Journal of Chemical, Environmental and Biological Engineering
2024; 8(1): 1-12
http://www.sciencepublishinggroup.com/j/jcebe
doi: 10.11648/jcebe.20240801.11
ISSN: 2640-2645 (Print); ISSN: 2640-267X (Online)

Effects of NPS and Cattle Manure on Growth, Yield and Yield Components of Garlic (*Allium sativum L.*) at Guder, West Shewa Zone, Oromia, Ethiopia

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To cite this article:

Mulugeta Mitiku, Mosisa Chewaka, Girma Chala. (2024). Effects of NPS and Cattle Manure on Growth, Yield and Yield Components of Garlic (*Allium sativum* L.) at Guder, West Shewa Zone, Oromia, Ethiopia. *Journal of Chemical, Environmental and Biological Engineering*, *8*(1), 1-12. https://doi.org/10.11648/jcebe.20240801.11

Received: December 12, 2023; **Accepted**: January 6, 2024; **Published**: February 1, 2024

Abstract: Garlic (Alium sativum L) is an important vegetable crop in Ethiopia. However, the yield of the crop is often constrained by low and imbalance nutrient supply in the soil. Therefore a field experiment was conducted at Ambo University, Gudar campus experimental site to study the effect of inorganic NPS fertilizer and organic cattle manure on growth, yield and yield components of garlic (Alium sativum L) during 2019/2020 main cropping season. A Tsadey variety was used for the study. The treatment consisted of four levels of NPS (0, 50, 100 and 150kg ha^{-1}), and four levels of cattle manure (0, 5, 10 and 15 t ha^{-1}). The experiment was laid out as randomized complete block design (RCBD) in factorial arrangement, and replicated three times. The phonological data, such as plant growth, bulb yield and yield components of the crop was collected. The result revealed that the main effects of NPS fertilizer and cattle manure was significantly ($p<0.01$) affected growth, yield and yield components of garlic such as plant height, days to maturity, leaf length and leaf number per plant and the like. In addition the interaction effects of NPS and CM also significantly ($p<0.01$) influenced, fresh biomass yield, bulb diameter, total bulb yield and harvest index. The highest total bulb yield 8.62 t ha^{-1} was recorded from the combination of 150 kg NPS ha^{-1} and 10 t ha^{-1} of CM. Marketable yield and mean clove number was significantly influenced by the interaction effect of NPS and CM application, whereas unmarketable bulb yield does not significantly influenced by the interaction of NPS and CM. The highest 8.25 t ha^{-1} marketable yield was recorded from combined application of 150 kg NPS ha^{-1} with 10 t ha^{-1} of CM, while the lowest marketable yield was recorded from the control treatments. Maximum 75.4% harvest index was also recorded from the combined application of 150 NPS kg ha-1 and 10 t ha^{-1}, and the highest benefit (616890 ETB ha^{-1}) was recorded at combined application of 150 kg NPS ha^{-1} and 10 CM. it can, be concluded that, combined application of 150 kg NPS ha^{-1} and 10 t CM. led to the maximum growth, yield and yield component of the garlic crop and it is recommended at the study area.

Keywords: Garlic, NPS, Cattle Manure, Yield Component

1. Introduction

Garlic (*Allium sativum* L. *2n=16*) is a member of Alliaceae family, and is one of the most important bulb vegetable crops next to onion (*Allium cepa*) in importance [49]. In Ethiopia, garlic is one of the important bulb crops produced for home consumption as spice or condiment in the preparation of soup, pickle and other preservatives as well as a source of income to many rural farmers in many parts of the country [3]. It is used for seasoning in many foods worldwide. It also has higher nutritive value compared to other bulb crops in addition to antibiotics like garlicin and allistatin it contains [34]. Generally, it is a fundamental component of many or most dishes in various countries including Ethiopia [39].

Garlic is used for flavoring in cooking and is unique because of its high sulfur content. In addition to sulfur, garlic also contains arginine, oligosaccharides, flavonoids, and selenium, all of which may be beneficial to health.

In Ethiopia, the total area under garlic production in 2018/19 reached 21754.49ha^{-1} and the production is estimated to be over 1957400.45quintals 6.71distributions and yield 89.98 quintal/ha^{-1} [16]. Production of garlic is done on sandy soil with higher organic matter content, pH 6-7 at altitude of 1800-2500 m.a.s.l, rainfall 600-700 mm and temperature of 15-24°C. Economic significance of garlic in Ethiopia is fairly considerable and contributes to the national economy as export commodity [22] and important for small holder farmers [19].

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

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

Despite its importance, great potential for production and high market demand, the current garlic production and productivity is limited and remain seasonal. Low soil fertility is one of the factors limiting the productivity of different crops in Ethiopia mainly at the study area. Due to this reason the production and yield of the crop is very low. Therefore the present study was conducted to evaluate the effect of mineral NPS fertilizer and Composted Cattle manure on growth, yield and yield components of garlic at Guder, Ethiopia.

2. Materials and Methods

2.1. Description of the Study Site

An experiment was conducted at Gudar cumpus experimental site in Ambo district at 2019/2020 cropping season, which was planted by rain feed with supplemental irrigation. it is the potential garlic growing district located at the western parts of Oromia region. It is one of the west shoa zone wereda districts which are located located 120 km West of Addis Ababa. The testing site is located at 8°98' North latitude and 37°83' East longitude. Ambo district has a total geographical area of 83,598.69 sq. km, with elevation of 2,068 meters above sea level. Annual rainfall ranged from 900-1100 mm and temperature ranged from 10-27°C, with an average of 18°C. The soil type of the study site is nitosol with a pH value of 6.8 [15].

