# Effect of Vermicompost 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 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 vermicompost (0, 2.5 and 5 t ha$^{-1}$). The experiment was laid out as a randomized complete block design (RCBD), and replicated three times. Data were collected on phenology, plant growth, bulb yield, and quality of the crop. The results revealed that increasing rate of vermicompost significantly ($P < 0.05$) affected days to emergence. The effect of 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 bulb dry matter percent (51.05) and total bulb yield (7.78 t ha$^{-1}$) was recorded at 5 t vermicompost ha$^{-1}$. Increasing level of vermicompost also significantly ($P < 0.05$) affected marketable and unmarketable bulb yield, and mean clove number. The highest marketable and the lowest unmarketable yield was obtained at 5 t ha$^{-1}$ vermicompost. 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. Total soluble solid was also increased from 5.13 to 5.69 $^{o}$Brix by applying 5 t vermicompost ha$^{-1}$ over the control. Harvest index was also significantly ($P < 0.05$) affected by the increased application of vermicompost. The maximum harvest index 68.36% was also recorded at application of 5 t vermicompost ha$^{-1}$. It can, thus be concluded that, application of 5 t ha$^{-1}$ vermicompost led to the maximum growth, yield and quality of the garlic crop.
**Keywords:** vermicompost, garlic, organic fertilizer, earth worm, *Eisenia foetida*, yield, quality

## 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 (Palm *et al.*, 1997). On the other hand, 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 solid 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.

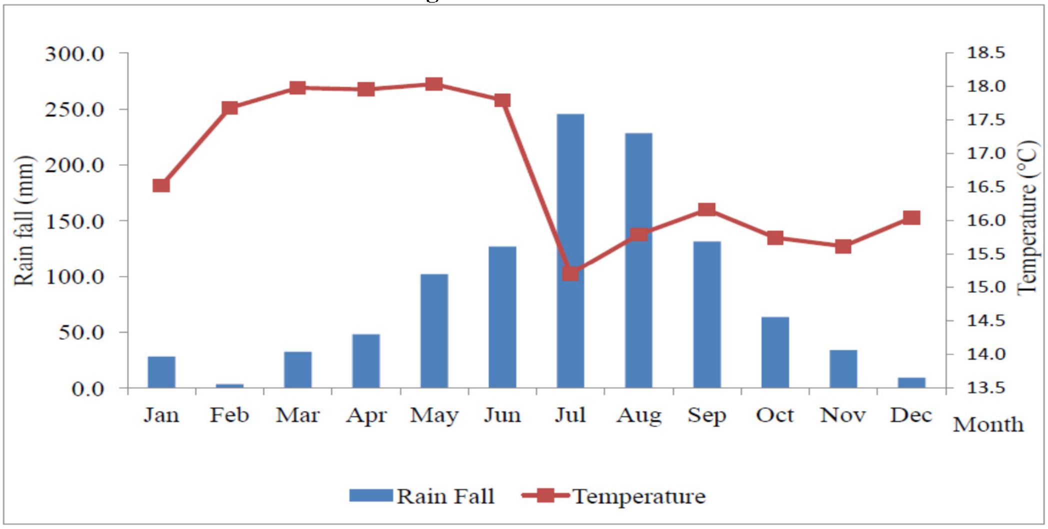
Garlic is one of the most important and widely used vegetable crops being produced in the highlands and mid-altitudes of Enebse Sar Midir District, Eastern Zone of Gojjam, using local cultivars under rain-fed and supplemental irrigation. However, the yield and quality of the crop is very low due to the 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 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$^o$50' latitude and 38$^o$16' longitude with elevation of 2450 meters above sea level according to GPS reading. It is about 370 km and 184 km away from Addis Ababa and Bahir Dar, respectively. The annual rainfall of the area is about 900-1400 mm and temperature of 16 to 25$^o$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. The fertilizer material, vermicompost was used as an organic fertilizer supplying all elements required by the plant. 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 vermicompost (0, 2.5, 5 t $ha^{-1}$). The experiment was laid out in a randomized complete block design (RCBD) 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), 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. 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 after harvest 3 composited samples were collected from the 9 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.**

| | Physical properties | | | | Chemical properties | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Clay % | Silt % | Sand % | Soil texture | N (%) | P (ppm) | K [Cmol(+)/kg] | OC (%) | OM (%) | pH |
| 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 |
| 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 carbon, OM = organic matter, VC = vermicompost, SBP= soil before planting, ppm = parts per million.**

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

| Treatment | N (%) | Rating | P (ppm) | Rating | K [Cmol(+)/kg] | Rating | OC (%) | Rating | OM (%) | Rating | pH | Rating |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.04 | V. low | 4.62 | V. low | 0.48 | Medium | 0.78 | Low | 1.50 | Low | 6.83 | Neutral |
| 2.5 | 0.07 | Low | 4.83 | V. low | 0.52 | Medium | 1.90 | High | 3.62 | High | 6.92 | Neutral |
| 5 | 0.19 | Medium | 9.88 | Low | 0.69 | High | 3.77 | V. high | 6.84 | V. high | 6.94 | Neutral |

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

### *3.2.* ***Phenological parameters***

#### 3.2.1. Days to emergence

The effect of vermicompost significantly ($P < 0.001$) influenced days to emergence (Table 3). With the increase in the rate of 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 vermicompost emerged from the soil later than plants that were treated with the fertilizer. Thus, 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 was recorded for the 5.0 t vermicompost ha$^{-1}$. The hastened duration for emergence due to the increased application of the fertilizer 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. 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. However, the longest duration in days for emergence was required by cloves treated with no vermicompost.

