academicJournals

Vol. 13(2), pp. 27-35, 11 January, 2018
DOI: 10.5897/AJAR2017.12708
Article Number: 35FAF0055619
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Response of garlic (*Allium sativum* L.) to vermicompost and mineral N fertilizer application at Haramaya, Eastern Ethiopia

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Received 3 September, 2017; Accepted 21 September, 2017

Garlic (*Allium sativum* L.) is an important vegetable crop in Ethiopia. The yield of the crop is often constrained by low and unbalanced nutrient supply in the soil. This study was undertaken to assess response of garlic variety Chelenko I to vermicompost and mineral N fertilizer application on growth and bulb yield of the crop during the 2016/2017 main rainy season. The treatment consists of a factorial combination of four levels of vermicompost (0, 2.5, 5 and 7.5 t ha^{-1}) and five levels of mineral N fertilizer (0, 52.5, 80, 105 and 130 kg N ha^{-1}), laid out in a randomized complete block design in a factorial arrangement and replicated three times. Data was collected on plant growth, yield component and bulb yield of garlic. Results revealed that significant ($P < 0.05$) maximum leaf length (41.08 cm), bulb weight (39.17 g/bulb), harvest index (63.94%) and total bulb yield (12.93 t ha^{-1}) were recorded at the rate of 7.5 t ha^{-1} of vermicompost application while maximum average leaf width (1.25 cm), clove number (13.57 cm), and bulb dry matter (51.66%) were obtained at maximum rate of 130 kg ha^{-1} mineral N fertilizer. The results indicated that application of vermicompost at 7.5 t ha^{-1} and 130 kg Nha^{-1} mineral fertilizer gave the highest total garlic bulb yield of 12.9 and 12.69 t ha^{-1}, respectively.

Key words: *Chelenko* I, marketable bulb yield, response, total bulb yield, vermicompost.

INTRODUCTION

Garlic (*Allium sativum* L.) is primarily grown for its cloves, which are used mostly as food flavoring condiments due to groups of sulphur containing compounds: allin and allicin (Messiaen and Rouamba, 2004). Green tops are eaten fresh and cooked especially in tropical areas and consumption of immature bulbs for salad use is also popular (Block, 2010).

Despite its importance, in Ethiopia, imbalanced fertilizer use, lower soil fertility status in many soil types and lack of proper marketing facilities are among key production constraints (Getachew and Asfaw, 2000; Mohamed et al., 2014) which considerably reduce yield. Among the

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primary macronutrients, nitrogen (N), phosphorous (P) and potassium (K) are the most commonly reported deficient plant nutrients in most Ethiopian soils (Yohannes, 1994).

Crop nutrient requirements vary with species, variety, soil type and season, a blanket recommendation of 105 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} each of N and P fertilizer are being used for garlic variety 'Tseday' production in many areas (EARO, 2004). This is also used for 'Chelenko I' (Tewdros et al., 2014) without research recommendation. This is one of the gaps addressed in the study area.

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 labour demands for processing and application (Pratap et al., 2012). As interaction of organic and inorganic is valued, Verma et al. (2013) reported that the combined application of organic and inorganic fertilizers provided all the essential nutrients required by plants for its growth and development.

In addition, the application of bio-fertilizers like vermicompost (VC) has 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).

An important feature of VC is that, during 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 P and soluble K, Ca and Mg (Suthar and Singh, 2008). Therefore, complementary use of chemical fertilizers and organic manures has assumed great importance nowadays to maintain as well as sustain a higher level of soil fertility and crop productivity (Shalini et al., 2002).

In Ethiopia, garlic cultivation decreased from 16,411.19 ha, in 2013/14 to 15,381 ha in 2016/17 with a total production of 159,093.58 and 138,664.3 tons of bulbs with the productivity of 9.7 and 9.02 t ha^{-1}, respectively (CSA, 2017). Though the area covered by garlic, its production and productivity were not indicated in Eastern Hararghe, about 50,683 farmers produced local varieties of garlic. The yield of recently released garlic variety, 'Chelenko I', gave 9.3 t ha^{-1} on research field appreciated and selected for Eastern and Western Hararghe areas (Tewdros et al., 2014).

Varieties may also differ in their response to source and rate of applied fertilizers (Zhou et al., 2005). Moreover, no work has been done on effect of mineral N and VC on the performance of garlic in the area. Therefore, the study was initiated to assess the effect of VC and mineral N fertilizer on growth and bulb yield of garlic.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Haramaya University main campus, Rare research field during the main crop growing season, August to December 2016. The area is geographically located eastern part of the country at altitude of about 2006 m above sea level. The site has a bimodal rainfall distribution pattern and is representative of a sub-humid, mid-altitude agro-climatic zone. The mean annual rainfall is 790 mm (Belay et al., 1998; Simret et al., 2014) and the minimum and maximum temperatures are 3.8 and 25°C, respectively (Tekalign and Hammes, 2005). The soil of the experimental site is a well-drained deep alluvial with sandy loam texture (Simret et al., 2014).