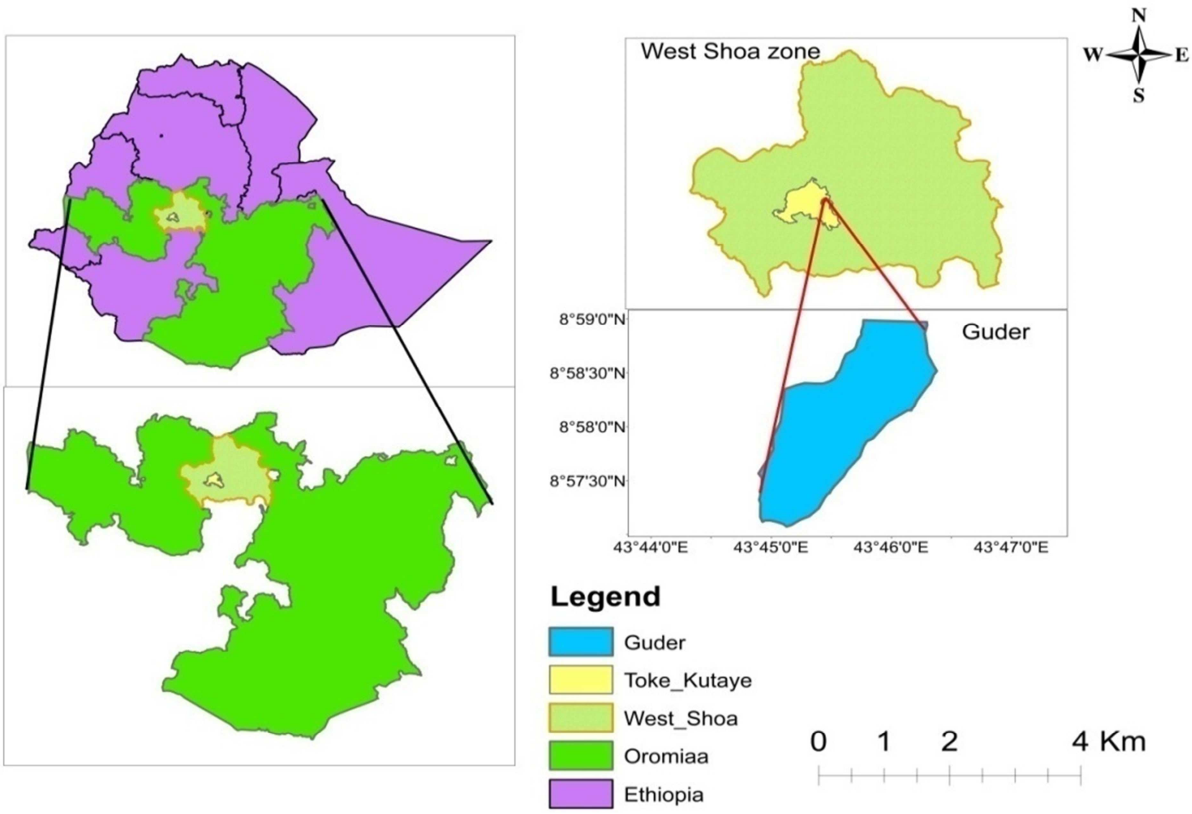

Figure 1. *Map of the Study Area.*

2.2. Experimental Materials

In this study, the planting materials; garlic cloves (Tsedeyi 92) were obtained from Debrazeit agricultural research center and NPS fertilizers and Cattle manure are obtained from Ambo university experimental sites.

2.3. Treatments and Experimental Design

The experiment was laid out in a randomized complete block design (RCBD) with three replications. The experiment was arranged in 3 x 16 factorial combinations (48 treatments). Uniform, healthy and vigorous clove of garlic cultivars was planted on two row ridges, 1m between blocks, 0.5m between plots, 0.30m between rows and 0.10m between plants in the row. The treatments are set from different rates of NPS fertilizer and cattle manure. Sixteen (16) treatments was obtained by combination of four NPS fertilizer rates (0, 50kg/ha^{-1}, 100kg /ha^{-1} and 150kg /ha^{-1}) and Four levels of CM rates (0, 5 t/ha^{-1}, 10t/ha^{-1}, and 15 t/ha^{-1}) which have been set based on 200kg/ha^{-1} of national recommended NPS and the Cattle manure is based on 10 to 20t/ha^{-1} of FYM recommended for the garlic production [20]. The total length of the experimental size was (1mx16)+(0.5x16)=24m and the total width of experiment was (1.5m+1.5+1.5m+1m+1m+1m) =7.5m. There are five rows per plot and 10 plants per row with a total of 50 plants per plot in a plot size of (1m x1.5 m) = 1.5m^2. In length and width, respectively. Plants in the two rows at the extreme end of both sides of each plot and the two plants at the end of each row were not considered as experimental plants. The spacing between blocks and plots is 1 m and 0.5m, respectively. There were sixteen treatment combinations, which were assigned to each plot randomly.

2.4. Experimental Procedure and Crop Management

The experimental field was ploughed and leveled properly before planting. The cattle manure was produced in a trench under shade to avoid evaporation loss of nutrients. The manure becomes ready for use after four to five month after plastering. Then after, the application of CM to experimental units was done on plots that received CM as sole or in combination of inorganic fertilizer depending on the treatments and randomization made by lottery method. The CM was mixed with soil by hand hoeing of experimental unit. The health planting materials (cloves) were planted with the tip in upright position and the basal part of the clove down. The spacing between rows and plant which was proposed to be used in this experiment was adopted from the previous recommendation for the variety 'Tsedey' which was planted on a ridge with the spacing 0f 30 cm between rows and 10 cm between plants. It was concluded that spacing 10 cm x 30cm is optional for better production of garlic [39]. Weeding, cultivation, and ridging were done at the appropriate time to facilitate root, vegetative and bulb development of garlic. The crop was grown under irrigation with the agronomic managements were applied as per the recommendation made for the crop. Planting clove was done on July 2019 at Ambo University's Research Experimental Farm during the main cropping season of 2019. In addition to this some operation regarding management practice and other agronomic practices was done in sequential order as required.

2.5. Soil and Cattle Manure Sampling and Analysis

Before planting, physical and chemical properties of the experimental field soil was determined. Therefore, a representative soil sample was collected from the experimental field randomly in a zigzag pattern at depth of 0-30 cm before applying cattle manure using an auger. The soil samples were composited and a one kg sample was taken as a working sample. A representatives of soil was also taken from each plot after harvest and then composited into its representative treatments for analysis. Crumbs of soil was broken into pieces and sieved. The collected composite sample was air dried on paper trays, and sieved to pass through a 2 mm sieve for chemical analysis.

The soil analysis includes determination of total nitrogen, available phosphorus, potassium, organic matter, soil pH, CEC, Organic carbon and textural analysis (sand, silt, and clay). Cattle manure also analyzed for selected chemical composition such as total nitrogen, soil pH, OC, Available phosphorus using the appropriate laboratory procedures. The soil pH was measured in 1:2:5 soil water ratios using an electrode pH Metter. Organic carbon content of the soil was determined by Walkley and Black method [47], while Available phosphorus was estimated following the standard procedure of Olsen and total nitrogen was estimated by Kjeldahl method.

