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Effects of Vermicompost and Inorganic NP Fertilizers on Growth, Yield and Quality of Garlic (Allium sativum L.) in Enebse Sar Midir District, Northwestern Ethiopia

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Abstract
Garlic (*Allium sativum* L.) is an important vegetable crop in Ethiopia. However, the yield of the crop is often constrained by low and imbalanced nutrient supply in the soil. Therefore, a field experiment was conducted at Mertule Mariam ATVET College to study the effect of vermicompost and inorganic NP fertilizers on growth, yield and quality of garlic (*Allium sativum* L.) during 2013 main rainy season. A locally grown garlic cultivar called Tsedey 92 (G-493) was used for the study. The treatment consisted of three levels of nitrogen (0, 23 and 46 kg ha^{-1}), three levels of phosphorus (0, 46 and 92 kg P_2O_5 ha^{-1}) and three levels of vermicompost (0, 2.5 and 5 t ha^{-1}). The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement, and replicated three times. Data were collected on phenology, plant growth, bulb yield, and quality of the crop. The results revealed that the main effects of phosphorus and vermicompost significantly ($P < 0.05$) affected days to emergence whereas nitrogen had no significant effect on days to emergence. The main effects of nitrogen, phosphorus and vermicompost also significantly ($P < 0.05$) influenced days to maturity, leaf number, leaf area index, mean clove weight, mean bulb weight, fresh biomass yield, total bulb yield, dry matter percent and total soluble solid. The highest total bulb yield 7.96 t ha-1 was recorded at 92 kg P_2O_5 ha^{-1}. At lone application of 46 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}, similar amount of maximum total soluble solid 5.79^{o}Brix was recorded. Conversely, the interaction effects of nitrogen, phosphorus and vermicompost significantly ($P < 0.05$) influenced plant height. The interaction effects of nitrogen and phosphorus and the main effect of vermicompost significantly ($P < 0.05$) affected marketable and unmarketable bulb yield, and mean clove number. The highest marketable yield 7.87 t ha^{-1} and 6.99 t ha^{-1} were recorded from combined application of 46 kg N ha^{-1} and 92 kg P_2O_5 and sole application of 5 t vermicompost ha^{-1} respectively. Harvest index was also significantly ($P < 0.05$) affected by the interaction effects of nitrogen and phosphorus. The maximum harvest index 68.36% was also recorded at combined application of 46 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}. The highest benefit (280542.00 ETB ha^{-1}) in the partial budget was recorded at 5 t ha^{-1} vermicompost followed by (172569.00 ETB ha^{-1}) at combined application of 46 kg N and 92 kg P_2O_5 ha^{-1}. It can, thus be concluded that, lone application of 5 t ha^{-1} vermicompost or combined application of 46 kg N ha^{-1} plus 92 kg P_2O_5 ha^{-1} led to the maximum growth, yield and quality of the garlic crop.
Keywords: vermicompost, garlic, organic fertilizer, inorganic fertilizer, earth worm, *Eisenia foetida*

1. Introduction

Garlic belongs to the family *Alliacea* and is one of the main *Allium* vegetable crops known worldwide with respect to its production and economic value (Diriba *et al*, 2013). It is primarily grown for its cloves, which are used mostly as food flavoring condiments due to groups of sulphur containing compounds, allin and allicin. Green tops are eaten fresh and cooked especially in tropical areas and consumption of immature bulbs for salad use is also popular. Garlic is one of the important and widely cultivated spice crops used for food as well as medicinal purposes (Diriba *et al*, 2013).

In Ethiopia, the *Allium* groups (onion, garlic and shallot) are important bulb crops produced for home consumption and are sources of income to many smallholder farmers in many parts of the country (Getachew and Asfaw, 2000). Garlic (*Allium sativum* L.) is the most widely used *Allium* crops next to onion and has a wide range of climatic and soil adaptation and is grown mainly in the mid-altitudes and highlands of the country. The bulk of garlic for domestic market is produced in homestead gardens of subsistence farmers (CACC, 2002). Moreover, it has been produced by Horticultural Development Corporation at Debrezeit, Guder and Tseday state farms (Getachew and Asfaw, 2000) mainly as a cash crop. The country is used to earning foreign currency by exporting it to Europe, the Middle East, and USA. Homestead gardens of smallholder farmers characterized by very low yields of about 11.7 tonnes ha^{-1} (CSA, 2010).

The acreage of garlic cultivation increased from 6,042 ha in 2001/02 to 12,481 ha in 2005/06 and to 15,361 ha in 2009/10 with a total production of about 79,421, 107,171.9, and 179,657.8 tonnes of bulbs with the productivity of 13.2, 8.6 and 11.7 t ha-1, respectively (CACC, 2002; CSA, 2006 and 2010).

A number of problems associated with biotic and abiotic stresses as well as improper agronomic practices account for the low yield of garlic in Ethiopia. Specifically, major production constraints include lack of proper planting material (of improved varieties), inappropriate agronomic practices, absence of proper pest and disease management practices (garlic rust, downy mildew, basal rot, white rot, purple blotch and onion thrips), absence of marketing facilities, and low soil fertility status in many soil types (Getachew and Asfaw, 2000). Lack of quality seed suitable for different agro-ecological zones, low soil fertility, and lack of appropriate fertilizer recommendations have often led to low yield and quality of garlic in Ethiopia. Particularly for *Allium* crops, adequate sulphur (S) supply is needed for the development of pungent flavours and for healthy growth of the plants (Randle, 1997). A study by Lancaster *et al.* (2001) showed that onions grown with very low sulphur produced softer bulbs than those grown with adequate supplies of the nutrient.

Most smallholder farmers in Ethiopia, particularly at Enebse Sar Midir District, appreciate the value of fertilizers, but they are seldom able to apply them at the recommended rates and at the appropriate time because of high cost, lack of credit, delivery delays, and low and variable returns. Organic inputs are often proposed as alternatives to mineral fertilizers. However, the traditional organic inputs such as crop residues, and animal manures cannot meet crop nutrient demand over large areas because of the limited quantities available, the low nutrient content of the materials, and the high labor demands for processing and application. Therefore, farmers should use integrated organic and inorganic inputs (Palm *et al.*, 1997).

The application of bio-fertilizers such as vermicomposts have been recognized as an effective means for improving soil aggregation, structure and fertility, increasing microbial diversity and populations, improving the moisture-holding capacity of soils, increasing the soil Cation Exchange Capacity (CEC) and increasing crop yields (Hargreaves *et al*., 2008). They also reported that municipal soil waste compost can also reduce the volume of the waste, kills' pathogens that may be present, decreases germination of weeds in agricultural fields, and destroys malodorous compounds. Earthworms have an important influence on soil structure, forming aggregates and improving the physical conditions for plant growth and nutrient uptake (Ansari and Sukhraj, 2010). During vermicomposting, earthworms eat, grind, and digest organic wastes with the help of aerobic and some anaerobic micro-flora, converting them into a much finer, humified, and microbial active material.