Experimental materials, treatments and experimental design

Garlic variety '*Chelenko I* ' which was released in 2014 for mid to high altitude garlic growing areas of eastern and western Hararghe Zones by Haramaya University, was used. It is well adapted with productivity of 9.3 t ha^{-1} and moderately susceptible to garlic rust in Eastern Ethiopia. It takes about 132 days to mature (Tewodros et al., 2014).

The treatments consist of four rates of VC (0, 2.5, 5.0 and 7.5 t ha^{-1}), and five mineral N fertilizer rates (0, 52.5, 80, 105 and 130 kg N ha^{-1}); thus, the total treatments were 20. The experiment was laid out in randomized complete block design with three replications in a factorial combination.

Experimental procedures and crop management

Experimental field was ploughed by a tractor and plots were leveled and ridges of about 20 cm high were prepared. The gross plot size was 2.0 x 1.5 m (3.0 m^2). In between blocks and plots 0.75 m and 0.5 m space was left, respectively. VC was applied about two weeks before planting to randomly assigned treatments to each plot. One fourth, half and the remaining one fourth of the N fertilizer as per the treatment was also applied as urea at planting, and three weeks and six weeks after emergence of the garlic plants, respectively. In all the plots P (92 kg P_2O_5 ha^{-1}) was applied at planting through triple superphosphate. Healthy and uniform medium-sized cloves of 1.5 to 2.50 g (Fikreyohannes et al., 2008), were selected and planting was done on 11 August 2016 at the depth of 3 to 4 cm. The cloves were planted on the ridge at a 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. Thus, the net plot size was 0.9 x 1.8 m = 1.62 m^2. When 70% the plants showed neck fall (Getachew and Asfaw, 2000; EARO, 2004), harvesting of bulbs was done (on the 16^{th} of December 2016).

Vermicompost and soil sample analysis

Vermicompost sample, obtained made from *Lantana camara, Partinium hystrophorous* and farmyard manure, was analyzed before applying on the soil. Samples were taken randomly from the entire bag. It was broken into small crumbs and prepared for determination of chemical properties. The sample was air-dried and sieved through a 2 mm sieve. It's EC and pH 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. 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 ($NaHCO_3$) according to the methods of Olsen et al. (1954). Exchangeable K was determined with a flame photometer after extraction with 0.5 ammonium acetate according to Hesse (1971). Organic carbon of soil was determined by the Walkley-Black (1934) method.

In similar a way, soil sampling was done before planting. The samples were taken randomly using an auger in a zigzag pattern from the entire experimental field. 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).

Data collection and measurement

Growth parameters

Leaf width (cm): Leaf width of 10 individual leaves of the above selected plants was measured from the widest point of leaves and the average was taken as the leaf width.

Leaf length (cm): The length of the leaf from leaf sheath to the tip of the leaf was measured from 10 randomly taken plants and their average was expressed as leaf length.

Yield components and yield

Mean bulb weight (g): Ten bulbs were randomly taken from the net plot area and their weight was recorded by using sensitive balance. The average weight was expressed as bulb weight.

Clove number per bulb: The number of cloves was counted from the above 10 bulbs and their mean were taken as clove number per bulb.

Total bulb yield (t ha^{-1}): This was determined by weighing plants in the three central rows (sum of marketable and unmarketable bulbs) leaving the plants in both end of the row and weighed after curing at ambient condition using a sensitive balance and converted t ha^{-1}.

Bulb dry matter (%): The average dry matter weight (g) of bulbs after curing were measured by drying 10 randomly sampled bulbs in an oven with a forced hot air circulation at 70°C until a constant weight was obtained. The percent of bulb dry matter was calculated by taking the ratio of the dry weight to the fresh weight of the sampled bulbs and multiplying it by 100.

$$\text{BDM (\%)} = \frac{\text{Weight of bulb dry matter}}{\text{Bulb fresh weight}} \times 100$$

Harvest index (%): This was calculated as the ratio of bulb yield to biological yield (total weight of garlic plant including above and below ground yield) recorded from 10 plants sampled from the net plot area. This was computed by dividing mean weight of mature bulb of plants taken (economic yield) by the biomass yield of plants (biological yield) taken using the equation (Pessarakli, 2001):

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Data analysis

Data collected was subjected to analysis of variance (ANOVA) using SAS software version 9.0 and the means separated by using Turkey's Method at 0.05 level of significant if treatments are found significant.

RESULTS AND DISCUSSION

Physical and chemical properties of the soil

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) according to Jones (2003). The pH is in the range of 6.5 to 7.5 favorable for garlic production (Bachmann, 2001). The OM of the experimental soil was 2.55%. According to Tekalign (1991), OM ranging from 0.86 to 2.59 is low, hence the soil might respond to the applied VC and mineral N fertilizers, as its organic matter content was low.

