertilizers are especially very important to get the maximum yield of garlic. However the type of fertilizer application should be determined based on the results of soil tests that may be influenced by soil type, the previous crop grown, the rat of organic matter present and also the climatic conditions during the growing season. The application of fertilizer for garlic production in Ethiopia is based on a blanket recommendation set by EIAR (2007), which is 92 kg phosphorous and 105 kg nitrogen sourced from DAP and urea. Such recommendations did not consider the type and fertility of the soil, environmental conditions and other factors that could influence the rate of fertilizer application (Ewnetu *et at*., 2020).

Though, the use of fertilizers in crop production has generally increased in Ethiopia within the last few years, garlic producers still use fertilizers below the blanket recommendation. Furthermore, they depend on fertilizers containing only N and P. Earlier, there is no fertilizers that contain potassium, sulfur and micronutrients that are important to increase production and productivity in garlic production that lead for nutrient level in the soil steadily declined. However, the government of Ethiopia recently introduced different blended fertilizer types containing nitrogen, phosphorous, boron, zinc and sulfur. Garlic plant showed differential responses to the different types of compound fertilizers (Diribaw, 2017).

However, the Ethiopian Soil Information System (EthioSIS) indicated that Ethiopian soils lack about seven nutrients Nitrogen (N), Phosphorus (P), potassium (K), sulfur (S), cupper (Cu), Zinc (Zn) and boron (B) in soil fertility assessment study conducted in different Woreda and Kebele (EthioSIS,2014).

Although a number of blended fertilizers containing multi-nutrients were formulated to be used in different areas of the country, those fertilizers were not evaluated for their effectiveness in different soils and agro-ecologies (Mulugeta and Abay 2017). The nutrient supplying powers of the soils and demanding levels of the plants need further conclusive site-soil-crop specific fertilizer recommendation with appropriate rate and type (Kedir *et al.,* 2016).

Even though Mihur- Aklil woreda has a potential for garlic production, research on variety performance and agronomic practices for improved garlic productivity had not yet conducted. Therefore farmers use only the local varieties with their own traditional production methods. As a result the average yield of the crop is very low 8.3t/ha^{-1} (MAWAO, 2021). Thereby the income generation from garlic production is still unsatisfactory. Therefore, this experiment was initiated to examine the effect of different types of blended fertilizer on yield and yield components of garlic varieties in Mihur-Aklil Woreda of Gurage Zone, Ethiopia.

1.1. Objectives

1.1.1. General objective

- To evaluate the growth and yield response of Garlic *(Allium sativum L)* varieties to different types of blended fertilizers in Mihur- Aklil district, Gurage zone, Ethiopia.

1.1.2. Specific objectives

- To evaluate Garlic varieties with better productivity in the study area
- To identify the best type of blended fertilizer that maximizes Garlic productivity in study area.
- To determine the economic feasibility of different blended fertilizers on Garlic production in the study area

2. LITERATURE REVIEW

2.1. Origin and Distribution of Garlic

The native land of garlic is Middle Asia. It beliefs that the exact origin of garlic is originates from West China, around Tien Shan Mountains to Kazakhstan and Kyrgyzstan (Biljana *et al.,* 2010). Evidence for its use as a medicinal plant dates to more than 1550 B.C. and its distribution to other parts of the world has made possible by nomadic traders. Today, it is cultivated in many countries worldwide including Asia, Europe, America, and Africa where it is consumed as a spice or therapeutic food (Timothée *et al.,* 2021). Garlic species are widely distributed in boreal areas having temperate climates and mountainous areas from tropical regions. Most of the species diversity is found from Mediterranean countries to Central Asia. USA being as a center for Alliumdiversification (Héctor *et al*.,2012).

2.2. Importance of Garlic

Garlic (*Allium sativum* L.) is one of the world's most important vegetables cultivated both for its culinary and health properties. Garlic cloves are recognized as a valuable source of bioactive compounds for functional foods, natural health products, cosmetics, and medicine for people and animals. Garlic could be a seasonal vegetable, which loses its beneficial substances during long-term storage (Aneta *et al.,* 2020). It is old as a spice and flavor agent for foods and is a fundamental component in most dishes of an assortment of the world. It's frequently balanced with onion, tomato, or ginger and is hypothetical to be in use raw, boiled or mixed with honey, meat, cheese, butter and with milk or with coffee.

Clinical studies have shown that garlic reduced blood pressure in more than eighty percent of patients (Bayan *et al.,* 2014). Eating a clove of garlic a day was associated with cholesterol levels dropping about nine percent. It may also boost the immune system, balance blood sugar and prevent heart disease. It also prevents heart disease in two ways: by reducing free radicals that cause damage to cholesterol and by inhibiting the infiltration of damaged fats and cholesterol through the wall of our arteries (Nelson, 2019).Garlic is rich in sugar, protein, fat, calcium, potassium, phosphorus, sulfur, iodine, fiber and silicon in addition it contains vitamins (Abdisa *et al.,* 2021).

2.3. Suitable Climatic and Soil conditions for Garlic Production

Garlic grows under different agro-climatic conditions and a variety of soil types. Ethiopia has diversified agro ecological conditions suitable for garlic production (Dessie and Mulat 2019). Preferring higher elevations ranging from 1800–2800 (m.a.s.l.) and temperatures12–24°C in soil having pH ranging from 6.0-8.4 (Betewulign *et al.* 2014, Shege *et al.,* 2017 and Amandeep *et al.,* 2017). But heavy black soil holds water during the rainy season and cracks during the dry season, it prevent bulb growth. However a good yield can be obtained by carefully irrigating the black vertisoil. Slightly decomposed soils are suitable for plants (Getachew *et al.*, 2019).

The ecological requirement of garlic is with reasonably mild winter regions which have some rainfall followed by a sunny dry summer, in good maturity and harvesting of the bulbs are ideal for garlic production. It is easily stressed by insufficient moisture and water logging during its growing period (Brewster, 1994).

2.4. Status, Potentials and Constraints of Garlic Production in Ethiopia

The annual national production and productivity of garlic are 178,221 tons and 9.18 ton ha^{-1}, which were produced on 19,412.5 hectares of land. The number of householders practicing garlic farming is likely to be 1,782,218.93 farmers, which are much less than that of grains or cereals crops (CSA, 2018). Ethiopia is ranked 13th in the world garlic production. But, the share of Ethiopian garlic to the world market is very small, only about (0.1%) from the total production (FAO, 2018). The yield differences showed by Ethiopia compared to the world average (18.42 t ha^{-1}) most likely reflect differences in technological resources and aspects related to the management of the crop, rather than to differences in genetic related and performance of the cultivars used.

Ethiopia is one of the countries in Africa which have enormous potential for the development of different varieties of horticultural crops such as, favorable agro-ecological conditions and natural resources, government policy encouragement, proximity to European and Middle Eastern markets and cheap labors which are suitable for the cultivation of horticultural products meanwhile, the farmers never reached its full potential for the production of garlic crop (Kassa, 2015).

However, small growers in the highlands grow garlic traditionally but due to obsolete cultural practices, yields are generally low Several factors are responsible for low garlic yield among which, major production constraints include lack of improved varieties, inappropriate agronomic practices, absence of proper pest and disease management practices and marketing facilities, and lower soil fertility status in many soil types (EIAR, 2007).

Ethiopian Institute of Agricultural Research (EIAR) which operates at federal level and regional agricultural institutes are working on the improvement of crop varieties including garlic however, much of their work is concentrated on grain crops than horticultural crops (DZARC, 2003). Garlic growers use their own saved planting material or purchase local varieties from market through informal planting material system; this influence garlic yield in terms of productivity and quality (Amsalu *et al.*, 2014).

2.5. The Role of Varieties on Garlic Yield and Yield Components

Variety selection plays an important role in enhancing the productivity of garlic (Yogesh, 2017). Apart from its adaptation, the variety should have high yield potential, tolerance to biotic and abiotic stresses, good marketability and high consumer preferences (Yemane *et al.*, 2017).

The character of yield reflects the performance of all plant components and might be considered as the end result of many others i.e. every plant contains an inherent physiological production capacity that operates on the energy required for normal plant performance through all accessions didn't have the same inherent physiological capacity to yield. Breeders commonly find yield to be a very complex array of plant component interactions and by the manipulation of those genetic systems as yield is improved as the result of plant efficiency improvement (Yemane *et al.,* 2017).

Garlic variety on morphological characters such as plant height and number of leaves per plant, fresh weight of leaves, root dry weight, yield attributing traits such as bulb diameter and the number of cloves per bulb and bulb yield has a significant difference (Rahman *et al.,* 2020). Its germplasm is diverse in Ethiopia and in recent years, the collection has been carried out by the Ethiopian Institute of Agricultural Research (EIAR) at Deberziet Agricultural Research Center (DZARC and screening trials were conducted on-station at Deberzeit (Yebirzaf *et al.,* 2018).

2.6. Response of Garlic to Fertilizer

Allium species including garlic have low nutrient extraction capacity than most plants because of their shallow and un-branched root system. Thus they require and frequently respond well to additional fertilizers application (Brewster, 1994). Fertilizer requirements of garlic crop vary with fertility status of the soil, availability of soil moisture, variety of the crop, purpose for which the crop is grown. Fertility status of the soils significantly affecting garlic crop yield (Diriba, 2016). Garlic requires intensive and complete fertilization system to obtain high yield and good quality (Nasef *et al.,* 2016).

2.6.1. Type and Characteristics of Blended Fertilizers.

Blanket fertilizer application recommendations regardless of differences in crop need soil types and agroecology. Fertilizer blending is a special type of fertilizer mixing; containing nitrogen (N), phosphorus (P), sulfur (S) and other essential plant nutrients. Where blended are prepared by the mechanical mixing of two or more granular materials of fairly uniform size and density in defined proportions. It originated in the USA and now dominates the fertilizer market in many countries (ATA, 2015).

