Response of Garlic (*Allium sativum* L.) Growth and Bulb Yield to Application of Vermicompost and Mineral Nitrogen Fertilizers in Haramaya District, Eastern Ethiopia

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Abstract: Yield of garlic is often constrained by low and unbalanced nutrient supply in the soil. This study was conducted to assess the effect of application of vermicompost (VC) and mineral nitrogen (N) fertilizer on growth and bulb yield of a garlic variety named 'Chelenko I' The experiment was conducted during the 2016–main rainy season. The experiment was laid out as a randomized block designed in a factorial arrangement and replicated three times per treatment. The treatments consisted of four rates of vermicompost (VC) (0, 2.5, 5.0 and 7.5 t ha^{-1}), and five rates of mineral nitrogen (N) fertilizer (0, 52.5, 80, 105 and 130 kg N ha^{-1}. Data were collected on days to maturity, plant height, leaf number, yield components, namely, bulb length and clove weight, and marketable and unmarketable bulb yield of garlic. The data were analyzed and computed using SAS software version 9.0 and the means were separated by using Turkey's Test at 0.05 probably level . The results revealed significant ($P < 0.05$) differences in early maturity (130.48 days) at control treatment (zero fertilizers) while late maturity (135.50 days) was at application of 7.5 t ha^{-1} of VC. Significantly ($P < 0.05$) maximum plant height (60.65 cm), clove weight (2.71 g/clove), and marketable bulb yield (12.32 t ha^{-1}) were recorded at the rate of 7.5 t ha^{-1} of VC. Due to combined application of VC (7.5 t ha^{-1}) and mineral N fertilizer (130 kg ha^{-1}) unmarketable bulb yield was reduced by 41.03% over the control treatment. The highest net benefit was recorded from the maximum marketable bulb yield of garlic at the application of 7.5 t ha^{-1} of VC and 130 kg N ha^{-1} . Thus, it is concluded that combined application of vermicompost and mineral nitrogen fertilizer resulted in optimum production of the crop in the study area.

Keywords: Chelenko I; Marginal return; Marketable bulb yield; Net benefit; Vermicompost.

1. Introduction

Garlic is an important vegetable crop in the world and in Ethiopia. The productivity of the crop in the world is? In Ethiopia, the acreage of garlic cultivation increased from 11,845.53 ha in 2015/16 to 15,381 ha in 2016/17 with a total production of about 107,743.5 and 138,664.3 tones of bulbs with the productivity of 9.10 and 9.02 t ha^{-1}, respectively (CSA, 2017). In Oromia region, the crop covered 6,430 ha of land with total production of 60,175.5 t and productivity of 9.4 tha^{-1} in 2016/17. Though acreage of garlic, production and productivity are not indicated for Eastern Hararghe Zone, about 50,683 farmers produced garlic in the area (CSA, 2017). The yield of recently released garlic variety, *Chelenko I, is* 9.3 t ha^{-1} on research field was appreciated and selected for Eastern and Western Hararghe Zones (Tewdros *et al.,* 2014).The product ivity of the crop could be increased to 13 t ha^{-1}.The yield differences exhibited is related to technological resources and the management of the crop rather than to differences in genetic background and performance of the cultivars used (Diriba, 2016). Optimum application of fertilizers to garlic crop is important for improving growth, yield and marketable bulb proportions as well as bulb quality (Diriba *et al.*, 2013). Mineral fertilizers of balanced doses increased leaf area, photosynthetic productivity, yield of garlic plant in particular, and resulted in substantial increases in production in general (Zhou *et al.*, 2005).

However, the crop nutrient requirements vary with species, variety, soil type and season. A blanket recommendation rates of 105 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} are being used for production of garlic variety 'Tseday'production in many areas (EARO, 2004). This is also used for 'Chelenko I' (Tewdros *et al.,* 2014) as a blanket recommendation. It means that there is no recommendation of optimum rats of fertilizer application for producing the crop in the study area. In general, fertilizers are applied based on blanket recommendations in the country without considering soil fertility levels of specific areas leading to uneconomic fertilizer application (Melaku *et al.*, 2017). This is one of the gaps to be bridged through conducting fertilizer trials. Additionally, continuous uses of chemical fertilizers also affect the environment through poisoning and exterminating soil microflora and microfauna, thereby adversely changing the chemical and physical properties of soil (Pratap *et al.*, 2011). Therefore; organic inputs are often proposed as alternatives to mineral fertilizers.