3. Results and Discussion

3.1. Physico-Chemical Properties of the Soil of the Experimental Site Before Planting

Composite soil sample of the experimental site was analyzed soil texture and chemical properties before planting. The soil particle distribution of the study site was, 20% of sand, 26% of silt and 54% of were clay and the soil was classified under clay soil texture according to USDA soil textural triangle. The pH of the soil was found in the range of slightly acidic (5.60) (Table 1). The total nitrogen content of soil is high 0.322 % (Table 1). This depends on the finding of Goronski, J. *et. al*., described that N content of soil between 0.15-0.25 percent is medium and greater than 0.25 % is high [29]. The cattle manure (CM) analysis results showed that the organic C and/or organic matter was high, implying that this organic fertilizer can be a good source of plant nutrients. Therefore, application of inorganic NPS fertilizers along with well decomposed cattle manure with very high nutrient content is justified to produce good yield of garlic at the study site. The TN and OM obtained from CM was 0.773 and 14.05, which was classified as very high and medium rating respectively (Table 1).

Table 1. *Physical and chemical properties of the experimental soil and cattle manure before planting.*

Parameter	Soil			CM
	Value	Rating	Reference	Value
1. PH	5.6	Moderately acidic	Hazelton and Murphy, 2007	7
2. % OC	2.8	Medium	Hazelton &Murphy (2007)	14.05
3. % TN	0.322	Very high	Bruce & Rayment (1982)	0.773
4. Av.P (ppm)	5.14	Low	Bray II (1954)	42.73
5. Av.S (ppm)	21.04	Medium	EthioSIS (2014)	
6. CEC (Cmol)	2.78	Medium	Landon J. R. (1991)	2.4
7. soil texture				
Sand	20			
Clay	54			
Silt	26			
8. Texturalclass	Clay			

Where: %OC= organic carbon percentage, %OM= Organic matter percentage TN-total nitrogen: Av. P= available phosphorous: S-sulfur: EC-electron conductivity: CEC-cation exchange capacity.

Available phosphorus of soil was categorized within very low (5.142 ppm) which was based on the ranges rated by [17]. The experimental soil was characterized by 2.84 % organic carbon and 1.7 % organic matters that were characterized as low. According to [17], soils having more than 3% organic matter may not need any side dressing of nitrogen fertilizer. If the soil has less than 3% organic matter, then half the total N can be applied pre-plant and the other half side dressed early in the crop growth cycle.

The soil of experimental site had 20.786 meq/100g cation exchange capacity (CEC) which is moderate according to [22] who related the soil texture with CEC content, the soil textures like sands, silts, clays and organic soils have 5-15, 8-30, 25-50 and ≥ 50 meq/100 g ranges of CEC, respectively. Cation exchange capacity (CEC) is a measure of the soil's ability to hold exchangeable cations such as hydrogen (H), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), iron (Fe), and aluminum (Al). Cation exchange capacity is measured in terms of milli equivalents (meq) per 100 grams of soil [36]. The soil sample analysis showed that the experimental site was deficient in some macro and micronutrients.

3.2. Effect of NPS Fertilizer and Cattle Manure on Growth and Phenological Parameters of Garlic

3.2.1. Days to 50% Emergence

The analysis of variance showed that days to 50% plant emergency was significantly (P<0.01) influenced by the main effects of NPS fertilizer and cattle manure (Table 3). With the increase in the rates of both NPS fertilizer and cattle manure application, the number of days required by the garlic sprouts to emerge above the soil surface was decreased. This means that plants that were not treated with the two fertilizers emerged from the soil later than plants that were treated with the fertilizers. Thus, increasing the rate of NPS from nil to 50, 100 and 150kg ha^{-1} hastened emergence of garlic sprouts from the soil by 4.0 and 7.0%, respectively. Similarly, increasing the rate of from nil to 5, 10 and 15 t ha^{-1} hastened the emergence of garlic sprouts from the soil by 3.4 and 6.64%, respectively. The smallest numbers of days to emergence were recorded for the 150 kg NPS ha^{-1} followed by 10 t ha^{-1} of Cattle manure. However, the longest duration in days for emergence was required by cloves treated with no NPS and cattle manure or from the control ones.

Table 2. *Main effect of NPS and cattle manure on days to emergency and days to maturity.*

NPS kg ha^{-1}	Days to 50% emergency	Days to maturity
0	11.73^{a}	123.67^{d}
50	11.06^{b}	129.58^{c}
100	9.87^{c}	134.67^{b}
150	9.41^{d}	142.17^{a}
Mean	10.52	132.52
CR (%)	0.31	4.07
CM (t ha^{-1})		
0	10.91^{a}	128.25^{b}
5	10.64^{b}	132.75^{a}
10	10.29^{c}	135.50^{a}
15	10.23^{c}	133.58^{a}
Mean	10.52	132.52
CR (%)	0.31	4.07
CV (%)	2.80	3.69
Level of significance		
NPS	**	**
CM	**	
NP*CM	NS	NS

Means followed by the same later(s) are not significantly difference at 5% probability level (DMRT); NS indicates non-significant, *, ** significant difference p<0.05 and p<0.01, respectively. CV= coefficient of variation; CR=critical range.

The hastened duration for emergence due to the increased application of the two fertilizers may be attributed to the influence of P and other nutrients released from cattle manure on root initiation and development which might lead to early shoot emergence. Days to emergence decreased by 6.65% over the control treatment with increased application of cattle manure from 0, 5, and 10 t ha^{-1}. Similarly, [16] found that seedlings emergence of tomato, cabbage, and radish was much faster in higher rates of cattle manure and vermicompost than in nil application. This finding was in line with the finding of [33] observed that the use of organic manure such as cattle manure as a substrate produced an earlier shoot emergence and earlier start of bulbification.

3.2.2. Days to Maturity

Days to physiological maturity for garlic defined as number of days from emergence to maturity when 75% of the plants of different treatments were reached to harvest accompanied with senescence of the leaf. The analysis of variance revealed days to maturity was significantly influenced by the main effects of NPS ($P < 0.01$), and cattle manure ($P < 0.05$) but not by the interaction effects of any of the two factors (Table 2) This indicates that increasing the rates of all the two fertilizers prolonged the maturity of the garlic plants. Thus plants that were supplied with the fertilizers matured later than those in the control treatments.