The application of balanced fertilizers is the basis to produce more crops output from existing land under cultivation. Understanding the plant nutrients requirement of a given area has a vital role in enhancing crop production and productivity on a sustainable basis The main advantages of using blended fertilizer for the farmers are: Nutrients are supplied in ratios to suit the requirement of particular soils and crops, the cost per unit of plant nutrient is usually low and the cost of transportation and spreading is low because of the high analysis of bulk blends (ATA, 2015).

Indicating that the particular amount of fertilizer to use depends on soil fertility, crop variety and fertilizer use efficiency of the variety. Recently acquired soil inventory data from Ethiopian Soil Information System (Ethio-SIS) revealed that additionally to N and P, nutrients like S, B, and Zn are deficient in most soils of Ethiopia(ATA, 2015).

2.6.2. Response of Garlic for NPS Fertilizers

Application of inorganic N, P and S fertilizers significantly influenced the growth of plant height, leaf number, neck diameter and leaf area index of garlic, and better performances of those attributes at rates of 92 kg N, 40 kg P and 30 kg S ha^{-1} (Diriba *et al.,* 2016).

Experiment conducted on garlic varieties treated by NPS fertilizer showed that significant difference for growth parameters (Bewuket, 2021). Nitrogen (N) and phosphorus (P) are referred to as the primary macronutrients because of the probability of being deficient in plants and their large quantities are taken up from the soil relative to other essential nutrients (Murphy, 1995).

Kakara *et al.,* (2002) reported that the effects of nitrogen on the growth and yield performance of garlic and similar vegetables are reported by researchers in many parts of the world. It affects mostly vegetative growth like plant height, leaf count and area, fresh and dry weight of garlic plants. Bulb yield of garlic could be a complex parameter that's resulted from the interaction of various yield components like bulb length, bulb diameter, number of cloves and single bulb weight which are also affected by nitrogen fertilizer. Appropriate nitrogen fertilizer rates are very significant factor to increase the productivity, bulb quality and marketability of garlic (Tadesse, 2015).

In the study conducted by Zaman *et al.*, (2011) indicated that all yield components of garlic were positively affected by the application of nitrogen up to 200 kg/ha. However, the mean values of most yield components obtained from garlic plots treated with 150 kg/ha and 200 kg/ha nitrogen was statistically similar. Similarly, maximum bulb yield of garlic was obtained from plants that were supplied with 150 kg/ha nitrogen. Yield as well as yield components was at a low level in garlic plants that were not supplied with nitrogen fertilizer.

Phosphorus had a significant influence on the number of leaves per plant and bulb yield of garlic. It was reported that leaf per plant and bulb yield had significantly affected by the interaction effect of N and P (Abreham *et al.,* 2014).

The outcome of N and P fertilizer application on the performance of different garlic varieties suggested that both the fertilizer type significantly enhanced plant height, produced the marketable and total bulb yield. As reported by (Shamim *et al.,* 2018) maximum bulb yield had recorded garlic treated at 200 kg ha^{-1} of N and K from the different rate of application.

Sulfur application in garlic also enhanced the uptake of N, P, K, and Ca by the crop. It has a very important role of plant protein synthesis and some hormone formation (Abraha *et al.,* 2015). It is also necessary for enzymatic action, chlorophyll formation, and synthesis of certain amino acids and vitamins, hence it helps to have good vegetative growth leading to get high yield (ElShafie *et al.*, 2002). Sulphur plays an important role in plants' growth and development. The mean bulb yield of garlic increased significantly with successive increases in the level of Sulphur up to 25mg kg^{-1}. The plant height, the number of leaves per plant and chlorophyll content of leaves increased significantly up to application of Sulphur 60 kg ha^{-1} (Kavita, 2015). The garlic yield attribute namely the average weight of clove, the average weight of bulb and bulb yield/plot and bulb yield/hectare increased significantly with the application of Sulphur (Choyal *et al*., 2022).

2.6.3. Response of Garlic for Boron Fertilizer

Boron is an essential micronutrient required for normal plant growth and development (Rashid *et al.,* 2019). Boron applications at higher levels (4 kg/ha) significantly improved total soluble solid, Sulphur uptake, boron uptake, total chlorophyll content and volatile oil content of garlic bulbs as compared to lower levels of boron. This might have been caused by increased production of carbohydrates during photosynthesis due to increased uptake of nutrients by crops and photosynthates might have been translocating from leaves to the bulb.

2.6.4. Response of Garlic for Zinc Fertilizer

Zinc application markedly increased the number of cloves per bulb and weight of the cloves (Shukla *et al.,* 2018).It is involved in a diverse range of enzymatic system, auxin metabolism, influence on the activities of dehydrogenase and carbonic anhydrate enzymes, synthesis of cytochrome and stabilization or ribosomal fractions (Rashid *et al.,* 2019). Zinc is essential for the regular growth, development and reproduction of plants. Furthermore, the application of zinc was found to increase the green pigments of necrotic leaf of plants (Trivedi *et al*., 2013). Application of zinc significantly influenced the plant height, number of clove/bulb, bulb weight, 100-clove weight and bulb yield of garlic. Yield per unit area was also remarkably influenced by the application zinc fertilizers. The highest bulb yield (6.84 t ha^{-1}) was obtained with the application of 2 kg Zn perhactar which was 11.2 t/ha^{-1} higher than the control (6.15 t ha^{-1}) (lslam *el al.,* 2012). Biochemical pathways affected by Zn in plants include protein synthesis, hormone regulation and energy production.Zinc, copper, boron and molybdenum played an important role in increasing the growth and bulb yield of garlic (Yousuf *et al.,* 2016).

Micro minerals (Zn and Fe) supplementation played a vital role in enhancing the growth, yield and quality of garlic (Alam *et al.,* 2019). Zinc helped in the translocation of constituents from one part to the other. Zinc application markedly increased the number of cloves bulb and weight of cloves. The improvement in weight and number of cloves might be due to increase in size and weight of bulb under the influence of zinc, which might be due to rapid transformation and storage of food material in the bulb which ultimately increased the number of cloves bulb and weight of cloves. The improved vegetative growth of plant and yield attributing characters due to zinc application and has also direct relation in improvement of bulb development and increase in bulb yield (Uzma *et al.,* 2016). The application of zinc and potassium significantly influenced the uptake of Zn and K by garlic. It is an essential component and activator of many enzymes involved in auxin biosynthesis and photosynthesis (Sakarvadia *et al.,* 2009). Micro minerals Zn 5 kg ha^{-1} supplementation played a vital role in enhancing the growth, yield and quality of garlic (Shariq *et al.,* 2019).

3. MATERIALS AND METHODS

3.1. Description of the study area

A field experiment was conducted in Mihur Aklil Woreda, Yasinawra Kebele under rain fed condition during the main cropping season of 2023 G.C. The area is located at 215 km away from Addis Ababa to Jimma road in a south-west direction to the Gurage Zone and 37^0 52' 00" to 38^0 18' 00" E latitude and 8^0 7 00" to 8^0 20' 00" N longitude and an elevation ranges from 1712 to 3467 meter above sea level (Sahle, 2018). The administrative capital of the district is Hawariat town that shares borders with Meskan woreda in East, Kebena woreda in West, Kokir-Gedebano woreda in North, and Eza woreda in the southwest (Mengistu, 2016).

The agro-climatic zones account for 53% is Sub-tropical (Woina Dega) and 47% high land (Dega) having an altitude ranges 1712-2500m and 3301-3467m respectively (Sahle, 2018). The specific location for the experiment (Yasinawra) is founded in the highland range where the altitude is 2850 to 2482m. The average annual rainfall of the area is between 1000mm to 1400mm. The maximum and minimum annual average temperature of the area is 22 ^oC and 11 ^oC respectively (Mesfin 2018).

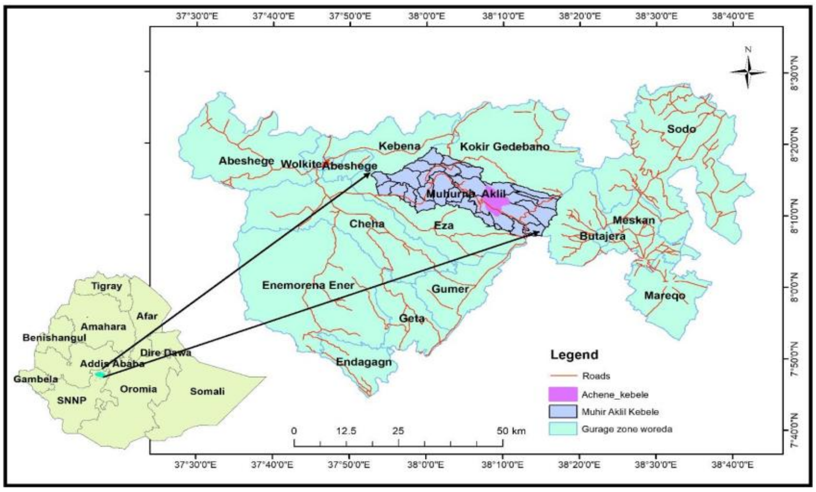

Figure 1: Location map of the study area (EMA, 2020)

3.2. Experimental Materials

3.2.1. Planting Materials

Four nationally released garlic varieties Chefe (G-104-1/94, Kuriftu (G-59-2/94), Holeta (G-HL),) and Tsedey 92 which are obtained from Deberziet Agricultural Research Centre and one local variety (“Tumma”) where obtained from Farmers of study area used for the experiment.

Table 1: Description of the four improved garlic varieties and one local check selected for the study.