Due to lack of enough organic material, recently combined application is being appreciated. Verma *et al.* (2013) reported that combined application of organic and inorganic fertilizers provided plants with all essential elements required for growth and

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development. Combined application of 50 kg N ha^{-1} and 10 t manure ha^{-1} increased total bulb yield of garlic crops (Tadila, 2011). Therefore, farmers should use integrated organic and inorganic inputs (Palm *et al*., 1997). However, the traditional organic inputs such as crop residues, and animal manures cannot meet crop nutrient demand over large areas because of requiring higher amount, the low nutrient content of the materials, and the high labor demands for processing and application (Pratap *et al*., 2011).

The VC helps in reducing C: N ratio, increased humic acid content and provide nutrient in the readily available form to the plants such as nitrate, exchangeable phosphorus, soluble potassium, calcium and magnesium (Talashilkar *et al.,* 1999). Besides, Alemu *et al.* (2016) reported that increased levels of VC from 0 to 5 t ha^{-1} increased soil fertility with increased economic return.

Integrated nutrient supply approach is one of the opportunities for obtaining fairly high productivity with substantial fertilizer leading to sustainable agriculture (Bhagwan *et al.,* 2012). Therefore, combination of VC and mineral N fertilizer is crucial to increase productivity of plants with reduced pollution of environment. Enhancing garlic productivity in Eastern Hararghe Zone is an important objective of research on crops. However, no significant improvement in yield has been recorded so far. Farmers in Haramaya district produce local varieties of garlic crop in homesteads. The garlic variety *Chelenko I* was developed and newly released by Haramaya University in 2013 (Tewdros *et al.,* 2014). Varieties may also differ in their response to source and rate of applied fertilizers (Zhou *et al*., 2005). So far, no research has been conducted to elucidate the effect of applying mineral nitrogen and VC on the performance of garlic in the area. It is imperative to conduct research on vermicompost and inorganic nitrogen fertilization to increase productivity with recently released variety of garlic. Therefore, the study was initiated to evaluate the effect of vermicompost and mineral nitrogen fertilizer rates on garlic productivity and production.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Haramaya University main campus, Rare Research Field in 2016 main cropping season (August-December). The experimental site is geographically located in eastern part of Ethiopia, which is located at the distance of about 25 km in the north-easterly direction from the town of Harar, at altitude of 2006 meters above sea level, latitude of 9°24"N latitude, and longitude of 42°03"E. The site has a bimodal rainfall distribution pattern and is representative of a sub-humid, mid-altitude agro-climatic zone. The soil of the experimental site is sandy loam in texture (Simret *et al*., 2014).

2.2. Experimental Materials and Design

Garlic variety 'Chelenko I' was used which was released in 2014 for mid to high altitude garlic growing areas of eastern and western Hararghe Zones by Haramaya University. It takes about 132 days to mature with productivity of 9.3 t ha^{-1}(Tewodros *et al*., 2014). The treatments consisted of four rates of VC (0, 2.5, 5.0 and 7.5 t ha^{-1}), and five nitrogen fertilizer rates (0, 52.5, 80, 105 and 130 kg N ha^{-1}) total of 20 treatments. The experiment was laid out as a randomized complete block design in a factorial arrangement and replicated three times per treatment.

2.3.Experimental Procedures and Crop Management

Experimental field was ploughed by a tractor. The plots were leveled and ridges at 20 cm high were prepared. The gross plot size was 2.0 m x 1.5 m (3.0 m^2). Spacing between blocks and plots were 0.75 m and 0.5 m, respectively. VC was applied two weeks before planting to randomly assigned treatments to each plot and worked into the soil. One-fourth, half and the remaining one-fourth of the N fertilizer as per the treatment was applied at planting, three weeks and six weeks after emergence of the garlic plants, respectively. To all of the plots, phosphorus (92 kg P_2O_5 ha^{-1}) was applied at planting through triple superphosphate (TSP). Healthy and uniform medium-sized cloves of 1.5-2.50 g (Fikreyohannes *et al*., 2008), were selected and planted on 11 August 2016 at the depth of 3-4 cm. The cloves were planted on the ridge at the spacing of 30 cm between rows and 10 cm between plants. Thus, there were five rows in each plot and 20 plants in a row. The outer most one row on each side of a plot and 20 cm on both ends of each row were considered as border rows. Thus, the net plot size was 0.9 m x 1.8 m (1.62 m^2). The treatments were harvested on 16 December 2016, when 70% of the plants senesced and showed neck fall in the plots (Getachew and Asfaw, 2000; EARO, 2004).