Plants grown in the treatment that receive 150 kg NPS ha^{-1} matured later than those without fertilized plots. The delayed in maturity in response to the application of NPS fertilizer maybe due to the availability of sufficient nutrients, which could [42] prolong life span as plants take up sufficient nutrients and delay in partition of net assimilation from activity of photosynthesis. Likewise, [3] also stated that increasing the rate of nitrogen and phosphorus fertilizers level prolonged maturity of garlic plant. The results was in agreement with the findings of [31] who observed that plants grown with the highest level of nitrogen took the longest period to complete the vegetative growth, and produced the highest bulb yield by showing the best performance in almost all the yield components.

Days to maturity also showed a significant difference due to the application of different level of cattle manure. The shortest days to physiological maturity (128 days) was recorded from treatments which not received cattle manure whereas the longest days to maturity (135) was recorded from 10 t ha^{-1} of cattle manure, but statistically similar with the dose of15 t ha^{-1}. Prolonged maturity in response to increasing rate of cattle manure may be ascribed to the availability of optimum nutrients contained in cattle manure that may have led to prolonged maturity through enhanced leaf growth and photosynthetic activities thereby increasing partition of assimilate to the storage organ. This result is supported by the findings of [47] who reported prolonged maturity on garlic in response to combined application of N and manure.

Moreover, [44] reported that the application of N resulted in significantly delayed physiological maturity. The presence of N in excess promotes development of the above ground organs, Synthesis of proteins and formation of new tissues are stimulated, resulting in vigorous vegetative growth. This increases the days of physiological maturity.

3.3. Growth Parameters

3.3.1. Plant Height

Plant height was significantly ($P<0.001$) influenced by the application of NPS fertilizer and cattle manure (Table 5). The longest (48.11) plant height was recorded from the application of 150 kg NPS ha^{-1} and the shortest (35.65) plant height was obtained from the control treatment. The increase in plant height with the application of NPS may be due to the quick and readily availability of chemical fertilizer s from inorganic NPS. [18] Reported that the nitrate nitrogen in NP and applied urea significantly increased almost in all growth stage parameters.

Application of cattle manure also significantly affect the garlic plant height in increasing the height of garlic plant by 13.33% due to the application of 10 t ha^{-1}CM as compared to the control one. However, application of 15 t ha^{-1} of CM shows statistical similar with that of 10 t ha^{-1}. The increase in plant height may be due to the slow release of essential plant nutrients from organic Cattle manure to the plant in all plant growth stage.

Application of CM in combination with NP fertilizers might be attributed to provision of sufficient micro and macro nutrients, which most likely have helped in enhancing the metabolic activity in the early growth phase which in turn probably have encouraged the overall growth [43]. The findings are also in conformity with the work of [26] who reported that organic manure and inorganic fertilizer supplied most of the essential nutrients during growth stage resulting in increase of growth variables including plant height. Similar to our result, [15] reported that plants applied with N and P fertilizer and CM were significantly taller than those in the control plots. Generally, it was observed that treatments that received both organic and inorganic fertilizer produced plants with more height as compared to plants in unfertilized plot.

3.3.2. Leaf Number

The main effects of NPS fertilizer ($P < 0.001$), and cattle manure ($P < 0.001$) significantly influenced leaf number per plant. However, the interaction effect of NPS and cattle manure supplementation did not significantly affect leaf number of garlic (Table 3). Compared to the control treatment, number of leaves per plant was significantly increased by 33.8% in response to increasing the rate of NPS from 0 to 150 kg NPS ha^{-1} (Table 5). This attributed that, since nitrogen is a constituent of chlorophyll, the increase of which with added nitrogen might have resulted in increased synthesis of photosynthesis, leading to better vigour [30]. This result is supported by that of [38] who found significantly increased number of leaves per plant for onion in response to the increased application rate of N from 40kg N ha^{-1} to 120 kg N ha^{-1}. Similarly, [1] also showed that the number of onion leaves increased by about 8% in response to the application of 92 kg N ha^{-1} over the control treatment with further increases in N resulting in a reduction in leaf number. The maximum (9.18) leaf number of garlic leaves was recorded at the rate of 150 kg of NPS ha^{-1} which was increased by 33.8% compared to the leaf number obtained in the control treatment (Table 4). This result is in agreement with that of [24] found that the main effects of P significantly ($P\leq0.05$) increased leaf number per plant on garlic plant. This could be that phosphorus is the second major nutrient being essential constituent of cellular protein and nucleic acid might have encouraged meristematic activity of plants resulting in increased plant height, number of leaves per plant and leaf area. In addition to that Sulfur is also reported to enhance the photosynthetic assimilation of N in crop plants.

Hence, the application of N and S fertilizers increases the net photosynthetic rate in crop plants, which in turn increases their dry matter and grain yield, as 90% of the plant's dry weight is considered to be derived from products formed during photosynthesis.

Cattle manure significantly ($P < 0.01$) affected leaf number. Number of leaves per plant was increased by about 22.8% in response to increasing cattle manure rate from 0 to 10 t ha^{-1}. This result is supported by the findings of [21] who observed that, the application of compost at two rates significantly increased vegetative growth characters, i.e. plant length, average number of leaves, and fresh and dry weight of whole plant and its different organs of onion plant. [6] reported that significantly higher plant height, number of leaves per plant, leaf area per plant and leaf area index over lower levels of vermicompost was recorded in response to application of vermicompost at the rate of 6 t ha^{-1}. Cattle manure is known to contain micronutrients apart from major nutrients. Besides this, cattle manure has been reported to contain several plant growth promoters, enzymes, beneficial bacteria and mycorrhizae [30]. Therefore, the availability of higher quantity of nutrients, improvement in the physical properties of soil and increased activity of microbes with higher levels of organics might have helped in increasing plant height, number of leaves, leaf area and leaf area index. Similarly, significantly taller garlic plants in response to vermicompost application were reported by [46]. Higher levels of farm yard manure (FYM) significantly increased the plant height, number of leaves per plant and leaf area per plant in onion. This might be due to increased number of leaves and leaf area per plant resulting in better photosynthesis and accumulation of photosynthesis leading to more vigor. Higher levels of organics recorded significantly higher number of leaves per plant on garlic. This is attributed to the increased growth performance with respect to plant height, number of leaves per plant and leaf area per plant.