No	Varieties	Optimum Altitude (m.a.s.l.)	Average productivity on farmer filed qt./ha	Year of Released	Breeder /Maintainer
1	Local “Tumma”	>2500	83	-	Farmers of study area
2	Chefe(G-104-1/94)	>1800	65.9	2015	DzARC
3	Kuriftu (G-59-2/94)	2100 – 2400	41	2010	DzARC
4	Holeta (G-HL)	>1800	66.5	2015	DzARC
5	Tsedey 92(G-493)	1900 – 2400	85	1999	DzARC

Source: Deberzeit Agricultural Research Center (EIAR, 2019).

3.2.2. Fertilizers

The fertilizers used for the experiment were: Blended NPS fertilizer (19.0% N, 38.0% $P_2O_5$and 7% S); Blended NPSB fertilizer (18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B); and Blended NPSZn fertilizer (18%N, 35.9% P_2O_5, 7.7% and S, 2.2% Zn)

3.3. Treatments and Experimental Design

The experiment covered a total area of 243.6 m^2 (43.5 m*5.6 m). The treatments were arranged in Randomized Complete Block Design (RCBD) with three replications under factorial arrangement. Each block contained 20 plots with randomized treatments. The size of each plot was 2.04 m^2 (1.7 m * 1.2 m). The spacing between plots was 0.5m and 1.0m between block. Each plot accommodated four single rows with 17 plants in each row and a total of 68 plants. As shown under Table 2 below, the experiment had a total of 20 treatment combinations and with a total of 60 experimental units (plots). The treatments consisted of improved and one local varieties of garlic, three blended fertilizer types(containing five nutrients, i.e. N, P, S, B, and Zn) and one control (without fertilizer).

Table 2: Treatment combinations and their adjusted fertilizer rate

Treatment	Blended fertilizer rate (kg/ha)	Varieties used	Calculated/adjusted elemental composition of the fertilizer rates (kg/ha)				
			N	P_2O_5	S	B	Zn
T1 control	-	Local “Tumma”	-	-	-	-	-
T2 control	-	Chefe	-	-	-	-	-
T3 control	-	Kuriftu	-	-	-	-	-
T4 control	-	Holeta	-	-	-	-	-
T5 control	-	Tsedey 92	-	-	-	-	-
T6NPS	242	Local Nech	105.75	91.96	16.94	-	
T7NPS	242	Chefe	105.75	91.96	16.94	-	
T8NPS	242	Kuriftu	105.75	91.96	16.94	-	
T9NPS	242	Holeta	105.75	91.96	16.94	-	
T10NPS	242	Tsedey 92	105.75	91.96	16.94	-	
T11NPSB	245.8	Local Nech	105.64	92.36	17.02	0.25	-
T12NPSB	245.8	Chefe	105.64	92.36	17.02	0.25	-
T13NPSB	245.8	Kuriftu	105.64	92.36	17.02	0.25	-
T14NPSB	245.8	Holeta	105.64	92.36	17.02	0.25	-
T15NPSB	245.8	Tsedey 92	105.64	92.36	17.02	0.25	-
T16NPSZn	256	Local Nech	105.88	91.9	19.71	-	5.632
T17NPSZn	256	Chefe	105.88	91.9	19.71	-	5.632
T18NPSZn	256	Kuriftu	105.88	91.9	19.71	-	5.632
T19NPSZn	256	Holeta	105.88	91.9	19.71	-	5.632
T20NPSZn	256	Tsedey 92	105.88	91.9	19.71	-	5.632

3.4. Experimental Procedure and Management

The experimental field was ploughed and harrowed to prepare fine seedbeds before planting. Raised beds were then prepared with 20cm height from the ground level in order to provide good soil drainage, reduce soil compaction, etc. (Muluken, 2021). Subsequently, the cloves were planted in each plot at a depth of 5cm across the single rows with intra-row spacing of 10cm and inter-row spacing of 30cm as commonly used in Ethiopia (MoA, 2019).

Healthy and uniform medium-sized cloves (2g) that were nationally recommended (Bizuayehu *et al.*, 2021) used as planting materials. Planting was carried out during the main rainy season of 23 June 2022. The blended fertilizers were applied at the time of planting using the banding method as recommended by Betewulign *et al. (*2014) but top-dressing of Urea is in two splits. 1st top-dressing is a week after emergence while 2nd top-dressing is 4 weeks after 1st application (MoA, 2019). All other necessary agronomic and management practices such as cultivation and weeding were applied uniformly across all plots of the experiments as stated in the DZRC (EIAR) record sheet. Finally, harvesting was carried out when75% of the tops of the plants were dried out and collapsed (Abdisa, 2021).

3.5. Data Collected

3.5.1. Soil sampling and analysis

The soil sample was collected before planting diagonally along the cross-section of the experimental site using the auger at a depth of 30cm from six spots. The total Nitrogen (mg/kg ppm), Phosphrous (mg/kg (ppm) and the available of Zinc (mg/kg (ppm). Organic matter (%), soil pH, Cation Exchange Capacity (CEC) and soil texture were determined in Wolkite Soil Laboratory. Soil pH was measured in 1:2.5 soil water ratio using an electrode pH meter, organic carbon content of the soil was determined by Walkley and Black method (Walkley and Black, 1934), available phosphorus was estimated following the standard procedure of (Olsen *et al.*, 1954) and total nitrogen was estimated by the Kjeldahl method (Jackson, 1958). The available Zn in soils is extracted using a chelating agent DTPA (diethylenetriaminepentaacetic acid) (Lemma *et al.*, 2021).

3.5.2. Growth and yield parameters

3.5.2.1. Phenological parameters

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

- **Days to maturity**: The number of days from planting to maturity when 75% of the leaves of the plants in each plot become yellow, dry, and/or show senescence (Dickerson, 1999).

3.5.2.2. Growth parameters

- **Plant height (cm):** is the mean vertical length from the base of the pseudo stem up to the tip of leaf. It was measured from ten randomly selected plants from the two central rows by using ruler at physiological maturity from each plot.
- **Leaf length (cm)**: The average length of the longest leaf, at physiological maturity was measured in cm from the two central rows of ten randomly taken plants.
- **Leaf width (cm):** was measured from the two central rows of ten randomly taken plants per plot considering the widest part leaves and the average value recorded as width of single leaf.
- **Leaf number per plant**: number of healthy leaves was counted from the ten randomly plants in the central rows and the average value recorded as number of leaf per plant.
- **Leaf area index**: The average LAI was recorded from ten randomly taken plants from each plot; one leaf from each sample plant was measured at the widest part at the time of physiological maturity. It was determined using the value of the leaf area divided by the area of the land occupied by the plants using the formula leaf area index (LAI) = LAm× N/A.

  Where:

  (1) LAI= mean leaf area of the plant multiplied by N = number of leaves on the plant divided by the area (cm^2) occupied by one plant in the cropping area

  (2) Leaf Area (LA) = LA = LL*LW*0.733 Where: LAm = mean leaf area of the plant LL = leaf length LW = maximum leaf width 0.733 = conversion factor for leaf area.

3.5.2.3. Yield parameters

- **Bulb diameter (mm):** Bulb size was recorded at harvest and average bulb diameter measured from ten randomly taken garlic plants of two central rows using side caliper and the mean value was recorded and used for analysis.

- **Bulb length (cm):** It was measured at the basal end point from the bottom scar of the bulb to the tip point of the bulb using graduated caliper in cm from two central rows ten randomly selected plants after curing.
- **Bulb weight per plant (g):** The bulb fresh weight was measured from two central rows ten randomly taken bulbs and divided for the number of sampled plants and then expressed as bulb weight per plant after ten days curing.
- **Number of cloves per bulb:** the total number of cloves produced from two central rows ten randomly taken plants was counted and divided by the number of bulbs.
- **Average clove weight (g):** It was determined by weighting the cloves of ten bulbs harvested from the net plot area and dividing the weight by the total number of cloves.
- **Clove width (cm):** width of clove was measured at the widest point in the middle portion of the clove using graduated caliper in cm from the two central rows of ten randomly selected after ten days curing.
- **Total yield per hectare (t ha^{-1}):** total bulb yield of plants grown a plots was measured after bulbs were cured or exposed for ten days to sunlight. The yields obtained from plots were converted to hectare base.

$$\text{Yield per hectare in tones} = \frac{\text{Yield per net plot (kg) x } 10000 \text{ m}^2}{\text{Net area of the plot } (\text{m}^2) \text{ x1000kg}}$$

- **Marketable bulb yield per hectare (t ha^{-1}):** Bulbs which were free of mechanical damage, disease and insect pest damages, healthy, compact were considered as marketable bulb and the yield was calculated and expressed as tone per hectare using similar formula for total bulb yield
- **Unmarketable yield per hectare (t ha^{-1}):** bulbs which were defected, diseased, badly stained skins, and damaged, that did not acceptable by the market weighted and converted to tons per hectare as unmarketable bulbs.

3.5.3. Economic analysis (Partial Budget Analysis)

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

- **Gross Average Bulb Yield (kg ha^{-1}) (AvY):** is the average yield of each treatment.
- **Adjusted Yield (AjY):** is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers. AjY = AvY-(AvY-0.1).
- **Gross Field Benefit (GFB):** is computed by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield. GFB = AjY*field/farm gate price
- **Total cost:** is the cost of blended fertilizer used for the experiment. Their prices were based on 2014 price during planting. The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, crop protection and harvesting were assumed to remain the same or were insignificant among treatments
- **Net Benefit (NB):** is calculated by subtracting the total costs from gross field benefits for each treatment. NB = GFB – total cost.
- **Marginal Rate of Return (MRR %):** is calculated by dividing change in net benefit by change in cost which was the measure of increasing in return by increasing input.

3.6. Data analysis

All agronomic data were analyzed using analysis of variance (ANOVA) and the general linear model using SAS version 9.3 .Wherever treatment effects were significant at 5% probability level, the means were separated using Least Significant Difference (LSD) (Gomez and Gomez, 1984).