2.4. Vermicompost and Soil Sample Analysis

Vermicompost, which was made from Lantana camara, Partinium hystrophorous and farmyard manure, was analyzed before applying to the soil. Composite samples were taken and broken into small crumbs and prepared for determining chemical properties. The sample was air-dried and sieved through a 2- mm sieve. The pH value of vermicompost was determined from the filtered suspension of 1:2.5 soils to water ratio using a glass electrode attached to a digital EC meter and pH meter (Jones, 2003). The sample was analyzed for electric conductivity (EC), total N, available P, exchangeable K, organic matter and organic carbon. Total N was determined using the Kjeldhal method (Jackson, 1958). Available P was determined by extraction with 0.5 M sodium bicarbonate (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 of the soil was determined by the Walkley-Black method (1934).

The soil samples were taken randomly using an auger in a zigzag pattern from the entire experimental site before planting. Ten soil samples were taken from the top soil layer to a depth of 20 cm and composited in a bucket to represent the site. 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 chemical content of the soil was determined using similar procedures used for the VC as it was developed for the soil. Soil texture was determined by Bouyocous hydrometer method (Moodie et al., 1954).

2.5. Data Collection and Measurement

Data were collected on growth parameters, namely, plant height, number of leaves per plant, days to 90% physiological maturity, and yield components, bulb length, clove weight, and marketable and unmarketable bulb yield and measured timely as per the recommendation to produce the crop (EARO, 2004).

Plant height (cm): height of 10 randomly selected and pre tagged plants from the net area in each plot was measured from the soil surface to the tip of the plant using ruler and their average was expressed as plant height per plant.

Number of leaves (plant-1): the number of leaves of the above pre tagged plants was counted and their average was taken and expressed as number of leaves per plant.

Days to 90% physiological maturity: it was recorded as the number of days required from planting to the time when 90% of the plants in each plot show senescence of leaves.

Bulb length (cm): the length of 10 bulbs that was used for bulb diameter was measured from the base of the bulb to the point where neck of the bulb begins with vernier caliper.

Clove weight (g): the weight of all the counted above cloves was taken and the average was expressed as clove weight.

Marketable bulb yield (t ha-1): Bulbs harvested at 90% physiological maturity of the plants from the net plot area and were cured for 10 days under ambient condition by thinly spreading. The bulbs then in a plot free from diseases, damages or blemishes and greater than 1 g cloves sized bulb (Fikreyohannes et al., 2008) were recorded and converted into t ha-1.

Unmarketable bulb yield (t ha-1): The bulbs which were diseased damaged or blemished and bulb size of less than 1 g cloves were recorded as unmarketable bulb and expressed as unmarketable bulb yield.

2.6. Data Analysis

Collected data were subjected to analysis of variance (ANOVA) using SAS software version 9.0 and the means were separated by using Turkey's Method at 0.05 probably level of significant.

2.7. Partial Economic Analysis

The partial budget analysis as described by CIMMYT (1988) was done to determine the economic feasibility of the garlic production using the prevailing market prices for inputs at planting and for the outputs at the time of crop harvest. It was calculated by taking into account the additional input and labor cost involved due to additional input and the gross benefits obtained from garlic production. Average yield was adjusted downward by 10% to reflect the difference between the experimental yield and farmers'yield could obtain under their management practices as described by CIMMYT (1988).

The field price of garlic was calculated as (sale price minus the costs of harvesting, cleaning, bagging and transportation). The net benefit was calculated as the difference between the gross field benefit in Ethiopian birr per hectare (ETB ha-1) and the total variable costs (ETB ha-1)

$$\text{Marginal rate of return (\%)} = \frac{\text{Change in net benefit}}{\text{change in total cost}} \times 100$$

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Marginal rate of return (MRR %) was calculated by dividing change in net benefit or gross benefit by change in cost which was the measure of increasing in return by increasing input. This means by subtracting gross benefit at control treatment from gross benefit of each treatment and divide by total variable cost of each treatment and multiplying each value by 100%.

3. Results and Discussion

3.1. Soil Sample Analysis and Vermicompost

3.1.1. Physical and Chemical Properties of Soil of the Experimental Site

The result of laboratory analysis of selected physical and chemical properties of soils of the experimental area is presented in Table 1.

The textural class of the soil was sandy clay loam based on the soil textural triangle of the International Society of Soil Science system (Moodie et al., 1954; Rowell, 1994). The pH of the experimental soil was 7.4 which is moderately alkaline on the basis of pH limit (7.4 to 7.8) as described by Jones (2003). The pH is in the range of 6.5 to 7.5, which is favorable for garlic production. The organic matter (OM) content of the experimental soil is 2.55%. According to the rating of Tekalign (1991), OM ranging from 0.86 to 2.59 is low. Hence, the soil of the experimental site is low.