The generated product is stable and homogeneous; having desirable aesthetics such as reduced levels of contaminants, and this converted product can be used as a fertilizer or as a source of nitrogen for microbial populations which can be beneficial to plant growth. Chanda *et al.* (2011) showed that vermicompost and compost can meet the nutrient demand of greenhouse and field crops and significantly reduce the use of fertilizers and for vermicompost particularly, it increases soil fertility without polluting the soil, as well as the quantity and quality of crops. Moreover, beneficial effects of compost or vermicompost on plant growth under water deficit conditions may be due to better aeration to the plant roots, increasing amount of readily available water, induction of N, P and K exchange there by resulting better growth of the plants. Vermicompost increases the bulb dry weight by the accumulation of non structured carbohydrates whole distribution patterns change, thus favoring the metabolism of fructan precursors and accumulating as scorodose (Juan *et al.*, 2006). Such reserve substance accumulation in the vermicompost treatment occurs for longer period due to the earlier start of bulbing this response translate into a 2-fold increase of the bulb's dry weight, increased size, and therefore, higher quantity and quality and yield at harvest.

Vermicomposting had been an easy technology, environmentally-friendly process used to treat organic waste. This organic fertilizer was being therefore increasingly considered in agriculture and horticulture as a promising alternative to chemical fertilizers. However, the effects of vermicompost on garlic were not yet fully understood in Ethiopian condition. Therefore, the present research was focused on studying the effect of vermicompost in combination with chemical fertilizers on the yield and quality of garlic.

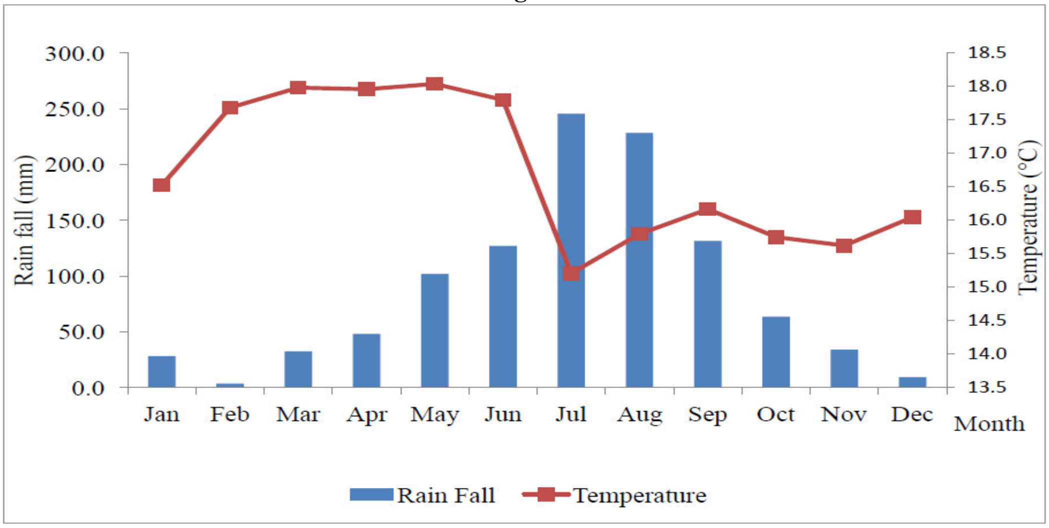
Garlic is one of the most important and widely used vegetable crops being produced in the highlands and mid-altitudes of Enebse Sar Midir District, Eastern Zone of Gojjam, using local cultivars under rain-fed and supplemental irrigation. However, the yield and quality of the crop is very low due to the use of low rates of fertilizers as well as fertilizers that are sources of only nitrogen and phosphorus. However, the plant requires optimum supply of nutrients to enhanced yield and quality of the crop. This research was therefore, conducted to study the influence of inorganic NP fertilizers and vermicompost on the bulb yield and quality of garlic.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Mertule Mariam Agricultural Technical and Vocational Education and Training (MMATVET) College, which is situated in Amhara National Regional State, Northwest of Ethiopia. The college is located at 10°50' latitude and 38°16' longitude with elevation of 2450 meters above sea level according to GPS reading. It is about 370 km and 184 km away from Addis Ababa and Bahir Dar, respectively. The annual rainfall of the area is about 900-1400 mm and temperature of 16 to 25°C average temperatures (Tafesse, 2008; ESMWAO Report, 2004).The soil texture of the experimental site had clay (clay of 54%, silt of 36% and sand of 10%, and pH 6.83.

Figure 1. The four years (2008-2011) average rainfall and temperature pattern of Enebse Sar Midir district based on the data from Bahir Dar meteorological stations.



Source: National meteorological data, Bahir Dar stations, 2011.

2.2. Description of the Experimental Material

A locally grown garlic cultivar called Tsedey 92 (G-493) was used for the study. The cultivar was obtained from Mertule Mariam, town in the market from known farmers. Fertilizer materials urea (CO ([NH_2]$_2$)) (46% N) and TSP (triple superphosphate [Ca (H_2PO_4)$_2$.H_2O] which constitutes (46% P_2O_5) was used as sources of nitrogen and phosphorus, respectively. Vermicompost was used as an organic fertilizer. The vermicompost was prepared from organic materials such as green plants, animal dung, poultry manure, sheep manure, leaves, ash etc. The raw materials were put up in layers in the following sequence according to Suparno *et al*. (2013): A layer of crop residues/green plants (20 cm) = 60%, a layer of topsoil/ash (2-4 cm) = 10%, A layer of manure (animal dung, poultry manure, sheep manure) (5-10 cm) = 30%. The decomposition process was facilitated by earth worms and fresh organic matters incorporated in the compost bin and above 75% moisture was maintained for free motility and breathe of the worms. Then; when decomposition properly begins, about four weeks later, the worms, species of *Eisenia foetida* collected from Adet Agricultural Research Center were added into the bedding and they feed on fresh organic matter. Four months later on after incorporation of worms, the important end product vermicompost (the worm casting) was ready for fertilization.

2.3. Treatments and Experimental Design

The treatments consisted of three rates of nitrogen (0, 23, 46 kg N ha^{-1}), three rates of phosphate (0, 46, 92 kg P_2O_5 ha^{-1}), and three rates of vermicompost (0, 2.5, 5 tonnes ha^{-1}). The experiment was laid out in a randomized complete block design (RCBD) in a factorial arrangement and replicated three times per treatment.

2.4. Experimental Procedures

The land was ploughed by oxen. Soil clods were broken by human labor and experimental plots were laid out on fine seedbeds prepared. Medium to large (1.5 - 2.5 g) cloves (Fikreyohannes, 2005), cloves from bulbs stored for about 6 months with dry tops attached were prepared for planting. The experimental plots were planted on 27 June 2013. Vermicompost was applied one month before planting by cutting open furrows and incorporating it into planting rows at the depth of about 10 - 15 cm. Triple superphosphate at the specified rates was applied at planting by ring application method. Nitrogen was applied in three splits: 1/4 at planting 1/2 four weeks after plant emergence (active stage of vegetative growth), and the other ¼ eight weeks after plants have emerged (just at the start of bulbing) by ring application method. Weed control was done by hoeing and shallow earthing up. Seven weeks after plant emergence, the fungicide Teel (tilt) was applied at a rate of 400 ml ha-1 by mixing with water in a ratio of 25 ml per 100 l water to prevent infection of some diseases. Other crop management practices were done as required after plant emergence. Harvesting was done when 70% of the leaves senesced. The harvested bulbs were windrowed in the field and sun-dried for ten days, folding the leaves over the bulbs to protect them from sunburn. After a week of drying, tops and roots were trimmed.

2.5. Soil Sampling and Analysis

Soil sampling was done before planting as well as after harvesting. Soil samples were taken randomly using an auger in a zigzag pattern from the entire experimental field. Before planting, thirty soil samples were taken from the top soil layer to a depth of 20 cm and composited in a bucket to represent the site and 27 composited samples were collected from the 81 plots for each treatment combination. The soil was broken into small crumbs and thoroughly mixed. From this mixture, a composite sample weighing 1 kg was filled into a plastic bag. The sample was duplicated and prepared for determining physico-chemical properties.