Correlation analysis was carried out using Pearson’s simple correlation coefficients for growth, yield and yield components of garlic as affected by, NPS, NPSB and NPSZn applications to garlic varieties.

4. RESULTS AND DISCUSSION

4.1. Soil Sample Analysis

The composite soil sample of the experimental site was analyzed for soil texture and chemical properties before planting. Based on the analysis results, the texture of the soil of the experimental site was clay loam based on the soil textural triangle of the International Society of Soil Science System (Rowell, 1994). The clay texture indicates a good deal of plant nutrients and supports most types of plants and crops.

The experimental site had a pH of 6.3, which is close to the neutral range (EthioSIS, 2013). Conferring to Landon (1991) soils having pH value in the range 5.5 to 7.5 is considered suitable for most agricultural crops. In addition, Bachmann (2001) indicated that pH in the range of 5 to 7.5 is favorable for garlic production. Hence, the pH of the experimental soil was within the range optimum for productive soil.

Soil organic matter content of before plant was 1.89 % (Table 3), which is medium according to Meron (2018), i.e. < 1% Very low, 1 – 2% Low, 2 – 4% medium, 4.2 – 6% High and > 6% Very high. The cation exchange capacity (CEC) of the soil was ranged from 28 meq/100g (Table 3). It is medium according to rating of (Egel *et al.*, 2014). 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.

Total nitrogen of the experimental soil was 0.12 (%) (Table 3), according to EthioSIS (2013) this value is low. The soil analysis result indicated that the need to apply N for garlic crop to get optimum yield and quality. The available phosphorus of the experimental soil was 16 (PPM). Hence, available Phosphrous of soil was categorized within optimum (160 ppm) which was based on the ranges rated by (Egel *et al.*, 2014).

The availability of sulfur in experimental soil was 7.5 (mpp). According to Bashour and Sayegh (2007) this value is very low. It indicate that how much precipitation an area receives, or at least how much water is running through the soil profile or if the sulfur is low, that means it's getting leached out. But he availability of zinc in experimental soil was medium 9.5 (mpp) (Lindsay and Norvell, 1978). The availability of boron in experimental soil was 0.5 (mpp) Where soil B levels are less than 0.5 mg kg soil–1, deficiency is likely to occur for most crops. However, where levels are greater than about 5.0 mg kg soil, toxicity may occur. Thus, there is a narrow range between sufficiency and toxicity levels (Lemma *et al.*, 2021).

The soil sample analysis results showed that the experimental site was deficient in some macro and micronutrients as shown in Table 3 below. This complies with the previous ATA (2014) report that the following seven soil nutrients are deficient in SNNPR (i.e. total nitrogen, available phosphorus, exchangeable potassium, available sulfur and extractable iron, zinc and boron). As reported by Tegbaru (2016), the soil critical point concept of P, K, S, Zn, Cu and B are considered deficient when they are respectively below 30, 190, 20, 0.5, 0.9, and 0.8 ppm; which confers with the present study results.

Table 3: Soil physicochemical properties of the study Site

Soil physical property	Value	Soil status	Reference
Clay (%)	36	-	-
Sand (%)	31	-	-
Silt (%)	33	-	-
Soil Texture	-	Clay loam	Rowell, (1994).
Soil chemical property			
Total N (%)	0.12	Low	EthioSIS (2013)
Available P (ppm)	16	Optimum	Egel *et al.*, (2014)
Available S (ppm)	7.5	Very low	Bashour and Sayegh (2007)
Available B (ppm)	0.5	Very low	Tegbaru (2016),
Available Zn (ppm)	9.5	Optimum	Lindsay and Norvell, (1978).
Organic matter (%)	1.89	Low	Meron (2018)
CEC meq/100g	28	Medium	Egel *et al.*, (2014).
pH	6.3	Moderately acidic	EthioSIS, (2013).

4.2. Phenological Parameters

4.2.1. Days to emergence

The analysis of variance showed that both the variety and blended fertilizer had highly significantly ($P<0.01$) influenced but their interaction effect had non-significant ($p<0.05$) effect on garlic days to 50% emergency (appendix table 1).

Tsedey-92 took 11.58 days to emerge 50% whereas the local variety “Tumma” took longest days (15.33) taking 3.75 days more than tsedey92 .On the other hand Chefe and Holeta varieties had statistically similar days to 50% emergence (table 4). These may due to genetic makeup of the different cultivars. Asrat *et al.*, (2015) who proved that variety had a highly significant effect on days to 50% emergence. And also it might be the day of harvesting and time to break their dormancy period varied.

Bewuket *et al.*, (2017) who observed, the main effect of variety and different forms of fertilizer significantly influenced days to emergence. However, the interaction effect of variety and different forms of fertilizer application did not significantly affected days to emergence of garlic.

The blended fertilizer types had also highly ($P<0.01$) significant effect on garlic days of emergence (appendix 1) and hence, the earliest day to emergence (12.10) was recorded by NPSB fertilizer followed by NPSZn (13.1). The latest day for emergence (15.10 was recorded from garlic plots with zero (0) fertilizer application (Table 4). This could be attributed to the impact of nitrogen on enhancing leaf and root formation during the earliest period of plant growth. Moreover, (Getachew and Temesgen. 2020) observed the earliest days to emergence at optimum fertilizer level is due to the role of phosphorous in root initiation

Table 4: Effects of varieties and blended fertilizers on days to 50% emergence of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping season

Variety	Days to emergence
Local (‘’Tumma’’)	15.33[a]
Chefe	14.25[b]
Kuriftu	12.25[c]
Holeta	13.50[b]
Tsedey	11.58[c]
LSD (0.05)	0.88**
Blended fertilizer	**Days to emergence**
0 (Without fertilizer)	15.06[a]
NPS	13.33[b]
NPSB	12.07[c]
NPSZN	13.07[b]
LSD (0.05)	0.78**
CV (%)	7.926776

Where: *Means represented with same letter(s) are not significantly different from each other ***

4.2.2. Days to maturity

Both the main of varieties and fertilizer types had a highly ($P<0.01$) significant effect While their interaction had non-significant ($p<0.05$) effect on days to maturity (Appendix Table 1).

Chafe and Holeta varieties were early matured taking 137.750 and 139.583 days respectively than the remaining varieties used for the experiment which were statistically similar for days to maturity (table 5). This may due to varieties have genetic variations that influence their growth and development and, adaptation to the environment resulting in different morphological and physiological senescence.

The result is also in agreement with the finding of (Dessie and Mulat 2019) and (Mulu *et al.* 2020), who reported that garlic varieties showed different days to maturity suggesting that the variation in maturity among the varieties might be due to their genetic differences. Days to maturity ranges from 127.4 to 140.4 days. Tsedey 92 took a long time of 140.4 days to mature, while the local variety took shorter days of 127.4 to mature. Also Ministry of Agriculture reported that reported that Tsedey takes 120 days, Kuriftu 140 days and Tsedey 138 days to maturity (MoA, 2019).

The earliest day to maturity (136.80) recorded when the plots were tread with zero fertilizer (control plot) whereas the prolonged day to maturity (146.67) was recorded when a treatment treated with NPSB blended fertilizer types. Though, it was statistically at par days to maturity in response to the rest blended fertilizer types (table 5). 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.

Delay in days to maturity with high levels of N could be attributed to delayed senescence of the canopy of the crop (garlic) and extended physiological activity and continuing in photosynthesis (Abreham *et al.*, 2014).

Table 5: Effects of varieties and blended fertilizers on days to 75% physiological maturity of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping seasons

Variety	Days to 75% physiological maturity
Local (''Tumma'')	144.58[a]
Chefe	137.75[b]
Kuriftu	147.08[a]
Holeta	139.58[b]
Tsedey	147.17[a]
LSD(0.05)	4.57*
Blended fertilizer	**Days to 75% physiological maturity**
0 (Without fertilizer)	136.80[b]
NPS	143.33[a]
NPSB	146.67[a]
NPSZN	146.13[a]
LSD(0.05)	4.08**
CV (%)	3.857164

Where: *Means represented with same letter(s) are not significantly different from each other*

4.3. Growth Parameters

4.3.1. Plant height (cm)

As observed from analysis of variance, plant height had highly significantly ($p<0.01$) influenced by both main effect but significantly ($p<0.05$) influenced on their interaction effects (Appendix Table 1).

The longest (77.8cm) plant height was recorded by Tsedey with NPSB type of blended fertilizer application followed by (72.2cm) of Tsedey variety treated with NPS type of blended fertilizer. Shortest plant height (48.389cm) was recorded by Holeta variety with zero (0) fertilizer application which, was statistically to Chefe variety treated with NPS type of blended fertilizer (Table 6). This might be due to the differences of the cultivars genetic constituted to respond to the applied fertilizer in enhancing meristematic elongation.

This result is in agreement with (Hassan *et al.,* 2015) who observed significant result of interaction effects cultivars and fertilizer types on plant height. Tadesse, (2015), also reported that cultivars had different plant height at different rates of nitrogen fertilizer.

Under his observation a wide range of variation was measured in plant height among different garlic varieties.

Table 6: Interaction effects of varieties and blended fertilizers on plant height (cm) of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping season

	Plant height (cm)			
Variety	0 (Without fertilizer)	NPS	NPSB	NPSZN
Local (‘’Tumma’’)	$53.53^{f\text{-}h}$	$62.78^{f\text{-}c}$	$66.5^{b\text{-}e}$	$58.38^{e\text{-}g}$
Chefe	$55.33^{f\text{-}h}$	53.44^{hg}	$65.39^{b\text{-}e}$	$64.67^{b\text{-}e}$
Kuriftu	$59^{f\text{-}c}$	$67.94^{b\text{-}d}$	$68.08^{b\text{-}d}$	68.5^{bc}
Holeta	48.39^{h}	$58^{e\text{-}g}$	$65.82^{b\text{-}e}$	$55^{f\text{-}h}$
Tsedey	$66.56^{b\text{-}e}$	72.19^{ba}	77.8^{a}	$69.42^{a\text{-}c}$
LSD(0.05)				9.28
CV (%)				8.95

Where: Means represented with same letter(s) are not significantly different from each other

4.3.2. Leaf length (cm)

Output from the analysis of variance indicated that the main effects of variety and the main effects of blended fertilizers and varieties showed that there is highly significant difference ($P<0.01$) while their interaction effect of variety and blende fertilizer was significantly ($P<0.05$) influenced leaf length of garlic plants (Appendix Table 1).

