Improving Yield and Economic Benefits of Garlic (*Allium sativum* L.) Through Integrated Use of Organic and Inorganic Fertilizers on Different Soil Types

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Abstract

Soil fertility depletion is among the major impediments to sustained crop productivity because of limited application of fertilizers in Ethiopia. Crops yield can be enhanced through balanced application of inorganic and organic soil nutrients. Thus, field experiment was conducted to investigate the effect of chicken manure (CM) with reduced levels of inorganic nitrogen (N) and phosphorus (P) fertilizers on garlic growth, yields and economic benefits at Debrezeit Agricultural Research Centre on two soil types (Andosols and Vertisols) in 2013/14 cropping season. The treatments consisted of factorial combinations of three levels each N (0, 46, 92 kgha^{-1}), P (0, 20, 40 kgha^{-1}) and CM (0, 10, 20 tha^{-1}); which were laid out in randomized complete block design with three replications at each site. The analysis result showed that there was a significant main effect of N, P, CM and soil type on the evaluated growth and yield traits in the experiments. Effect of the manure on growth and yield of garlic bulb were significantly higher on both soils than the mineral NP fertilizers but the highest bulb yield of garlic was recorded from Vertisols than from Andosols. The applied fertilizers interacted and significantly influenced the yield attributes of garlic on both soils. The highest bulb yield was obtained with the application of 46 kg N ha^{-1}, 40 kg P ha^{-1} and 20 t CM ha^{-1} on Andosols and with the application of 46 kg N ha^{-1}, 20 kg P ha^{-1} and 20 t CM ha^{-1} combination on Vertisols. There was a yield advantage of 110% and 139% due to these two combinations over the lowest yield obtained from the control plot on Andosols and Vertisols, respectively. Application of fertilizers at the combination rates of 46 kg N ha^{-1}, 20 kg P ha^{-1} and 20 t CM ha^{-1} significantly improved bulb yield by 57% on Vertisols than the yield produced on Andosols. Moreover, the mean bulb yield produced on Vertisols was higher by 21% compared to that of Andosols. In addition, the higher economic yield and marginal rate of return was obtained by the application of 10 t CM ha^{-1} along with 46 kg N ha^{-1} and 20 kg P ha^{-1} on Andosols. Thus, application of 10/20 tha^{-1} CM saved the recommended levels of N and P fertilizers by 50%, without reducing the bulb yield and economic benefits of garlic.

Keywords: Bulb yield, chicken manure, economic benefits, inorganic fertilizer

Introduction

Garlic (*Allium sativum* L.) is one of the most important vegetable crops produced in the world. It ranked second of *Allium* species next to onion. Garlic is produced for economic value, spices and medicinal purposes (Brewster, 1994; Fritsch and Friesen, 2002). In Ethiopia, it is one of the most widely used horticultural crops and its production is increasing from time to time although many garlic producing farmers have limited knowledge of the different agronomic practices influencing the growth and yield of the crop (Getachew and Asfaw, 2000; FAO, 2003). In many areas, lack of available nutrients is frequently the limiting factor next to the soil water. It has been reported that most tropical soils are deficient in N and P because of declining soil organic matter from year to year due to continuous cultivation of land and leaching effects (Chien and Menon, 1995). Soil fertility studies conducted at different locations in Ethiopia for different crops have shown good yield responses to applied N and P fertilizers, confirming the low N and P status of the soils (Berga *et al*., 1994).

The central highlands of Ethiopia, which is one of the major garlic growing regions in the country next to onion, is dominated by two major soil types, Vertisols and Andosols. Vertisols (black clay loam soil) are known for their extensive cracking up to the depth of 50 cm or more with seasonal drying, and they occupy about 12.6 million hectare in Ethiopia (Woldeab, 1987). Their poor physical properties such as poor drainage considerably restricted productive potential of crops, which can be improved with organic matter amendments. Andosols (light gray and sandy loam soil) on the other hand are characterized by well drained properties and low soil pH which renders the greater portion of such nutrients as phosphorus unavailable to crops due to favored chemical fixation, thus ultimately lowering crop yield (M'Nen, 1992).