The soil was air-dried and sieved through a 2 mm sieve. Soil pH was determined from the filtered suspension of 1:2.5 soils to water ratio using a glass electrode attached to a digital pH meter. Texture of the soil was determined by sedimentation method (Hazelton and Murphy, 2007). The soil samples were analyzed for total nitrogen, available phosphorus, exchangeable potassium, organic matter and organic carbon. Total nitrogen was determined using the Kjeldhal method (Jackson, 1958). Available phosphorus was determined by extraction with 0.5 M NaHCO3 according to the methods of Olsen *et al.* (1954). Exchangeable potassium was determined with a flame photometer after extraction with 0.5 ammonium acetate; according to Hesse (1971). Organic carbon was determined by the method of Nelson and Sommers (1982). The chemical content of the vermicompost was determined using similar procedures used for the soil.

2.6. Data Collection and Measurement

Data on phenological, growth and yield parameters were recorded starting from planting to harvesting and postharvest. phenological parameters: Days to emergence, Days to bulb maturity; Growth parameters: Plant height, Number of leaves per plant, Leaf area index, Yield and quality of bulb: Mean bulb weight, Mean clove number per bulb, Mean clove weight, Total fresh biomass yield (g/plant) Total number of bulbs, Marketable fresh bulb yields (t ha^{-1}), Unmarketable, Total fresh bulb yield (kg), Bulb dry matter percent, Harvest Index, Total soluble solid was recorded.

2.7. Data Analysis

Data were subjected to analysis of variance (ANOVA) using GenStat 15th edition, version 15.1. All significant pairs of treatment means were compared using the LSD (Least Significant Difference) Test at 5% level of significance. Correlation analysis was performed to detect the linear relationships among yield, quality, and growth attributes.

3. Results and Discussion

3.1. Soil Analysis Results

Table 1. Physical and chemical properties of the experimental soil and the vermicompost before planting the garlic crop.

No.	Physical properties				Chemical properties					
	Clay %	Silt %	Sand %	Soil texture	N (%)	P (ppm)	K [Cmol(+)/kg]	OC (%)	OM (%)	pH
1. SBP	54	36	10	Clay	0.07	5.94	0.62	0.79	1.36	6.83
Rating	Clayey				Low	Low	Moderate	Low	Low	Optimum
2. VC					1.80	48	1.67	12.15	20.95	7.03
Rating					Very high	Very high	Very high	Very high	Very high	Optimum

According to Hazelton and Murphy, 2007. Where, OC = organic carbo, OM = organic matter, VC = vermicompost, ppm = parts per million.

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Table 2. Chemical properties of the experimental soils after harvesting the garlic crop.

No.	Treatment	N (%)	Rating	P (ppm)	Rating	K [Cmol(+)/kg]	Rating	OC (%)	Rating	OM (%)	Rating	pH	Rating
1.	0,0,0	0.04	V. low	4.62	V. low	0.48	Medium	0.78	Low	1.50	Low	6.83	Neutral
2.	0,0,2.5	0.07	Low	4.83	V. low	0.52	Medium	1.90	High	3.62	High	6.92	Neutral
3.	0,0,5	0.19	Medium	9.88	Low	0.69	High	3.77	V. high	6.84	V. high	6.94	Neutral
4.	0,46,0	0.05	Low	5.47	Low	0.47	Medium	0.74	Low	1.45	Low	6.87	Neutral
5.	0,46,2.5	0.09	Low	6.02	Low	0.62	High	1.86	High	3.02	High	6.93	Neutral
6.	0,46,5	0.20	High	12.34	Moderate	0.82	High	2.73	High	4.89	High	7.03	Neutral
7.	0,92,0	0.04	V. low	14.16	Moderate	0.31	Medium	0.82	Low	1.74	Moderate	6.56	S. acidic
8.	0,92,2.5	0.08	Low	14.72	Moderate	0.56	Medium	1.84	High	3.32	High	6.89	Neutral
9.	0,92,5	0.34	High	26.84	V. high	0.83	High	2.98	High	5.41	V. high	6.99	Neutral
10.	23,0,0	0.13	Low	4.66	V. low	0.37	Medium	0.79	Low	1.45	Low	5.94	Neutral
11.	23,0,2.5	0.21	Medium	5.54	Low	0.61	High	1.89	High	3.62	High	6.46	S. acidic
12.	23,0,5	0.26	High	7.88	Low	0.67	High	3.64	V. high	6.82	V. high	6.83	Neutral
13.	23,46,0	0.18	Medium	11.92	Moderate	0.25	Low	0.81	Low	1.52	Low	6.43	S. acidic
14.	23,46,2.5	0.29	High	8.65	Low	0.57	Medium	1.74	Moderate	3.24	High	6.74	Neutral
15.	23,46,5	0.89	V. high	13.37	Moderate	0.69	High	2.94	High	5.66	V. high	6.89	Neutral
16.	23,92,0	0.12	Low	15.02	Moderate	0.35	Medium	0.88	Low	1.62	Low	6.31	S. acidic
17.	23,92,2.5	0.23	Medium	18.28	High	0.63	High	1.64	Moderate	3.13	High	6.62	S. acidic
18.	23,92,5	0.74	V. high	24.44	High	0.88	High	2.94	High	5.68	V. high	6.95	Neutral
19.	46,0,0	0.81	V. high	4.36	V. low	0.64	High	0.78	Low	1.41	Low	5.97	M. acidic
20.	46,0,2.5	0.88	V. high	4.78	V. low	0.74	High	1.76	Moderate	3.42	High	6.38	S. acidic
21.	46,0,5	1.02	V. high	8.24	Low	0.83	High	3.02	V. high	5.89	V. high	6.96	Neutral
22.	46,46,0	0.74	V. high	7.34	Low	0.53	Medium	0.98	Low	1.73	Low	6.03	S. acidic
23.	46,46,2.5	0.78	V. high	9.22	Moderate	0.58	Medium	1.82	High	3.38	High	6.49	S. acidic
24.	46,46,5	1.04	V. high	14.55	Moderate	0.76	High	2.89	High	5.70	V. high	6.91	Neutral
25.	46,92,0	0.78	V. high	17.75	High	0.15	V. low	1.03	Moderate	1.99	Moderate	6.25	S. acidic
26.	46,92,2.5	0.92	V. high	19.66	High	0.38	Medium	1.65	Moderate	3.21	High	6.65	Neutral
27.	46,92,5	0.99	V. high	26.78	V. high	0.87	High	2.94	High	5.77	V. high	6.89	Neutral

According to Hazelton and Murphy, 2007. Where, OC = organic carbo, OM = organic matter, VC = vermicompost, ppm = parts per million.

3.2. Phenological parameters

3.2.1. Days to emergence

The main effect of nitrogen was not significant on the number of days required for emergence of the plant above the soil surface. On the other hand, the main effects of P and vermicompost significantly ($P < 0.001$) influenced days to emergence. However, the interaction effect of N, P and vermicompost application did not significantly influence days to emergence.

With the increase in the rates of both phosphorus and vermicompost 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 phosphorus from nil to 46 and 92 kg P_2O_5 ha^{-1} hastened emergence of garlic sprouts from the soil by 4.0 and 7.0%, respectively. Similarly, increasing the rate of vermicompost from nil to 2.5 and 5.0 t ha^{-1} hastened the emergence of garlic sprouts from the soil by 4.0 and 5.0%, respectively. The smallest numbers of days to emergence were recorded for the 92 kg P_2O_5 ha^{-1} followed by 5.0 t vermicompost ha^{-1}. However, the longest duration in days for emergence was required by cloves treated with no phosphorus and vermicompost. 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 vermicompost on root initiation and development which might lead to early shoot emergence.