As per the rating (0.12 to 0.25%) described by Berhanu (1980), the total N content of the soil (0.18%) was 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. According to the rating (5 to 9 mg P kg^{-1}) suggested by Cottenie (1980), the available P of the soil was low (Table 1). This may be because of low percent of OM content of the soil (Table 1) which is also in agreement with the suggestion of Clark et al. (1998) who indicated that soil OM influences P availability to crops directly by contributing to P pool. However, Toung et al. (2000) reported that P response is likely in soils that have less than 20 mg kg^{-1} extractable P. The CEC of the experimental soil was 18.61 (cmol (+) kg^{-1}). This value was 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. Hazelton and Murphy (2007) categorized exchangeable soil K contents of 0.3 to 0.7 Cmolc kg soil^{-1} as medium. In accordance with this category, the exchangeable soil K content of the experimental soil is in medium category. This indicates external application of mineral and/or organic fertilizers containing K is important for enhancing the fertility of the crop and yield of the crop.

Vermicompost analysis result

It is crucial to analysis nutrient contents of VC as it is soil activator, soil conditioner, and soil fertility booster with all required plant nutrient, vitamins, enzymes, growth

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

Soil property	Value	Rating
Sand (%)	61	
Clay (%)	23	
Silt (%)	16	
Textural class	Sandy clay loam	
pH 1: 2.5 (H_2O)	7.4	Moderately alkaline
OC	1.48	Moderate
OM (%)	2.55	Low
Total N (%)	0.18	Medium/ moderate
Available P (mg kg^{-1})	5.58	Low
Exchangeable K (Cmolc kg^{-1})	0.32	Medium
CEC (cmol (+) kg^{-1})	18.61	Medium

OC, organic carbon; OM, organic matter.

Table 2. Chemical properties of vermicompost.

VC	Chemical properties						
	Total N (%)	Available P (ppm)	Exchangeable K [Cmol(+)/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

OC, Organic carbon; OM, organic matter; VC, vermicompost; ppm, parts per million; EC, electric conductivity.

hormones and beneficial micro-organisms.

Chemical analysis of VC is given in Table 2. Its component is EC: 8.83 msm^{-1}, pH: 7.25, total N 0.56%, 25.82 ppm of available P, exchangeable K 23.69 Cmol(+)/kg VC, 15.39% of OM and OC 8.92% as indicated in Table 2. These VC increases soil fertility without polluting the soil, as well as the quantity and quality of crops. Moreover, beneficial effects of VC 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, thereby resulting in better growth of the plants. Application of bio-fertilizers such as VC 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 and increasing crop yields. Municipal solid waste compost can also reduce the volume of the waste, kill pathogens that may be present, decrease germination of weeds in agricultural fields, and destroy malodorous compounds (Hargreaves et al., 2008).

Growth parameters

Leaf width

Analysis of variance showed that main effect of VC and mineral N fertilizer significantly ($P < 0.05$) affected leaf width but there was no significant observation due to their interactions. Application of 5 t VC ha^{-1} gave significantly optimum leaf width over the application rate of 2.5 t VC ha^{-1} and control, but statistically same with the application rate of 7.5 t VC ha^{-1} (Table 3). Verma et al. (2013) reported that chlorophyll contents of garlic leaf that contribute to leaf width increased significantly with application of 5 t VC ha^{-1}. Similarly, Mehdi et al. (2012) reported significantly increased leaf area index in response to the applied municipal solid waste and VC under well-watered, moderate and severe stress conditions. Abou El-Magd et al. (2012) also reported that the highest vegetative growth parameters were recorded with application of organic materials like poultry manure, farm-yard manure, sheep manure and compost.

N fertilization at the rate of 105 kg ha^{-1} gave significantly optimum higher leaf width over the other low N rates and statistically at par with application of 130 kg ha^{-1} (Table 3). As N increased from 0 to 105, leaf widths was increased by 15%. Adequate application of N plays an important role in the production of vigorous vegetative and optimum leaf expansion of garlic and influences garlic bulb size produced (Stork et al., 2004). Kakar et al. (2002) reported that N fertilization is necessary for ensuring successful vegetative growth of garlic. Similarly, Tadesse (2015) also reported that application of N significantly increased leaf width in comparison with lower

Table 3. Main effects of vermicompost and N on leaf width and leaf length of garlic.

Factor	Treatment	Leaf width (cm)	Leaf length (cm)
	0	1.09^{c}	34.55^{c}
VC (t ha^{-1})	2.5	1.18^{b}	37.17^{b}
	5	1.20^{ab}	38.44^{b}
	7.5	1.23^{a}	41.08^{a}
LSD (0.05)		0.05	1.81
	0	1.08^{c}	34.56^{d}
	52.5	1.16^{b}	36.70^{dc}
N (kg ha^{-1})	80	1.20^{ab}	38.31^{bc}
	105	1.23^{a}	39.63^{ab}
	130	1.25^{a}	40.94a
LSD (0.05)		0.06	2.16
CV %		4.80	4.86

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

dose and nil application of N fertilizer. The result revealed that leaf width increase with increased levels of fertilizers is directly proportion to leaf area index.

Leaf length

Analysis of variance indicated that the main effect of VC and N fertilization rate showed significant differences ($p < 0.05$) on leaf length but their interaction did not.