Garlic can be grown in diverse soil types from black heavy soils (Vertisols) to red soils (Andosols) in the central highlands of Ethiopia. Despite its importance, the productivity of this crop is low mainly due to many environmental factors and poor agronomic practices such as poor fertilization (Liu *et al*., 2004). Integrated nutrient management is used to reduce inorganic fertilizer requirement, to restore the organic matter in soil and to increase nutrient use efficiency, to maintain quality in terms of physical, chemical and biological properties of soil. Tolessa and Friesen (2001) reported that the application of 25% recommended inorganic NP fertilizers and enriched FYM resulted in the highest marginal rate of return in maize indicating that the integrated approach can enable to save up to 75% of commercial fertilizers. Likewise, Bayu *et al*. (2006) and Balemi (2012) reported the possibility of saving up to 50% of the recommended NP fertilizers due to amendment with 5-15 t ha^{-1} FYM and 10-20 t ha^{-1} cattle manure to sorghum and potato crops, respectively without significantly affecting the optimum possible yield that can be obtained with the application of full dose of inorganic NP fertilizers alone.

Animal manures have been used for plant production effectively for centuries. Chicken manure has long been recognized as the most desirable organic amendments because of its high nitrogen content (Eliot, 2005; Ghanbarian *et al*., 2008). The chicken manure seems to be directly responsible in increasing crop yields either by accelerating the metabolic process by increasing cell permeability by hormone growth action or by combination of all these processes (Islah, 2010). It supplies different nutrients and improves physical properties of soil such as aggregation of soil, permeability and water holding capacity (Ghanbarian *et al*., 2008). However, information on the use of these organic manures alone or in combination with inorganic fertilizers on garlic is limited; although research findings pertaining to this aspect on other bulb crops are reviewed. Thus, this study was designed to assess the influence of integrated use of chicken manure and inorganic N and P fertilizers on productivity of garlic under two soil types in mid altitude area of Debrezeit, Ethiopia.

Materials and Methods

Experimental Site and Materials

The experiment was conducted at Debrezeit Agricultural Research Centre (DZARC), which is found at $08^0$44"N latitude, $38^0$58"E longitude with an altitude of 1860 meters above sea level in central Ethiopia. The experiment was conducted on two soil types prevailing in the area (Andosols and Vertisols) during main rainy season of 2013/2014. The area has mean annual maximum and minimum temperatures of 27^{o}C and 10^{o}C respectively, with a sub-humid tropical climate type. It has a mean annual rainfall of about 740 mm with a mean relative humidity of 57% in the crop year (Figure 1). The experimental fields were under tef [*Eragrostis tef* (Zucc.) Trotter] cultivation for the two previous consecutive cropping seasons. The physical and chemical properties of the experimental soils and chemical contents of the applied chicken manure were analyzed following the procedures of Jackson (1967) as indicated in Table 1. Cloves of “Tseday” garlic cultivar, inorganic nitrogen and phosphorus fertilizers, and organic chicken manure were used as experimental materials on both soil types.

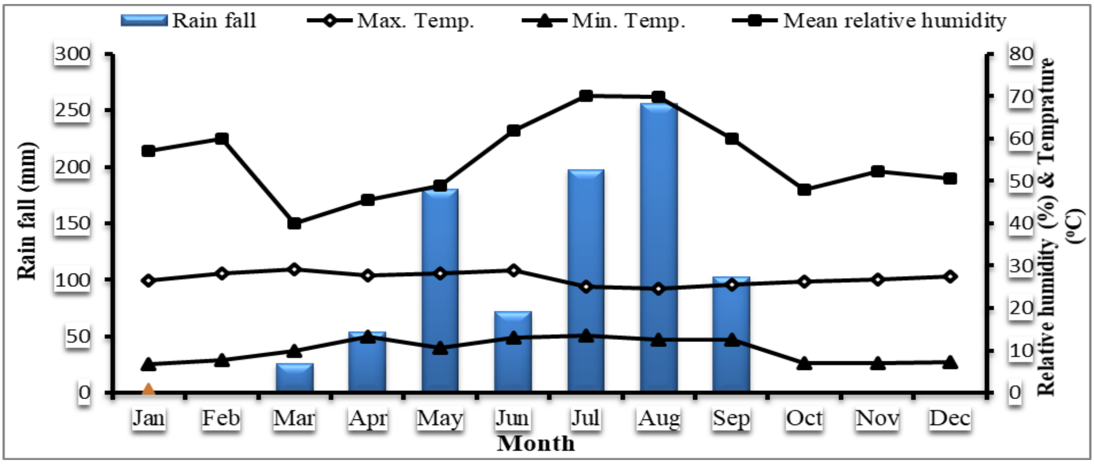

Figure 1. Monthly rainfall, mean relative humidity, and maximum and minimum temperatures of the study for the period 2012 crop season

