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EFFECT OF VERMICOMPOST AND MINERAL FERTILIZER ON ECONOMIC PERFORMANCE OF GARLIC (*Allium sativum* L.), IN HARAMAYA, EASTERN ETHIOPIA

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Abstract
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 assessed the response of garlic variety (*Chelenko I*) to vermicompost and mineral Nitrogen (N) fertilizer application on growth and bulb yield of the crop during the 2016/2017 rainy season in Haramaya University main campus, Ethiopia. The treatment consist of a factorial combination of four levels of vermicompost (0, 2.5, 5 and 7.5 tha^{-1}) and five levels of mineral N fertilizer (0, 52.5, 80, 105 and 130 kg N ha^{-1}), were laid out in a randomized complete block design under a factorial arrangement and replicated three times. Results revealed early maturity (130.48 days) at no fertilizer application, while late maturity (135.50 days) was with application of 7.5tha^{-1} of vermicompost. Significant ($P < 0.05$) maximum clove weight (2.71g/clove), and marketable bulb yield (12.32tha^{-1}), were recorded at the rate of 7.5tha^{-1} of vermicompost, followed by lower dose of mineral N fertilizer. Also, leaf number (13.33) was recorded at combined application of maximum rate of vermicompost (7.5tha^{-1}) and mineral N fertilizer (130kgha^{-1}). Due to combined application of vermicompost (7.5tha^{-1}) and mineral N fertilizer (130kgha^{-1}), unmarketable bulb yield was reduced by 41.03% over the control. The highest net benefit was estimated due to the maximum marketable bulb yield of garlic obtained along with application of 7.5tha^{-1} of vermicompost and 130kgha^{-1} of mineral N fertilizer. Therefore, these rates could be considered in the production of garlic in the study area.

Keywords: *Chelenko I, Nitrogen Fertilizer, Vermicompost, Marketable Yield, and Net benefit*

Introduction
In Ethiopia, garlic cultivation decreased from 16411.19ha in 2013/14 to 9257.71ha in 2014/15 with total production of about 1.59 and 0.93tonnes of bulbs, and productivity of 9.7 and 10.1tha^{-1} respectively. Though acreage of garlic production and productivity were not indicated in Eastern Hararghe, but about 27,190 farmers produce garlic (CSA, 2015). The yield of recently released garlic variety (*Chelenko I*), was estimated at 9.3tha^{-1} on a researcher managed field for Eastern and Western Hararghe (Tewdros *et al.,* 2014), though its productivity is less than national productivity. Optimum application of fertilizer to garlic crop is important for enhanced growth, yield and marketable bulb proportions and bulb quality (Diriba *et al.*, 2013). Mineral fertilizers of balanced doses increased the leaf area, photosynthetic productivity, and yield of garlic plant in particular, and led to substantial increase in production in general (Zhou *et al.*, 2005).

However, the crop nutrient requirements vary with species, variety, soil type and season. A blanket recommendation of 105kgNha^{-1} and 92kgP$_2$O$_5$ha^{-1} each of N and P fertilizer are being used for *Tseday* (garlic variety) production in many areas (EARO, 2004), and also used for *Chelenko I* (Tewdros *et al.,* 2014) without research recommendation. This is one of the gaps addressed in this study area. Mostly in Ethiopia, fertilizers are applied based on blanket recommendation without considering soil fertility levels of specific areas leading to uneconomic fertilizer application (Melaku *et al.*, 2015). Also, continuous use of chemical fertilizers are also jeopardizing the environment through poisoning and exterminating soil microflora and microfauna by adversely altering the chemical and physical properties of soil (Pratap *et al.*, 2011). Therefore, organic inputs are often proposed as alternatives to mineral fertilizers.