As per the rating (0.12 to 0.25%) described by Berhanu (1980), the total N content of the soil (0.18%) is medium. This value showed that the crop might respond to the applied VC and mineral N fertilizers (Table 1) due to increased soil fertility with application of both fertilizers. The cation exchange capacity (CEC) of the experimental soil was 18.61 (cmol (+) kg-1). This value is medium according to the rating (15 to 25) suggested by Landon (1991). This indicated that the soil of the experimental site might respond to the different VC and mineral N fertilizer. In accordance with Hazelton and Murphy (2007) category, the exchangeable soil potassium content of the experimental soil is in medium category. This indicates external application of mineral and/ organic fertilizers containing potassium is important for enhancing the fertility of the crop and yield of the crop

3.1.2. Analysis of Vermicompost

It is crucial to analysis nutrient contents of VC as it is soil activator, soil conditioner, and soil fertility booster with all be required plant nutrient, vitamins, enzymes, growth hormones and beneficial microorganisms (Anonymous, 2006). The analysis of VC indicated that the total nitrogen content, exchangeable K, and OC as per Hazelton and Murphy (2007) were found very high (Table 2). According to Tekalign (1991) and Landon (1991) reports, the OM and EC of VC also recorded very high, respectively. The available P is moderate as rating indicated by Hazelton and Murphy (2007) and the pH neutral (Jones, 2003). VC contains 5 times high N and 7 times higher K and 1.5 time than the first 15 cm top soil (Parkin and Berry, 1994). According to Khan and Ishaq (2011), the exchangeable potassium content of VC is 58 times higher compared to garden soil. The application of VC increased growth and yield of many horticultural crops (Najar and Khan, 2013). The high EC, OC, OM, nitrogen percent, and exchangeable K and moderate available P, contents of the VC used in garlic production largely contributed to better garlic growth and bulb yield. The application of higher doses of VC resulted in a significantly higher plant growth, yield components and yield compared to the application of lower doses (Table 3, 4, 5 and 6)

Table 1. Textural class and chemical properties of the soil of the experimental site at Haramaya, Eastern Ethiopia.

Soil property	Value	Rating	Reference
Sand (%)	61		
Clay (%)	23		
Silt (%)	16		
Textural class	Sandy clay loam		Moodie *et al.* (1954) and Rowell (1994)
pH 1: 2.5 (H_2O)	7.4	Moderately alkaline	Jones (2003)
OC	1.48	Moderate	Hazelton and Murphy (2007)
OM (%)	2.55	Low	Tekalign (1991)
Total N (%)	0.18	Medium or moderate	Berhanu (1980) and Hazelton and Murphy (2007)
Available P (mg kg^{-1})	5.58	Low	Hazelton and Murphy (2007)
Exch. K (cmolc kg^{-1})	0.32	Medium	Hazelto and Murphy (2007)
CEC (cmol (+) kg^{-1})	18.61	Medium	Landon (1991)

Note: OC, organic carbon; OM, organic matter; EC, electric conductivity

Table 2. Chemical properties of vermicompost.

VC	Chemical properties						
	Total N (%)	Available P (ppm)	Exchangeable K [C mol(+)/kg]	OM (%)	OC (%)	pH	EC (msm^{-1})
Value	0.56	25.82	23.69	15.39	8.92	7.25	8.83
Rating	Very high	Moderate	Very high	Very high	Very high	Neutral	Very high

Note: OC, organic carbon; OM, organic matter; VC, vermicompost; ppm, parts per million; EC, electric conductivity (Hazelton and Murphy, 2007).

3.2. Vegetative Growth and Phenological Response to Fertilizers Application on Garlic

3.2.1. Plant Height

The analysis of variance showed that main effect of VC and N showed significant differences ($P < 0.05$) in plant height. However, the interaction of VC and nitrogen rate did not show any significant differences.