Table 1. Physical and chemical properties of the experimental soils before planting the crop and chemical properties of chicken manure before applying to the soils

			Physical properties					
Soil	**Clay (%)**	**Silt (%)**	**Sand (%)**	**Soil texture**				
Andosols	8.85	27.17	63.98	Sandy-Loam				
Vertisols	29.88	22.66	47.46	Clay-Loam				
			Chemical properties					
Factors	**Total N (%)**	**Available P (ppm)**	**Available SO_4 (mg kg^{-1})**	**C:N Ration**	**Organic carbon (%)**	**Organic matter (%)**	**ECe (ds m^{-1})**	**pH (1:25 H_2O)**
Andosols	0.153	23.41	18.60	9.54	1.46	2.51	1.25	7.22
Vertisols	0.085	18.84	15.80	12.00	1.02	1.75	0.83	6.98
Chicken manure	3.57	53.31	25.91	9.35	29.82	51.23	3.10	8.19
	Exchangeable Cations (C.mol (+) kg^{-1})				**Micronutrients (ppm)**			
	K	**Na**	**Ca**	**Mg**	**Cu**	**Fe**	**Mn**	**Zn**
Andosols	1.87	0.441	44.25	5.73	2.84	31.52	12.17	0.862
Vertisols	1.45	0.352	49.72	5.98	2.24	29.45	37.65	0.671
Chicken manure	2.55	1.89	39.76	11.17	131.6	2363.9	242.5	191.7

Treatments and Experimental Design

The treatments consisted of three levels of each of nitrogen, phosphorus and chicken manure fertilizers. Thus, the 27 treatments of the experiment were arranged in a factorial and were laid out as a randomized complete block design with three replications for each soil type. The area of each plot was 3.6m^2 (1.8m x 2m) with a spacing of 10 cm between plants and 30cm between rows. The plot consisted of six rows with 20 plants per row comprising 120 plants per plot. A distance of 1m was maintained between plots and 1.5m between replications.

Experimental Procedure

The study consisted of two fields of Andosols and Vertisols sites, where integrated use of organic and chemical fertilizers were evaluated for improving the production and productivity of garlic. Bulbs of garlic ('Tseday' cultivar) were separated into cloves. Healthy and uniform sized (2.0-2.5 g) cloves were planted on ridges of about 20cm height at a depth of 2cm on Andosols and 4 cm on Vertisols. Harvesting was done from the four central rows leaving side rows and crops to reduce border effect. Other crop management practices were carried out as per the recommendations of DZARC (Getachew and Asfaw, 2000).

Previously, 92 kg N ha^{-1} and 40 kg P ha^{-1} were recommended for maximum growth and yield of garlic production on both Andosols and Vertisols (Diriba-Shiferaw *et al*., 2015). Consequently, in this experiment three levels of each of N and P (0, 50 and 100% of the recommended N and P) were used viz.: 0, 46 and 92 kg N ha^{-1} and 0, 20 and 40 kg P ha^{-1} on both soils; integrated with three levels of chicken manure (0, 10 and 20 t ha^{-1}). The fertilizers were applied to both soils in the form of Urea, Triple Super Phosphate (TSP), and Chicken Manure (CM), respectively. All doses of TSP and one fourth of urea was applied at planting, whereas half and the remaining one fourth of urea was side dressed three and six weeks after plant emergence, respectively.

Organic fertilizer, which was prepared from chicken manure, was piled and stored for more than three months to decompose into fine textures before application to the experimental fields. The decomposition of the manure was done in well prepared dig from a blocket and covered by a plastic cover. After the manure was decomposed, it was applied to the plots at the specified levels on both soils just one week before planting the cloves.

Data Collection and Analysis

Growth indices were recorded at different time intervals until harvest maturity on the following characters: plant height (cm), neck diameter (mm) and leaf area index. Yield and yield attributes recorded after matured bulbs harvested were: bulb weight per plant (g), number of cloves per bulb, mean clove weight (g), bulb length and diameter (cm) and total bulb yield (t ha^{-1}). Garlic bulb yield was determined after curing harvested plants for ten days under ambient condition of the area by thinly spreading on wooden shelves in a diffused light store constructed with wire-mesh wall and corrugated iron roofing. The economic returns of produced garlic was calculated from the cost incurred and economic yields obtained during the study. By subtracting the total net cost of production from the returns of a crop, a net profit number was determined and used to compare different inputs. The partial economic analysis of different fertilizers applied viz., nitrogen, phosphorus and chicken manure were compared for both Andosols and Vertisols.