3.3.3. Leaf Length

The analysis of variance revealed that leaf length was significantly ($P<0.01$) influenced by the effect of NPS fertilizer and cattle manure but, the interaction of the both factor was not significantly affect the leaf length of garlic (Table 4). The longest (29.43) leaf length was recorded from the application of 150 kg NPS ha^{-1} and the shortest 23.7) leaf length was obtained from the control treatment. This indicates that, the leaf length was increased with the increase of NPS fertilize at optimum level (Table 4). The increase in leaf length of garlic can be associated again with the fact that nitrogen is important for plant cell division and elongation [10]. Moreover, nitrogen plays significant role for the synthesis of chlorophyll, enzymes and proteins which are important for plant growth including garlic. Adequate production of amino acids hastens the transportation of protein in the plant tissues also due to sulfur. Sulfur reported to improves the other major nutrient uptake of crops including garlic [14] As noted before, nitrogen is the major constituent of proteins and its abundant presence tends to increase the size of the leaves, which brings about an increase in carbohydrate synthesis [11]. The results of this study are in agreement with [44] and [32] who reported that the length and width of onion leaves increased with increased nitrogen rates. The results obtained in this experiment are generally in agreement with the findings of various Researchers where the application of NPS fertilizer alone or in combination increased the growth and development of garlic including the number, length and size of garlic leaves [5].

Also application of cattle manure significantly affect the garlic leaf length in increasing the length of garlic plant leaf by 12.75% due to the application of 10 t ha^{-1}CM and followed by statistical deference with the cattle manure rate of 15 t ha^{-1} as compared to the control. Further FYM would have helped the soil by improving the nutrient status and water holding capacity of those soils. The significance of organic manuring in sustainable agriculture is well established. [46] Recovery of P from organic manure is slightly better than from fertilizers as CO_2 released by decomposition improves availability from soil. [28] The better efficiency of organic manures might be due to the fact that organic manures especially FYM would have provided the micronutrients such as Zn, Cu, Fe, Mn and Mg in an optimum level. Zinc is involved in the biochemical synthesis of most important phytohormone, Indole Acetic Acid through the pathway of conversion of IAA. Iron is involved in chlorophyll synthesis pathway. Copper and Manganese are the important coenzymes for certain respiratory reaction. Magnesium is involved in chlorophyll synthesis which in turn increases the rate of photosynthesis. Application of organic manure thus would have helped in the plant metabolic activity through the supply of such important micronutrients in the early vigorous growth [3].

Table 3. *Effects of NPS and cattle manure on plant height, leaf length, number of leaf and leaf width.*

NPS (kg/ha^{-1})	PH (cm)	LL (cm)	NL	LW (cm)
0	35.65^{d}	23.70c	6.86^{c}	1.07^{d}
50	39.26^{c}	26.40^{b}	7.63^{b}	1.33^{c}
100	43.37^{b}	27.11^{b}	8.18^{b}	1.40^{b}
150	48.11^{a}	29.43^{a}	9.18^{a}	1.52^{a}
Mean	41.60	26.66	7.96	1.33
CR (%)	3.10	1.49	0.64	0.07
CM (t/ha^{-1})				
0	39.39^{b}	25.24^{c}	7.27^{c}	1.25^{b}
5	40.39^{b}	$25.89b^{c}$	$7.63b^{c}$	1.30^{b}
10	44.64^{a}	28.46^{a}	8.93^{a}	1.39^{a}
15	41.97^{ab}	27.06^{ab}	8.03^{b}	1.38^{a}
Mean	41.60	26.66	7.96	1.33
CR (%)	3.1	1.49	0.64	
CV (%)	8.96	6.71	9.64	6.13
Level of signf				
NPS	**	**	**	**
CM	*	**	**	**
NPS*CM	NS	NS	NS	NS

Means followed by the same later(s) are not significantly difference at 5% probability level (DMRT); NS indicates non-significant, *, ** significant difference p<0.05 and p<0.01, respectively. PH=plant height; LL= leaf length; NL= number of leaf; LW= leaf width; CV= coefficient of variation; CR=critical range.

3.3.4. Leaf Width

Leaf width (cm) ($p<0.01$) of garlic was significantly influenced by the main effects of NPS fertilizer and cattle manure ($p<0.01$) level application while their interaction effect did not affect significantly (Table 4). The increased rates of NPS fertilizer from lower to higher in kg ha^{-1} improve the garlic leaf width at garlic physiological maturity. The maximum (1.52) leaf width were obtained from 150 kg of NPS $ha^{-1}$and the minimum (1.06) leaf width were obtained from the control. The increase in width of garlic leaves can be associated again with the fact that nitrogen is important for plant cell division and elongation [10]. The higher and better performance of garlic leaf width might be attributed to improve photosynthetic activities that in turn increase chlorophyll content of the leaves.

Application of cattle manure significantly affect the garlic leaf width in increasing the width of garlic plant leaf due to the readily and quick availability of essential nutrients which are crucial for plant growth by the application of Cattle manure. The highest (1.38) leaf width was recorded by the application of 10 t ha^{-1} of cattle manure and the lowest (1.25) was recorded from the control. Application of CM might be attributed to provision of sufficient micro and macro nutrients, which most likely have helped encouraged the overall growth [43]. The findings are also in conformity with the work of [26] who reported that organic manure supplied most of the essential nutrients during growth stage resulting in increase of growth variables including leaf width.

3.4. Yield and Yield Component Parameters

3.4.1. Bulb Diameter

Table 4. *Interaction effects of NPS and cattle manure on bulb diameter.*

NPS (kg/ha $^{-1}$)	Cattle manure (t/ha $^{-1}$)				
	0	5	10	15	Mean
0	3.21^{i}	3.43^{hi}	3.62^{ghi}	3.73^{ghi}	3.50
50	3.78^{fghi}	3.88^{fgh}	4.00^{fgh}	4.11^{efg}	3.94
100	4.18^{efg}	4.33^{def}	4.66^{de}	4.83^{dc}	4.50
150	4.79^{dc}	5.24^{bc}	6.60^{a}	5.42^{b}	5.51
Mean	3.99	4.22	4.72	4.52	
CR (%)		0.26			
CV (%)		7.27			
Significance level					
NPS **					
CM **					
NPS*CM *					

Means followed by the same later(s) are not significantly difference at 5% probability level (DMRT); NS indicates non-significant, *, ** significant difference $p<0.05$ and $p<0.001$, respectively. Coefficient of variation; CR=critical range.

