Effects of Organic and Inorganic NP Fertilizers on the Performance of Garlic (Allium Sativum L.) Varieties at Koga, Northwestern Ethiopia

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Abstract
Garlic (Allium sativum L.) is an important cash and spice crop produced for home consumption and as a source of income to many smallholder farmers in many parts of the Ethiopia. However, the yield of the crop is often constrained by low and imbalanced nutrient supply in the soil. Therefore, a field experiment was conducted at Adet Agricultural Research Center, Koga irrigation trial site in 2015/2016 cropping season with the objectives of assessing the effects of combined application of vermicompost and NP fertilizers on the performance of garlic varieties and determining the economically profitable fertilizer rates for higher yield of garlic under irrigation. Three garlic varieties (Bishoftu Netch, Tsedey and a local cultivar) and six forms of fertilizer [no fertilizer;128/92 kg ha^{-1} N and P_2O_5 (recommended nitrogen and phosphorus, RNP); 5 ton ha^{-1} vermicompost (VC); 50% RNP + 5 ton ha^{-1} VC; 50% RNP + 2.5 ton ha^{-1} VC and 100% RNP + 2.5 ton VC ha^{-1}) were tested in 3 x 6 factorial arrangement in Randomized Complete Block Design with three replications. The results showed that both varieties and forms of fertilizer had significant interaction effect on all characters except the non-significant interaction effect on days to emergence, number of leaves per plant, mean clove number, unmarketable bulb yield and bulb dry matter percent. Bishoftu Netch variety gave significantly the highest total and marketable bulb yield 8.65 and 8.50 ton ha^{-1}, respectively, that exhibited 24 and 57% advantages over Tseday and the local cultivar, respectively. The highest values of mean bulb weight (34.90 g), mean clove number (10.89), mean clove weight (5.31 g), total fresh biomass yield (44.82 g/plant) and bulb dry matter (20.64%) was obtained from treatments that received 50% RNP + 5 ton ha^{-1} VC. Bishoftu variety gave the highest benefit of Birr 296053.35 and 285566.67 per ha at 100% RNP alone and 50% RNP + 5 ton ha^{-1} VC, respectively that was 31% and 58% higher than Tseday and local cultivar at 100% RNP only and 27% and 63% higher than Tsedey and the local cultivar at application of 50% RNP + 5 ton ha^{-1} VC, respectively. According to the partial budget analysis, the highest economic benefit was recorded from Bishoftu variety at the application of RNP only. Therefore, it can be concluded that producers in the study area could use Bishoftu Netch variety using the recommended inorganic NP fertilizer alone for optimum garlic production and maximum economic benefit. However, for sustainable soil health conditions on successive crops, combinations of 50% RNP and 5 ton ha^{-1} vermicompost for all varieties could be used.
Keywords: Variety, Marketable bulb yield, Total bulb yield, soil health and Economic benefit

1. Introduction

Garlic (*Allium sativum* L.) is one of the main *Allium* vegetable crops known worldwide with respect to its production and economic value. It is native to southern Europe and western Asia (Etoh and Simon, 2002). It is used for seasoning in many foods worldwide; without garlic many of our popular dishes would lack the flavor and character that make them favourites. In Ethiopia, the total area under garlic production in 2013/2014 reached 16,412 ha and the production is about 15,909 ton of bulbs respectively (CSA, 2014).

Looking at the high nutrient requirement of different varieties of garlic, farmers often use inorganic fertilizers as they provide quick supply of nutrients to the plants. As a result of this, only urea and DAP as fertilizer sources of N and P, respectively, are applied to crops by smallholder farmers. Because of an increasing cost of inorganic fertilizers and shifts in policies with respect to subsidize fertilizer costs, the use of inorganic fertilizers by small scale producers is becoming unaffordable (Tadila, 2011). However, continuous use of chemical fertilizers is creating huge problems like diminishing of soil health through nitrate poisoning and exterminating soil microflora and microfauna by adversely altering the chemical and physical properties of soil. Besides, crop yield cannot be maintained through the use of inorganic fertilizers alone under continuous cultivation.

Currently, remarkable work is done in creating awareness in order to minimize side effects of using inorganic fertilizer for extended period of time. Integration of organic and inorganic fertilizers is being advocated as one of the strategic solutions to maintain soil fertility and to increase production in Ethiopia and has been highly emphasized for the Growth and Transformation Plan, in which the Agricultural Growth Programme is an essential component (Gezahegn *et al*., 2014). Integrated nutrient application not only ensures the supply of essential nutrients to plants but also has some positive interactions to increase nutrient use efficiency and thereby reduce environmental hazards (Ahmad *et al.*, 1996; Khaliq *et al*., 2004).

Among the many organic fertilizers, vermicompost is a potential organic nutrient source which provides additional plant nutrients that are not found in inorganic fertilizers (Kale *et al.,* 1992). Vermicomposts are finely divided peat like materials with high porosity, aeration, drainage and water-holding capacity and usually contain most nutrients in available forms such as nitrates, phosphates, exchangeable calcium and soluble potassium (Atiyeh *et al.,* 2002; Arancon *et al.,* 2004).They also enhance uptake of nutrients by plants (Nagavallemma *et al.,* 2004). Palm *et al.* (1997) reported that the uptake of nitrogen, phosphorus, potassium, zinc, manganese, copper and iron were increased significantly by crops when 50% of organic fertilizers in combination with 50% inorganic fertilizers were applied.

In Ethiopia, information on the integrated effect of organic vermicompost and inorganic NP fertilizers on garlic growth, yield and yield components is limited. Evidence is also lacking on the effect of integrated application of vermicompost and inorganic NP fertilizers on soil fertility improvement. Thus, keeping in view of creating sustainable soil health condition for sustainable agriculture in one side and considering garlic as one of the potential vegetable crop for consumption as well as for market in the other side, it is imperative to increase its productivity along with desirable attributes through production management practices and application of other sources of nutrients beyond urea (46%N) and DAP (18% N and 46% P_2O_5). Therefore, the present study was designed to assess the effects of combined application of vermicompost and NP fertilizers on the performance of garlic varieties and to determine the economically profitable fertilizer rates for higher yield of garlic under irrigation.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Adet Agriculture Research Center, Koga Irrigation Trial Site which is found in West Gojjam Administration Zone of Amhara National Regional State. The site is situated at 10°30'0" N latitude and 37°30'02.4" E longitude at an altitude of 1960 masl. It is about 42 km southwest of Bahir Dar and 535 km northwest of Addis Ababa. The mean annual rainfall for the area is 1500 mm and the average temperature is 16-20 ^{O}C. The soil texture of the experimental site was clay (clay 53%, silt 12% and sand 35%) and pH was 5.0.