Manure and soil analysis*:* A two kilogram composite chicken manure sample was collected from a heap of well-decomposed chicken manure for laboratory study. The chemical compositions of the manure was analyzed; viz, total N, available P and S, exchangeable cations, micro-nutrients, organic carbon, soil cation exchangeable capacity and pH. Soil samples of 0-30 cm depth from both the experimental soils were taken using Auger before planting the cloves at random to represent the whole plot and then composited and divided into five representatives soil samples of the fields before application of chicken manure. The soil samples collected were air-dried under shade and ground to pass through a 2 mm sieve to exclude non-soil particles, and both physical and chemical properties of both soils were analyzed following their respective procedures (Table 1).

The data obtained were subjected to analysis of variance using SAS statistical software version 9.0 and treatment effects were compared using Fisher's Least Significant Differences test at 5% level of probability.

Results

Physical and Chemical Properties of the Experimental Soils

The physical and chemical properties of the soils has shown a textural class of sandy-loam and clay-loam with an organic matter of 2.51 and 1.75%, total nitrogen of 0.153 and 0.085%, available P of 23.41 and 18.84 ppm in Andosols and Vertisols, respectively (Table 1). Generally, the organic matter and macronutrients content of Andosols is higher than that in Vertisols. In addition, according to the rating of Hazelton and Murphy (2007), the organic matter and nitrogen content of Andosols is low and that of Vertisols is very low. While, available phosphorus of both soils are categorized within low ranges rated by Holford and Cullis (1985) cited in Hazelton and Murphy (2007). In addition, the exchangeable potassium content of both soils is high according to Hazelton and Murphy (2007). Landon (1991) stated that K fertilizer application is not required when a soil has an exchangeable K content of higher than 0.50 C.mol (+) kg^{-1} soil. The sulphate-S content of both soils is low according to the rating of Bashour (2001) cited in Bashour and Sayegh (2007), as he reported that the soluble sulphate content of a soil of arid or semi-arid regions is low when the ranges fall between 10 and 20 mg kg^{-1} soil. The analysis of the chicken manure used for the study as presented in Table 1 gave 3.57% of nitrogen, 53.31 ppm of available P, 2.55 C.mol(+) kg^{-1} manure of exchangeable K, 25.91 mg kg^{-1} manure of sulphate-S and 51.23% of organic matter. The nutrients content of the manure was higher as compared to with that of the soils; because of that, it was used through integrating with the reduced levels of both inorganic nitrogen and phosphorus fertilizers.

Growth Parameters

Plant height

The main effects of nitrogen, phosphorus, chicken manure and soil types significantly influenced plant height of garlic at 30, 60, 90 and 120 days after planting (DAP) of the growth stages. Nitrogen and chicken manure application significantly influenced plant height at all growth stages. However, application of phosphorus did not have significant influence on plant height at both 30 and 60 DAP. The difference between the soil types at 60 DAP was also non-significant (Table 2). Height of garlic plant significantly increased with the application of progressively increased N rates up to 46 kg N and 20 kg P ha^{-1} at each growth stage. Also plant height significantly increased with applied rates of chicken manure up to 20 t ha^{-1} at all growth stages. Plant height was improved on Vertisols at 30 and 120 DAP, and at 90 DAP on Andosols. The average heights of garlic plants fertilized with 46 kg N, 20 kg P and 20 t CM ha^{-1} were 65.92, 66.21 and 67.25 cm, respectively at 120 DAP. In addition, the average height of the plant grown on Vertisols was higher by about 4% as compared to those grown on Andosols at 120 DAP (Table 2).