The highest leaf length (52.33cm) was recorded by the application of NPSB on Tsedey variety. It was statistically insignificant to the same variety treated with NPSZn (50.56cm). However, the smallest leaf length (34.83) was recorded from zero fertilizer application on Holeta variety. There was 50.02% higher than the smallest leaf length (34.833cm) Holeta variety of non-fertilized treatments but it was statistically similar to Chefe variety treated with without fertilizer (Table 7).

The higher leaf length at the Tsedey treated with NPSB and NPSZn blended fertilizer type may be due to the positive effect of nutrients in blended fertilizer especially boron and zinc on vegetative growth and leaf expansion .Similarly, it may be associated with the fact that nutrients in blended fertilizer is important for plant cell division, elongation, synthesis of chlorophyll, enzymes and proteins which are important for plant growth.

This result is in agreement with the findings of Ahmed *et al.,* (2007) who reported that availability nutrients that allowed young garlic plants to be more vigorous in their growth and development.

Table 7: Interaction effects of variety and blended fertilizers on leaf length (cm) of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping season

	Leaf length (cm)			
Variety	0 (Without fertilizer)	NPS	NPSB	NPSZN
Local (''Tumma'')	37.33^{h-f}	43.11^{b-f}	46.33^{d-a}	40.67^{h-c}
Chefe	35.56^{h}	36^{hg}	40.67^{h-c}	46^{e-a}
Kuriftu	40.22^{h-d}	42.56^{b-g}	47.11^{a-c}	46.33^{d-a}
Holeta	34.83^{h}	39.67^{e-h}	46.11^{e-a}	38.44^{h-f}
Tsedey	46.11^{e-a}	48.56^{ba}	52.33^{a}	50.56^{a}
LSD(0.05)				6.66
CV (%)				9.38

Where: Means represented with same letter(s) are not significantly different from each other

4.3.3. Leaf number/plant

Results of analysis of variance of this study indicated that both main effects variety and blended fertilizer showed very highly significant differences ($P<0.001$) in contrast to this their interaction effects were not significantly ($P<0.05$) influenced leaf number of garlic plants (Appendix Table 1).

The highest number of leaves (9.55) was recorded from Tsedey variety followed by (8.47) from Kuriftu variety but the lowest number of leaves (7.20) was recorded from Holeta cultivar. This significant difference may be due to the genetic difference of the varieties in their adaptation and growth performance.

The present experimental result is in line with that of Abera, (2015) he observed Variety showed significant difference on leaf number plant. The highest leaf number (10.9) was observed on the plot with the variety Tsedey however, the lowest leaf number (8.44) was observed in plot planted with the variety Chefe. The finding of (Ayalew *et al.,* 2015) stated that Varieties had significant effect on number of leaves per plants. Significantly highest number of leaves per plant was recorded from the local variety than Kuriftu and Tsedey 92

NPSB fertilizer enables to produce an increased number of leaves (9.05) followed by NPS fertilizer, it produces (7.97) numbers of leaves however 0 fertilizer application (without fertilizer) was given the smallest number of leaves (Table 8). Abera (2020) who reported that the highest leaf number was recorded from NPS rate of 305.5kg ha^{-1} (10.34) and the lowest leaf number (7.94) recorded from zero application respectively. 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.

Table 8: Effects of variety and blended fertilizers on leaf number/plant of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping season

Variety	Leaf number/plant
Local (''Tumma'')	7.33^{c}
Chefe	7.55^{c}
Kuriftu	8.47b
Holeta	7.20^{c}
Tsedey	9.55^{a}
LSD(0.05)	0.57**
Blended fertilizer	**Leaf number/plant**
0 (Without fertilizer)	7.27^{c}
NPS	7.97^{b}
NPSB	9.05a
NPSZN	7.77^{cb}
LSD(0.05)	0.52**
CV (%)	8.69

Where: *Means represented with same letter(s) are not significantly different from each other*

4.3.4. Leaf width (cm)

The main effects of variety and blended fertilizer, and their interaction showed a significant influence on leaf width (Appendix table 1).

The widest leaf width was recorded from the cultivar Tsedey (1.04cm) when the plant received NPSZn blended fertilizer followed by (1.02cm) Tsedey variety treated with blended NPS fertilizer. However, the smallest leaf width (0.56cm) was recorded from variety Holeta with no nitrogen fertilizer and from the cultivar Chefe (0.63s cm) when the variety is received no nitrogen fertilizer (Table 9). These results revealed that leaf width was more related to the function of genetic makeup in the cultivars and the application of fertilizer. Tadesse, (2015) stated that varieties and nitrogen rates showed highly significance differences of leaf width among the treatments.

Table 9: Interaction effects of variety and blended fertilizers on leaf width (cm) of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping season

	Leaf width(cm)			
Variety	0 (Without fertilizer)	NPS	NPSB	NPSZN
Local (''Tumma'')	0.82^{d-g}	0.89^{a-f}	0.89^{a-f}	0.88^{a-f}
Chefe	0.63^{hi}	0.69^{g-i}	0.73^{i-f}	0.78^{e-h}
Kuriftu	0.92^{e-a}	0.84^{c-f}	0.95^{d-a}	0.87^{b-f}
Holeta	0.57^{i}	0.72^{i-f}	0.89^{a-f}	0.73^{i-f}
Tsedey	1.01^{a-c}	1.02^{ba}	0.89^{a-f}	1.04^{a}
LSD(0.05)				0.18
CV (%)				12.18

Where: *Means represented with same letter(s) are not significantly different from each other.*

4.3.5. Leaf area (cm²)

The analysis of variance indicated that the main effects variety and blended fertilizer had very highly significant difference (P<0.001) while their interaction effects were also had significantly influenced (P<0.05) leaf area of garlic plants (Appendix Table 1).

The widest leaf area was recorded from the variety Tsedey ($38.81cm^2$) when the plant received NPSB blended type of fertilizer however the smallest leaf width ($17.52cm^2$) was recorded from variety Chefe with no fertilizer application which, was without significance difference between this varieties planted with NPS type of blended fertilizer (Table 10).

This might be due to the differences of the cultivars genetic constituted to respond to the applied fertilizer in enhancing meristematic elongation. This nutrients can promote healthy leaf growth and increased the leaf size of garlic plant by improve soil fertility and increase the availability of nutrients to the plants. This can lead to better nutrient uptake by the plants which can result in larger and healthier leaves.

Table 10: Interaction effects of variety and blended fertilizers on leaf area (cm2) of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping season

	Leaf area (cm^2)			
Variety	0 (Without fertilizer)	NPS	NPSB	NPSZn
Local (''Tumma'')	23.96^{g-c}	28.16^{f-b}	30.35^{d-a}	28.80^{f-b}
Chefe	17.52^{h}	18.40^{gh}	22.16^{d-h}	27.15^{g-c}
Kuriftu	28.57^{f-e}	26.72^{g-c}	31.54^{a-c}	29.47^{b-e}
Holeta	19.84^{f-h}	20.88^{e-h}	28.67^{f-e}	20.81^{e-h}
Tsedey	31.72^{a-c}	36.91^{ba}	38.81^{a}	38.7^{a}
LSD(0.05)				9.04
CV (%)				19.91

Where: *Means represented with same letter(s) are not significantly different from each other*

4.3.6. Leaf area index (LAI)

The analysis of variance revealed that the main effects blended fertilizer showed highly significant difference (P<0.001) while the main effect of variety and their interaction effects were significantly (P<0.05) influenced leaf area of garlic plants (Appendix Table 1).

Variety Tsedey resulted in significantly higher leaf area index of (1.25) from application of NPSB type of blended fertilizer, which was 267.64% higher than the leaf area index of garlic variety Holeta treated without fertilizer. But it was statistically similar to some other treatment combinations. However the smallest leaf area index (0.34) of garlic was recorded Holeta variety planted without fertilizer, which was statistically similar with Chefe variety (0.38) planted without fertilizer (Table 11).

The increase in leaf area index with blended fertilizer may due to the fact that fertilizer greatly increases leaf area by delaying leaf, sustained leaf photosynthesis and extended leaf area, which ultimately resulted in maximum leaf area index. (Fikru and Fikreyohannes. 2020) stated that Leaf area index was significantly affected by application of N. Nitrogen supplement at a rate of 130 kg ha-1 increased leaf area index of garlic by 71.6% compared to control. Similarly Abreham *et al.*, (2014) stated that in all the sampling periods, the highest values of LAI were recorded at 150 kg N ha-1 and the lowest from the control.

Table 11: Interaction effects of variety and blended fertilizers on Leaf area index (LAI) of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping season

	Leaf Area Index (LAI)			
Variety	0 (Without fertilizer)	NPS	NPSB	NPSZn
Local (''Tumma'')	0.50[e-h]	0.66[g-d]	0.84[b-d]	0.63[d-h]
Chefe	0.37[gh]	0.45[f-h]	0.63[d-h]	0.71[fedc]
Kuriftu	0.71[f-c]	0.771[b-e]	1.04[ba]	0.78[b-e]
Holeta	0.34[h]	0.48[e-h]	0.85[b-d]	0.49[e-h]
Tsedey	0.96[a-c]	1.25[a]	1.20[a]	1.15[a]
LSD(0.05)				0.30
CV (%)				24.80

Where: *Means represented with same letter(s) are not significantly different from each other*

4.4. Yield and yield components

4.4.1. Bulb diameter (mm)

The analysis of variance revealed that both the main effect variety and fertilizers show very highly significant ($P<0.001$) influence on bulb diameter however their interaction effect was significant at ($P<0.05$ (Appendix Table 2).