3.2.2. Days to maturity

The analysis of variance revealed days to maturity was significantly influenced by the effect of vermicompost ($P < 0.001$) (Table 3).

Increasing the rate of the vermicompost prolonged the maturity of the garlic plants. Thus plants that were supplied with the vermicompost matured later than those in the control treatments. 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.

### *3.3. **Growth parameters***

3.3.1. Leaf number

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

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. The effect of 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.) |
|---|---|---|---|---|---|
| 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 ($P < 0.05$) affected by increased level of vermicompost. Maximum plant height of garlic was recorded at the application of 46 5 t $ha^{-1}$ vermicompost whereas the shortest plant height of garlic was recorded at the nil application. The application of 5 t $ha^{-1}$ vermicompost increased plant height by 36.01%.

The increase in height due to increased rate of vermicompost could be attributed to the fact that vermicompost contains a good range of essential micronutrient other than NPK fertilizers, required for healthy plant growth (Surindra, 2009) and sufficient N from vermicompost which 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. Surindra (2009) concluded that the application of vermicompost 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).

### *3.4. **Yield and Yield Related Components of Garlic***

#### 3.4.1. Mean clove number

The effect of vermicompost showed significant ($P < 0.001$) difference on mean clove number (Table 3). This attributes to vermicompost 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). This result is in line with the findings of Gezachew (2006) who showed that the effect of compost significantly increased total and marketable tuber number of potato. 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.

#### 3.4.2. Mean clove weight

Vermicompost ($P < 0.001$) showed significance difference on mean clove weight (Table 4). 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

Vermicompost did not significantly affect mean clove weight.

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 4. Effect of vermicompost on mean bulb weight and mean clove weight of garlic.**

| Factor | Treatment | Plant height (cm) | Mean clove number | Mean clove weight (g/p) | Mean bulb weight (g) |
|---|---|---|---|---|---|
| Vermicompost t $ha^{-1}$ | 0 | 37.07c | 13.28c | 1.67b | 21.42c |
| | 2.5 | 46.25b | 13.51b | 1.71b | 21.95b |
| | 5 | 50.45a | 13.56a | 1.80a | 23.15a |
| LSD (5%) | | 1.721 | 0.1098 | 0.03844 | 0.4855 |
| CV (%) | | 2.3 | 9.0 | 4.1 | 4.0 |

#### 3.4.4. Fresh biomass yield

Vermicompost ($P < 0.001$) significantly influenced fresh biomass yield (Table 8). Fresh biomass yield increased by 4.71% as the vermicompost is increased from 0 to 5 t $ha^{-1}$. 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).

#### 3.4.5. Total bulb yield

Total bulb yield was significantly influenced by the effect of vermicompost ($P < 0.001$).

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%.

**Table 5. The effect of vermicompost on fresh biomass yield and total bulb yield of garlic.**

| Factor | Treatment | Fresh biomass yield (g/p) | Total bulb yield (t ha$^{-1}$) |
|---|---|---|---|
| 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 effect vermicompost ($P < 0.001$).

Marketable yield of garlic was increased by 10% with increased application rate of vermicompost from 0 to 5 t ha$^{-1}$ (Table 6). 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 6. 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

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 74. The 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 effecs of vermicompost ($P < 0.001$).

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 ($P < 0.001$) influenced by increased application of vermicompost.

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 85. The effect of vermicompost on dry matter and total soluble solid of garlic.**

| Factor | Treatment | Dry matter (%) | TSS (ºBrix) |
|---|---|---|---|
| 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

Increased application of vermicompost significantly affected harvest index (Table 14). As the soil texture of the experimental site is clayey, the response of the garlic plant 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 96. Tffect of vermicompost on harvest index of garlic.**

| Factor | Treatments | Harvest index (%) |
|---|---|---|
| Vermicompost t ha$^{-1}$ | 0 | 61.54c |
| | 2.5 | 66.16b |
| | 5 | 68.36a |
| LSD (5%) | | 3.710 |
| CV (%) | | 5.9 |

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

## 4. Summary and Conclusion

The effects of vermicompost 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 vermicompost on the bulb yield and quality of garlic.

The results revealed that all of the garlic phenological, growth and yield characteristics were significantly affected by the application of different levels of vermicompost. Phenological characters days to emergence and days to maturity were significantly affected by vermicompost.

Growth parameters such as leaf number, plant height and leaf area index had significantly influenced by the applied organic fertilizer. Maximum leaf number was recorded at the rate of 5 t ha$^{-1}$ vermicompost. The other growth parameter, leaf area index was significantly influenced by the vermicompost and maximum leaf area index was recorded at the rate of 5 t ha$^{-1}$.

Yield and yield related traits showed significant differences in response to the application of different levels of vermicompost. Among the yield and quality related traits, 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 5 t ha$^{-1}$ vermicompost. Marketable bulb yield and unmarketable yield were significantly influenced by the applied organic fertilizer. The highest marketable and the lowest unmarketable yield was obtained at 5 t ha$^{-1}$ vermicompost. 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.

Thus, it can be reasonably generalized that on short time basis, the application of moderate amounts of vermicompost can result higher bulb yield than the lower doses. 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 significantly increased in response to the application of the fertilizer. Therefore, there is a possibility that significantly more growth and yield of the crop could have been obtained if the rate of the vermicompost 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 5 t ha$^{-1}$ vermicompost. 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 vermicompost fertilizer, similar experiments should be carried out using additional higher rates over several seasons and locations to make a conclusive recommendation.

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