Due to inadequate organic material, recently, combined application is being advocated. Verma *et al.*, (2013), reported that combined application of organic and inorganic fertilizers provide all the essential nutrients required by plants for its growth and development. Combined application of 50kgNha^{-1} and 10t of manure ha^{-1} increased total bulb yield of garlic crops (Tadila *et al*., 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 up with crop nutrient demand over large areas, because of the limited quantities available, low nutrient content of the materials, and high labour demands for processing and application (Pratap *et al*., 2011). According to Alemu *et al.,* (2016), combined application of vermicompost (VC) and mineral N fertilizer increased clove number of garlic over the control. Vermicompost (VC) helps in reducing C:N ratio, increased humic acid content and provide nutrient in 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 5tha^{-1} increased soil fertility with increased economic returns.

Integrated nutrient supply approach is only the liable way for obtaining fairly high productivity with substantial fertilizer for 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. Possibilities to enhance garlic productivity in the Eastern Hararghe, Ethiopia have been the domain of investigation in recent years, though nationally, expected yield is not yet achieved. Farmers around the study area, Haramaya, produce the local varieties of garlic crop in homesteads. Recently, Haramaya University released new garlic variety *Chelenko I* (Tewdros*et al.,* 2014). Varieties may also differ in their response to source and rate of applied fertilizers (Zhou *et al*., 2005). Moreover, no study has been done on effect of mineral nitrogen and VC on the performance of garlic in the area. Therefore, the study investigated the effect of vermicompost and mineral nitrogen fertilizer on economic performance of garlic in the study area.

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-December) of 2016. The Area is geographically located within the eastern part of the country, 20km North-West of Harar town, altitude of about 2006m above sea level, 9°24" latitude and 42°03" longitude. 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 texture (Simret *et al*., 2014).

Experimental materials

Chelenko I, released in 2014 for mid to high altitude garlic growing areas of Eastern and Western Hararghe Zones by Haramaya University was used. Its yield is stable over seasons and locations in the eastern highlands of the country. It is well adapted with productivity of 9.3tha^{-1}and moderately susceptible to garlic rust in Eastern Ethiopia. It takes about132 days to mature (Tewodros *et al*., 2014).

Treatments and experimental design

The treatments consist of four rates of VC (0, 2.5, 5.0 and 7.5tha^{-1}), and five rates of mineral nitrogen fertilizer (0, 52.5, 80, 105 and 130kgNha^{-1}), giving total treatment combinations of 20. The experiment was laid out in randomized complete block design with three replications in factorial combination.

Experimental procedures and crop management

Experimental field was ploughed with a tractor, plots leveled and ridges of about 20cm high prepared. The gross plot size was 2.0m x 1.5m (3.0m^2), with in between blocks (0.75m) and plots (0.75m) spaces left. VC was applied about two weeks before planting to randomly assigned treatments on each plot. One fourth (1/4), half (1/2) and the other one fourth (1/4) of the N fertilizer per treatment were applied as urea at planting, three weeks and six weeks after emergence of the garlic plants respectively. In all the plots, phosphorus (92kg P_2O_5 ha^{-1}) was applied at planting as triple superphosphate (TSP). Healthy and uniform medium-sized cloves of 1.5-2.5g (Fikreyohannes *et al*., 2008) were selected and planting done on 11 August 2016 at depth of 3-4cm. The cloves were planted on the ridge at a spacing of 30cm between rows and 10cm between plants. Thus, there were five rows in each plot and 20 plants in a row. The outer row on each side of a plot and 20cm on both ends of each row were considered as border, thus, the net plot size was 0.9m x 1.8m=1.62m^2. When 70% the plants senesced (Getachew and Asfaw, 2000; EARO, 2004) harvesting of bulbs started.

Vermicompost and soil sample analysis

VC sample, made from *Lantana camara, Partinium hystrophorous* and farmyard manure, was analyzed before application to the soil. Samples were taken randomly from the entire bag, broken into small crumbs and prepared for determination of chemical properties. Samples were air-dried and sieved through a 2mm sieve. It's electric conductivity (EC) and pH were determined from the filtered suspension at 1:2.5 soil to water ratio using a glass electrode attached to a digital EC meter and pH meter (Jones, 2003). Samples was analyzed for EC, total N, available P, exchangeable K, organic matter and organic carbon. Total N was determined using the Kjeldhal's method (Jackson, 1958). Available P was determined by extraction with 0.5M sodium bicarbonate ($NaHCO_3$), according to the method 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 soil was determined by the Walkley and Black (1934) method. Before planting, soil samples were taken randomly using an auger in a zigzag pattern from the entire experimental field. Ten composite soil samples were taken from the top soil layer to a depth of 20cm in a bucket to represent the site. The soil was broken into small crumbs and thoroughly mixed. From this mixture, a composite sample weighing 1kg 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