So Tsedey variety treated with NPSB type of blended fertilizer resulted in significantly widest (24.2733mm) bulb diameter followed by this variety treated with NPSZn types of blended fertilizer (24.1367mm). In contrast to this the narrowest bulb diameter (17.2400mm) was recorded from Chefe variety when it is treated without fertilizers. It was statistically insignificant with Holeta variety when it planted without fertilizer. (Table 12)

This significant difference on garlic bulb diameter might have attributed 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. Additionally, boron stimulate the enzymatic actions and chlorophyll formation which might increase bulb size of garlic

Also in agreement with this finding, Abera, (2020) recorded the widest bulb diameter (5.1 cm) was recorded from the variety Tsedey treated by fertilizer treatment level of 305.5 kg ha^{-1} NPS fertilizer however, narrowest bulb diameter (2.11 cm) was recorded from the unfertilized Chefe variety.

Table 12: Interaction effects of variety and blended fertilizers on bulb diameter (mm) of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping season

	Bulb diameter (mm)			
Variety	0 (Without fertilizer)	NPS	NPSB	NPSZn
Local (''Tumma'')	18.28^{k-i}	18.95^{g-k}	20.41^{d-h}	20.25^{e-i}
Chefe	17.24^{k}	18.48^{k}	19.74^{f-j}	19.82^{f-j}
Kuriftu	19.62^{g-j}	20.88^{g-c}	22.67^{a-c}	22.22^{b-e}
Holeta	17.98^{kj}	19.87^{f-j}	21.41^{f-c}	20.26^{e-h}
Tsedey	21.25^{f-c}	22.27^{b-d}	24.27^{a}	24.13^{ba}
LSD(0.05)				1.9868*
CV (%)				5.862765

Where: *Means represented with same letter(s) are not significantly different from each other*

4.4.2. Mean bulb weight

Both the main effects of garlic variety and blended fertilizer had very highly significantly (P<0.001) influenced but their interaction effect was significant at (P<0.05) influenced the bulb weight of garlic (Appendix Table 2).

Tsedey variety treated with NPSB type of blended fertilizer resulted in maximum (37.27g) bulb weight then the next maximum bulb weight (36.87g) obtained from Kuriftu variety when it was planted with NPSB type of blended fertilizer. However, the smallest average bulb weight (29.40g) was recorded from Chefe variety without fertilizer, which was statistically insignificant with Chefe variety with NPS type of blended fertilizer (Table 13). This could be recognized 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 photosynthetic assimilate production and allocation to the bulbs.

4.

Abraha *et al.,* (2015), In agreement with the current experimental result, variety Tsedey with produced significantly highest average bulb weight of 35.74 g at the rate of 242 kg ha^{-1} NPS blended fertilizer. On the other hand, variety Chefe with 0 kgha^{-1} NPS rate gave the lowest average bulb weight of 5.22 g.

5.

Table 13: Interaction effects of variety and blended fertilizers on Average bulb weight (g) of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping season

	Bulb weight (g)			
Variety	0 (Without fertilizer)	NPS	NPSB	NPSZN
Local (''Tumma'')	31.92^{i-f}	33.24^{g-f}	34.65^{a-f}	34.25^{b-f}
Chefe	29.4^{i}	30.03^{i}	30.54^{g-i}	30.40^{hi}
Kuriftu	33.74^{ef}	33.60^{ef}	36.88^{ba}	36.25^{e-a}
Holeta	33.18^{h-f}	33.88^{e-f}	34.55^{a-f}	34.06^{c-f}
Tsedey	34.69^{a-f}	36.69^{d-a}	37.27^{a}	36.81^{a-c}
LSD(0.05)				2.8156*
CV (%)				5.03882

Where: *Means represented with same letter(s) are not significantly different from each other*

4.4.3. Clove weight

The analysis of variance revealed that the main effects blended fertilizer and varieties showed significant difference (P<0.001) while their interaction effect were significantly (P<0.05) influenced clove weight of garlic plants (Appendix Table 2).

In light of this, variety Kuriftu resulted in significantly maximum (2.70g) from application of NPSZn type of blended fertilizer, which was statistically insignificant with Tsedey variety treated by NPSZn types of blended fertilizer. But it was statistically similar to some other treatment combinations. However the smallest clove weight (1.88g) of garlic was recorded Holeta variety planted without fertilizer, which was statistically similar with local "Tumma" variety (1.9567g) planted without fertilizer (Table 14). Similarly this might be increased photosynthetic assimilate production and allocation, thereby increasing partitioning of assimilate to the storage organ (cloves).

The finding of Abera, (2020) indicate that Varieties and NPS blended fertilizer had significant effect on average clove weight. The highest average clove weight (2.98 g) was recorded by cultivar Tsedey at 242 kg ha-1 NPS. On the other hand, the lowest average clove weight of 0.44 g was recorded from unfertilized Chefe.

Table 14: Interaction effects of variety and blended fertilizers on Average clove weight (g) of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping season

	Clove weight (g)			
Variety	0 (Without fertilizer)	NPS	NPSB	NPSZn
Local (''Tumma'')	1.9567^{ji}	2.2037^{h-e}	2.24^{h-d}	2.44^{d-c}
Chefe	2.03^{h-j}	1.96^{ji}	2.11^{f-i}	2.37^{e-c}
Kuriftu	2.07^{j-g}	2.26^{d-g}	2.44^{d-c}	2.70^{a}
Holeta	1.8867^{j}	2.25^{h-d}	2.28^{d-g}	2.39^{e-c}
Tsedey	2.14^{f-i}	2.33^{f-c}	2.51^{a-c}	2.64^{ba}
LSD(0.05)				0.22
CV (%)				5.90

Where: *Means represented with same letter(s) are not significantly different from each other*

4.4.4. Number of cloves

The analysis of variance revealed that the main effects variety and blended showed a very highly significant difference (P<0.001) influenced the number of cloves/plants. Despite their interaction effect variety and blended fertilizers were not significantly (P >0.05) influence the number of cloves (Appendix Table 2).

Consequently, the maximum average clove number (15.98) was recorded from Kuriftu variety followed by (14.65) from Tsedey 92. On the other hand the smallest average clove numbers (12.94) were recorded from Chefe cultivar and Holeta varieties (13.69). Then again the largest average clove numbers (14.94) were observed on garlic plants planted at blended NPSB fertilizer followed by blended NPSZN fertilizer (14.63). Whereas garlic varieties are planted without fertilizer gives the smallest clove number (13.19) (Table 15). The variation in number of cloves per bulb of garlic variety might be attributed to genetic difference among the varieties.

This finding is supported with the results of (Abara *et al.,* 2015), application of combined fertilizers and compost significantly increased number of cloves per bulb of garlic over control in both seasons. The maximum numbers of cloves per bulb (8.69 in 2012/2013 and 11.0 in 2013/2014) were recorded in plots fertilized with N, P, S, and Zn nutrients while the minimum values (4.48 in 2012/2013 and 4.60 in 2013/2014) were recorded in plants where no fertilizers was applied.

Table 15: Effects of variety and blended fertilizers on Average number of cloves/bulb of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping season

Variety	Number of cloves/bulb
Local (''Tumma'')	13.81[cb]
Chefe	12.94[c]
Kuriftu	15.98[a]
Holeta	13.69[c]
Tsedey	14.65[b]
LSD(0.05)	0.94**
Blended fertilizer	**Numbers of cloves/bulb**
0	13.19[c]
NPS	14.09[b]
NPSB	14.94[a]
NPSZN	14.63[ba]
LSD(0.05)	0.84**
CV (%)	8.03

Where: *Means represented with same letter(s) are not significantly different from each other*

4.4.5. Total bulb yield (t ha^{-1})

Both the main effect of variety and blended fertilizer influenced highly significantly (P<0.001) the Total bulb yield of garlic. However, their interaction effect variety and blended fertilizers were significantly (P <0.05) influenced the Total bulb yield of garlic (Appendix Table 2).

The highest total bulb yields (17.08t ha^{-1}) and (16.76 ha^{-1}) were obtained from Tsedey 92 and Kuriftu varieties treated with NPSB types of blended fertilizer respectively, while, the lowest total bulb yield (9.09 t ha^{-1}) was recorded from Chefe variety planted without fertilizer and (10.63t ha^{-1}) from Holeta variety which was treated without fertilizers (Table 16). The highest total bulb yield recorded from large improved garlic variety planted with blended fertilizer might be due to an genetic potential of variety and blended fertilizer provide optimum nutrient for the plant yield and yield components (Table 16).

Similar to the present result, Abera, (2020) reported that the highest total bulb yield of 12.9 t ha^{-1} was recorded from the variety Tsedey at 242 kg ha^{-1} NPS blended fertilizer treatment level. However, the lowest yield (1.87 t ha^{-1}) was accrued from unfertilized Chefe variety.