2.2. Description of the Experimental Materials

2.2.1. Plant Materials

Two garlic varieties named Tseday and Bishoftu Netch which were released by one of the pioneer agricultural research centers in Ethiopia called DebreZeit Agricultural Research Center; and one local cultivar were used. The two garlic varieties are among the most and common commercial garlic varieties

2.2.2. Fertilizer Material

Urea (46% N) and DAP (18% N and 46% P_2O_5) were used as sources of inorganic NP fertilizer. Likewise, vermicompost was used as source of organic fertilizer.

2.3. Treatments and Experimental Design

The treatments consisted of three garlic varieties (Tsedey, Bishoftu and local cultivar) and six forms of fertilizers [no fertilizer, 128/92 kg ha^{-1} N and P_2O_5 (recommended nitrogen and phosphorus, RNP); 5 ton ha^{-1} vermicompost (VC); 50% RNP + 5 ton ha^{-1} VC; 50% RNP + 2.5 ton ha^{-1} VC; 100% RNP + 2.5 ton ha^{-1} VC]. The experiment was laid out in 3 x 6 factorial arrangements in a randomized complete block design and replicated three times.

2.4. Experimental Procedures

2.4.1. Cultural Practices

The experimental field was ploughed three times and well harrowed. Soil clods were broken by human labor and experimental plots were laid out on fine seedbed. Medium-sized cloves from bulbs stored for about 5 months with dry tops attached were prepared for planting. At planting time, cloves were separated from the bulbs, sorted and graded according to size category. Large to medium size (2.5 to 1.5 g) cloves (Fikreyohannes, 2005) were used for planting. Garlic varieties were planted during 2015/2016 cropping season at Adet Agricultural Research Center; Koga Irrigation Trial Site which is found in West Gojam Zone of the Amhara Region. Weed control was done by hoeing and shallow earthing up. The fungicide Teel (tilt) was applied two times to prevent garlic rust at a rate of 400 ml ha^{-1}. Other crop management practices were done as required after plant emergence. Harvesting was done when 70% of the leaves senesced. The harvested bulbs were windrowed in the field and sun-dried for ten days, folding the leaves over the bulbs to protect them from sunburn. After a week of curing, tops and roots were trimmed.

2.4.2. Time and Rate of Fertilizer Application

Vermicompost was applied using the specified rates by mixing it with the soil at the time of planting. As per the recommendation for garlic production, 128 kg N ha^{-1} and 92 kg P ha^{-1} was used for the experiment. Nitrogen was applied in three splits ¼ at planting, ½ six weeks after plant emergence (active stage of vegetative growth) and the other ¼ twelve weeks after plants had emerged (just at the start of bulbing). Phosphorus was applied as a basal application during planting in the form of DAP.

2.4.3. Soil Sampling and Analysis

Soil sampling was done before planting. Soil samples were taken randomly using an auger in a zigzag pattern from the entire experimental field. Fifteen soil samples were taken from the top soil layer to a depth of 20 cm and composited in a bucket. The soil was broken into small crumbs and thoroughly mixed. From this mixture, a composite sample weighing 1 kg was filled into a plastic bag. The sample was duplicated and prepared for determining physico-chemical properties.

2.5. Data Collection and Measurement

Data on phenological, growth and yield related agronomic parameters of garlic varieties were recorded starting from planting to harvesting. Phonological parameter: days to emergence, days to bulb maturity; growth parameters: plant height, number of leaves per plant, leaf area index; yield parameters: mean bulb weight, mean clove number per bulb, mean clove weight, total fresh biomass yield (g/plant), total number of bulbs, marketable bulb yield (t ha^{-1}), unmarketable bulb yield (ton ha^{-1}), total bulb yield (ton ha^{-1}), bulb dry matter percent, harvest Index was recorded.

2.6. Data Analysis

Data were subjected to analysis of variance (ANOVA) using GenStat 15thedition, version 15.1. Whenever treatment differences were found to be significant, means were separated using the Least Significant Difference (LSD) test at 5% level of significance. Correlation analysis was performed to detect the linear relationships among yield, and growth attributes. The economic analysis was also done according to CIMMYT (1988) using the concept of partial budget.

3. Results and Discussion

3.1. Soil and Vermicompost Analysis Results

Table 1. Physical and chemical properties of the experimental soil and the vermicompost

	Value	
Soil property	Soil	Vermicompost
Chemical Properties		
Total N (%)	0.19	1.89
Available P (*mg/kg*)	8.7	43.80
Available K (*Cmolkg^{-1}*)	0.768	1.77
Organic Carbon (%)	0.95	11.86
CEC (*cmol(+)/kg)*	26.00	48.91
Organic Matter (%)	2.75	34.35
pH	5.0	7.21
Physical properties		
Clay (%)	53	
Silt (%)	12	
Sand (%)	35	
Soil texture	Clay	

CEC = Cation Exchange Capacity

3.2. Phonological Parameters

3.2.1. Days to Emergence

The main effect of variety and different forms of fertilizer significantly (P<0.001) influenced days to emergence. However, the interaction effect of variety and different forms of fertilizer application did not significantly affected days to emergence. Bishoftu Netch emerged 2 days earlier than the local cultivar and 3 days earlier than Tsedey, whereas, Tsedey emerged 1 day later than the local cultivar.

Combined application of inorganic NP fertilizers with organic vermicompost decreased number of days required to emerge above the soil by 5-9 days. Combined application of 50% RNP fertilizer and 5 ton ha^{-1} vermicompost hastened the emergence of garlic sprouts from the soil by about 9 days as compared to the control. Similarly, application of RNP + 2.5 ton ha^{-1} vermicompost and 50% RNP + 2.5 ton ha^{-1} vermicompost accelerated sprouting of garlic cloves by about 9 and 5 days as compared to the control, respectively. In addition, sole application of 5 ton ha^{-1} vermicompost and RNP hastened emergence by about 9 and 5 as compared to the control. This result is in agreement with findings of that of Alemu (2014) who reported that with increase in the rates of both NP and vermicompost application, the number of days required to emerge above the soil surface was decreased.

The hastened duration of emergence due to the different combination of fertilizer application might attributed to the influence of available N, P and other nutrients of vermicompost on root initiation and development which might have led to early shoot emergence. Using vermicompost as a substrate produced an earlier shoot emergence and earlier start of bulbification which corresponds to increase in the total soluble carbohydrates and a subsequent modification in the non-structural carbohydrate distribution patterns, and hence a modification in the pattern of fructan (scorodose) metabolism (Argüello et al.,2006).

3.2.2. Days to Maturity

The analysis of variance showed that days to maturity was significantly influenced by the main effects of varieties and forms of fertilizers as well as by their interaction effect at P<0.001 level of significance.