As shown in Table 3, the average maximum leaf length was found at the maximum rate of application of VC (7.5 t ha^{-1}) which was significantly superior to rest of the treatments. Nil application of VC gave significant minimum leaf length and leaf length increased by 18.90% with the application of 7.5 t VC ha^{-1} as compared to nil VC application (Table 3). This increase in the vegetative growth might also be due to the effect of nutrients which are exerted by bio-enriched (Gomaa, 1995). This result is also in line with that of Mehdi et al. (2012) who reported significantly increased leaf area index in response to the applied municipal solid waste and VC under well-watered, moderate and severe stress conditions.

The analysis of variance indicated that N significantly affected leaf length. Optimum leaf length was recorded with application of 105 kg N ha^{-1}. Application of N at rate of 105 kg ha^{-1} increased leaf length by about 14.67% as compared to untreated plot (Table 3). The increase in leaf length in response to the increased rate of N application may be attributed to the positive effect of N on vegetative growth and leaf expansion as suggested by Marschner (1995) and Halvin et al. (2003).

Similarly, Betewulign and Solomon (2014) reported that leaf length of garlic increased with increased rate of mineral N fertilizer. Kakar et al. (2002) also reported that N accounts for a higher percentage of the variation in leaf area when it was increased from 50 to 200 kg ha^{-1}. The leaf area is due to increased leaf length and width. Dirba et al. (2013) found that leaf area index of garlic treated with different levels of fertilizers was significantly increased over the untreated (control) plot at all sampling growth stages.

Yield components and yield

Bulb weight and clove number per bulb

Significant variations ($p < 0.05$) were obtained among bulb weights and clove number per bulb due to the main effect of VC and N application rate. However, their interaction had no significant influence on them (Table 4).

Significant maximum mean bulb weight was obtained from plots treated with VC at the rate 7.5 t ha^{-1} as compared to the rest treatments. The maximum VC application rate gave 29.23% increase in bulb weight over the nil VC received plots (Table 4). The increase in mean bulb weight in response to increase in the rate of VC may be ascribed to several growth promoters, enzymes, beneficial bacteria and mycorrhyzae contained in it that led to high mean bulb weight by facilitating improved leaf growth and photosynthetic activities; thereby, increasing portioning of assimilate to the storage organ (Gupta, 2005). Alemu et al. (2016) reported that application of VC at the rate of 5 t ha^{-1} increased mean bulb weight by 8% as compared to the control plots. Weight of the bulb increased significantly up to the highest dose of 7.5 t VC ha^{-1} (Verma et al., 2013).

Application of highest level of mineral N fertilizer rate produced significantly increased bulb weight by 25.47% over the control. The increase in mean fresh bulb weight in response to N application could be attributed to the increase in number of leaves produced, leaf length, and extended physiological maturity in response to the

Table 4. Main effects of application vermicompost and N on bulb weight and clove number per bulb of garlic.

Factor	Treatment	Bulb weight (g/p)	Clove number per bulb
VC (t ha^{-1})	0	30.31^{d}	12.35^{b}
	2.5	32.73^{c}	12.98^{a}
	5	36.33^{b}	13.07^{a}
	7.5	39.17^{a}	13.22^{a}
LSD (0.05)		1.77	0.47
N (Kg ha^{-1})	0	30.68^{d}	12.41^{c}
	52.5	32.26^{cd}	12.59^{c}
	80	33.51^{c}	12.76^{bc}
	105	35.78^{b}	13.19^{ab}
	130	38.43^{a}	13.57^{a}
LS (0.05)		2.12	0.57
CV %		5.31	3.78

g/p, gram per plant. Means followed by the same letter within a column are not significantly different at 5% level of significance.

fertilization, all of which may have led to increased assimilate production and allocation to the bulbs (Kokobe et al., 2013). According to Bhagwan et al. (2012), successive levels of N fertilizers significantly increased the weight of garlic bulb. Besides, Tadesse (2015) also observed that the application of N significantly increased weight of bulb in comparison with lower dose and nil application of N fertilizer.

Results indicated in Table 4 for clove number per bulb, VC application at the rate of 2.5, 5 and 7.5 t ha^{-1} showed significantly increased garlic cloves number per bulb over the control. Statistically, these three levels were not different. Agarwal (1999) reported that VC is a nutritive organic fertilizer rich in macronutrients, micronutrients, beneficial soil microbes like N-fixing bacteria and mycorrhizal fungi. Additionally, VC contain enzymes like amylase, lipase, cellulase and chitinase, which continue to break down organic matter in the soil (to release the nutrients and make it available to the plant roots) even after they have been excreted (Gupta, 2005). Clove number of garlic increased significantly up to 5 t ha^{-1} of VC (Verma et al., 2013). Surindra (2009) found 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. Alemu et al. (2016) also reported that application of VC showed significant difference in mean clove number.