Table 16: Interaction effects of variety and blended fertilizers on total bulb yield (t ha-1) of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping season

	Total bulb yield (t ha^{-1})			
Variety	0 (Without fertilizer)	NPS	NPSB	NPSZn
Local (''Tumma'')	11.34^{l-j}	12.92^{-g}	14.10^{ef}	12.73^{i-g}
Chefe	9.09^{m}	11.04^{lk}	13.02^{i-f}	12.05^{i-k}
Kuriftu	12.76^{i-g}	14.42^{ed}	16.77^{ba}	15.77^{bc}
Holeta	10.63^{l}	12.21^{h-j}	13.35^{e-h}	12.82^{i-g}
Tsedey	13.70^{e-g}	15.32^{dc}	17.09^{a}	15.95^{a-c}
LSD(0.05)				1.16*
CV (%)				5.28

Where: *Means represented with same letter(s) are not significantly different from each other*

4.4.6. Marketable bulb yield (t ha^{-1})

The analysis of variance shows that both the main effect of variety and blended fertilizer influenced highly significantly (P<0.001) the marketable bulb yield of garlic. However, their interaction effect variety and blended fertilizers were significantly (P<0.05) influenced the marketable bulb yield of garlic (Appendix Table 2).

Based on these, the highest marketable bulb yield (14.94 t ha^{-1}) was recorded from Tsedey 92 variety treated with NPSB type of blended fertilizer and (14.65t ha^{-1}) achieved by Kuriftu cultivar which was treated with NPSB type of blended fertilizer. Still, the lowest marketable bulb yield (7.95t ha^{-1}) was recorded by Chefe variety when it was planted without fertilizer and (9.28) t $ha^{-1}$was recorded by Holeta variety when it was planted without fertilizer (Table 18).

This significant difference on marketable bulb yield might have attributed to the synergistic role played by the three nutrients in providing balanced supply of nutrients to the crop and due to variation in yield potential of varieties.

In agreement with the current experimental result, Abera (2020) reported that the variety Tsedey with produced the significantly highest marketable bulb yield of 12.9 t ha^{-1} from application of 242 kg ha^{-1} NPS blended fertilizer. The lowest (1.02 t ha^{-1}) was observed from unfertilized Chefe variety.

Table 17: Interaction effects of variety and blended fertilizers on Marketable bulb yield (t ha-1) of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping season

	Marketable bulb yield (t ha^{-1})			
Variety	0 (Without fertilizer)	NPS	NPSB	NPSZn
Local (''Tumma'')	9.92^{L-j}	11.28^{i-g}	12.31^{ef}	11.12^{i-g}
Chefe	7.95^{m}	9.64^{Lk}	11.37^{i-f}	10.53^{i-k}
Kuriftu	11.13^{i-g}	12.60^{ed}	14.65^{ba}	13.77^{c}
Holeta	9.28^{l}	10.66^{h-j}	11.67^{e-h}	11.21^{i-g}
Tsedey	11.96^{e-g}	13.38^{dc}	14.94^{a}	13.93^{a-c}
LSD(0.05)				1.01*
CV (%)				5.26

Where: *Means represented with same letter(s) are not significantly different from each other.*

4.4.7. Unmarketable bulb yield (t ha^{-1})

Both the main effect of variety and blended fertilizer influenced significantly (P<0.001) the unmarketable bulb yield of garlic. However, their interaction effect none significantly (P >0.05) influence the unmarketable bulb yield of garlic (Appendix Table 2).

The highest unmarketable bulb yield (1.99t ha^{-1}) of garlic was achieved by Tsedey 92 variety whereas the lowest unmarketable bulb yield (1.34t ha^{-1}) was recorded by local “Tumma” variety. The highest unmarketable bulb yield (1.97t ha^{-1}) recorded from NPSB type blende fertilizer application statistically similar NPSZn fertilizer (1.76 t ha^{-1}). In contrast to this the lowest unmarketable bulb yield (1.23t ha^{-1}) was recorded plants treated without fertilizer and (1.70t ha^{-1}) from NPS types of blended fertilizer (Table 18). This may be related to the variety of garlic been grown like poor growing condition, bulb splitting (some varieties in particular Tsedey prone to bulb splitting, which can result in smaller and unmarketable bulb).

Abera, (2020) who stated that 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 18: Effects of variety and blended fertilizers on Unmarketable bulb yield (t ha-1) of garlic in Yasinawra Kebele of Mihur-Aklil Woreda, Gurage Zone, 2022/23 cropping season

Variety	Unmarketable bulb yield (t ha^{-1})
Local (''Tumma'')	1.34^{d}
Chefe	1.63^{bc}
Kuriftu	1.84^{bc}
Holeta	1.54^{dc}
Tsedey	1.99^{a}
LSD(0.05)	0.44**
Blended fertilizer	**Unmarketable bulb yield (t ha^{-1})**
0 (Without fertilizer)	1.23^{c}
NPS	1.71^{b}
NPSB	1.97^{a}
NPSZN	1.76^{ba}
LSD(0.05)	0.21**
CV (%)	17.39

Where: *Means represented with same letter(s) are not significantly different from each other*

4.5. Correlation coefficient of yield and yield components of garlic varieties and types of blended fertilizers

The correlation between growth and yield parameters of garlic as influenced by variety and blended fertilizer was computed to measure the relationship between any two parameters as explained by Gomez and Gomez (1984). Accordingly, the total bulb yield of garlic was a positive and significant relation with Physiological maturity (r=0.7295**), plant height (r= 0.600**), leaf length (r= 0.672**), leaf width (r= 0.636**), leaf number (r= 0.6417**), leaf area (r= 0.631**), leaf area index (r= 0.7268**), bulb diameter (r= 0.8051**), bulb weight (r= 0.79**), clove number (0.69**), clove width (r= 0.483**) and marketable bulb yield (r= 0.875**). Whereas, the day to emergency(r= -0.6377**) and unmarketable bulb yield (r= -0.08**) of garlic were highly and negatively correlated with total tuber yield.

Marketable bulb yield also showed a positive and highly significant relationship with all growth and yield parametric data except day to emergency, it was a negative and highly significant relation with marketable bulb yield (Table19).

Hence, it increases the photosynthetic efficiency of the plant for the production of photosynthetic assimilates which increased mean bulb diameter and weight. Generally, improving the plant height, diameter and weight of bulbs and clove weight by manipulating the variety and blended fertilizer helps to increase marketable bulb yield of garlic.

Table 19: Correlation coefficient among yield and yield Components of garlic varieties as influenced by different types of blended fertilizers

Parameters	DE	PM	PH	LL	LW	LN	LA	LAI	BD	BW	CN	CW	MBY	UMBY	TBY
DE	**1**														
PM	-0.6188**	1													
PH	-0.4800**	0.5894**	1												
LL	-0.5179**	0.6350**	0.654**	1											
LW	-0.3912ns	0.5901**	0.521**	0.762**	1										
LN	-0.6036**	0.6591**	0.702**	0.774**	0.6514**	1									
LA	-0.4301ns	0.5576**	0.500**	0.836**	0.9295**	0.66953**	1								
LAI	-0.5748**	0.6900**	0.649**	0.906**	0.8697**	0.89954**	0.9**	1							
BD	-0.7546**	0.7234**	0.666**	0.647**	0.6272**	0.74821**	0.635**	0.7683**	1						
BW	-0.5110**	0.6664**	0.500**	0.584**	0.5517**	0.54968**	0.567**	0.6287**	0.691**	1					
CN	-0.5618**	0.6793**	0.455ns	0.451ns	0.4933**	0.42525ns	0.43ns	0.4763**	0.62***	0.67**	1				
CW	-0.4486ns	0.6818**	0.3914*	0.4176*	0.3343*	0.28609*	0.307*	0.3734*	0.4987**	0.47*	0.5946**	1			
MBY	-0.6103**	0.7680**	0.626**	0.693**	0.507**	0.637**	0.514**	0.6723**	0.6697**	0.73**	0.6225**	0.605**	1		
UMBY	0.16022ns	-0.325ns	-0.26ns	-0.26ns	0.05ns	-0.2109ns	0.036ns	-0.132ns	0.0103ns	-0.1ns	-0.084ns	-0.44ns	-0.55ns	1	
TBY	-0.6377**	0.7295**	0.600**	0.672**	0.636**	0.6417**	0.631**	0.7268**	0.8051**	0.79**	0.6977**	0.483**	0.875**	-0.08**	**1**

***Where**: **= highly significant (P<0.01); *= significant (P<0.05); ns= not significant; DE= Date to emergency; DM= Date to maturity; PH= Plant height; LL= Leaf length; LL= Leaf width LN= Leaf number; LA= Leaf Area; LAI= Leaf area index; BD= Bulb diameter; BW= Bulb weight; CW= Clove weight; CN= Clove number; MBY= Marketable bulb yield; UMBY= Unmarketable bulb yield and TBY = Total bulb yield.*

4.6. Partial Budget Analysis (PBA)

Partial budget analysis was done based on the methodology described by CIMMYT (1988) where the cost of fertilizers is considered as fixed cost while bulb and labor costs are considered as variable costs. The marketable bulb yield was adjusted or downscaled by 10% to make comparable to yields of farmers. Moreover, the sale and purchase prices of garlic during the experimental period were 75 Birr kg^{-1} for local variety and 100 Birr kg^{-1} for improved varieties whereas 150Birr kg^{-1} for local variety and 200 Birr kg^{-1} for improved varieties respectively. According to CIMMYT (1988), the highest net benefit (963881.281Eth-Birr ha^{-1}) was recorded from Tsedey a variety plant which was treated using NPSB blended fertilizer (Table 20).