The interaction effect of variety by forms of fertilizer indicated that all varieties with the application of 50% RNP +5 ton ha^{-1} vermicompost showed the longest maturity days than the other treatments. The longest maturity days (144) was recorded on Tsedey by application of 50% RNP +5 ton ha^{-1} vermicompost whereas the shortest day (121) was also observed on the same variety with application of no fertilizer). All garlic cultivars matured earlier in the unfertilized plots, whereas the combination of 50% RNP +5 ton ha^{-1} vermicompost delayed. Tseday with combined application of 50% RNP +5 ton ha^{-1} vermicompost, matured about 9 days later than Bishoftu Netch and about 11 days later than the local cultivar. This result is in line with Yesigat (2008) who reported that Tseday matured 6 days later than Bishoftu Netch. Maturity day of Tseday decreased by about 10 when it was supplied with 50% RNP + 2.5 ton ha^{-1} vermicompost than in the application of 50% RNP + 5 ton ha^{-1} vermicompost. Alemu (2014) reported increasing the rates of N, P and vermicompost fertilizers prolonged maturity of garlic plants. Zerihun (2011) also showed that days to maturity were prolonged in response to increased level of Farm Yard Manure. This result is in agreement with that of the findings of Tadila (2011) who reported prolonged maturity on garlic in response to combined application of N and manure.

Table 2. Interaction effects of garlic varieties and different forms of fertilizer on days to bulb maturity

	Varieties		
Forms of Fertilizer	Bishoftu Netch	Local	Tsedey
No fertilizer (control)	125.67^{h}	121.33^{i}	120.67^{i}
128/92 kg ha^{-1} N and P_2O_5 (RNP)	131.33^{fg}	125.00^{h}	136.00^{c}
5 ton ha^{-1} VC	132.33^{ef}	133.33^{de}	133.00^{def}
RNP + 2.5 ton ha^{-1}VC	136.67^{c}	130.00^{g}	140.67^{b}
50% RNP + 2.5 ton ha^{-1} VC	130.33^{g}	130.00^{g}	134.67^{cd}
50% RNP + 5.0 ton ha^{-1}VC	135.67^{c}	133.67^{de}	144.33^{a}
LSD (5%)	1.746		
CV (%)	2.8		

*Means followed by the same letter within a column are not significantly different at 5% level of significance
RNP = Recommended rates of nitrogen and phosphorus, VC = vermicompost

3.3. Growth Parameters

3.3.1. Plant Height

Plant height was significantly (P < 0.001) affected by the main effect of variety, forms of fertilizer as well as by their interaction.All varieties showed taller heights with application of 50% RNP + 5 ton ha^{-1} vermicompost than other treatments. Similarly, they showed shorter heights with no application of fertilizers. Maximum height (27.97 cm) was attained by the local cultivar with application of 50% RNP + 5 ton ha^{-1} vermicompost.

Plants that received 50% RNP + 5 ton ha^{-1} vermicompost were significantly taller than those which received other rates. The application of 50% NP +5 ton ha^{-1} vermicompost, increased plant height by about 18, 16, 16% in cultivars Bishoftu Netch, local and Tseday, respectively, as compared to application of 50% RNP + 2.5 ton ha^{-1} vermicompost. The increase in plant height due to increased rate of vermicompost could be attributed to the fact that vermicompost contains a good range of some very essential macro and micronutrients other than N and P which are required for healthy plant growth (Surindra, 2009). Similarly, application of RNP + 2.5 ton ha^{-1} vermicompost increased plant height by about 5.3, 6.1 and 5.2% in cultivars Bishoftu Netch, local and Tseday, respectively as compared to application of 50 % RNP + 2.5 ton ha^{-1} vermicompost. The effect of NP on cell division and elongation lead to growth of plants which increased their height. The difference in plant height between the varieties could be ascribed to the genotypic variability. The result is in agreement with findings of Kassahun (2006) who observed a wide range of variation in plant height among different garlic varieties. Etoh and Simon (2002) also reported wide variation among garlic varieties in plant height.

Table 3. Interaction effects of garlic varieties and forms of fertilizer on plant height (cm)

Forms of Fertilizer	Varieties		
	Bishoftu Netch	Local	Tsedey
No fertilizer (control)	19.85^{hi}	20.25^{h}	19.38^{i}
128/92 kg ha^{-1} N and P_2O_5 (RNP)	23.45^{ef}	24.13^{e}	22.97^{fg}
5 ton ha^{-1} VC	23.02^{fg}	26.17^{cd}	22.85^{fg}
RNP + 2.5 ton ha^{-1} VC	24.07^{e}	25.52^{d}	23.87^{e}
50% RNP + 2.5 ton ha^{-1} VC	22.85^{fg}	24.05^{e}	22.68^{g}
50% RNP + 5.0 ton ha^{-1} VC	27.05^{b}	27.97^{a}	26.33^{c}
LSD (5%)	0.701		
CV (%)	1.8		

*Means followed by the same letter within a column are not significantly different at 5% level of significance
RNP = Recommended rates of nitrogen and phosphorus, VC = vermicompost

3.3.2. Number of Leaves per Plant

The analysis of variance revealed that the main effect of varieties and forms of fertilizer significantly ($P < 0.001$) influenced leaf number per plant. However, there was no interaction between the two factors.

The local cultivar and Tsedey did not significantly differ in leaf number. However, Bishoftu Netch produced significantly more number of leaves per plant than the other cultivars. Higher number of leaves (13) were recorded from plants supplied with fertilizer rate of 50% RNP + 5 ton ha^{-1} vermicompost while the number of leaves was reduced by 9-31% in other fertilizer rates. The lowest number of leaves (9) was recorded at the control treatment. Treatments that received 50% RNP + 5 ton ha^{-1} vermicompost fertilizer produced about 17% more number leaves as compared to treatments that received 50% RNP + 2.5 ton ha^{-1} vermicompost. This result is in line with Bagali *et al* (2012) who reported significantly higher plant height, number of leaves per plant, leaf area per plant and leaf area index over lower levels of vermicompost was recorded in response to application of vermicompost at the rate of 6 ton ha^{-1}. Vermicompost is known to contain micronutrients apart from major nutrients. Moreover, vermicompost is reported to contain several plant growth promoters, enzymes, beneficial bacteria and mycorrhizae (Gupta, 2005). Therefore, the availability of higher quantity of nutrients, improvement in the physical properties of soil and increased activity of microbes with higher levels of organics might have helped in increasing number of leaves. Reddy and Reddy (2005) observed higher levels of farm yard manure significantly increased the plant height and number of leaves per plant. Similar results were also obtained by Sampathkumar (1988) and Thimmiah (1989) where higher levels of organics recorded significantly higher number of garlic leaves. This might be due to better photosynthesis and accumulation of photosynthates leading to increased number of leaves.