Table 2. Effects of nitrogen (N), phosphorus (P), chicken manure (CM) and soil types on plant height of garlic at different growth stages

Treatment	Plant height (cm)			
	Days after planting			
	30	60	90	120
N (kg ha^{-1})				
0	31.45^{b}	49.90^{b}	59.26^{b}	63.04^{b}
46	32.74^{a}	50.55^{ab}	60.55^{a}	65.92^{a}
92	32.84^{a}	51.29^{a}	59.52^{ab}	65.99^{a}
LSD	0.96*	1.06*	1.06*	1.08***
P (kg ha^{-1})				
0	31.74	49.99	58.22^{b}	63.29^{b}
20	32.58	50.82	60.71^{a}	66.21^{a}
40	32.71	50.93	60.41^{a}	65.46^{a}
LSD	ns	ns	1.06***	1.08***
CM (t ha^{-1})				
0	31.02^{b}	48.49^{c}	56.74^{c}	61.95^{c}
10	32.65^{a}	51.03^{b}	60.72^{b}	65.75^{b}
20	33.36^{a}	52.23^{a}	61.89^{a}	67.25^{a}
LSD	0.96***	1.06***	1.06***	1.08***
Soil				
Andosols	31.17^{b}	50.26	61.51^{a}	63.79^{b}
Vertisols	33.51^{a}	50.91	58.05^{b}	66.18^{a}
LSD	0.78***	ns	0.86***	0.88***
C.V.(%)	8.25	5.49	4.57	4.17

Where ns, non-significant, and *, ** and ***, indicate significant difference at 0.5, 0.1 and 0.01 levels of probability, respectively

Neck diameter

Considerable growth in neck diameter occurred until 60 DAP and between 90 and 120 DAP. Neck thickness of garlic plants was not significantly influenced by the applied fertilizers at 30 days but at 60, 90 and 120 DAP the neck diameter was significantly increased up to 46 kg N, 20 kg P ha^{-1} and 10 t CM ha^{-1} (Table 3). Average neck thickness increased from 4.39 to 10.69 mm in plants produced with 46 kg N ha^{-1}, 4.32 to 10.57 mm in plants produced with 20 kg P ha^{-1} and 5.19 to 10.63 mm in plant produced with 20 t ha^{-1} chicken manure as the plant growth increased from 30 to 120 DAP, respectively. The neck diameter was improved by 13%, 7% and 14%, respectively in response to the application of 46 kg N, 20 kg P and 20 t CM ha^{-1} application as compared to the plant grown on the control plot during the growth period of 120 DAP. Growth in neck diameter was significantly higher on Vertisols than on Andosols at all growth stages except at 60 DAP. The growth of garlic neck diameter was increased by 142% and 116% on Andosols and Vertisols, respectively within the growth period of 30 to 120 days (Table 3).

Table 3. Effects of nitrogen (N), phosphorus (P), chicken manure (CM) and soil types on neck diameter of garlic at different growth stages

Treatment	Neck diameter (cm)			
	Days after planting			
	30	60	90	120
N (kg ha^{-1})				
0	4.35	6.31^{b}	7.35^{b}	9.47^{b}
46	4.39	6.92^{a}	8.47^{a}	10.69^{a}
92	4.69	6.86^{a}	8.24^{a}	10.53^{a}
LSD	ns	0.28***	0.29***	0.31***
P (kg ha^{-1})				
0	4.27	6.37^{c}	7.71^{c}	9.91^{c}
20	4.32	7.05^{a}	8.35^{a}	10.57^{a}
40	4.84	6.67^{b}	7.99^{b}	10.21^{b}
LSD	ns	0.28***	0.29***	0.31***
CM (t ha^{-1})				
0	3.92	6.37^{b}	7.37^{b}	9.50^{b}
10	4.32	6.85^{a}	8.30^{a}	10.56^{a}
20	5.19	6.88^{a}	8.39^{a}	10.63^{a}
LSD	ns	0.28**	0.29***	0.31***
Soil				
Andosols	4.15	6.83^{a}	7.86^{b}	10.04^{b}
Vertisols	4.81	6.56^{b}	8.18^{a}	10.42^{a}
LSD	ns	0.23*	0.24**	0.25**
C.V.(%)	8.83	9.84	8.72	6.79

Where ns, non-significant, and *, ** and ***, indicate significant difference at 0.5, 0.1 and 0.01 levels of probability, respectively