Table 20: Partial Budget Analysis (PBA) of garlic varieties as influenced by different types of blended fertilizers

Treatment combination		Input cost	Labor cost	TVC	MBY	GI	AY	NB	Rank
Fertilizer	Variety	(Eth-Birr)	(Eth-Birr)	(Eth-Birr)	(t ha-1)	(t ha-1)	(Eth-Birr)	(Eth-Birr)	
0 fert.	1	127130.5	213166.1	340296.6	7.958	7.1622	358110	17813.3558	17
0 fert.	2	145292	213166.1	358458.1	9.9208	8.92872	892872	534413.856	18
0 fert.	3	145292	213166.1	358458.1	11.1384	10.02456	1002456	643997.856	11
0 fert.	4	145292	213166.1	358458.1	9.2895	8.36055	836055	477596.856	14
0 fert.	5	145292	213166.1	358458.1	11.9638	10.76742	1076742	718283.856	10
NPS	1	136592.7	225705.3	362298	9.6488	8.68392	434196	71897.9708	16
NPS	2	154754.2	225705.3	380459.5	11.2879	10.15911	1015911	635451.471	15
NPS	3	154754.2	225705.3	380459.5	12.6049	11.34441	1134441	753981.471	9
NPS	4	154754.2	225705.3	380459.5	10.6684	9.60156	960156	579696.471	12
NPS	5	154754.2	225705.3	380459.5	13.3886	12.04974	1204974	824514.471	6
NPSB	1	136851.9	225705.3	362557.2	11.3795	10.24155	512077.5	149520.281	19
NPSB	2	155013.4	225705.3	380718.7	12.3198	11.08782	1108782	728063.281	8
NPSB	3	155013.4	225705.3	380718.7	14.6562	13.19058	1319058	938339.281	2
NPSB	4	155013.4	225705.3	380718.7	11.6749	10.50741	1050741	670022.281	5
NPSB	5	155013.4	225705.3	380718.7	14.94	13.446	1344600	963881.281	1
NPSZN	1	133817.6	225705.3	359522.9	10.5341	9.48069	474034.5	114511.601	20
NPSZN	2	151979.1	225705.3	377684.4	11.1296	10.01664	1001664	623979.601	13
NPSZN	3	151979.1	225705.3	377684.4	13.7753	12.39777	1239777	862092.601	4
NPSZN	4	151979.1	225705.3	377684.4	11.2108	10.08972	1008972	631287.601	7
NPSZN	5	151979.1	225705.3	377684.4	13.9361	12.54249	1254249	876564.601	3

Where: *TVC= Total variable cost; MBY = Marketable bulb yield; AY= Adjustable yield; GI= Gross income; NB= Net benefit; Cost of local garlic variety = 150 Eth-Birr* kg^{-1}*and improved variety= 200 Eth-Birr* kg^{-1}*and while; Selling price of local variety = 75 Eth-Birr* kg^{-1}*and improved variety=100Eth-Birr* kg^{-1}*and; and Labor cost =150 Birr man-day*

4.7. Marginal Rate of Return (MRR)

The marginal rate of return (MRR) was analyzed using the technique described by CIMMYT (1988) to assess or compare the costs and net benefits of the treatments. Accordingly, MRR was calculated as a change of net benefit divided by the change of costs in the treatment and expressed as a percentage. The highest MRR (140124.2%) was recorded from Tsedey variety, which was treaded by NPSB blended fertilizer (Table 21).

Table 21: Marginal rate of return of garlic varieties as influenced by different types of blended fertilizers

Treatment combination		TVC	NB	MRR (%)	Rank
Fertilizer	Variety	(Eth-Birr)	(Eth-Birr)		
0 fert.	1	340296.6	17813.36		
0 fert.	5	358458.1	534413.9	3063.591	4
0 fert.	4	358458.1	643997.9		
0 fert.	3	358458.1	477596.9		
0 fert.	2	358458.1	718283.9		
NPSZN	1	359522.9	71897.97	-26073.3	
NPS	1	362298	635451.5	-2057.04	
NPSB	1	362557.2	753981.5	38278.22	2
NPSZN	5	377684.4	579696.5	4313.916	3
NPSZN	3	377684.4	824514.5		
NPSZN	2	377684.4	149520.3		
NPSZN	4	377684.4	728063.3		
NPS	5	380459.5	938339.3	2136.436	5
NPS	3	380459.5	670022.3		
NPS	2	380459.5	963881.3		
NPS	4	380459.5	114511.6		
NPSB	5	380718.7	623979.6	140124.2	1
NPSB	2	380718.7	862092.6		
NPSB	3	380718.7	631287.6		
NPSB	4	380718.7	876564.6		

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

5. SUMMURY AND CONCLUSION

Garlic is a high value crop that has great potential for production and high market demand of the crop in Ethiopia in particular the study area. But its productivity and production is very low compared to the world average. Based on this fact, the current study was done during 2022/2023 main cropping season under rain-fed to investigate the effect of blended fertilizer type on growth, yield and yield attributes of garlic varieties at Mihur-Aklil district, Ethiopia. Twenty treatments formed by a factorial combination of five Garlic varieties (Tsedey, Kuriftu, Chefe, Holeta and one local) and four types of blended fertilizers (0 (without fertilizer, NPS, NPSB and NPSZn) that 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 of varieties and blended fertilizer type and their interactions.

The highest plant height (77.8cm) was recorded from variety Tsedey when treated with NPSB fertilizer. Similarly, the longest length of leaves (52.33cm), the largest leaf area (38.8cm^2) and LAI (1.144) were recorded from variety Tsedey when planted with blended NPSB fertilizer. However, the largest leaf width (1.04cm) was recorded from variety Tsedey varieties when treated with NPSZN blended fertilizer.

Yield and yield components such as bulb diameter (24.27mm), bulb weight (37.27g), total bulb yield (17.08t/ha) and marketable yield (14.94t/ ha) were recorded from variety Tsedey when planted with NPSB blended fertilizer. However, the highest clove weight (2.4g) was recorded by variety Tsedey when planted with NPSZN blended fertilizer.

The highest number of cloves (15.98) were obtained from variety Kuriftu when supplied with blended NPSB fertilizer while the highest unmarketable yield (1.95t/ha) was recorded from variety Tsedey supplied and NPSB types of blended fertilizer.

The highest net benefit (963,881.3ETB) was obtained from variety Tsedey when supplied with blended NPSB. Similarly, the highest Marginal Rate of Return, MRR (140124.2%) was obtained from variety Tsedey variety when supplied with blended NPSB fertilizer.

The results of the present study indicated that the use of the best garlic variety along with appropriate types of blended fertilizer is so imperative in order to increase the yield of garlic in the study area. Since the use of variety Tsedey planted with blended NPSB fertilizer gave both the highest net benefit and the highest Marginal Rate of Return (MRR), it is recommended for production in the study area as well as areas with similar agroecology settings.

However, since the study was limited to only one season as well as a single location, it is recommended that the experiment be repeated across more seasons and locations.

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APPENDICES

Appendix Table 1: Analysis of variances for growth parameters of garlic as affected by varieties and blended fertilizers at Mihur-Aklil District Yasinawra kebele 2023 cropping season

		Mean square of analysis of variance							
source of Variation	DF	Day to 50% Emergency	Day to 75% physiological Maturity	plant height	Leaf Length	Leaf number	Leaf Width	Leaf Area	Leaf Area Index
Replication	2	0.62^{ns}	14.07*	111.12*	106.73*	2.03*	0.02*	108.92*	0.12*
Variety	3	10.26**	55.53***	370.50***	164.28**	8.44***	0.01*	44.44*	0.28*
Fertilizer	4	27.27***	76.77***	410.53***	200.30**	11.75***	0.17**	441.13**	0.76**
Variety*fertilizer	12	0.42^{ns}	0.07^{ns}	31.97*	16.19*	0.34^{ns}	0.01*	32.85*	0.02*
Error	38	1.12	1.45	31.53	16.21	0.48	0.01	29.89	0.03

Where*: *= significant (p<0.05); *** = very highly significant (P<0.001); ns= not significant; DF = degree of freedom; SD = significance difference; NS= Non significance difference*

Appendix Table 2: Analysis of variances for yield and yield attribute of garlic as affected by varieties and blended fertilizer at Mihur-Aklil District Yasinawra kebele 2023 cropping season

source of Variation	DF	Mean square of analysis of variance						
		Bulb Diameter	Bulb diameter	Clove weight	Clove number	Total Bulb yield	Marketable bulb yield	Unmarketable bulb yield
Replication	2	0.22*	0.17ns	0.11*	1.02*	1.77*	7.13***	1.13***
Variety	3	3.23***	9.04***	0.64***	8.82*	29.96***	22.93***	1.45***
Fertilizer	4	33.08***	66.47***	0.18***	16.11***	38.76***	29.48***	0.78***
variety*fertilizer	12	0.19*	1.13***	0.01*	0.02ns	0.38*	0.29*	0.03ns
Error	38	0.12	0.33	0.02	1.3	0.4988979	0.38	0.08447568

***Where**: *= significant (p<0.05); *** = very highly significant (P<0.001); ns= not significant; DF = degree of freedom; SD = significance difference; NS= Non significance differences*

APPENDICES FIGURS

Appendix Figure 1: Preparation of the experimental fertilizers and planting materials (cloves) of the varieties

Appendix Figure 2: Field layout and preparation of the experimental plot

Appendix Figure 3: Advisors' field evaluation during the vegetative growth stage of the experiment.

Appendix Figure 4: Bulb harvesting and data collection

BIOGRAPHIC SKETCH

The author, **Habtemariam Fikadu Bereka,** was born on19th January 1987 in Mihur-Aklil Woreda of Gurage Zone, Ethiopia. He attended his elementary school at Mihur Cheza Junior Elementary School (1994 to 2001) and his Senior Secondary School at Mihur Cheza Senior Secondary School (2002 to 2003). In 2004, he joined Dilla ATVET College and graduated in 2006 with a Diploma in Plant Sciences. Subsequently, in 2007, he was employed by Mihur-Aklil Woreda Agriculture Office and served as a Development Agent (DA) as well as a supervisor of the DAs therein. In 2010, he joined Dilla University College of Agriculture, Department of Plant sciences and graduated in 2014 with BSc. in Plant Sciences Finally, following some years (2015 to 2020) of additional service in the same woreda Agriculture Office, he joined the postgraduate program of Wolkite University, College of Agriculture and Natural resources, Department of Horticulture in 2021 to pursue his specialized study in horticulture at an MSc. level.