As compared to control, plant height was increased by 13.22% with the application rate of 7.5 t VC ha^{-1}. This increase in plant growth might be due to the effect of auxins and nutrients which are exerted by bio-enriched (Gomaa, 1995). Moreover, it could be attributed to the fact that VC contains a good range of additional essential micronutrient other than NPK fertilizers, required for healthy plant growth (Surindra, 2009). Plots which received 105 kg N ha^{-1} gave optimum plant height. Increased level of N from 0 to 105 kg ha^{-1}, increased plant height by 8.89% (Table 3). Increasing plant growth by increasing N level might be due to its role in photosynthesis, protein synthesis, cell division and enlargement which are the basal steps of plant growth. In addition, N plays an important role in the enzyme activity which reflects more products needed in plant growth (Hassan, 2015). Nitrogen is a constituent of many fundamental cell components and plays a vital role in all living tissues of the plant. Therefore, it has such an effect on promoting vigorous plant growth. Kakar *et al.* (2002) reported that N accounts for a higher percentage of the variation in plant height when it was increased from 50 to 200 kg ha^{-1}. Hore *et al.* (2014) also reported that plant height increased from 53.98 cm to 69.14 cm with increasing level of N from 50 kg ha^{-1} to 200 kg ha^{-1}.

3.2.2. Leaf Number

According to the analysis of variance for leaf number revealed that the main factor of N and VC, and its interaction showed significant ($P < 0.05$) influences on leaf number.

The highest number leaves per plant were recorded at the combined application of maximum rate of VC and mineral N rates (Table 4). Application of 7.5 t VC ha^{-1} in combination with 130 kg N ha^{-1} increased leaf number by 64.56% over the control plots. The combined application of VC with chemical fertilizer increased the availability of essential soil micronutrients which ultimately promotes the plant growth. The use of organic manure is more beneficial when combined with inorganic fertilizers (Mugwira and Murwira, 1998). In agreement with present study, Mozumder *et al.* (2007) obtained significant and maximum number of garlic leaves with a fertilizer combination.

3.2.3. Days to Maturity

The main effects of VC and mineral N fertilizer significantly ($P < 0.05$) influenced days to maturity. However, the interaction effect of VC and mineral N fertilizer application did not significantly influence days to maturity (Table 3).

In response to increasing the rates of both VC and mineral N fertilizer application, the number of days required for garlic maturity was increased. As VC is suitable for plant growth due to its content of balanced nutrient and plant growth hormone, it prolongs senescence of plants (Pashanasi *et al.*, 1996). Plots that received VC at the rates of 7.5 t ha^{-1} matured in 135.53 days which was significantly longest duration with nil, 2.5 and 5 t VC ha^{-1} application rate as indicated in Table 3. Prolonged maturity in response to increasing rate of VC may be ascribed to the availability of optimum nutrients contained in VC that may have led to prolonged maturity through enhanced leaf growth and photosynthetic activities thereby increasing partition of assimilate to the storage organ. In agreement with this result, Alemu *et al.* (2016) reported prolonged maturity days of garlic at the rate of 5 t VC ha^{-1} application. Anonymous (2009); and Agarwal (1999) showed that VC contains significant amounts of micro-nutrients elements such as copper, zinc, iron and manganese. This content helps the plant to complete their life cycle without nutrient stress that hastens their senescence.

Increasing mineral N fertilizer level significantly increased days to maturity. Average days to maturity was delayed by 4.66 days when 130 kg N ha^{-1} was applied compared with the control, but the result was in statistical parity with the application of 105 kg N ha^{-1} (Table 3). Delay in days to maturity with high levels of N could be attributed to delayed senescence of the canopy of the crop (garlic) and extended physiological activity and continued in photosynthesis. Nitrogen, being the major constituent of protein, component of protoplasm and cell wall of the cell, might have imparted favorable effect on the chlorophyll content of leaves. That in turn might have led to increased synthesis of photosynthates, which may have been further utilized for increasing cell growth, resulting in prolonged maturity of garlic. Significantly early matured bulb was obtained from the nil nitrogen fertilizer. Inadequate N can hasten maturity and limit yield (Batal *et al.*, 1994). This result is in agreement with the findings of Abreham and Essubalew (2015) who reported maturity was delayed by 13 days when 150 kg N ha^{-1}compared with the control, but the value was in statistical parity with the one obtained in response to the application of 100 kg N ha^{-1}. Shawol (2010) and Tesfaye *et al.* (2007) also reported that as high rate of N increased days to maturity in onion. Islam *et al.* (2010) noted that plants grown with the highest rate of N took the longest period to complete the vegetative growth.

Table 3. Main of effects of vermicompost and nitrogen in days to plant height and maturity on garlic.