Garlic bulb diameter was significantly ($p<0.01$) affected by combined application of NPS fertilizer and cattle manure (Table 7). The maximum bulb diameter (6.60 cm) was obtained from treatment treated with 150 kg/ ha^{-1} of NPS fertilizer combined with 10 t/ ha^{-1} of cattle manure and followed by 150 kg/ ha^{-1} of NPS with 15 t/ha^{-1} of cattle manure. While the minimum (3.21cm) garlic bulb diameter was recorded from treatment that did not receive any fertilizer and cattle manure or in broad sense the treatment that did not receive application of either NPS or cattle manure. The increase in garlic bulb diameter might be due to the increase of nutrient supply from NPS fertilizer and cattle manure and further increase in bulb size with the readily availability of inorganic and organic fertilizers in a soil solution that quickly utilized and revealed in a better performance of plant growth and development.

The diameter and weight of bulbs were significantly improved with the application of NPS fertilizer. It also might be due to adequate nutrient supply which favored the enlargement of bulb and its weight. This finding is supported by work of [23] who reported significant increase in onion yield components including mean bulb diameter with the application of optimum amounts of organic manure and mineral fertilizers. [49] In their study also documented that application of organic manure and fertilizers significantly increased the yield parameters including bulb diameter.

3.4.2. Total Bulb Yield

Total bulb yield of garlic was significantly influenced by main effects of NPS fertilizer and cattle manure ($P < 0.001$), and also their interaction effects ($p<0.05$) (Table 5). The highest bulb yield of (8.62 t/ha^{-1}) was obtained from the combined application of 150 kg ha^{-1} of NPS with 10 t ha^{-1} of cattle manure and is followed by application of 150 kg ha^{-1} of NPS with 15 t ha^{-1} of cattle manure. This indicates that plots which received optimum doses of fertilizer application showed higher yield as compared with the unfertilized plots.

Table 5. *Interaction effect of NPS and cattle manure on total bulb yield.*

NPS fertilizer (kg /ha $^{-1}$)	Cattle manure (t/ha $^{-1}$)				
	0	5	10	15	Mean
0	4.87^{K}	5.20^{j}	5.40^{j}	5.67^{i}	5.28
50	5.83^{hi}	6.03^{h}	6.53^{g}	6.77^{fg}	6.29
100	6.80^{f}	6.93^{f}	7.20^{e}	7.70^{d}	7.16
150	7.93^{dc}	8.13^{bc}	8.62^{a}	8.30^{b}	8.25
Mean	6.36	6.58	6.94	7.11	
CR (%)		0.12			
CV (%)		2.12			
Level of significance					
NPS		***			
CM		***			
NPS*CM		**			

Means followed by the same later(s) are not significantly difference at 5% probability level (DMRT); NS indicates non-significant, *, ** significant difference $p<0.05$ and $p<0.01$, respectively. Coefficient of variation; CR=critical range.

This finding depends on the findings of Muhammad, S. J, Reported that the presence of nutrients in manure and balanced supplement of nitrogen and phosphorus through mineral fertilizers might have contributed to increased cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency and regulation of water intake into the cells, resulting in the enhancement of yield parameters [40]. Similarly in onion, the application of compost and combinations of N, P, and S to soils somehow increased the bulb diameter [25]. The results are in agreement with the findings of [45]. Higher yield response due to organics is ascribed to improvement in physical and biological properties of soil resulted in better supply of nutrients led to good crop growth and yield.

Our finding is also similar to the works of [9] who reported that application of 20 or 30 t ha^{-1} FYM + 66.6% of the recommended inorganic NP fertilizers significantly increased total tubers yield. [17] Maximum tuber yield (36.8 t ha^{-1}) was obtained by using 150 kg N ha^{-1} + 20 t CM ha^{-1}. The increase in bulb yield in response to the increasing rates of organic manure and inorganic fertilizer such as NPS, at optimum level may be attributed to a good performance partitioning of assimilates to the bulbs, this in turn increase the total bulb yield of garlic crops. In harmony with this study, [49] reported higher garlic yield at combined application of 50% recommended dose of NPK + 120 q/ha FYM. Similarly, [9] also documented that 50% RNP (recommended nitrogen and phosphorus; 128: 92 kg/ha) + 5 t/ha^{-1} vermicompost produced the highest total bulb yield. Gebremikael *et al*. (2017) on the other side stated that application of 5 t/ha^{-1} vermicompost + 50% RDF (69 kg/ha N) recorded the highest marketable yield for onion. [38] on his part reported the highest total onion bulb yield was obtained with the application of 20 t/ ha manure plus 80 kg/ha N and 40 kg/ha P. In contrast, [2] reported better garlic yield by combining (130:20:21:15 kg/ha N, P, S and Zn fertilizers) compared to compost at 12,000 kg/ha^{-1} alone or their combinations.

3.4.3. Marketable Bulb Yield

Table 6. *Interaction effect of NPS and cattle manure on marketable bulb yield.*

NPS rate (kg /ha $^{-1}$)	Cattle manure (t/ha^{-1})				
	0	5	10	15	Mean
0	3.99^{k}	4.38^{j}	4.69^{i}	4.94^{h}	4.50
50	5.17^{h}	5.47^{g}	6.03^{f}	6.30^{e}	5.74
100	6.28^{e}	6.44e	6.75^{d}	7.26^{c}	6.68
150	7.44^{c}	7.71^{b}	8.25^{a}	7.80^{b}	7.80
Mean	5.72	6.00	6.43	6.57	
CR (%)		0.12			
CV (%)		2.31			
Significance level					
NPS		***			
CM		***			
NPS*CM		**			

Means followed by the same later(s) are not significantly difference at 5% probability level (DMRT); NS indicates non-significant, *, ** significant difference p<0.001 and p<0.01, respectively. Coefficient of variation; CR=critical range.