I. 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.

ii. Growth parameters

***Number of leaves/plant*:** The number of leaves of the pre tagged plants were counted and average taken and expressed as number of leaves per plant.

iii. Yield and yield components

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

Marketable bulb yield (t ha^{-1}): Bulbs harvested at 90% physiological maturity of the plants from the net plot area were cured for 10 days under ambient condition by thinly spreading. Then the bulbs free from diseases, damages or blemishes, and not small sized bulb (not less than 1g cloves) (Fikreyohannes *et al*., 2008) were recorded and converted to tha^{-1}.

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

Data analysis

Data collected were subjected to analysis of variance (ANOVA), using SAS software version 9.0, and means separated using Turkey's Method at 0.05 level of significance.

Partial economic analysis

The partial budget analysis as described by CIMMYT (1988), was estimated to determine the economic feasibility of the garlic production using 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 downwards by 10% to reflect the difference between the experimental yield and the yield farmers could obtain under their management practices as described by CIMMYT (*ibid*). The field price of garlic was calculated as sale price less cost of harvesting, cleaning, bagging and transportation. The net benefit was calculated as the difference between the gross field benefit in Ethiopian Birr per hectare (ETBha^{-1}) and the total variable costs.

Marginal rate of return (MRR %), was estimated by ratio of change in net benefit or gross benefit to change in cost, multiplied by 100%, which was the measure of increase in returns to increase in inputs.

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

Results and Discussion

Physical and chemical properties of soil

The result of the 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) described by Jones (2003). The pH is in the range of 6.5 to 7.5, favorable for garlic production (Bachmann, 2001).

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

Soil property	Value	Rating	References
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)
Exchangeable K(Cmolc kg^{-1})	0.32	Medium	Hazelton and Murphy (2007)
CEC (cmol (+) kg^{-1})	18.61	Medium	Landon (1991)

Where: OC=organic carbon; OM=organic matter; EC=electric conductivity

The organic matter (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 soil 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. The cation exchange capacity (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 indicates 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/or organic fertilizers containing potassium as important for enhancing the fertility and yield of the crop.

Chemical properties of vermicompost

It is important to analyse nutrient contents of VC because it is a soil activator, conditioner, and fertility booster, with all required plant nutrients, Vitamins, enzymes, growth hormones and beneficial micro organisms. Chemical analysis of VC indicates it increases soil fertility (Table 2) without polluting the soil, and 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 to 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, increase in microbial diversity and populations, improving the moisture-holding capacity of soils, increase in the soil cation exchange capacity and increase in 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 destruction of malodorous compounds (Hargreaves *et al*., 2008).

Table 2: Chemical properties of vermicompost

VC	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

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

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 4). Increasing the rates of both VC and mineral N fertilizer application, the number of days required for garlic maturity 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 7.5tha^{-1} matured in 135.53 days which was significantly longest duration with no application, 2.5 and 5t 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, Alemu *et al*., (2016), reported that prolonged maturity days of garlic at 5t VC ha^{-1} application which was maximum level in their study. Agarwal (1999) noted that VC contains significant amounts of micro-nutrients elements such as copper, zinc, iron and manganese. This content helps plant to complete their life cycle without nutrient stress that hastens senescence.

Increasing mineral N fertilizer level significantly increased days to maturity. Average days to maturity were delayed by 4.66days when 130kgNha^{-1} was applied compared with the control, but statistically at par with the application of 105kgNha^{-1} (Table 3). Delay in days to maturity with high levels of N could be because of delayed senescence of the canopy of the crop, extended physiological activity and continued photosynthesis. Nitrogen, being 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 increase in synthesis of photosynthesis, which was further utilized in building up of new cells, and prolonged maturity of garlic. Significant early matured bulb was obtained from from non application. 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 13days when 150 kgNha^{-1} was applied, compared with the control, but significantly at par with the application from 100kgNha^{-1}. Shawol (2010) and Tesfaye *et al*., (2007), also reported that 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 longest period to complete the vegetative growth.