Analysis of variance showed that application of 105 kg ha^{-1} mineral N fertilizer gave optimum clove number per bulb. This might be due to the fact N is a constituent of many fundamental cell components and plays a vital role in all living tissues of the plant. This result is in line with the result of Bhagwan et al. (2012) who reported that successive levels of fertilizers significantly increased the number of cloves per bulb. According to Zaman et al. (2011) and Hossein et al. (2014), the highest number of cloves per bulb was obtained from 150 and 125 kg N ha^{-1}, respectively and the lowest was found in the control treatments.

Harvest index

The main effect of VC and N significantly ($p < 0.05$) influenced harvest index of garlic. The interaction effect of VC and mineral N fertilizer did not show significant effect on harvest index.

Significant maximum harvest index (63.94%) was recorded at the rate of 7.5 t VC ha^{-1} application over the other rate of application and followed by 5 t VC ha^{-1} application rate (Table 5). There was consistent increase in percent of harvest index. This could be attributed to the strong movement of assimilates from the leaves to the bulbs during the growing period. An important feature of VC is that, during the processing of the various organic wastes by earthworms, many of the nutrients that it contains are changed to forms that are more readily taken by plants such as nitrate or ammonium nitrate, exchangeable P and soluble K, calcium and magnesium (Suthar and Singh, 2008). Alemu et al. (2016) reported that VC had no significant effect on harvest index.

Application of 130 kg N ha^{-1} N gave significantly highest harvest index (60.52%) over other rates of mineral N fertilizer except 105 kg N ha^{-1}. Significantly lowest percent harvest index (51.82) was obtained from plots that did not receive N fertilization followed by 55.87 percent harvest index obtained from 52.5 kg N ha^{-1} application. N application at the rate of 52.5 kg ha^{-1} had significantly higher percent harvest index from nil application of N but was not significantly different as compared to the application rate of 80 kg N ha^{-1} (Table 5). The observed improvement in harvest index could be attributed to enhanced production of photosynthate due

Table 5. Main effects of vermicompost and N on percent harvest index, bulb dry matter and total bulb yield of garlic.

Factor	Treatments	Harvest index (%)	Bulb dry matter (%)	Total bulb yield (t ha^{-1})
VC (t ha^{-1})	0	51.76^{d}	47.12^{c}	9.32^{d}
	2.5	55.42^{c}	48.44^{b}	10.80^{c}
	5	59.96^{b}	49.37^{ab}	12.00^{b}
	7.5	63.94^{a}	49.88^{a}	12.93^{a}
LSD (0.05)		2.08	0.97	0.58
N(kg ha^{-1})	0	51.82^{d}	46.10^{c}	10.12^{d}
	52.5	55.87^{c}	46.88^{c}	10.64^{cd}
	80	57.04^{bc}	48.21^{b}	11.06^{c}
	105	58.92^{ab}	50.72^{a}	11.82^{b}
	130	60.52^{a}	51.66^{a}	12.69^{a}
LSD (0.05)		2.48	1.16	0.69
CV %		3.69	2.05	5.21

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

to increased leaf area, hence, greater partitioning of the photosynthate to the bulbs.

The finding of Dargie (2015) showed that increased rate of N fertilizer from 0 to 64 kg ha^{-1} increased harvest index of onion by about 5.0%. This shows that mineral N fertilizer contributed to increase in harvest index.

Bulb dry matter

Significant increase in percent dry matter content of garlic bulbs were recorded due to main effect of VC and N fertilizers applied ($p < 0.05$). However, bulb dry matter percent was not significantly affected by their interaction effects.

Bulb dry matter percent was increased by 5.86% due to increased level of VC rate from 0 to 7.5 t ha^{-1}. Optimum bulb dry mater percent was obtained from the application rate of 5 t VC ha^{-1} which was significantly not different from the application of 5 t VC ha^{-1} (Table 5). Juan et al. (2006) showed that application VC 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 authors further explained that reserve substance (scorodose) accumulation in the VC treatment represented by scorodose polysaccharide, occurs for a longer period due to the earlier start of bulbing. This response translates into 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.

Application of 105 kg N ha^{-1} which was 50.72% dry matter, did not differ significantly from the application of 7.5 t VC ha^{-1} but significantly differ from the others low application rates. N application at the rate of 130 kg N ha^{-1} gave significantly highest dry matter percent (51.66%) over the nil application, 52.5 and 80 kg N ha^{-1}. Hence, the application 130 kg N ha^{-1} gave 12.06% increase in bulb dry matter when compared with the control.

Hassan (2015) elaborated that increase of plant growth that contribute to bulb dry weight 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. The author indicated that as N level increased, dry weight per plant increased up to the highest N level. Kakar et al. (2002) reported that N accounts for a higher percentage of the variation in dry plant mass when it was increased from 50 to 200 kg ha^{-1}. Alemu et al. (2016) also figured out that bulb dry matter percent was increased by 14.21% due to increased level of N rate from 0 to 46 kg ha^{-1}. Increasing rate of N application from nil to 130 kg N ha^{-1} bulb dry matter was increased by 12.06%.