Factor	Treatment	Plant height (cm)	Days to maturity (days)
VC (t ha^{-1})	0	53.57c	130.48c
	2.5	56.71b	132.66b
	5	57.64b	133.46b
	7.5	60.65a	135.53a
LSD (0.05)		1.67	0.99
N (kg ha^{-1})	0	53.57c	130.50d
	52.5	53.57c	131.83c
	80	57.80b	133.66b
	105	58.33ab	134.41ab
	130	60.20a	135.16a
LSD	(0.05)	1.99	1.19
CV %		3.00	0.77

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

3.3. Yield Components Response to Fertilizers Application on Garlic

3.3.1. Bulb Length

The main effects of VC and N fertilizers showed significant ($P < 0.05$) differences in garlic bulb length, while their interaction was not showed significant differences in bulb length.

Table 4. Interaction effect of vermicompost and nitrogen on leaf number of garlic grown in Haramaya district during the 20, main growing season.

Treatment Nitrogen (Kg ha^{-1})	Leaf number (No.) Vermicompost (t ha^{-1})			
	0	2.5	5	7.5
0	8.10^{i}	8.64^{hi}	8.96^{efghi}	9.18^{defghi}
52.5	8.39^{hi}	8.73^{ghi}	9.02de^{fghi}	9.62^{cdefgh}
80	8.69^{fghi}	9.78^{cdefgh}	9.94^{cdefg}	10.22^{cde}
105	8.74^{fghi}	10.05^{cdef}	10.38^{bcd}	11.64^{b}
130	9.07^{defghi}	10.22^{cde}	10.60^{bc}	13.33^{a}
LSD (0.05)	1.40			
CV%	4.67			

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

As result indicated in Table 5, significantly optimum bulb length was recorded with application 7.5 t VC ha^{-1}. Significantly lowest bulb length of garlic was obtained from plots that received no VC. There was a significant increase in bulb length of garlic as the rate increased from nil to maximum VC application. The increase is consistent with the postulation that vermicompost is soil activator, soil conditioner, and soil fertility booster with all required plant nutrient, Vitamins, enzymes, growth hormones and beneficial micro organisms (Anonymous, 2006). Pramanik *et al.* (2007) reported that humic acids released from VC enhanced nutrient uptake by the plants by increasing the permeability of root cell membrane, and stimulating root growth. As reported by Talware *et al.* (2011) bulb diameter of garlic was increased with increased rate of farmyard manure.

Analysis of variance showed that application of 130 kg N ha^{-1} resulted in the optimum bulb length as compared with other treatments and control (Table 5). This is because of the fact that nitrogen is responsible for vegetative growth of plants and later it increases the bulb length. In line with this finding, Zaman *et al.* (2011) indicated that the highest length of bulb (3.12 cm) was recorded in response to the application of 150 kg N ha^{-1} followed by 200 kg N ha^{-1} (3.05 cm) and 250 kg N ha^{-1} (3.03 cm) whereas the lowest bulb length (2.28 cm) was found in the control plots that received no fertilizer. Talware *et al.* (2011) also reported that bulb length of garlic revealed that bulb length was significantly influenced by different treatments of nutrients management.

3.3.2. Clove Weight

The main effects of both VC and N application rates significantly ($P < 0.05$) influenced mean clove weight (Table 5). The highest clove weights were recorded at the application rate of 7.5 t ha^{-1} which was increased by 22.62% over the control treatment (Table 5). The increased mean clove weight due to the increase in VC rate could be due to VC which is known to contain micronutrients apart from major nutrients. Pramanik *et al.*, (2007) also reported that humic acids released from VC enhanced nutrient uptake by the plants by increasing the permeability of root cell membrane, and stimulating root growth. Verma *et al.* (2013) also reported that clove weight of garlic was increased significantly up to the highest dose of 5 t VC ha^{-1}.

Compared to the control treatments, clove weight was significantly increased by 18.47% in response to increasing the rate of N to 130 Kg ha^{-1}. Increased mean clove weight in response to increasing rate of N may be ascribed to the availability of optimum N that may have led to high mean clove weight through facilitating improved leaf growth and photosynthetic activities thereby increasing portioning of assimilate to the storage organ. This result is in conformity with the findings of Wolde (2014) who reported that the highest mean clove weight (4.42 g) was with 138 kg N ha^{-1}application rate over the control treatment. Bichi (1997) also reported that garlic clove weights obtained from plots fertilized with 69 kg and 92 Kg N ha^{-1} were 1.82 and 1.62 g, respectively and the lowest mean clove weight was obtained from the unfertilized plots.

3.4. Effects of Fertilizer Application on Yield of Garlic

3.4.1. Marketable Bulb Yield

The analysis of variance on marketable bulb yield showed significant ($P < 0.05$) variation due to main effect of VC and N while the interaction effect of VC and mineral N fertilizer did not show significant differences (Table 6).