Leaf area index

Leaf area index (LAI) of garlic did not show significant variation due to N and P fertilization at 30 DAP but, chicken manure and soil type significantly influenced LAI. However, LAI significantly increased, when N application increased from zero to 46 kg N ha^{-1} but did not change when N rate is further increased to 92 kg ha^{-1}. Likewise, increasing the P application rate from zero to 20 kg P ha^{-1} at 60, 90 and 120 DAP significantly increased the leaf area index, while further increasing the P rate to 40 kg ha^{-1} did not result in a significantly different leaf area index (Table 4). On the other hand, the application of chicken manure significantly progressively increased the LAI with the increase in the rates of the CM at all growth stages. The LAI of the crop increased by 15%, 10% and 27% when the plants were fertilized with 46 kg N, 20 kg P and 20 t CM ha^{-1} respectively over their respective controls. Plants grown on Vertisols had 20% higher LAI than those grown on Andosols at 120 DAP. The LAI increased linearly with increasing time of growth. The average LAI increased from 2.43 to 9.06, 2.72 to 8.92 and 2.73 to 9.44 in plants grown with the application of 46 kg N ha^{-1}, 20 kg P ha^{-1} and 20 t CM ha^{-1}, respectively as the plant growth extends from 30 to 120 DAP. More LAI was achieved on Vertisols than on Andosols at all growth stages and increased by 50, 12, 17 and 19% in the respective growth stages. The LAI of the plant increased from 2.00 to 7.79 on Andosols and from 3.01 to 9.32 on Vertisols when the growth of the crop extends from 30 to 120 DAP (Table 4).

Table 4. Effects of nitrogen (N), phosphorus (P), chicken manure (CM) and soil types on leaf area index (LAI) of garlic at different growth stages

Treatment	Leaf area index			
	Days after planting			
	30	60	90	120
N (kg ha^{-1})				
0	2.36	6.43^{b}	6.95^{b}	7.88^{b}
46	2.43	7.32^{a}	8.09^{a}	9.06^{a}
92	2.71	7.30^{a}	7.71^{a}	8.72^{a}
LSD	ns	0.37***	0.36***	0.38***
P (kg ha^{-1})				
0	2.41	6.74^{b}	7.04^{b}	8.09^{b}
20	2.72	7.26^{a}	7.85^{a}	8.92^{a}
40	2.39	7.05^{ab}	7.87^{a}	8.65^{a}
LSD	ns	0.37*	0.36***	0.38**
CM (t ha^{-1})				
0	2.25^{b}	6.09^{c}	6.49^{c}	7.41^{c}
10	2.53^{ab}	7.14^{b}	7.93^{b}	8.80^{b}
20	2.73^{a}	7.82^{a}	8.33^{a}	9.44^{a}
LSD	0.33*	0.37***	0.6***	0.38***
Soil				
Andosols	1.998^{b}	6.61^{b}	6.97^{b}	7.79^{b}
Vertisols	3.009^{a}	7.43^{a}	8.20^{a}	9.32^{a}
LSD	0.27***	0.30***	0.30***	0.31***
C.V.(%)	8.87	14.11	13.63	13.34

Where ns, non-significant, and *, ** and ***, indicate significant difference at 0.5, 0.1 and 0.01 levels of probability, respectively

Yield and yield attributes

Analysis of variance showed that yield contributing characters such as: bulb weight, bulb diameter and length, mean clove weight, and clove number per bulb were significantly influenced by the main effect of inorganic N and P fertilizers, and chicken manure (CM) on both soil types. However, the main effect of N did not significantly influence the mean clove weight on Andosols and P did not influence bulb length and mean clove weight on Vertisols. In addition, the main effect of P did not influence clove number on both soils and CM on Vertisols (Table 5). Mean bulb weight was also significantly influenced by the interactions of the applied fertilizers on both soil types except the interaction of N and P on Vertisols. Bulb diameter was significantly influenced by the interactions of the fertilizers (N, P & CM) on both soils except the interactions of N and P as well as P and CM on Andosols. Mean clove weight was also significantly influenced by the interactions of fertilizers except that of N and P on Andosols, and N and CM as well as P and CM on Vertisols. However, bulb length and clove number per bulb was not significantly influenced by the interaction of all factors (Table 5).

The main effects of all fertilizer factors significantly increased most of the yield contributing parameters on both soil types. Bulb length and clove number per bulb produced with the application of 46 and 92 kg N ha^{-1} did not significantly differ but they were significantly higher compared to the plants grown in the control treatment on both soils (Table 6). The application of P significantly increased bulb length as compared to the unfertilized control although there was no significant bulb length difference between the plants grown with the application of 20 and 40 kg P ha^{-1} on Andosols. On the other hand, clove number was not significantly influenced by application of different rates of phosphorus on both soils. Bulb length was significantly affected by the application of different chicken manure rates on both soils. Bulb length produced on Vertisols was significantly increased when the rates of chicken manure increased from zero to 10 t ha^{-1} although further increasing the CM rate to 20 t ha^{-1} did not bring any change in to bulb length. Large bulb length and more number of cloves per bulb were produced on Vertisols than on Andosols with 2.6% and 16% improvement, respectively (Table 6).