Total bulb yield

Yield is a complex parameter that results from the interaction of various yield contributing characters. The maximum total bulb yield (12.93 t ha^{-1}) was recorded with application of 7.5 t VC ha^{-1} which was statistically different from the rest of the treatments (Table 5).

As indicated in Table 5, there was an increase of 38.73% in total bulb yield by application of VC at rate of 7.5 t ha^{-1} over control. This might be due to the fact that organic manure supplied to balanced nutrition to the crop, improved soil condition; thereby, resulting in better growth and development leading to higher yield attributes and yield. Pramanik et al. (2007) found that humic acids released from VC enhanced nutrient uptake by the plants by increasing the permeability of root cell membrane, and stimulating root growth.

Plots that received mineral N fertilizer at the rate of 130 kg ha^{-1} increased by 25.40% in yield as compared to the control or nil application of N. Mineral N fertilizer application at the rate of 130 kg N ha^{-1} resulted in significantly maximum total bulb yield (12.69 t ha^{-1}) followed by 105 kg N ha^{-1} application rate which gave 11.82 t ha^{-1}. The least bulb yield was recorded from nil application of fertilizers (Table 5). This result suggests that N application to the soil is important to improve bulb yield of garlic significantly. This might be due to the fact that N is a major part of all amino acids that increases the vegetative growth and produces good quality foliage and promotes carbohydrate synthesis through photosynthesis and ultimately increased yield of plants.

Bulb crops are a heavy feeder, requiring optimum supplies of N, P, K and S and other nutrients which can adversely affect growth, yield and quality of bulbs under suboptimal levels in the soil (Gubb and Tavis, 2002). According to Bhagwan et al. (2012) successive levels of fertilizers significantly increased the weight of bulb, number of cloves per bulb and bulb yield. The authors reported that maximum bulb yield (13.86 t ha^{-1}) was obtained with application of 100% recommended dose of fertilizer, which is 41.7% higher than the control. Singh and Singh (2006) and Kokebe et al. (2013) also reported that increase in the rate of N from 0 to 100 kg N ha^{-1} resulted in progressive increments in total bulb yield of onion.

Conclusions

Research was conducted to study the response of garlic to VC and mineral N fertilizer application rates with the objectives of assessing the effect of VC and mineral N fertilizer on growth and bulb yield of garlic. Growth parameters such as leaf width and leaf length were significantly influenced by the applied VC and N fertilizers. The highest leaf width (1.25.cm) and leaf length (41.08 cm) were recorded for 7.5 t VC ha^{-1} and 130 kg N ha^{-1}, respectively.

Yield components and yield traits showed significant differences ($p < 0.05$) in response to the application of VC and mineral N fertilizer. Maximum bulb weight (39.17 g/plant), harvest index (63.94%) and total bulb yield (12.93 t ha^{-1}) were recorded from the application rate of 7.5 t VC ha^{-1}. The highest clove number (13.57) and bulb dry matter (51.66%) were recorded from highest rate of 130 kg N ha^{-1}. Significantly highest total bulb yield, 12.93 and 12.69 t ha^{-1}, was obtained from maximum application rate of 7.5 t VC ha^{-1} and 130 kg N ha^{-1} mineral fertilizer, respectively.

Thus, it can be reasonably generalized that on short term basis, application of high amounts of VC fertilizers can result in highest total bulb yield than other low doses of either VC and mineral N fertilizer or their combination. Therefore, from the results of this study, it can be concluded that, the maximum total bulb yield of garlic was obtained with the application of 7.5 t VC ha^{-1} fertilizer as it also has positive impacts on soil biological, aggregation and chemical condition.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors are thankful to the Ethiopian Ministry of Education for financing this work. The first author is also thankful to Dilla University for granting him a leave of absence to conduct this research work.

REFERENCES

Abou El-Magd MM, El-Shourbagy T, Shehata SM (2012). A comparatives study on the productivity of four Egyptian garlic cultivars grown under various organic material in comparison to conventional chemical fertilizer. Vegetable research department, National research center, Cairo, Egypt. Aust. J. Basic Appl. Sci. 6(3):415-421.

Agarwal S (1999). Study of vermicomposting of domestic waste and the effects of vermicompost on growth of some vegetable crops. PhD. Thesis awarded by University of Rajasthan, Jaipur, India.

Alemu D, Nigussie D, Fikreyohannes G (2016). Effect of vermicompost on growth, yield and quality of garlic (*Allium sativum* L.) in Enebse Sar Midir District, Northwestern Ethiopia. J. Nat. Sci. Res. 6:3.

Bachmann, J. (2001). Organic Garlic Production. National sustainable agriculture information service. Davis, California, USA.

Belay SC, Wortman W, Hoogenboom G (1998). Haricot bean agro-ecology in Ethiopia: definition using agro-climatic and crop growth stimulation models. Afr. Crop Sci. J. 6:9-18.

Berhanu D (1980). The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia.

Betewulign EA, Solomon TT (2014). Evaluating the role of N and P on the growth performance of garlic (*Allium sativum* L.). Asian J. Agric. Res. 8:211-217.