The maximum level of VC (7.5 t VC ha^{-1}) revealed 43.26 % yield advantage over the control treatment. This result could be associated with VC application in which plots treated with VC showed to establish better compared with those untreated plots. Because VC might have provided enough nutrients and avoid competition for nutrients, and hence produced better clove and bulb that contribute for better marketable bulb yield. In agreement with this, best quality garlic can be produced through application of balanced fertilizers (Cantwell *et al.,* 2006).Pramanik *et al.* (2007) explained that humic acids released from VC enhanced 'nutrient uptake' by the plants by increasing the permeability of root cell membrane, and stimulating root growth. This increases marketable bulb yield due to adequate nutrient that contribute for good shape and higher bulb size that accounts for marketable bulb yield. Similarly, Alemu *et al.* (2016) reported that increased VC from 0 to 5 t ha^{-1} increased garlic bulb yield by 10%.

As observed from this result application of maximum level of N fertilizer (130 kg N ha^{-1}) increased the proportion of marketable bulb yield of garlic by 29.17% over control (Table 6). This is due to N attributes as it is so vital because it is an essential constituent of metabolically active compounds such as of proteins, enzymes, and vitamins in plants, and is a part of the essential photosynthetic molecule and chlorophyll (Mukherjee, 1993). This all may have caused ? garlic to bear quality bulbs that would contribute to its marketability. In line with this result, Kilgori *et al.* (2007) reported a significantly increased cured bulb yield of garlic with increased N from 0 to 120 kg ha^{-1}. Maksoud *et al.* (1984) also reported significantly increased yield of cured marketable bulbs of garlic from 12.4 to 20.5 t ha^{-1} in two garlic cultivars with the addition of N at 360 kg ha^{-1}. Arboleya and Garcia (1993) also 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 $^{-1}$.

Table 5. Main effects of Application of Vermicompost and nitrogen in bulb length and clove weight on garlic.

Factor	Treatment	Bulb length (cm)	clove weight (g/clove)
VC (t ha^{-1})	0	2.86d	2.21d
	2.5	3.02c	2.34c
	5	3.13b	2.56b
	7.5	3.31a	2.71a
LSD (0.05)		0.08	0.12
N (Kg ha^{-1})	0	2.86d	2.22d
	52.5	2.92d	2.36dc
	80	3.04c	2.42bc
	105	3.19b	2.51ab
	130	3.37a	2.63a
LSD (0.05)		0.10	0.15
CV %		2.78	5.36

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

3.4.2. Unmarketable Bulb Yield

Unmarketable bulb yield was significantly ($P < 0.05$) influenced by the main effect of VC and nitrogen fertilizer rates and their interaction effects. Combination of VC and N at the rate of 7.5 t ha^{-1} and 130 kg N ha^{-1} produced significantly the lowest proportion of unmarketable bulb yield (0.46 t ha^{-1}) over the other combinations rates (Table 7). Maximum proportion of unmarketable bulb yield (0.78 t ha^{-1}) was recorded at the combination rate of nil VC and nil mineral nitrogen. This result could indicate that the potential of VC and inorganic N fertilizers combination reduced the proportion of unmarketable yield when they are applied together than they are applied separately.

Imbalanced fertilization and absence of application of micronutrients, less or no use of organic manures could result in the depletion of soil fertility (Palm *et al.,* 1997). Reduced soil fertility reduces quality and quantity of plant production. This indicates combination of nutrient is more appreciated than a single fertilizer application to reduce unmarketable bulb yield of garlic.

Table 6. Main effects of vermicompost and nitrogen on marketable bulb yield of garlic.

Factor	Treatment	Marketable bulb yield (t ha^{-1})
VC (t ha^{-1})	0	8.6d
	2.5	10.1c
	5	11.32b
	7.5	12.32a
LSD (0.05)		0.60
N(kg ha^{-1})	0	9.36d
	52.5	9.92cd
	80	10.38c
	105	11.17b
	130	12.09a
LSD (0.05)		0.71
CV %		5.69

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

Table 7. Interaction effect of nitrogen and vermicompost on unmarketable bulb yield of garlic.