Days to emergence decreased by 4.63% over the control treatment with increased application of vermicompost from 0 to 5 t ha^{-1}. Similarly, Edward and Burrows (1988) found that seedlings emergence of tomato, cabbage, and radish was much faster in higher rates of vermicompost than in nil application. Juan (2006) also observed that the use of vermicompost as a substrate produced an earlier shoot emergence and earlier start of bulbification. This corresponds to increase the total soluble carbohydrates and a subsequent modification in the non-structural carbohydrate distribution patterns, and hence a modification in the pattern of fructan (scorodose) metabolism. The author therefore concluded that scorodose accumulation is directly related to the harvest index and is shown as greater yield and bulb quality.

3.2.2. Days to maturity

The analysis of variance revealed days to maturity was significantly influenced by the main effects of N ($P < 0.05$), P ($P < 0.01$) and vermicompost ($P < 0.001$) but not by the interaction effects of any of the three factors.

Increasing the rates of all three 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 treated with 23 and 46 kg N ha^{-1} reached maturity later than plants supplied with no nitrogen. Prolonged maturity in response to increasing rate of vermicompost may be ascribed to the availability of optimum nutrients contained in vermicompost 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 Tadila (2011) who reported prolonged maturity on garlic in response to combined application of N and manure. The results are in agreement with the findings of Islam *et al.* (2010) 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. Consistent with these results, Plants supplied with 92 kg P_2O_5 ha^{-1} and 46 kg P_2O_5 ha^{-1} matured significantly later than plants that were supplied with nil P_2O_5 ha^{-1}. In contrast to this result, Sharma (1998) stated that as the availability of P increased in the soil, the physiological maturity of the plant was hastened. According to these investigators, excessive use of P fertilizer is associated with reduced yield by hastening the maturation process and reducing tuber size on potato. However, the prolonged days required by plants receiving increased P might be due to the low level of P at the experimental soil.

Similarly, plants that were treated with vermicompost at the rates of 5.0 t ha^{-1} matured significantly later than those supplied with nil and 2.5 t ha^{-1} vermicompost (Table 3). Prolonged maturity in response to increasing rate of vermicompost may be ascribed to the availability of optimum nutrients contained in vermicompost that led to prolonged maturity through facilitated enhanced leaf growth and photosynthetic activities thereby increasing partition of assimilate to the storage organ. This result is supported by the findings of Tadila (2011) who reported prolonged maturity on garlic in response to combined application of N and manure.

3.3. Growth parameters

3.3.1. Leaf number

The main effects of N ($P < 0.001$), P ($P < 0.001$) and vermicompost ($P < 0.001$) significantly influenced leaf number. However, the interaction effect of N, P and vermicompost supplementation did not significantly affect leaf number of garlic.

Compared to the control treatment, number of leaves per plant was significantly increased by 3.77% in response to increasing the rate of N from 0 to 46 kg N ha^{-1} (Table 3). This attributed that, since nitrogen is a constituent of chlorophyll, the increase of which with added nitrogen might have resulted in increased synthesis of photosynthates, leading to better vigour (Gupta, 2005). This result is supported by that of Melaku (2010) 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, Abdisa (2008) 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. In contrast, Gezachew (2006) found that the main effects of compost and NP fertilizers had non-significant influences on the main stem and leaf numbers of potato.

The maximum leaf number of garlic leaves was recorded at the rate of 92 kg P_2O_5 ha^{-1} which was increased by 6.25% compared to the leaf number obtained in the control treatment (Table 3). This result is in agreement with that of Gebrehawaria (2007) who found that the main effects of P significantly ($P < 0.05$) increased leaf number per plant on garlic plant. Tibebu *et al.* (2014) also recorded maximum numbers of leaves of onion at the rate of 69 kg P_2O_5.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.

Vermicompost significantly ($P < 0.01$) affected leaf number. Number of leaves per plant was increased by about 4% in response to increasing vermicompost from 0 to 5 t ha^{-1}. This result is supported by the findings of Fatma *et al.* (2014) who observed that, the application of compost at two rates significantly increased vegetative growth characters, i.e. plant height, average number of leaves, and fresh and dry weight of whole plant and its different organs of onion plant. Bagali *et al.* (2012) 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}. Vermicompost is known to contain micronutrients apart from major nutrients. Besides this, vermicompost has been reported to contain several plant growth promoters, enzymes, beneficial bacteria and mycorrhizae (Gupta, 2005). 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 Reddy and Reddy (2005). Higher levels of farm yard manure (FYM) significantly increased the plant height, number of leaves per plant (Reddy and Reddy, 2005) and leaf area per plant (Lal *et al*., 2002) in onion. This might be due to increased number of leaves and leaf area per plant resulting in better photosynthesis and accumulation of photosynthates leading to more vigor. Similar results were also obtained by Sampathkumar (1988) and Thimmiah (1989). 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.

3.3.2. Leaf area index

Leaf area index was significantly affected by the main effects of N ($P < 0.001$), P ($P < 0.001$) and vermicompost

($P < 0.001$) but not significantly by any of the interaction effects.

The highest leaf area index was recorded at the application rate of 46 kg N ha^{-1} which was increased by 34.69% over the control treatment (Table 3). The maximized leaf area index of garlic at higher rates of N may be attributed to enhanced vegetative growth and bulb filling (Tadila, 2011). Consistent with the results of this study, Borabash and Kochina (1989) reported that mineral fertilizers of balanced doses increased the leaf area, photosynthetic productivity and yield of garlic.

Leaf area index was increased by 21.32% by application of P at the rate of 92 kg P_2O_5 ha^{-1} over the control. This could be due to the influence of P on photosynthetic productivity and final leaf area index with the application of 39.27 kg P ha^{-1} to garlic crop as Borabash and Kochina (1989) reported.

Vermicompost supplement at a rate of 5 t ha^{-1} increased leaf area index of garlic by 15.15% compared to control. The increase in leaf area index in response to increasing rate of vermicompost may be ascribed to the availability of optimum nutrients contained in manure that led to high leaf area index through facilitated vegetative growth. This result is in line with that of Mehdi *et al*. (2012) 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 applied municipal solid waste and vermicompost under well-watered, moderate and severe stress conditions.

Table 3. Main effects of nitrogen, phosphorus, and vermicompost on days to emergence, leaf number per plant, leaf area index and days to maturity of garlic.

Factor	Treatment	Days to emergence (No.)	Leaf number per plant (No.)	Leaf area index	Days to maturity (No.)
Nitrogen (kg ha^{-1})	0	13.37	7.87c	0.91c	135.70b
	23	13.26	8.17b	1.09b	135.70b
	46	13.33	8.39a	1.23a	135.90a
LSD (5%)		Ns	0.1554	0.03343	0.2023
Phosphorus (kg P_2O_5 ha^{-1})	0	13.70 a	7.84b	0.95c	135.70b
	46	13.41b	8.26a	1.12b	135.80a
	92	12.85c	8.33a	1.16a	135.90a
LSD (5%)		0.2891	0.1554	0.03343	0.2023
Vermicompost (t ha^{-1})	0	13.56 a	7.95b	0.99c	135.50b
	2.5	13.44 a	8.21a	1.09b	135.70b
	5	12.96b	8.27a	1.14a	136.00a
LSD (5%)		0.2891	0.1554	0.03343	0.2023
CV (%)		4.0	3.5	5.7	0.3

Means followed by the same letter within a column are not significantly different at 5% level of significance; ns = non-significant

3.3.3. Plant height

Plant height significantly affected by all levels of treatments and their combination except P and vermicompost interaction. Plant height also significantly ($P < 0.05$) influenced by the interaction effect of N, P and vermicompost.