The main effect of forms of fertilizer also revealed that application of RNP + 2.5 ton ha^{-1} vermicompost increased production of leaves by about 6% as compared to treatments that received 50% RNP + 2.5 ton ha^{-1} vermicompost. This result is in agreement with the findings of Melaku (2010) who reported significantly increased number of leaves per plant in onion in response to application of 120 kg N ha^{-1}. Alemu (2014) also reported that maximum significant number of leaves was recorded by application of 46/92 kg ha^{-1} N and P_2O_5 respectively. The result was attributed to nitrogen which is a constituent of chlorophyll, the increase of which might have increased photosynthates, leading to better vigour (Gupta, 2005). Similarly, phosphorus the second major nutrient being essential constituent of cellular protein and nucleic acid, might have encouraged meristematic activity of plants resulting in increased plant height, number of leaves per plant and leaf area.

3.3.3. Leaf Area Index

The main effects of varieties, forms of fertilizer and their interaction significantly influenced leaf area index. The highest leaf area index (0.50) was recorded in local garlic cultivar fertilized with RNP + 2.5 ton ha-1 vermicompost. This fertilizer combination also produced the maximum (0.48) leaf area index in Bishoftu Netch while in Tseday 50% RNP combined with 2.5 ton ha-1 vermicompost gave the highest leaf area index. Tsedey and the local cultivar that received no fertilizer and Bishoftu Netch fertilized with vermicompost alone recorded the least leaf area index (0.11, 0.21 and 0.16, respectively). Although, leaf area index of Bishoftu Netch and the local cultivar were at par with each other at treatment application of 50% RNP + 5 ton ha^{-1} vermicompost, unlike the local cultivar, Bishoftu Netch showed increment in leaf area index when supplied with RNP + 2.5 ton ha^{-1} vermicompost. This increment in leaf area index may be attributed to enhanced vegetative growth and bulb filling by nitrogen (Tadila, 2011) and influence on photosynthetic productivity by phosphorus. Alemu (2014) also reported that application of vermicompost supplement at a rate of 5 ton ha^{-1} increased leaf area index of garlic by 15.15% over the control. The increase in leaf area index in response to increased rate of vermicompost might be ascribed to the availability of optimum nutrients contained in manure that led to high leaf area index through facilitated vegetative growth. Similarly, Mehdi et al., (2012) reported that the application of municipal solid waste and vermicompost significantly increased all the growth attributes such as plant height, stem diameter, number of leaves, and leaf area index under well-watered, moderate and severe stress conditions.

Table 4. Interaction effects of garlic varieties and different forms of fertilizer on leaf area index

Forms of Fertilizer	Varieties		
	Bishoftu Netch	Local	Tsedey
No fertilizer (control)	0.21gh	0.21gh	0.11j
128/92 kg ha-1 N and P2O5 (RNP)	0.34e	0.29f	0.36e
5 ton ha-1 VC	0.16i	0.20h	0.16i
RNP + 2.5 ton ha-1 VC	0.48a	0.50a	0.44bc
50% RNP + 2.5 ton ha-1 VC	0.41cd	0.24g	0.34e
50% RNP + 5.0 ton ha-1 VC	0.39d	0.40d	0.45b
LSD (5%)	0.029		
CV (%)	5.6		

*Means followed by the same letter within a column are not significantly different at 5% level of significance
RNP = recommended rates nitrogen and phosphorus, VC = vermicompost

3.4. Yield and Yield Components

3.4.1. Mean Bulb Weight

The main effects of varieties, forms of fertilizer and interaction of the two factors were highly significant (P<0.001). The interaction effect revealed that maximum mean bulb weight (34.90 g) was recorded for the local cultivar at the combined application of 50% RNP and 5 ton ha^{-1} vermicompost which was statistically at par with Bishoftu Netch and Tsedey at the same rate of application. The minimum mean bulb weight (25.14 g) was recorded in Tsedey at the control treatment. Irrespective cultivars of the unfertilized plots produced lower mean bulb weight (18-25%) compared to those supplied with 50% RNP and 5 ton ha^{-1} vermicompost. Application of 50% RNP and 5 ton ha^{-1} vermicompost, mean bulb weight of Bishoftu Netch, local and Tsedey increased by about 10, 9.8 and 7.3% respectively than in application of 50% RNP and 2.5 ton ha^{-1} vermicompost.

The current study is in agreement with findings of Tadila (2011) who reported increased mean fresh bulb weight of garlic with increasing rate of N up to 100 kg ha^{-1}. Melaku (2010) also indicated increasing the rates of nitrogen fertilizer significantly increased mean bulb weight of onion with the highest value at 80 kg ha^{-1}. Tibebu *et al.* (2014) showed the highest dry bulb yield of 17 ton ha^{-1} from 69 kg N ha^{-1} while the lowest 13.9 ton ha^{-1} was from the control. Likewise, Alemu (2014) reported that P supply at the rate of 92 kg P_2O_5 ha^{-1} increased mean bulb weight by 20.72% over the control. The author also indicated application of organic vermicompost at the rate of 5 ton ha^{-1} increased mean bulb weight by 8% as compared to the untreated control. The increased mean bulb weight as a result of using vermicompost could be due to the availability of major macro and micro nutrients in the vermicompost. Besides this, vermicompost has been reported to contain several plant growth promoters, enzymes, beneficial bacteria and mycorrhyzae which increase plant growth (Gupta, 2005).

Table 5. Interaction effects of garlic varieties and forms of fertilizer on mean bulb weight (g)

Forms of Fertilizer	Varieties		
	Bishoftu Netch	Local	Tsedey
No fertilizer (control)	28.50^{g}	26.52^{h}	25.14^{i}
128/92 kg ha^{-1} N and P_2O_5 (RNP)	33.31^{bc}	33.90^{abc}	31.95^{def}
5 ton ha^{-1} VC	34.20^{ab}	30.83^{f}	31.95^{def}
RNP + 2.5 ton ha^{-1} VC	33.87^{abc}	33.14^{bcd}	32.82^{cde}
50% RNP + 2.5 ton ha^{-1} VC	31.58^{ef}	31.77^{ef}	31.37^{f}
50% RNP + 5.0 ton ha^{-1} VC	34.78^{a}	34.90^{a}	33.68^{abc}
LSD (5%)	1.267		
CV (%)	2.4		

*Means followed by the same letter within a column are not significantly different at 5% level of significance
RNP = recommended rates of nitrogen and phosphorus, VC = vermicompost

3.4.2. Mean Clove Number

The main effects of variety and forms of fertilizer showed significant difference (P<0.001) on mean clove number. However, variety and forms of fertilizer did not interact significantly to influence mean clove number per bulb.