Treatment	Unmarketable bulb yield (t ha^{-1})			
Nitrogen	Vermicompost (t ha^{-1})			
(Kg ha^{-1})	0	2.5	5	7.5
0	0.78^{i}	0.76^{hi}	0.75^{ghi}	0.73^{efghi}
52.5	0.74^{fghi}	0.73^{efghi}	0.71^{defghi}	0.69^{cdefgh}
80	0.71^{defghi}	0.68^{cdefg}	0.66^{cde}	0.64^{cdef}
105	0.69^{cdefgh}	0.67^{cdef}	0.65^{cd}	0.56^{b}
130	0.66^{cde}	0.64^{cd}	0.62^{bc}	0.46^{a}
LSD (0.05)	0.076			
CV%	3.86			

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

Complementary use of chemical fertilizers and organic fertilizers has assumed great importance nowadays to maintain as well as sustain a higher level of soil fertility and crop productivity (Shalini *et al.,* 2002). Some of the works who did on different sources and levels of nitrogen fertilizer indicated that higher marketable yield of garlic due to application of nitrogen was attributed to significantly higher bulb yield (Maryam *et al.,* 2012). Higher marketable yield of garlic was observed in plots fertilized with high VC and N rates ha^{-1}. The possible justification for this higher result could be due to combined effect of the contributions of VC and nitrogen to chlorophyll, enzymes, and proteins synthesis.

3.5. Economic Analysis

As indicated in Table 8, partial economic analysis was done for economic performance of garlic under VC and mineral N fertilizer application. The variable cost considered was VC and mineral N fertilizer cost with their application cost as well as extended days for gardener (60 ETB per (day + night) of each treatment over control was considered.

Table 8. Partial budget analysis of the economic performance of garlic under vermicompost and mineral N fertilizer.

Factors VC (t ha^{-1})	Treatments N (kg ha^{-1})	Average yield (t ha^{-1})	Adjusted yield (t ha^{-1})	Gross benefit (ETB ha^{-1})	Total variable cost (ETB ha^{-1})	Net benefit (ETB ha^{-1})	%MRR
0	0	7.69	6.92	276840	---	276840	---
	52.5	8.07	7.27	290628	1810	288818	761.77
	80	8.45	7.61	304200	2587	301613	1057.60
	105	9.19	8.27	330840	3299	327541	1636.86
	130	9.60	8.64	345600	4012	341588	1713.86
2.5	0	9.26	8.33	333360	26450	306910	213.69
	52.5	9.59	8.63	345240	28260	316980	242.04
	80	9.93	8.94	357480	29037	328443	277.71
	105	10.66	9.59	383760	29749	354011	359.41
	130	11.07	9.96	398520	30462	368058	399.45
5	0	9.66	8.69	347760	52900	294860	134.06
	52.5	10.83	9.75	389880	54710	335170	206.62
	80	11.24	10.12	404640	55487	349153	230.32
	105	12.12	10.91	436320	56199	380121	283.78
	130	12.74	11.47	458640	56912	401728	319.44
7.5	0	10.83	9.75	389880	79350	310530	142.46
	52.5	11.19	10.07	402840	81160	321680	155.25
	80	11.90	10.71	428400	81937	346463	184.97
	105	12.71	11.44	457560	82649	374911	218.66
	130	14.94	13.44	537600	83362	454238	312.80

Note: Price of N = 26.09 ETB kg-1 N + application cost of 320.00 ETB per ha-1. Price of vermicompost = 10.00 ETB kg-1 + application cost of 1390.00 ETB per 2.5 t ha-1 or 2780.00 ETB per 5 t ha-1 + 4170.00 ETB per 7.5 t ha-1. Garlic selling price = 40.00 ETB kg-1. (Garlic selling price at Haramaya district, 2017).

4. Conclusion

Agronomic traits and yield of garlic were significantly affected by the application of both organic and inorganic fertilizers. Yield components and yield traits showed significant differences ($P < 0.05$) in response to the application of VC and mineral nitrogen fertilizer. The maximum clove weight (2.71 g) and marketable bulb yield (12.32 t ha^{-1}) were recorded at the rate of 7.5 t VC ha^{-1}. Using combined application of VC at 7.5 t ha^{-1} and mineral N fertilizer at 130 kg ha^{-1}, unmarketable bulb yield was reduced by 41.03% over control (No application). The highest net benefit of 454,238 ETB ha^{-1} was obtained from the highest total variable cost of 83,362 ETB ha^{-1}. The combined application of 7.5 t VC ha^{-1} and 130 kg N ha^{-1} respectively, resulted in higher marketable bulb yield than other low doses of either VC and mineral N fertilizer or their combination.

The results of the experiment revealed that agronomic traits and yield of garlic plants did not reach optimum since all significantly increased in response to the application of each of the fertilizers or the combined highest rates of the fertilizers.

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