Maximum plant height of garlic was recorded at the application rate of 46 and 92 kg ha^{-1} N and P respectively with 5 t ha^{-1} vermicompost whereas the shortest plant height of garlic was recorded at the nil application of N, P and vermicompost. The application of 46 and 92 kg ha^{-1} N and P respectively with 5 t ha^{-1} vermicompost increased plant height by 36.01%.

The increase in height due to increased rate of the combination application of N, P and vermicompost could be attributed to the fact that vermicompost contains a good range of additional essential micronutrient other than NPK fertilizers, required for healthy plant growth (Surindra, 2009) and N from vermicompost as well as the inorganic N application is one of the important building blocks of amino acids ($-NH_2$), where they link together and form proteins and make up metabolic processes required for plant growth. Bungard *et al*. (1999) stated that N is a constituent of many fundamental cell components and plays a vital role in all living tissues of the plant. No other element has such an effect on promoting vigorous plant growth. This result is in harmony with those reported by Rizk (1997) who concluded that increasing the application rate of N increased growth parameters of onion plant. Warren (1992) showed that plants supplied with adequate amount of P were reported to form good root system as a result crop of which, water uptake is promoted resulting in strong stem, early maturity and higher yield.

Surindra (2009) concluded that the combination of vermicompost with chemical fertilizer increased the budget of essential soil micronutrients and promotes microbial population, which ultimately promotes the plant growth and production at sustainable basis. Mehdi *et al*. (2012) also reported that vermicompost showed more vigorous growth of lettuce seedlings as a consequence of the optimization of the use of water and carbon. An increase in leaf area index increases light interception and the source/sink strength for heat, water and CO_2 exchange. It can also start a negative feedback loop by increasing drag on wind, decreasing wind velocity that acts to reduce mass and energy exchange (Albertson *et al.*, 2001).

Table 4. Interaction effect of nitrogen, phosphorus and vermicompost on plant height of garlic.

Treatments		Plant height (cm)			
N (kg ha^{-1})	P (kg P_2O_5 ha^{-1})	VC (t ha^{-1})	0	2.5	5
0	0		37.07l	39.50k	40.70k
	46		39.80k	44.01hij	44.56ghi
	92		42.54j	44.37hi	45.45fgh
23	0		39.56k	43.20ij	45.61fgh
	46		46.25efg	46.75def	47.36cde
	92		45.56fgh	47.73bcde	48.40bcd
46	0		46.55ef	46.54ef	47.78bcde
	46		48.36bcd	48.72bc	49.18ab
	92		48.83abc	49.21ab	50.45 a
LSD (5%)			1.721		
CV (%)			2.3		

Means followed by the same letter are not significantly different at 5% level of significance; where, N = nitrogen, P = phosphorus, VC= vermicompost, PH= plant height

3.4. Yield and Yield Related Components of Garlic

3.4.1. Mean clove number

The main effects of N ($P < 0.001$), P ($P < 0.001$) and vermicompost ($P < 0.001$) showed significant difference on mean clove number. The analysis of variance revealed that the interaction effect of N and P ($P < 0.01$) and N and vermicompost ($P < 0.05$) significantly influenced mean clove number.

Maximum clove numbers of garlic were recorded at the combined application of N and Phosphorus at the rates of 23 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} respectively which were in statistical parity with the application of 46 kg N and 92 kg P_2O_5 (Table 3). This attributes to combination of vermicompost with chemical fertilizer increases the budget of essential soil micronutrients and promotes microbial population, which ultimately promotes the plant growth and production at sustainable basis (Mugwira and Murwira, 1998).The authors also reported that the use of organic manure is more beneficial when combined with inorganic fertilizers. This result is in line with the findings of Gezachew (2006) who showed that the interaction effect of compost and NP fertilizers significantly increased total and marketable tuber number of potato. Baghour *et al.* (2001) reported that vegetative growth, yield and quality of onion significantly improved through nitrogen and phosphorus fertilization.

Table 5. Interaction effect of nitrogen and phosphorus on mean clove number of garlic.

Treatments	Mean clove number		
N (kg ha^{-1})	P (kg P_2O_5 ha^{-1})		
	0	46	92
0	13.21f	13.37d	13.57 c
23	13.23ef	13.65bc	13.78a
46	13.33de	13.65bc	13.70ab
LSD (5%)	0.1098		
CV (%)	0.9		

Means followed by the same letter are not significantly different at 5% level of significance.

A combination application of N and vermicompost at the rates of 23 kg N ha^{-1} and 5 t ha^{-1} vermicompost was significantly increased mean clove number of garlic by 4.33% over the control and it was statistically at par with a clove number found at a combination application of 46 kg N ha^{-1} and 2.5 t ha^{-1} vermicompost. Similarly Surindra (2009) showed that integrated nutrient supply, in the form of traditional inorganic NPK and in the form of organic manures, brings an excellent biochemical changes in soil structure, which ultimately promotes plant growth and production. However, the earthworm casts not only affects soil's physio-chemical structure, it but also promotes biological properties of it.

Table 6. Interaction effect of nitrogen and vermicompost on mean clove number of garlic.

Treatments	Mean clove number		
N (kg ha^{-1})	VC (t ha^{-1})		
	0	2.5	5
0	13.28e	13.38de	13.49 c
23	13.45cd	13.51c	13.70a
46	13.51c	13.62ab	13.56bc
LSD (5%)	0.1098		
CV (%)	0.9		

Means followed by the same letter are not significantly different at 5% level of significance

3.4.2. Mean clove weight

The main effects of N ($P < 0.001$), P ($P < 0.001$) and vermicompost ($P < 0.001$) showed significance difference on mean clove weight (Table 5). However the interaction effect of N, P and vermicompost did not significantly affected mean clove weight.

N supply at the rate of 46 kg N ha^{-1} increased mean clove weight by 13.33% compared to the control. This result is in agreement of Gebrehaweria (2007) who found that the highest mean clove weight (2.83 g) at the rate of 120 kg N ha^{-1} compared with control. Sharma and Singh (1991) also reported that nitrogen application at 80 kg ha^{-1} caused 38% increase in bulb weight over the control.

Application of 46 kg P_2O_5 ha^{-1} significantly increased mean clove weight by 20.49% over the control. This could be due to the influence of P on assimilating leaf area; photosynthetic productivity and final bulb yield with the application of 39.27 kg P ha^{-1} to garlic crop as Borabash and Kochina (1989) reported.

Vermicompost supply at the rate of 5 t ha^{-1} increased mean clove weight by 7.99% compared to the control traetment. The increase in mean clove weights in response to increasing the rate of Vermicompost may be ascribed to several growth promoters, enzymes, benefitial bacteria and mycorrhyzae contained in vermicompost that led to high mean clove weight through facilitating improved leaf growth and photosynthetic activities thereby increasing portioning of assimilate to the storage organ. This hypothesis is supported by that of Sibale and Smith (1997) who reported significant increase in potato tuber yield components with the application of organic manure.