The highest mean clove number (9.78) was recorded in Bishoftu Netch while the local cultivar and Tsedey had statistically equal clove number. Combined application of 50% RNP and 5 ton ha^{-1} vermicompost gave the highest mean clove number (10.89) which was 55.57% higher than the control treatment. Likewise, 50% RNP + 2.5 ton ha^{-1} vermicompost and RNP + 2.5 ton ha^{-1} vermicompost increased mean clove number by 38.9 and 42.8%, respectively as compared to the control treatment. The increase in mean clove number could be due to the increase in budget of essential soil micronutrients and microbial population, which ultimately promotes plant growth and production of more cloves (Mugwira and Murwira, 1998). The authors also reported that the use of organic manure is more beneficial when combined with inorganic fertilizers. Results of the present study is also in line with the findings of Gezachew (2006) which showed that the interaction effect of compost and NP fertilizers significantly increased total and marketable tuber number of potato. Similarly, Baghour *et al*. (2001) reported that vegetative growth, yield and quality of onion were significantly improved due to nitrogen and phosphorus fertilization.

3.4.3. Mean Clove Weight

The main effects of variety, forms of fertilizer as well as their interaction showed significance ($P<0.001$) difference on mean clove weight. Bishoftu Netch fertilized with 50% RNP and 5 ton ha^{-1} vermicompost produced the highest mean clove weight (5.31 g) which was 155% more than the least mean clove weight recorded in the local cultivar from non-fertilized plot. Application of RNP only and RNP +2.5 ton ha^{-1} vermicompost in Bishoftu Netch also increased mean clove weight by 95.9% and 94%, respectively; compared to non-fertilized (control) Bishoftu Netch plants. Application of 50% RNP + 5 ton ha^{-1}vermicompost produced 104% and 31% more mean clove weight as compared to unfertilized plots in the local cultivar and Tsedey, respectively.

Application of 50% RNP and 5 ton ha^{-1} vermicompost increased the mean clove weight of Bishoftu Netch, local and Tseday by about 21%, 38% and 25%, respectively as compared to those which received 50% RNP and 2.5 ton ha^{-1} vermicompost. The increment in clove weight due to increased vermicompost might be ascribed to several growth promoters, enzymes, beneficial bacteria and mycorrhyzae contained in vermicompost that led to high mean clove weight through facilitating improved leaf growth and photosynthetic activities thereby increasing portioning of assimilate to the bulb.

Moreover, in a treatment that received RNP and 2.5 ton ha^{-1} vermicompost, mean clove weight of Bishoftu Netch, local cultivar and Tsedey were increased by 9%, 11% and 17% over treatments that received 50% RNP and 2.5 ton ha^{-1} vermicompost. This result is in agreement with the findings of Alemu (2014) who reported that supply of 46 kg N ha^{-1}, 46 kg P_2O_5 ha^{-1} and 5 ton vermicompost ha^{-1} increased mean clove weight by 13.33%, 20.49% and 7.99% respectively as compared to the control. Similarly, Gebrehaweria (2007) indicated that the highest mean clove weight (2.83 g) was attained at the rate of 120 kg N ha^{-1} as compared to unfertilized. The increment in mean clove weight due to increased NP might be due to the facts that nitrogen promotes rapid vegetative growth (leaf and stems), serves as a vital element in the formation and function of chlorophyll and has a role in synthesis of amino acids which in turn form protein. Moreover, phosphorus has an influence on assimilating leaf area, photosynthetic productivity and final bulb yield.

Table 6. Interaction effects of garlic varieties and forms of fertilizer on mean clove weight (g)

	Varieties		
Forms of Fertilizer	Bishoftu Netch	Local	Tsedey
No fertilizer (control)	2.46^{gh}	2.08^{h}	2.24^{h}
128/92 kg ha^{-1} N and P_2O_5 (RNP)	4.82^{b}	3.02^{def}	2.71^{fg}
5 ton ha^{-1} VC	4.02^{c}	3.29^{de}	2.43^{gh}
RNP + 2.5 ton ha^{-1} VC	4.78^{b}	3.41^{d}	2.73^{fg}
50% RNP + 2.5 ton ha^{-1} VC	4.40^{bc}	3.07^{def}	2.34^{gh}
50% RNP + 5.0 ton ha^{-1} VC	5.31^{a}	4.25^{c}	2.93^{ef}
LSD (5%)	0.446		
CV (%)	8.0		

*Means followed by the same letter within a column are not significantly different at 5% level of significance
RNP = recommended rates of nitrogen and phosphorus, VC = vermicompost

3.4.4. Total Fresh Biomass Yield

The main effect of varieties, forms of fertilizers and their interaction significantly ($P<0.001$) influenced fresh biomass yield.

The maximum fresh biomass yield (44.82 g) was recorded on Bishoftu Netch with application of 50% RNP + 5 ton ha^{-1} vermicompost which was statistically at par with the local cultivar that received the same treatment but was 16% higher than Tseday at the same rate of fertilizer. Tseday showed the lowest fresh biomass yield (26.55 g) than the other cultivars when unfertilized. Likewise, RNP + 2.5 ton ha^{-1} vermicompost and 50% RNP + 5 ton ha^{-1} vermicompost resulted in 61% and 45% more biomass yield in Tsedey; and 22% and 26% more biomass yield in local cultivar than in respective control treatment that did not receive any fertilizer.

Compared to the fresh biomass yield obtained at nil fertilizer application, the fresh biomass yield obtained by Bishoftu Netch and the local cultivar at the application of 50% RNP + 2.5 ton ha^{-1}vermicompost were significantly increased by 22% and 17%, respectively. Unlike, Bishoftu Netch and the local cultivar, Tseday attained highest fresh biomass yield (42.82 g) at the application of RNP + 2.5 ton ha^{-1} vermicompost which was about 62% higher than the unfertilized (control) treatment.Tseday and the local cultivar at the application of RNP + 2.5 ton ha^{-1} vermicompost produced about 11 and 5% higher fresh biomass yield respectively, than in 50% RNP + 2.5 ton ha^{-1} vermicompost application. However, Bishoftu Netch at application of RNP + 5 ton ha^{-1} vermicompost produced about 10% lower fresh biomass yield than in 50% RNP + 2.5 ton ha^{-1} vermicompost. In all cultivars, the unfertilized plots produced lower mean fresh bulb yield than fertilized plots. The current study is in agreement with that of Alemu (2014) who reported application of 46 kg N ha^{-1} increased fresh biomass yield by 14.67% as compared unfertilized. Kilgori *et al* (2007) also observed that increasing levels of N from 0 to 120 kg ha^{-1} resulted in a significant increase of fresh biomass yield of garlic. The author also reported that the highest fresh bulb yield of 8.4 ton ha^{-1} was recorded with 120 kg N ha^{-1}. The increase in fresh biomass yield due to NP fertilizer application might due to effect of these nutrients which are an integral component of many essential plant compounds like chlorophyll, proteins and amino acids. Plant compounds increase the vegetative growth and produces good quality foliage. These in turn promote carbohydrate synthesis through photosynthesis and ultimately increased yield of plants (Brady and Weil, 2002). Vermicompost has been reported to contain several plant growth promoters, enzymes, beneficial bacteria and mycorrhyzae (Gupta, 2005). Garg *et al*. (2006) indicated that besides containing essential plant nutrients; vermicompost has a role in making nutrients available in soil by amending the soil physical properties.