Growth parameters

a. Number of Leaves

According to the analysis of variance for leaf number, revealed that the main factor of N and VC, and its interaction showed significant effect ($P < 0.05$) on the leaf number. The highest number of leaves per plant was recorded at combined application of maximum rate of VC and mineral N rates (Table 4). Application of 7.5t VC ha^{-1} in combination with $130kgNha^{-1}$ 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 and promotes microbial population, which ultimately promotes the plant growth and production at sustainable basis. 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 fertilizer combination.

Table 3: Interaction effect of vermicompost and nitrogen fertlizer on leaf number of garlic

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

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

Yield and yield components

a. Clove weight

The main effects of both VC and N application rates showed significant ($P < 0.05$) affect on the mean clove weight (Table 4). The highest clove weights were recorded with the application rate of $7.5tha^{-1}$ which was increased by 22.62% over the control treatment (Table 4). The increased mean clove weight due to increase in VC rate could be due to the role of VC, 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. This advances increment of clove weight due to uptake of enough nutrients. Verma *et al*., (2013) also reported that clove weight was increased significantly up to the highest dose at 5t of VC per ha. Compared to the control treatments, clove weight was significantly increased by 18.47% in response to increased rate of N from 0 to $130kgha^{-1}$. Increased mean clove weight in response to increased rate of N may be ascribed to the availability of optimum N 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 result is in conformity with the findings of Wolde (2014), who reported that the highest mean clove weight (4.42g) was with $138kgNha^{-1}$ application rate. Bichi (1997) also reported that garlic clove weights obtained from plots fertilized with 69kg and $92kgNha^{-1}$ were1.82 and 1.62g respectively, and the lowest mean clove weight was obtained from the unfertilized plots. Meseret and Mashilla (2018) reported the highest mean clove weight (2.83g) at the rate of $46kgNha^{-1}$ application.

Table 4: Main effects of application of vermicompost and nitrogen on days to maturity, clove weight and marketable bulb yield of garlic

Factor	Treatment	Days to maturity (days)	clove weight (g/clove)	Marketable bulb yield (t ha^{-1})
VC (t ha^{-1})	0	130.48c	2.21d	8.6d
	2.5	132.66b	2.34c	10.1c
	5	133.46b	2.56b	11.32b
	7.5	135.53a	2.71a	12.32a
LSD (0.05)			0.12	0.60
	0	130.50d	2.22d	9.36d
N (Kg ha^{-1})	52.5	131.83c	2.36dc	9.92cd
	80	133.66b	2.42bc	10.38c
	105	134.41ab	2.51ab	11.17b
	130	135.16a	2.63a	12.09a
LSD	(0.05)	1.19	0.15	0.71
CV %		0.77	5.36	5.69

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

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 effect (Table 4). Maximum level of VC (7.5t VC ha^{-1}) gave 43.26% over the control. These observations could be that garlic treated with VC application tend to establish better compared with those untreated, because of provision of enough nutrients, hence produce 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), noted 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 increased marketable bulb yield due to adequate nutrient that makes for good shape, appearance and free from diseases. Similarly, Alemu *et al.* (2016), indicated that increased application of VC from 0 to 5tha^{-1} increased garlic bulb yield by 10%.

As observed from this result, application of maximum level of N fertilizer (130 kgNha^{-1}) showed increased marketable bulb yield of garlic by 29.17% over the control (Table 8). This is due to N attributes, as it is so vital; being an essential constituent of metabolically active compounds (such as proteins, enzymes, and vitamins) in plants, and central part of the essential photosynthetic molecule and chlorophyll (Biswas and Mukherjee, 1993). In line with this, Kilgori *et al*., (2007), reported a significantly increased cured bulb yield of garlic with increased N from 0 to 120 kgha^{-1}. Maksoud *et al*., (1984), also reported significant increase in yield of cured marketable bulbs of garlic from 12.4 to 20.5tha^{-1} in with the addition of N at 360kgha^{-1}. Arboleya and Garcia (1993), also observed an increased marketable bulb yield from 4.66tha^{-1} at 0 kgNha^{-1} to 8.04tha^{-1} at 225kgNha^{-1}.