3.4.3. Mean bulb weight

The main effects of N ($P < 0.001$), P ($P < 0.001$) and vermicompost ($P < 0.001$) showed significant difference on mean bulb weight. But the interaction effect of N, P and vermicompost did not significantly affected mean clove weight.

N supply at the rate of 46 kg N ha^{-1} increased mean bulb weight by 13.9% compared to the control. This study is supported by the findings of Tadila (2011) who reported increased mean fresh bulb weight of garlic plant with increasing rate of N up to 100 kg N ha^{-1}. The increase in bulb weight could be attributed to the increase in number of leaves and plant height in response to the N treatments that might have increased dry matter production. Similarly, Srinivas and Nail (1987) found an increase in onion bulb yield from 16.51 t ha^{-1} at zero N to 56.30 t ha^{-1} at the highest N rate (200 kg ha^{-1}).

P supply at the rate of 92 kg P_2O_5 ha^{-1} increased mean clove weight by 20.7% over the control treatment. Tibebu *et al.* (2014) showed that, the highest dried bulb yield 17 t ha^{-1} was recorded from 69 kg P_2O_5 ha^{-1} while the lowest 13.9 t ha^{-1} was from 0 kg P_2O_5 ha^{-1}.

Application of vermicompost at the rate of 5 t ha^{-1} increased mean bulb weight by 8% as compared to the control plots. The increased mean bulb weight could be due to the role of vermicompost which is known to contain micronutrients apart from major nutrients. Besides this, vermicompost has been reported to contain several plant growth promoters, enzymes, beneficial bacteria and mycorrhizae (Gupta, 2005).

Table 7. Main effects of nitrogen, phosphorus and vermicompost on mean bulb weight and mean clove weight of garlic.

Factor	Treatment	Mean clove weight (g/p)	Mean bulb weight (g)
Nitrogen (kg ha^{-1})	0	1.61c	20.64c
	23	1.74b	22.37b
	46	1.82a	23.51a
LSD (5%)		0.03844	0.4855
Phosphorus (kg P_2O_5 ha^{-1})	0	1.54 c	19.79c
	46	1.78 b	22.85b
	92	1.86 a	23.89a
LSD (5%)		0.03844	0.4855
Vermicompost t ha^{-1}	0	1.67b	21.42c
	2.5	1.71b	21.95b
	5	1.80a	23.15a
LSD (5%)		0.03844	0.4855
CV (%)		4.1	4.0

3.4.4. Fresh biomass yield
The main effect of N ($P < 0.001$), P ($P < 0.001$) and vermicompost ($P < 0.001$) significantly influenced fresh biomass yield. However, fresh biomass yield did not significantly affected by any of the interaction effects.

Application of 46 kg N ha^{-1} increased fresh biomass yield by 14.67% compared to the control treatment. This result is in agreement with Kilgory *et al.* (2007) who observed that increasing levels of N from 0 to 120 kg ha^{-1} resulted significant increase in fresh biomass yield of garlic. The author also reported that, the highest fresh bulb yield of 8.4 t ha^{-1} was recorded with 120 kg N ha^{-1}. This result suggests that N application to the soil is important to improve bulb yield of onion significantly. This might be due to nitrogen is an integral component of many essential plant compounds like chlorophyll, proteins and it is a major part of all amino acids (Brady and Weil, 2002). It increases the vegetative growth and produces good quality foliage and promotes carbohydrate synthesis through photosynthesis and ultimately increased yield of plants.

On the other hand, Kilgori (2007) reported that application of varying rates of P had no significant impact on fresh biomass yield. But this study showed that increased application of P_2O_5 from 0 to 92 kg ha^{-1} significantly ($P < 0.001$) increased fresh biomass yield by 16.52%. This could be due to the influence of P on photosynthetic productivity and final leaf area with the application of 39.27 kg P ha^{-1} to garlic crop as Borabash and Kochina (1989) reported.

3.4.5. Total bulb yield
Total bulb yield was significantly influenced by main effects of N ($P < 0.001$), P ($P < 0.001$) and vermicompost ($P < 0.001$). On the other hand, the interaction effects showed non-significant difference.

The analysis of variance indicated that N significantly affected the total bulb yields of garlic. Application of N at a rate of 46 kg N ha^{-1} increased the total bulb yields by about 14.29% as compared to the untreated control. This positive response might be due to the role of N in promoting the growth of garlic plant (Surindra, 2009). This result is in line with that of Kilgori (2007) who found significantly increased bulb yield of garlic with increasing level of nitrogen from 0 to 120 kg N ha^{-1} and the highest yield was recorded at 120 kg N ha^{-1}. Abdisa (2008) also reported similar result that average bulb dry weight and average total dry biomass per plant on onion increased by about 24 and 20%, respectively, over the control due to the application of 69 kg N ha^{-1}. Ruiz (1985) also reported increased bulb yield of garlic from 4.6 to 10.6 t ha^{-1} in response to increased rate of applied N from 0 to 150 kg ha^{-1}.

The highest total bulb yield was recorded at the rate of 92 kg P_2O_5 ha^{-1} fertilizer which significantly increased by 20.61% over the control (Table 6). This result is supported by the findings of Kebede (2003) who found that phosphorus fertilization at the rate of 50 kg P_2O_5 ha^{-1} in irrigated shallot and 25 kg P_2O_5 ha^{-1} under rain fed condition with supplemental irrigation of shallot showed increased bulb yield and mean bulb weight (Kebede, 2003). Minard (1978) also reported that 114.75 kg P ha^{-1} as optimum for increased bulb yield of garlic among other parameters. The author attributed this effect to the influence of P on root development, which led to effective nutrients uptake and water absorption. Sims *et al*. (2003) stated that application of P from 29 to 48 kg P ha^{-1} would usually adequate for better garlic production while in the desert areas, however, rates of P up to 96 kg P ha^{-1} might be needed. But in this study total bulb yield was significantly increased until P rate reached 92 kg P_2O_5 ha^{-1}. This could be due to the influence of P on root development, which led to effective nutrients uptake and water absorption (Minard, 1978). Borabash and Kochina (1989) also recorded significant increase in leaf area; photosynthetic productivity and final bulb yield with the application of 39.27 kg P ha^{-1} to garlic crop. In contrast, Kilgori (2007) had observed a non-significant effect of increased application of phosphorus on cured bulb yield.

Increased application of vermicompost from 0 to 5 t ha^{-1} significantly increased the total bulb yield by 9.57%. This result is supported by the findings of Thanunathan *et al.* (1997) indicated that the use of vermicompost on onions increased growth and yield from 2.72g/plant to 38.05 g/plant. Similarly, Gezachew (2006) who reported that increased application of compost from 0 to 20 t ha^{-1} significantly increased the average tuber weight by 13.8%.

In contrast, the interaction effects of N, P and vermicompost did not cause significant difference on total bulb yield of garlic. However, Kilgori *et al*. (2007) reported a significantly increased in cured bulb yield of garlic with increased N from 0 to 60 and 120 kg ha^{-1}. Moreover, they found that higher dosage of 180 and 240 kg N ha^{-1} reduced the bulb yield. Tomati *et al*. (1987) demonstrated a great quantity of microorganisms, especially bacteria, and a high concentration of plant hormones such as auxins, gibberellins and cytokinins in earthworm-processed sewage sludge. Earthworm castings (worm manure) are rich in microbial activity and plant growth regulators, and fortified with pest repellence attributes as well (Suparno *et al*., 2013).

Table 8. Main effects of nitrogen, phosphorus and vermicompost on fresh biomass yield and total bulb yield of garlic.