Table 7. Interaction effects of garlic varieties and forms of fertilizer on mean total fresh biomass yield (g/plant)

	Varieties		
Forms of Fertilizer	Bishoftu Netch	Local	Tsedey
No fertilizer (control)	36.23^{ef}	33.00^{f}	26.55^{g}
128/92 kg ha^{-1} N and P_2O_5 (RNP)	42.92^{abc}	36.17^{ef}	36.18^{ef}
5 ton ha^{-1} VC	43.94^{ab}	38.87^{def}	40.53^{bcd}
RNP + 2.5 ton ha^{-1} VC	40.41^{bcd}	40.27^{cd}	42.82^{abc}
50% RNP + 2.5 ton ha^{-1} VC	44.27^{a}	38.50^{de}	38.50^{de}
50% RNP + 5.0 ton ha^{-1} VC	44.82^{a}	41.73^{abcd}	38.52de
LSD (5%)	3.596		
CV (%)	5.5		

*Means followed by the same letter within a column are not significantly different at 5% level of significance
RNP = Recommended rates of nitrogen and phosphorus, VC = vermicompost

3.4.5. Marketable Number of Bulbs

The analysis of variance revealed that the main effects of cultivar, forms of fertilizer and their interaction significantly ($P < 0.001$) influenced marketable number of bulbs per hactare. The highest marketable number of bulbs per hactare (332426) was recorded on the local cultivar at the application of 50% RNP + 5 ton ha^{-1} vermicompost which was 0.2% and 0.3% greater than Bishoftu Netch and Tseday at the same rate of fertilizer application (Table 13). The lowest marketable number of bulbs observed in Tsedey in the unfertilized plots. Bishoftu Netch supplied with 50% RNP + 5 ton ha^{-1} vermicompost produced 7561 and 5997 more number of bulbs than those which received application of 50% RNP + 2.5 ton ha^{-1} vermicompost and RNP + 2.5 ton ha^{-1} vermicompost, respectively. Tsedey variety in application 50% RNP + 5 ton ha^{-1} vermicompost produced 5801 and 6129 more marketable number of bulbs than in 50% RNP + 2.5 ton ha^{-1} vermicompost and RNP + 2.5 ton ha^{-1} vermicompost, respectively. Application of 50% RNP + 5 ton ha^{-1} vermicompost produced 2307 and 945 more marketable number of bulbs in local cultivar than when 50% RNP + 2.5 ton ha^{-1} vermicompost and RNP + 2.5 ton ha^{-1} vermicompost application, respectively.

Table 8. Interaction effects of garlic varieties and different forms of fertilizer on marketable number of bulbs per hectare

	Varieties		
Forms of Fertilizer	Bishoftu Netch	Local	Tsedey
No fertilizer (control)	315090^{h}	314165^{i}	311687^{j}
128/92 kg ha^{-1} N and P_2O_5 (RNP)	325627^{e}	331383^{b}	325140^{f}
5 ton ha^{-1} VC	323690^{g}	325649^{e}	326312^{d}
RNP + 2.5 ton ha^{-1} VC	326222^{d}	331481^{b}	325371^{ef}
50% RNP + 2.5 ton ha^{-1} VC	324063^{g}	330119^{c}	325699^{e}
50% RNP + 5.0 ton ha^{-1} VC	331624^{b}	332426^{a}	331500^{b}
LSD (5%)	451.20		
CV (%)	4.1		

*Means followed by the same letter within a column are not significantly different at 5% level of significance
RNP = recommended rates of nitrogen and phosphorus, VC = vermicompost

3.4.6. Marketable Bulb Yield

The analysis of variance indicated that the main effects of variety and forms of fertilizer as well as their interaction significantly ($P<0.001$) influenced marketable bulb yield. The interaction effect of marketable bulb yield revealed that significantly the highest marketable yield (8.50 ton ha^{-1}) was recorded in Bishoftu Netch with combined application of 50% RNP and 5 ton ha^{-1} vermicompost. The marketable yield was 24% and 56% higher than Tsedey and the local cultivar at the same rate of fertilizer application, respectively. Tseday showed significantly the lowest marketable yield (3.75 ton ha^{-1}) in the non-fertilized plots (Table 14). The local cultivar and Tsedey in the application of 50% RNP and 5 ton ha^{-1} vermicompost application produced 45% and 91% more marketable bulb yield over respective cultivar that did not receive fertilizer treatment. This combination of fertilizer treatment also showed marketable advantages of 5.4%, 6% and 11% for Bishoftu Netch, local cultivar and Tsedey plants treated with RNP alone, respectively.

The increment in marketable bulb yield due to the application of inorganic NP and vermicompost fertilizer could be attributed to the increment in vegetative growth and increased production of assimilate which is associated with increment in leaf area index and mean bulb. Alemu (2014) reported that higher marketable yield was recorded at a combination of inorganic N 46 kg ha^{-1}, P_2O_5 92 kg ha^{-1} and vermicompost 5 ton ha^{-1}. Moreover, the increase in marketable bulb yield in response to vermicompost may also be ascribed to the availability of optimum nutrients contained in manure that led to high leaf area index through facilitated leaf growth and photosynthesis. This result is in line with that of Mehdi *et al*., (2012) who reported that the application of municipal solid waste and vermicompost significantly increased growth attributes such as plant height, stem diameter, number of leaves, and leaf area index of canola under well-watered, moderate and severe stress conditions.

Table 9. Interaction effects of garlic varieties and forms of fertilizer on marketable bulb yield (ton ha^{-1})

	Varieties		
Forms of Fertilizer	Bishoftu Netch	Local	Tsedey
No fertilizer (control)	5.17^{h}	3.75^{i}	3.59^{i}
128/92 kg ha^{-1} N and P_2O_5 (RNP)	8.06^{ab}	5.14^{h}	6.15^{g}
5 ton ha^{-1} VC	7.05^{de}	5.01^{h}	6.12^{g}
RNP + 2.5 ton ha^{-1} VC	7.33^{cd}	4.04^{i}	6.42^{fg}
50% RNP + 2.5 ton ha^{-1} VC	7.78^{bc}	5.17^{h}	6.39^{g}
50% RNP + 5.0 ton ha^{-1} VC	8.50^{a}	5.45^{h}	6.86^{ef}
LSD (5%)	0.462		
CV (%)	4.6		

*Means followed by the same letter within a column are not significantly different at 5% level of significance
RNP = recommended rates of nitrogen and phosphorus, VC = vermicompost

3.4.7. Unmarketable Bulb Yield

Unmarketable bulb yield of garlic was significantly (P<0.001) influenced by variety and forms of fertilizer, but not by the interaction of the two main factors.