Bhagwan SC, Soni AK, Khaswan SL (2012). Growth, yield and quality of garlic (*Allium sativum* L.) as influenced by different nutrient management practices. Asian J. Agric. Res. 8:211-217.

Block E (2010). Garlic and other Alliums: The Lore and the Science. Royal Soc. of Chemistry. ISBN 0-85404-190-7. bulb yield of two garlic cultivars. Eur. J. Exp. Biol. 4(1):270-272.

Clark MS, Howarth WR, Shennan C, Scow M (1998). Changes in soil chemical properties resulting from organic and low input farming practices. Agron. J. 90:662-671.

Cottenie A (1980). Soil and plant testing as a basis of fertilizer recommendations. FAO soil bulletin 38/2. Food and Agriculture Organization of the United Nations. Rome, Italy.

CSA (Central Statistical Agency) (2017). Agricultural Sample Survey of 2016/17. Report on area and production of major crops (Private Peasant Holdings, Meher season). Addis Ababa, April 2017. Stat. Bull. 584:1.

Dargie M (2015). Influence of mineral N and phosphorus fertilizer rates on growth, yield components and bulb yield of onion (Allium cepa var.

cepa) at Kobo, Northern Ethiopia. M.Sc. Thesis, Haramaya University.

Dirba S, Nigussie D, Kebede W, Getachew T, Sharma JJ (2013). Growth and nutrients content and uptake of garlic (*Allium sativum* L.) as influenced by different types of fertilizers and soils. Afr. J. Agric. Res. 8(43):5387-5398.

EARO (Ethiopian Agricultural Research Organization) (2004). Directory of released crop varieties and their recommended cultural practices. Addis Ababa.

Fenwik GR, Hanley AB (1985). The genus Allium part 2. Crit. Rev. Food Sci. Nutr. 22(3):273-377.

Fikreyohannes G, Kebede W/Tsadik, Nigussie Dechassa and Tiwari A (2008). Effect of clove size and plant density on the bulb yield and yield components of Ethiopian garlic (*Allium sativum* L.). Pantnagar J. of Research. 6 (2):234-238.

Getachew T, Asfaw Z (2000). Achievements in shallot and garlic research. Report No. 36. Ethiopian Agricultural Research Organization. Addis Ababa, Ethiopia.

Gomaa AM (1995). Response of certain vegetable crop to bio-fertilization. Ph. D. Thesis, Faculty of Agriculture. Cairo University, Egypt.

Gubb IR, Tavis MSH (2002). Onion preharvest and postharvest considerations.. In: H.D. Rabinowitch, and L. Currah (eds.). Allim Crop Science. CABI publishing, UK. pp. 237-250

Gupta PK (2005). Vermicomposting for sustainable agriculture, Agrobios (India), Jodhapur. P 210.

Halvin JL, James DB, Samuel LT, Warner LN (2003). Soil fertility and fertilizer an introduction to nutrient management 6th (ed.), Pearson Education Inc. New Delhi, India.

Hargreaves JC, Adl MS, Warman PR (2008). A review of the use of composted municipal solid waste in agriculture. Nova Scotia, Canada. J. Agri-Ecosyst. Environ. 123:1-14.

Hassan A (2015). Improving growth and productivity of two garlic cultivars (*Allium sativum* L.) grown under sandy soil conditions. Middle East J. Agric. Res. 4(2):332-346.

Hazelton PA, Murphy B (2007). Interpreting Soil Test Results, What Do All The Numbers Mean? Commonwealth Scientific and Industrial Research Organization Publishing.

Hesse PR (1971). A text book of soil chemical analysis. John Murray, London.

Hossein M, Sharafzadeh S, Bazrafshan F (2014). The influence of N levels on growth and bulb yield of two garlic cultivars. Eur. J. Exp. Biol. 4(1):270-272.

Jackson ML (1958). Soil chemical analysis. Prentice Hall, Inc., Englewood Cliffs. NJ, America 521p.

Jones JB (2003). Agronomic hand book: Management of crops, soils and their fertility, CRC press, Boca Raton, FL, USA.482p.

Juan A, Arguello A, Ledesma SB, Nunez CH, Rodriguez M, Diaz G (2006). Vermicompost effects on bulbing dynamics, nonstructural carbohydrate content, yield and quality of Rosado Paraguayo' garlic bulbs. Hortic. Sci. 41(3):589-592.

Kakar AA, Abdullahzai AK, Saleem M, Qaim SSA (2002). Effect of N fertilizer on growth and yield of garlic. Asian J. Plant Sci. 1 (5):544-545.

Kokobe WY, Derbew B, Adugna D (2013). Effect of farmyard manure and N fertilizer rates on growth, yields and qualities of onion (*Allium cepa* L.) at Jimma Zone Ethiopia. Asian J. Plant Sci. pp. 1682-3974.

Landon JR (1991). Booker tropical soil manual. A handbook for soil survey and agricultural land evolution in the tropics and subtropics. Longman scientific and technical. Essex, New York 474p.