Factor	Treatment	Fresh biomass yield (g/p)	Total bulb yield (t ha^{-1})
Nitrogen (kg ha^{-1})	0	30.89c	6.87c
	23	34.35b	7.49b
	46	35.42a	7.85a
LSD (5%)		0.633	0.1874
Phosphorus (kg P_2O_5 ha^{-1})	0	30.69c	6.60c
	46	34.21b	7.64b
	92	35.76a	7.96a
LSD (5%)		0.633	0.1874
Vermicompost t ha^{-1}	0	32.91b	7.10c
	2.5	33.30b	7.33b
	5	34.45a	7.78a
LSD (5%)		0.633	0.1874
CV (%)		3.5	4.6

3.4.6. Marketable bulb yield

The analysis of this study showed that marketable bulb yield was significantly influenced by the main effects of N, P and vermicompost ($P < 0.001$) and the interaction effect of N and P ($P < 0.01$) fertilizers.

The highest marketable yield was recorded at the combined application of N and P fertilizers at 46 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} (Table 8). This finding is in agreement with the result of Maksoud *et al*. (1984) who found significantly increased marketable yield of garlic with increased N application. Similarly, Hanley *et al* (1965) reported the existence of positive interaction between N and P, indicating that these fertilizers increased yield when applied together than when they were applied separately. Arboleya and Garcia (1993) in a trial of garlic with N at 0, 75, 150, and 225 kg ha^{-1} observed an increased marketable bulb yield from 4.66 t ha^{-1} at 0 kg N ha^{-1} to 8.04 t ha^{-1} at 225 kg N ha^{-1}. In contrast, P application did not affect marketable yield significantly. In this study, the interaction effect of N and P produced significantly higher marketable yields indicating that the application of N and P fertilizers to be used for improving plant performance in the specified experimental site.

Table 9. Interaction effect of nitrogen and phosphorus on marketable bulb yield of garlic.

Treatments	Marketable bulb yield		
N (kg ha^{-1})	P (kg P_2O_5 ha^{-1})		
	0	46	92
0	5.538e	6.464d	6.578 d
23	5.631e	6.997c	7.482b
46	5.785 e	7.478b	7.870a
LSD (5%)	0.3680		
CV (%)	5.9		

Means followed by the same letter are not significantly different at 5% level of significance

Marketable yield of garlic was increased by 10% with increased application rate of vermicompost from 0 to 5 t ha^{-1} (Table 8). The increase in marketable bulb yield in response to increasing rate of vermicompost may be ascribed to the availability of optimum nutrients contained in manure that may have led to high leaf area index through improved leaf growth and photosynthesis. This result is in line with that of Mehdi *et al*. (2012) 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.

Table 10. Main effect of vermicompost on marketable bulb yield of garlic.

Treatment	Rate (t ha^{-1})	Marketable bulb yield (t ha^{-1})
Vermicompost	0	6.357c
	2.5	6.596b
	5	6.989a
LSD (5%)		0.2125
CV (%)		5.9

3.4.7. Unmarketable bulb yield

Unmarketable bulb yield was significantly influenced by main effect of vermicompost ($P < 0.001$), and the interaction effect of N and P ($P < 0.01$) fertilizers. The combination effect of N and P significantly decreased unmarketable yield by 68.04% (Table 9). Minimum unmarketable yield was recorded at a combination rate of 23 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} which is statistically at par with 46 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} and maximum unmarketable yield was recorded at nil combination application of both N and P which is statistically at par with combination application of 23 and 46 kg N ha^{-1} and nil P. This result could indicate that the potential of inorganic N and P fertilizers increased as they are applied together than they are applied separately.

Table 11. Interaction effect of nitrogen and phosphorus on unmarketable yield of garlic.

Treatments	Unmarketable yield		
N (kg ha^{-1})	P (kg P_2O_5 ha^{-1})		
	0	46	92
0	0.9410a	0.8126bc	0.7396cd
23	0.9054ab	0.6801d	0.5600e
46	0.8259abc	0.6279de	0.7200cd
LSD (5%)	0.1199		
CV (%)	16.7		

Means followed by the same letter are not significantly different at 5% level of significance

Vermicompost also showed a significant ($P < 0.05$) effect on unmarketable bulb yield. Unmarketable bulb yield significantly decreased by 12.83% at an application rate of 5 t ha^{-1} vermicompost over the control (Table 10). An important feature of vermicompost is that, during the processing of the various organic wastes by earthworms, many of the nutrients that it contents are changed to forms that are more readily taken by plants such as nitrate or ammonium nitrate, exchangeable phosphorous and soluble potassium, calcium and magnesium (Suthar and Singh, 2008a).

Table 12. Main effect of vermicompost on unmarketable bulb yield of garlic.

Treatment	Rate (t ha^{-1})	Unmarketable bulb yield (t ha^{-1})
Vermicompost	0	0.8111a
	2.5	0.7408b
	5	0.7189b
LSD (5%)		0.0692
CV (%)		16.7

Means followed by the same letter within a column are not significantly different at 5% level of significance

3.4.8. Bulb Dry matter percent

Bulb dry matter percent was significantly influenced by the main effects of N ($P < 0.001$), P ($P < 0.001$) and vermicompost ($P < 0.001$). However, bulb dry matter percent did not significantly affected by all interaction effects.

Bulb dry matter percent was increased by 14.21% due to increased level N rate from 0 to 46 kg ha^{-1}. Similar result was reported by Abdisa (2008) that average bulb dry weight and average total dry biomass per plant of onion have increased by about 24 and 20%, respectively, over the control due to the application of 69 kg N ha^{-1}. Narang and Dastane (1972) also reported that onion bulbs under low nitrogen and moisture regime were small in size, had low dry matter content and dried out earlier than those grown under adequate moisture and nutrition conditions. In contrast Tekalign *et al.* (2012) observed 4% reduction in dry matter of onion due to application of 138 kg N ha^{-1} compared to control.

Bulb dry matter percent of garlic was significantly increased by 21.03% as response of P application rate increment from 0 to 92 kg P_2O_5 ha^{-1}. The highest bulb dry matter percent was recorded at 92 kg P_2O_5 ha^{-1}. This result is in agreement with Hilman and Noordiyati (1988) who recorded a significant increase in bulb dry weight of garlic with the application of 150 kg ha^{-1} of triple super phosphate.

Garlic bulb dry matter percent was increased by 8.13% due to vermicompost application at 5 t ha^{-1} rate over the control. This result is supported by Juan *et al.* (2006) who showed that vermicompost increased the bulb dry weight due to the accumulation of non-structural carbohydrates whose distribution patterns change, thus favouring the metabolism of fructan precursors and accumulating as scorodose. The author further explained as such reserve substance (scorodose) accumulation in the vermicompost treatment represented by scorodose polysaccharide, occurs for a longer period due to the earlier start of bulbing. This response translates in to a 2-fold increase of the bulbs dry weight, increased size and therefore, higher quality and yield at harvest. Similarly Fenwik and Hanley (1985) reported that, in garlic, the fructan polysaccharide is the scorode which accounts for 53% of garlic dry matter.

3.4.9. Total soluble solid

Total soluble solid was also significantly influenced by the main effects of N ($P < 0.001$), P ($P < 0.001$) and vermicompost ($P < 0.001$). But no interaction effect was significantly affected total soluble solid.