Minimum unmarketable yield (0.11 ton ha^{-1}) was recorded at combined application of RNP and 2.5 ton ha^{-1} vermicompost which was 57.7% lower than the untreated control treatment. This result indicated that the combination effect of NP and organic vermicompost application significantly decreased unmarketable bulb yield. The current study is in agreement with that of Alemu (2014) who reported that minimum unmarketable yield at a combination of 23 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}. The studies of Alemu (2014) also indicated that uunmarketable bulb yield significantly decreased by 12.83% at an application rate of 5 ton ha^{-1} vermicompost as compared to the control treatment which received no fertilizer. In contrast, the maximum unmarketable yield was observed on the control treatment followed by treatments receiving sole application RNP and 5 ton ha^{-1} vermicompost. An important feature of vermicompost 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 phosphorous and soluble potassium, calcium and magnesium (Suthar and Singh, 2008).

3.4.8. Total Bulb Yield

Difference in total bulb yield appeared to be significant (P<0.001) due to the main effects of variety and the different forms of fertilizer as well as by their interaction effect. Biashofu Netch fertilized with 50% RNP + 5 ton ha^{-1} vermicompost produced the highest total bulb yield (8.65 ton ha^{-1}) which was about 24% and 57% higher than in Tsedey and local cultivar with the same rate of application, respectively. The lowest bulb yield (3.83 ton ha^{-1}) was found from Tseday with no fertilizer application.

Application of 50% RNP + 5 ton ha^{-1} vermicompost in Bishoftu Netch increased total bulb yield by 58% compared to unfertilized Bishoftu Netch plants. With local and Tsedey, treatments of 50% RNP + 5 ton ha^{-1} vermicompost produced 38% and 82% more tuber yield compared to unfertilized plots in respective cultivars. Moreover, Bishoftu Netch with application of 50% RNP + 5 ton ha^{-1} vermicompost showed about 5% yield increment than in application of 100% RNP fertilizer alone and 19% yield increment than in application of 5 ton ha^{-1} vermicompost only. Similarly, Tsedey showed significantly higher total bulb yield (6.98 ton ha^{-1}) with the application of 50% RNP + 5 ton ha^{-1} vermicompost which was about 10.4% and 11.3% higher than in application of RNP fertilizer alone and 5 ton ha^{-1} vermicompost alone, respectively. The local cultivar also showed significantly higher total bulb yield (5.50 ton ha^{-1}) with application of 50% RNP + 5 ton ha^{-1} vermicompost which was about 5% and 35% higher than in 50% RNP + 2.5 ton ha^{-1} vermicompost and RNP + 2.5 ton ha^{-1} vermicompost application, respectively.

Bishoftu Netch with the application of 5 ton ha^{-1} vermicompost alone gave about 16% and 41% more yield as compared to Tseday and the local cultivar at the same rate of application, respectively. Similarly, at the application of RNP only, Bishoftu Netch showed about 31% and 60% higher yield increment over Tseday and the local cultivar, in the same fertilizer application, respectively. Generally, the result attained by Bishoftu Netch indicated that it is superior in total yield at all forms of fertilizer considered. The current study was in agreement with that of findings of Tadila (2011) who reported that the maximum bulb yield was recorded in plots that received 50 kg N ha^{-1} and 10 ton manure ha^{-1} closely followed by the yield obtained at 100 kg N ha^{-1} alone, 20 ton manure ha^{-1} alone.

The increment in bulb yield due to nitrogen and phosphorus combination might be associated to the synergistic effect of the two nutrients on photosynthetic activity, translocation of assimilates and more absorption of nutrients by the plants (Marschner, 1995). As a result, the difference between the two varieties in response to the applied fertilizer could be attributed to the genotypic variability (Kassahun, 2006). The increase in total tuber yield in response to vermicompost may also be ascribed to several growth promoters, enzymes, beneficial bacteria and mycorrhyzae contained in vermicompost that led to high yield through facilitating improved leaf growth and photosynthetic activities thereby increasing portioning of assimilate to the storage organ. Similarly, treatments that received RNP + 2.5 ton ha^{-1} vermicompost, showed about 6% yield increment over treatments only receiving 5 ton ha^{-1} vermicompost.

Table 10. Interaction effects of garlic varieties and forms of fertilizer on total bulb yield (ton ha^{-1})

Forms of Fertilizer	Varieties		
	Bishoftu Netch	Local	Tsedey
No fertilizer (control)	5.49^{g}	3.98^{h}	3.83^{h}
128/92 kg ha^{-1} N and P_2O_5 (RNP)	8.27^{ab}	5.24^{g}	6.32^{f}
5 ton ha^{-1} VC	7.26^{cd}	5.14^{g}	6.27^{f}
RNP + 2.5 ton ha^{-1} VC	7.48^{c}	4.08^{h}	6.52^{ef}
50% RNP + 2.5 ton ha^{-1} VC	7.99^{b}	5.24^{g}	6.53^{ef}
50% RNP + 5.0 ton ha^{-1} VC	8.65^{a}	5.50^{g}	6.98^{de}
LSD (5%)	0.463		
CV (%)	4.5		

*Means followed by the same letter within a column are not significantly different at 5% level of significance
RNP = recommended rates of nitrogen and phosphorus, VC = vermicompost

3.4.9. Bulb Dry Matter

The main effect of variety ($P < 0.001$) and forms of fertilizer ($P < 0.05$) significantly influenced bulb dry matter. However, bulb dry matter did not significantly affected by the interaction of variety and forms of fertilizer.

The main effect of varieties revealed that Bishoftu Netch showed higher bulb dry matter percent as compared to Tsedey and the local cultivar. The maximum dry matter (20.64%) was observed in treatments that received 50% RNP + 5.0 ton ha^{-1} vermicompost which was about 15.24% and 12.67% higher than treatments that received sole application of RNP and 5 ton ha^{-1} vermicompost, respectively. Similarly, treatments that received application of RNP + 2.5 ton ha^{-1} vermicompost and 50% RNP + 2.5 ton ha^{-1} vermicompost showed about 55 and 48% increment over the control treatment. The current study agreed with that of Alemu (2014) who reported bulb dry matter percent increase by 14.21% due to increased level of N rate from 0 to 46 kg ha^{-1}. The author also described bulb dry matter percent of garlic was significantly increased by 21.03% in response to P application rate increment from 0 to 92 kg P_2O_5 ha^{-1}. Argüello (2006) showed that vermicompost increased the bulb dry weight by the accumulation of non-structural carbohydrates whose distribution patterns change, thus favouring the metabolism of fructan precursors and accumulating as scorodose. The author further explained as such reserve substance (scorodose) accumulation in the vermicompost treatment represented by scorodose polysaccharide occurs for a longer period due to the earlier start of bulbing which was correlated with vermicompost applications.