Unmarketable bulb yield

Unmarketable bulb yield was significantly ($P < 0.05$) influenced by main effect of VC and N fertilizer rates and interaction effects. Combination of VC and N at the rate of 7.5tha^{-1} and 130kgNha^{-1} gave significant lowest proportion of unmarketable bulb yield (0.46 tha^{-1}), over the other combinations rates (Table 5). Highest proportion of unmarketable bulb yield (0.78tha^{-1}) was recorded at a combination rate of no VC and no mineral nitrogen application. This result indicates that VC and N fertilizer combination at different rates reduced unmarketable yield than when 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). Decrease in soil fertility affects the quality and quantity of plant production. This implies that nutrient combination is more effective than single application to reduce unmarketable bulb yield of garlic. This result is in line with the findings of Gezachew and Yenegete (2006) that the interaction effect of compost and NP fertilizers significantly reduced unmarketable tuber number of potato. Currently, complementary use of chemical fertilizers and organic fertilizers has assumed great importance to maintain and sustain higher level of soil fertility and crop productivity (Shalini *et al.,* 2002).

Table 5: Interaction effect of nitrogen and vermicompost on unmarketable bulb yield of garlic

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

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

Economic analysis

Partial economic analysis was estimated for economic performance of garlic with VC and mineral N fertilizer application (Table 6). The variable cost considered was VC and N fertilizer cost, with application cost and extended days for gardener [60 ETB per (day + night)] for each treatment and control.

The highest net benefit 454238ETBha^{-1} was estimated with combined application of 7.5tha^{-1} and 130kgN$ha^{-1}$and highest total variable cost of 83362 ETB ha^{-1} incurred. This was followed by 401728 ETBha^{-1} net benefit with combined application of 5tVCha^{-1} and 130kgNha^{-1}. Although, there was no variable cost (the cost of fertilizer requirement and application were not included) in absolute control or no application of VC and mineral N fertilizer, gave the lowest net benefit cost (276840 ETBha^{-1}). Percent of marginal rate of return estimated with combined application of 7.5tha^{-1} and 130 kgNha^{-1}followed the recommendation by CIMMYT (1988).

Table 6: Partial budget analysis of the economic performance of garlic with vermicompost and mineral N fertilizer

Factors	Treatments	Average yield	Adjusted yield	Gross benefit	Total variable cost ($ETBha^{-1}$)	Net benefit	%MRR
VC ($t\ ha^{-1}$)	N ($kg\ ha^{-1}$)	(tha^{-1})	($t\ ha^{-1}$)	($ETBha^{-1}$)		($ETB\ ha^{-1}$)	
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

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)

Conclusion

Results show that with combined application of VC at 7.5tha^{-1} and mineral N fertilizer at 130kgha^{-1}, unmarketable bulb yield was reduced by 41.03%.The economic analysis showed the highest net benefit of 454238 ETBha^{-1} with combined application of 7.5tVC ha^{-1} and 130kgNha^{-1}. The percent of marginal rate of return obtained with combined application of 7.5tVCha^{-1}and 130kgha^{-1} was 312.80%, categorized as economically viable fertilizer application. VC also had positive impact on soil biological, aggregation, and chemical condition. Combined application of high amounts of VC and mineral N fertilizers increased higher marketable bulb yield, compared to low amounts of either VC and mineral N fertilizer or their combination at Haramaya, Eastern Ethiopia. However, the results of the experiment revealed that growth, yield components and yield of garlic did not express its optimum potential, because all significantly increased in response to the application of each of the fertilizers or the combined highest rates of the fertilizers. Therefore, there is a possibility that significantly more growth characters, yield components and yield of the garlic could have been obtained if the rates of the fertilizers had been increased.

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