Application of 46 kg N ha^{-1} increased TSS by 19.29% compared to control. This result is in line with Verma *et al*., (1996) who reported that application of 100 kg N ha^{-1} increased the total soluble solids (TSS) and dry matter of garlic. Lipiniski *et al.* (1995) also reported that application of 240 kg N ha^{-1} increased garlic yield only by 10-15% compared to the control in the soil with initial total nitrogen of 800-900 ppm.

Phosphorus application at the rate of 92 kg P_2O_5 ha^{-1} increased TSS by 20.74% over the control. The positive effects of P application on quality parameters could be due to the role of phosphorus which was extremely important as a structural part of many components, notably nucleic acid, and phospholipids (Juan *et al.,* 2006). In addition, phosphorus plays an indispensable role in energy metabolism, the high energy of hydrolysis of phosphate and various organic phosphate bonds being used to induce chemical reaction.

Application of 5 t vermicompost ha^{-1} increased TSS by 11.04% compared to control. It might be due to more accumulation of reserve substances in the bulbs. This result is supported by the findings of Singh *et al.* (2013) who found a higher fruit density and more TSS in tomato due to application of vermicompost as compared to the treatment to which vermicompost was not applied.

Table 13. Main effects of nitrogen, phosphorus and vermicompost on dry matter and total soluble solid of garlic.

Factor	Treatment	Dry matter (%)	TSS (°Brix)
Nitrogen (kg ha^{-1})	0	45.39c	4.85c
	23	49.48b	5.45b
	46	51.84a	5.79a
LSD (5%)		1.152	0.137
Phosphorus (kg P_2O_5 ha^{-1})	0	43.55c	4.79c
	46	50.45b	5.51b
	92	52.71a	5.79a
LSD (5%)		1.152	137
Vermicompost t ha^{-1}	0	47.21c	5.13c
	2.5	48.46b	5.27b
	5	51.05a	5.69a
LSD (5%)		1.152	137
CV (%)		4.3	4.7

Where, TSS = total soluble solid

3.4.10. Harvest index

The interaction effect of N and P significantly influenced harvest index of garlic (Table 12). The maximum harvest index (11.08%) was recorded at combination supply of 46kg N $ha^{-1}$and 92 kg P_2O_5 ha^{-1}.This could be attributed to the strong movement of assimilates from the leaves to the bulbs during the growing period.

Vermicompost has shown no significant effect on harvest index (Table 12). As the soil texture of the experimental site is clayey, the absence of response to vermicompost might be due to insufficient amount of organic matter to amend physical and chemical properties of the soil at the experiment site, including nutrient supplement; the added 5 t ha^{-1} vermicompost could not be met. In contrast, Juan *et al.* (2006) reported that vermicompost resulted in an increase in scorodose accumulation, which is directly related to the harvest index.

Table 14. Interaction effect of nitrogen and phosphorus on harvest index of garlic.

Treatments	Harvest index (%)		
N (kg ha^{-1})	P (kg P_2O_5 ha^{-1})		
	0	46	92
0	61.54c	66.16b	66.62ab
23	61.76c	67.18ab	67.31ab
46	64.51bc	67.19ab	68.36a
LSD (5%)	3.710		
CV (%)	5.9		

Means followed by the same letter are not significantly different at 5% level of significance

3.5. Economic Analysis

The result of partial budget based on total variable input cost indicated that the highest total variable cost (3623.00 ETB ha^{-1}) was incurred at combined application of 46 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} followed by (3073.00 ETB ha^{-1}) combined application of 23 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}. On the other hand, the highest benefit (280542.00 ETB ha^{-1}) in the partial budget was recorded at 5 t ha^{-1} vermicompost followed by (172569.00 ETB ha^{-1}) at combined application of 46 kg N and 92 kg P_2O_5 ha^{-1}. The least total variable cost (300.00 ETB ha^{-1}) and benefit (129559.00 ETB ha^{-1}) was recorded at nil application of N and P_2O_5.

4. Summary and Conclusion

The effects of vermicompost and inorganic NP fertilizers on growth, yield and yield components was studied in a field experiment conducted during 2013 main cropping season with the objective of identifying the optimum rate of inorganic NP fertilizers and vermicompost on the bulb yield and quality of garlic.

The results revealed that most of the garlic phenological, growth and yield characteristics were significantly affected by main effects of N, P and vermicompost. Phenological characters days to emergence and days to maturity were significantly affected by P and vermicompost where as N has shown non-significant effect on days emergence and significant effect on days to maturity.

Growth parameters such as leaf number, plant height and leaf area index had significantly influenced by the applied fertilizers. Plant height was significantly affected by the interaction effects of N, P and vermicompost. Leaf number was significantly influenced by the main effects of N, P and vermicompost. Maximum leaf number was recorded at the rate of 92 kg P_2O_5 ha^{-1} followed by 5 t ha^{-1} vermicompost. On the other hand, plant height was significantly influenced by the interaction effect of N, P and vermicompost. The other growth parameter, leaf area index was significantly influenced by the main effects of N, P and Vermicompost and maximum leaf area index was recorded at the rate of 46 kg N ha^{-1}.

Yield and yield related traits showed significant differences in response to the application of nitrogen, phosphorus and vermicompost. Most of growth and yield related traits significantly influenced by the main effects N, P & vermicompost.

Among the plant characters, maximum leaf number, mean clove weight, mean bulb weight, fresh biomass yield, total bulb yield, bulb dry matter percent, total soluble solid and harvest index were recorded at the rate of 92 kg P_2O_5 ha^{-1} followed by 5 t ha^{-1} vermicompost. On the other hand, mean clove number, marketable bulb yield and harvest index were significantly influenced by the interaction effect of N and P. Moreover, mean clove number was significantly affected by the interaction effect of N and P, and N and vermicompost. The marketable and unmarketable yields were significantly affected by the interaction of N & P application. The highest marketable and the lowest unmarketable yield was obtained from the combination application of 46 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} and 23 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} respectively. Marketable yield of garlic was increased by 9.96% and unmarketable bulb yield was decreased by 12.83% at an application rate of 5 t vermicompost ha^{-1} over the control and combination application of 23 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} reduced unmarketable yield by 68.04%.

The highest total variable cost of 3623.00 ETB ha^{-1} was incurred at combined application of 46 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}. On the other hand, the highest benefit (280542.00 ETB ha^{-1}) in the partial budget was recorded at 5 t ha^{-1} vermicompost followed by (172569.00 ETB ha^{-1}) at combined application of 46 kg N and 92 kg P_2O_5 ha^{-1}.

Thus, it can be reasonably generalized that on short time basis, the application of moderate amounts of vermicompost or combination of N and P fertilizers can result higher bulb yield than the high dose of either inorganic N fertilizer or a combination of the higher doses of the three fertilizers. However, the results of the experiment have revealed that growth, yield, and quality of garlic plants did not reach the optimum (did not plateau out) since both significantly increased in response to the application of each of the fertilizers or the combined highest rates of the fertilizers. Therefore, there is a possibility that significantly more growth and yield of the crop could have been obtained if the rates of the fertilizers had been increased.

Therefore, from the results of this study, it can be concluded that, the maximum growth, yield, and quality of the crop was obtained at 46 kg N ha^{-1} plus 92 kg P_2O_5 ha^{-1} or 5 t ha^{-1} vermicompost, where 5 t ha^{-1} vermicompost is most economical. However, since the experiment was done only once and at one location as well as because there was no sign of exhausting the growth, yield, and quality potential of the crop with the applied highest rates of the three fertilizers, similar experiments should be carried out using additional higher rates of the three fertilizers over several seasons and locations to make a conclusive recommendation.

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