Marketable bulb yield of garlic was highly (p<0.001) influenced by the main effects of NPS fertilizer and cattle manure and significantly (0.001) influenced by the interaction effects of both factors (Table 6). This indicates that the increase in marketable bulb yield is due to the combined application of organic cattle manure and inorganic NPS fertilizer resulting in improving the soil micro nutrients which is readily available in the soil. The highest marketable bulb yield (8.25 t ha^{-1}) was recorded with application of 150 kg NPS fertilizer ha^{-1} + 10 t CM ha^{-1} followed by 150 kg NPS fertilizer ha^{-1} + 15 t ha $^{-1}$ CM and 150 kg NPS fertilizer ha^{-1} + 5 t ha^{-1} CM with marketable bulb yield of 7.80 and 7.71 t ha^{-1} respectively, which are also statistically at par with this highest marketable bulb yield (Table 6). However, the lowest marketable bulb yield (3.99 t ha^{-1}) was recorded with the control treatment, which is less by 51.64% compared with highest value obtained with 150 kg NPS fertilizer ha^{-1} + 10 t CM ha^{-1}. The control plot recorded the lowest values for marketable bulb yield of garlic, due to the absence of adequate nutrient level needed for proper growth, development and yield.

The increase in marketable bulb yield in response to increasing rate of NPS fertilizer and cattle manure may be ascribed to the availability of optimum nutrients contained in the inorganic fertilizer and manure that may have led to high leaf area index through improved leaf growth and photosynthesis. This result is in line with that of [37] who reported that significantly increased all the growth attributes such as plant height, stem diameter, number of leaves, and leaf area index in response to the applied municipal solid waste and vermicompost under well-watered, moderate and severe stress conditions. In addition to the above point, The possible reasons for the maximum marketable bulb yield per ha^{-1} observed with the higher combined application of NPS fertilizer and CM could be due to a function of total biomass production, the percentage of biomass that is partitioned to the bulbs, the moisture content of the bulbs and the proportion of bulbs that are acceptable to the market, in terms of size and lack of defects; and great opportunities exist to increase garlic production and yield by improving nutrient management. The present finding is supported by many researchers [35] by which they indicated that higher marketable yield of garlic due to application of nitrogen was attributed to significantly higher bulb yield and quality.

3.4.4. Unmarketable Bulb Yield

Table 7. *Main effects of NPS and CM on unmarketable bulb yield.*

NPS rate (kg/ha)	Unmarketable bulb yield (t/ha)
0	0.78^{a}
50	0.55^{b}
100	0.48^{c}
150	0.45^{c}
Mean	0.56
CR	0.046
CM (t/ha)	
0	0.64^{a}
5	0.57^{b}
10	0.51^{c}
15	0.54^{bc}
Mean	0.56
CR	0.05
CV	9.93
Lssevel of significance	
NPS	**
CM	**
NPS*CM	Ns

Means followed by the same later(s) are not significantly difference at 5% probability level (DMRT); NS indicates non-significant, *, ** significant difference p<0.05 and p<0.001, respectively. Coefficient of variation; CR=critical range.

Unmarketable bulb yield was significantly influenced by the main effect of NPS fertilizer (P < 0.001), and cattle manure ($P < 0.001$) (Table 7). The plot which is unfertilized by any fertilizer were recorded the maximum unmarketable bulb yield than the plots which receive high dose of fertilizer. Similarly the maximum unmarketable bulb yield is obtained from the control treatments, this might be due to low soil fertility status of the study site which indicating the need for application of balanced fertilizer. Due to this reason, the highest unmarketable bulb yield was obtained from treatment which was not treated with NPS fertilizer and cattle manure whereas the lowest unmarketable bulb yield was obtained from the treatment which receive application of 150 kg ha^{-1} of NPS fertilizer which was nearly similar with application of 10 t ha^{-1} of cattle manure.

This result indicated that the effect of NPS and organic cattle manure application significantly decreased unmarketable bulb yield.

3.4.5. Harvest Index

The analysis of variance showed that the interaction effect of NPS fertilizer and cattle manure showed significant difference ($P<0.01$) on harvest index (Table 8). Application of 150 kg ha^{-1} NPS combined with 10 t ha^{-1} of cattle manure showed the maximum harvest index followed by 100 kg NPS with 10 t ha^{-1} of cattle manure.

And also the main effect of NPS fertilizer and cattle manure was significantly affect the harvest index of garlic. In response to increasing the rate of NPS fertilizer application with the increasing rate of the cattle manure, harvest index increased markedly. This could be attributed to the strong movement of assimilates from the leaves to the bulbs during the growing period. The highest harvest index at the optimum NPS fertilizer and optimum cattle manure (150 kg NPS ha^{-1}with 10 t ha^{-1} CM could be associated with comparatively high marketable bulb yield.

Table 8. *Interaction effect of NPS fertilizer and cattle manure on harvest index.*

NPS fertilizer (kg ha^{-1})	**Cattle manure (t ha^{-1})**				
	0	**5**	**10**	**15**	**Mean**
0	55.20^{j}	58.10^{i}	58.03^{i}	58.90^{hi}	57.56
50	59.00^{hi}	59.80^{gh}	60.53^{g}	60.87^{g}	60.05
100	62.83^{f}	63.87^{f}	65.53^{e}	65.97^{de}	64.55
150	67.07^{d}	69.27^{c}	75.40^{a}	71.23^{b}	70.74
Mean	61.03	62.76	64.88	64.24	
CR (%)	1.32				
CV (%)	1.26				
Level of significance					
NPS	**				
CM	**				
NPS*CM					

Means followed by the same later(s) are not significantly difference at 5% probability level (DMRT); NS indicates non-significant, *, ** significant difference p<0.05 and p<0.01, respectively. Coefficient of variation; CR=critical range.

Maximum (75.4) harvest index was observed at the combined application of 150 kg ha^{-1} of NPS with 10 t ha^{-1} of cattle manure and the lowest (55.2) was recorded from the control treatment. On the other hand, the lowest harvest index in the treatment combination of 0 kg NPS ha^{-1} and 0 t/ ha^{-1} cattle manure may be due to relatively lower marketable bulb yield. Similar results were obtained by [1] who reported that the lowest harvest index of onion occurred in response to the application of nil rate of nitrogen fertilizer. Generally the combined use of inorganic fertilizer with organic manure such as cattle manure have a beneficial effects on growth and yields of a crops including garlic in turn increasing harvest index of the given crop.