3.4.10. Harvest Index

The main effect of forms of fertilizer as well as its interaction with cultivar highly significantly ($P<0.001$) influenced harvest index. However, the main effect of variety did not significantly influence harvest index.

The highest harvest index (11.82%) was recorded in local cultivar fertilized with RNP only which was 66.5 % and 61.5% greater than local cultivar and Tsedey in their respective control treatment. This fertilizer rate also produced maximum harvest index of 11.15% in Tsedey which was 52.3% greater than when the same cultivar was unfertilized. Bishoftu Netch that received 5 ton ha^{-1} vermicompost had 26.7% more harvest index than when it didn't receive any fertilizer. The current study is in agreement with that of Alemu (2014) who reported that the maximum harvest index (11.08%) was recorded with the supply of 46 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} as compared to those which did not receive fertilizer. This could be attributed to the strong movement of assimilates from the leaves to bulbs during the growing period.

Table 11. Interaction effects of garlic varieties and forms of fertilizer on harvest index

	Varieties		
Forms of Fertilizer	Bishoftu Netch	Local	Tsedey
No fertilizer (control)	8.78[e]	7.10[f]	7.32[f]
128/92 kg ha^{-1} N and P_2O_5 (RNP)	10.79[bcd]	11.82[a]	11.15[b]
5 ton ha^{-1} VC	11.12[b]	10.51[cd]	10.91[bc]
RNP + 2.5 ton ha^{-1} VC	10.55[cd]	11.15[b]	10.52[cd]
50% RNP + 2.5 ton ha^{-1} VC	10.35[d]	10.58[cd]	10.55[cd]
50% RNP + 5.0 ton ha^{-1} VC	10.96[bc]	10.83[bc]	10.94[bc]
LSD (5%)	0.269		
CV (%)	2.7		

*Means followed by the same letter within a column are not significantly different at 5% level of significance RNP =recommended rates of nitrogen and phosphorus, VC = vermicompost

3.5. Economic Analysis

The result of partial budget based on total variable input cost indicated that the highest net benefit (Birr 296053.35) was obtained from variety Bishoftu Netch which received application of RNP only, followed by Bishoftu Netch that received combined application of 50 % RNP and 2.5 ton ha^{-1} vermicompost. The lowest (Birr 132593.35) was observed by the local variety which received combined application of RNP and 2.5 ton ha^{-1} vermicompost. Although the calculation of net benefits accounts for the costs that vary, it is necessary to compare the extra or marginal costs with the extra or marginal net benefits. The process of calculating the marginal rates of returns (MRR%) of alternative treatments, proceeding in steps from the least costly treatment to most costly treatment and deciding if they are acceptable to farmers is so called marginal analysis (). According to CIMMYT (1998), the highest Marginal Rate of Returns (MRR) 17763.38, 13551.34 and 11211.31% were recorded from Bishoftu Netch, Tsedey and the local cultivar, respectively, by the application of RNP fertilizer alone.

4. Summary and Conclusions

The effects of organic and inorganic NP fertilizers on the performance of garlic (*Allium sativum* L.) varieties was studied in a field experiment conducted during 2016 cropping season with the objective of assessing the effects of combined application of vermicompost and NP fertilizers on the performance of garlic varieties and determining the economically profitable fertilizer rates for higher yield of garlic under irrigation.

Results of the experiment showed the longest days to bulb maturity 144.33 and the shortest days to maturity 120.67 were recorded in Tsedey variety that received 50% RNP + 5 ton ha^{-1} vermicompost and control treatment, respectively. Similarly, the highest plant height (27.97cm) was attained by the local cultivar with application of 50% RNP + 5 ton ha^{-1} vermicompost and the minimum (19.38) was recorded in Tsedey that received no fertilizer. Moreover, highest leaf area index (0.50) was recorded in local cultivar with the application of RNP + 2.5 ton ha^{-1} vermicompost while the minimum (0.11) leaf area index was observed on Tsedey that relieved no fertilizer.

Significantly the highest mean clove weight (5.31 g), total fresh biomass yield (44.82 g/plant), marketable bulb yield (8.50 ton ha^{-1}) and total bulb yield (8.65 ton ha^{-1}) were recorded on Bishoftu Netch plants that were fertilized with 50% RNP + 5 ton ha^{-1} vermicompost. On the other hand the highest mean bulb weight (34.90 g) and marketable number of bulbs (332426) were recorded in the local cultivar fertilized with 50% RNP + 5 ton ha^{-1} vermicompost. In addition, the highest harvest index was recorded in local cultivar that received RNP only. Moreover, the interaction effect of varieties and forms of fertilizer highly significantly ($P<0.001$) affected days to bulb maturity, plant height, leaf area index, mean bulb weight, mean clove weight, total fresh biomass yield, marketable number of bulbs, marketable bulb yield, total bulb yield and harvest index. However, varieties and forms of fertilizer did not affect significantly days to emergence, number of leaves per plant, mean clove number, unmarketable bulb yield and bulb dry matter.

The economic analysis indicated that Bishoftu Netch gave the highest benefit of Birr 296053.35 and 285566.67 per ha at application of 100% RNP alone and 50% RNP + 5 ton ha^{-1} vermicompost respectively. The benefit was 31% and 58% higher than Tseday and local cultivar at RNP only and 27% and 63% higher than Tsedey and the local cultivar at application of 50% RNP + 5 ton ha^{-1} VC, respectively. The lowest net benefit Birr 132593.35 from local cultivar was observed from the treatment that received RNP + 2.5 ton ha^{-1} vermicompost. However, the highest MRR% (17763.38) was recorded from Bishoftu Netch that received only RNP fertilizer followed by MRR% (13551.34) from Tsedey variety that received 100% RNP fertilizer only and MMR% (11211.31) from local variety receiving RNP only. The analysis of MRR revealed that application of inorganic NP fertilizer lead to the production of higher MRR than combining it with organic vermicompost fertilizer. This result also indicated that applying inorganic NP fertilizer alone at the recommended rate could result the highest economic yield of the crop.

In conclusion, the result of the present study indicated that the highest total bulb yield was recorded from Bishoftu Netch by applying of 50% RNP + 5 ton ha^{-1} vermicompost, but, its MRR is lower than applying inorganic RNP fertilizer. Moreover, in the other two cultivars, this treatment showed relatively better marketable yield. Furthermore, the vermicompost is believed to improve the soil health which could have sustainable impact on successive crops. Therefore, it would be difficult to make definite conclusive recommendation based on the research results of one season and one location. As a result, similar experiments involving additional combinations under different locations should be conducted to come up with a decisive recommendation.