Marschner H (1995). Mineral nutrition of higher plants. 2nd Ed. Academic press, London.

Mehdi Ra, Hossein AA, Mehdi G (2012). Effect of vermicompost and municipal solid waste compost on growth and yield of canola under drought stress conditions. Int. J. Agric. Res. Rev. 2(4):395-402.

Messiaen CM, Rouamba A (2004). Garlic (Allium sativum L.) In: Grubben, GJH and Denton OA (Editors). PROTA 2: Vegetables/Légumes. Wageningen, Netherlands.

Moodie C, Smith D, McCreerry R (1954). Laboratory manual for soil fertility. Washington State College, Monograph pp. 31-39.

Olsen SR, Cole CV, Watanabe FS, Dean LA (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Dep. Agric. Circ. 939, USA.

Pramanik PGK, Ghosh P, Ghosal K, Banik P (2007). Changes in organic-C, N, P and K and enzyme activities in vermicompost of biodegradable organic wastes under liming and microbial inoculants. J. Bioresour. Technol. (98):2485-2494.

Pratap T, Gupta NK, Saket D (2012). Effect of organic, inorganic and biofertilizers on growth and productivity of garlic (*Allium sativum*) cv. G-323. Crop Res. 43(1to3):89-97.

Rowell DL (1994). Soil science: Method and applications. Addison, Wesley, England: Longman Scientific and Technical, Longman Group UK Limited 350p.

Shalini SB, Channal HT, Hebsur NS, Dharmatti PR, Sarangamath PA (2002). Effect of integrated N management on nutrient uptake in Knolkhol, yield and nutrient availability in the soil. J. Karanataka Agric. Sci. 15(1):43-46.

Simret B, Nugussie D, Tekalign T (2014). Influence of mineral N and K fertilizers on ware and seed potato production on alluvial soil in Eastern Ethiopia. Dire Dawa, Ethiopia. East Afr. J. Sci. 8(2):155-164.

Singh AK, Singh SP (2006). Effect of levels of N and phosphorus in conjunction with varying plant densities on some important bulb characters and yield of garlic (*Allium sativum* L.). Int. J. Agric. Sci. 2:490-492.

Stork PO, Potgieter JP, Van Den HE, Niederwieser JG (2004). Garlic production: Guide to garlic production in South Africa. Agricultural research council–vegetable and ornamental plant institute, Roodeplaat, Pretoria.

Surindra S (2009) Impact of vermicompost and composted farmyard manure on growth and yield of garlic (*Allium stivum* L.) field crop. Int. J. Plant Prod. 3(1):27-28.

Suthar S, Singh S (2008). Feasibility of vermicomposting in biostabilization sludge from a distillery industry. Sci. Total Environ. 393:237-243.

Tadesse AA (2015). Growth and yield response of garlic (Allium sativum l.) varieties to N fertilizer rates at Gantaafeshum, Northern Ethiopia. M.Sc. Thesis, Haramaya University, Ethiopia.

Tekalign T, Hammes PS (2005). Growth and productivity of potato as influenced by cultivar and reproductive growth ii. Growth analysis, tuber yield and quality. Sci. Hortic.105:29-44.

Tekalign T (1991). Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa.

Tewdros B, Fikreyohannes G, Nigussie D, Mulatua H (2014). Registration of Chelenko I Garlic (*Allium sativum* L.) Variety. East Afr. J. Sci. 8(1):71-74.

Toung TP, Kam SP, Wade L, Pandey S, Bouman BAM, Hardy B (2000). Characterizing and understanding rain fed environments. Proceeding of the international workshop on characterizing and understanding rain fed environment, 5-9 Dec. 1999. Bali, Indonesia. Los Banos (Philippines). Int. Rice Res. Inst. 488p.

Verma S, Choudhary MR, Yadav BL, Jakhar ML (2013). Influence of vermicompost and sulphur on growth and yield of garlic (*Allium sativum* L.) under semi arid climate. Department of Hort., S.K.N. College of Agriculture. Rajasthan, India. J. Spices Arom. Crops 22(1):20-23.

Walkley A, Black IA (1934). An examination for determining soil organic matter and a proposed chromic acid titration method. Soil Sci. 37:29-38.

Yohannes U (1994). The effect of N, p, K, and sulphur on the yield and yield components of Enset (*Ensete ventricosum* W.) in south east Ethiopia, Ph.D. dissertation. Institute of plant nutrition, faculty of Agriculture. Justus Liebig University, Giessen.

Zaman MS, Hashem MA, Jahiruddin M, Rahim MA (2011). Effect of N for yield maximization of garlic in old Brahmaputra flood plain soil. Bangl. J. Agric. Res. 36(2):357-367.

Zhou Y, Wang D, Zhu J, Liu Q, Fan MX (2005). The role of sulfur fertilizers in balanced fertilization. In: LJ De Kok and E. Schnug (eds.). Proceedings of the 1st Sino-German Workshop on Aspects of Sulphur Nutrition of Plants pp. 23-27.