3.5. Effects of NPS Fertilizer and Cattle Manure on the Economic Feasibility of Garlic Production

The results of the partial budget analyses revealed that the highest net returns of Birr 616890 was recorded in the treatment that received 150kg ha^{-1} of NPS fertilizer with combination of 10 t/ha^{-1} cattle manure followed by 150kg NPS/ ha^{-1} along with 15 t/ha^{-1} cattle manure. However, the lowest net returns of Birr 350640 was received 0-0 NPS kg/ha^{-1}and CM t/ha^{-1}. In economic analysis point of view the fertilizer cost was calculated for all levels of NPS and CM to determine the total variable costs. The price of NPS, urea and Cattle manure were ETB 16.00, 13.00 and 3.50/ KG respectively. Any treatment that has net benefits that are less than or equal to those of a treatment with lower costs that vary was consider dominated [15] High net return from the foregoing treatments could be attributed to high yield and the low net return was attributed to low yield. However, the maximum marginal rate of return was recorded from the treatment receiving 150 kg / ha^{-1} NPS + 10 t/ ha^{-1} cattle manure, which is followed by 100 kg NPS with combination of 5 t ha^{-1} of cattle manure. While the lowest marginal rate of return was recorded from the control treatment. From the economic point of view the treatment which have high marginal rate of return was advantages; however it was apparent from the results that treatments receiving 150 kg ha^{-1} of NPS fertilizer in combination with 10 t ha^{-1} of cattle manure was profitable than the rest of treatment combinations. Therefore, fertilizer rates of 150 kg ha^{-1} NPS with 10 t ha^{-1} of cattle manure was economically feasible for garlic production in Toke Kutaye area.

4. Conclusions and Recommendations

4.1. Conclusion

The results of this study showed that, combined application of nutrients from inorganic and organic source is one of the most valuable and important practices for enhancing the production and yield of garlic crop. However, the garlic production and productivity in Ethiopia including the study area is low due to the unbalanced use of inorganic and organic fertilizer by the farmer society. Due to this reason, an investigation was conducted to study the combined effect of NPS mineral fertilizer with organic Cattle manure on the garlic yield, production and productivity at Guder campus experimental site in the 2019/2020 main cropping season. The results revealed that most of the garlic phenological, growth and yield characteristics were significantly affected by main effects of NPS and cattle manure. Days to emergency and days to maturity were significantly affected by NPS fertilizer ($P < 0.01$) and cattle manure ($P < 0.001$). Growth parameters such as plant height, leaf number, leaf length, leaf width, neck diameter, shoot fresh weight and shoot dry weight had significantly influenced by the main effects of NPS fertilizers and cattle manure. plant height was significantly ($P < 0.01$) influenced by the main effect of NPS fertilizer and cattle manure maximum plant height was recorded from the rate of 150 kg /ha^{-1} of NPS. Leaf number was significantly influenced by the main effects of NPS ($P < 0.001$) and cattle manure ($P < 0.001$). Maximum leaf number was recorded at the rate of 150 kg NPS/ ha^{-1} followed by 10 t/ ha^{-1} of cattle manure. On the other hand The other growth parameter, leaf length was significantly ($P < 0.001$) influenced by the main effects of NPS and cattle manure and maximum leaf length was recorded at the rate of 150kg/ ha^{-1} NPS fertilizer.

Yield and yield related traits showed significant differences in response to the application of NPS fertilizer and cattle manure. Among the yield and yield related parameters, bulb length, mean clove number, mean clove weight was significantly affected by the main effects of NPS fertilizer and cattle manure and the maximum value was recorded from 150 kg /ha $^{-1}$ of NPS and 10 t / ha $^{-1}$ of cattle manure. On the other hand, bulb diameter, bulb fresh weight, total bulb yield, marketable yield and harvest index were significantly influenced by the interaction effect of NPS fertilizer and cattle manure application. The highest marketable and the lowest unmarketable yield was obtained from the combined application of 150 kg /ha^{-1} of NPS fertilizer with 10 t/ ha $^{-1}$ of cattle manure. Similarly the maximum total bulb yield is obtained from the combined application of 150 kg /ha^{-1} of NPS fertilizer with 10 t / ha^{-1} of cattle manure. Almost all parameters except unmarketable bulb yield had the highest values when the highest application rate of NPS blended fertilizers, cattle manure and their interaction was applied. In this study, it is found that there is a positive and significant association among response variables such as marketable bulb yield, total bulb yield, plant height number of leaf per plant, leaf length, bulb diameter, bulb fresh weight and bulb dry weight.

Generally, the present study indicated that the combined application of NPS fertilizer and CM improved growth, yield and yield component of garlic. Therefore, from the results of this study, it can be concluded that, the maximum growth, yield, and yield components of the crop was obtained at 150 kg/ ha^{-1} of NPS with the combined application of 10 t/ha^{-1} of cattle manure in the study area. Accordingly, optimum bulb yield was obtained from combined application of 150 kg /ha^{-1} NPS fertilizer and 10- 15 t/ha^{-1} composted cattle manure.

4.2. Recommendation

In light of the results and implications of this investigation, the following suggestions are proposed as a recommendation:

1) It is crucial to prioritize soil management practices that can augment soil fertility and elevate soil pH within this region.
2) In terms of economic point of view, combined application of 150 kg NPS kg ha^{-1} fertilizers and 10-15 t/ ha^{-1}CM found high net benefit with high marginal rate of return and economically feasible and recommended for garlic growing areas of Gudar district in Toke kutaye wereda.
3) The combined utilization of Cattle manure at a rate of 10-15t/ha^{-1} tons per hectare and NPS fertilizer at a rate of 150 kilograms per hectare may represent the most favorable integrated soil fertility management approach for Garlic production in this area, potentially replacing the exclusive use of inorganic fertilizers.
4) Nonetheless, it is advisable to conduct further research at diverse locations and over multiple cropping seasons to furnish more definitive recommendations for the sustainable production of Garlic.

Acknowledgments

The authors like to commence by acknowledging the divine Almighty God for providing me with the fortitude and determination required to finalize this study. Furthermore, the authors wish to convey his deep gratitude and genuine appreciation to his dear family, including his father, Mitiku Deressa Liban, and his mother, Shumitu Tola Gurmessa, and finally, for Ambo university Department of Horticulture, for their dedication and strong support throughout his study.

Conflicts of Interest

The authors declare no conflicts of interests.

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