Table 5. ANOVA results for yield and quality parameters of garlic as influenced by the main and interaction effects of inorganic nitrogen (N) and phosphorus (P) fertilizers, and chicken manure (CM) on two soil types

Factors	Soil	N	P	CM	N x P	N x CM	P x CM	N x P x CM
Bulb weight	Andosols	54.48***	11.01*	120.29***	10.28**	14.83***	23.13***	18.70***
	Vertisols	149.50***	27.96***	350.48***	3.96ns	18.97***	9.24*	23.76***
Bulb diameter	Andosols	1.92***	1.334***	1.615***	0.105ns	0.205**	0.097ns	0.092*
	Vertisols	2.35***	0.779***	3.99***	0.178*	0.294***	0.144*	0.122*
Bulb length	Andosols	0.217**	0.130*	0.257***	0.043ns	0.011ns	0.022ns	0.012ns
	Vertisols	0.151*	0.066ns	0.525***	0.0066ns	0.015ns	0.048ns	0.023ns
Mean clove wt	Andosols	0.031ns	0.069*	0.148***	0.034ns	0.059*	0.070**	0.074**
	Vertisols	6.54*	0.166ns	11.63**	10.85**	1.39ns	0.767ns	3.425*
Clove №/bulb	Andosols	20.85*	7.81ns	9.94**	6.27ns	4.62ns	4.34ns	3.91ns
	Vertisols	0.108*	0.055ns	0.735ns	0.140ns	0.005ns	0.051ns	0.058ns
Bulb yield	Andosols	57.05***	8.85***	14.09***	1.053***	1.596***	2.215***	1.89***
	Vertisols	155.21***	6.43***	35.03***	1.83***	1.44***	2.03***	0.73***

Key: ns = indicate non-significant; *, **, *** = significant at 0.05, 0.01 and 0.001 level of probability, respectively.

Table 6. Main effect of nitrogen (N), phosphorus (P) and chicken manure (CM) fertilizers on bulb length and clove number per bulb of garlic on both Andosols and Vertisols

Treatment	Bulb length (cm)		Clove number per bulb	
	Andosols	Vertisols	Andosols	Vertisols
N (kg ha^{-1})				
0	2.58^{b}	2.67^{b}	11.01^{b}	12.41^{b}
46	2.71^{a}	2.77^{ab}	11.93^{a}	13.87^{a}
92	2.76^{a}	2.82^{a}	11.79^{ab}	13.99^{a}
LSD	0.097	0.106	0.78	1.36
P (kg ha^{-1})				
0	2.61^{b}	2.70^{a}	11.61^{a}	13.06^{a}
20	2.69^{ab}	2.77^{a}	11.49^{a}	13.18^{a}
40	2.75^{a}	2.79^{a}	11.64^{a}	14.04^{a}
LSD	0.097	ns	ns	ns
CM (t ha^{-1})				
0	2.58^{b}	2.61^{c}	10.88^{b}	12.73^{a}
10	2.77^{a}	2.76^{b}	11.67^{ab}	13.86^{a}
20	2.71^{a}	2.89^{a}	12.19^{a}	13.69^{a}
LSD	0.097	0.106	0.78	ns
Mean	2.69	2.76	11.58	13.43
CV(%)	6.55	8.46	12.33	16.82

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

Moreover, in addition to the main effects, bulb weight, bulb diameter, mean clove weight and bulb yield were significantly influenced by the interaction effects of nitrogen, phosphorus and chicken manure on both Andosols and Vertisols. The highest bulb weight and diameter was produced when N-P-CM were co-applied at the rates of 92 kg N, 20 kg P and 20 t CM ha^{-1} on Andosols and at the rates of 46 kg N, 20 kg P and 20 t CM ha^{-1} on Vertisols (Table 7). The lowest bulb weight and diameter was produced from non-fertilized control plant on both soils. Bulb weight was significantly reduced by 89% and 117%, whereas bulb diameter by 50% and 58% in plants grown without fertilizer application as compared to their respective highest bulb weight and diameter on Andosols and Vertisols, respectively. The highest bulb weight and diameter produced on Vertisols in response to the combined application of 46 kg N, 20 kg P and 20 t CM ha^{-1} was improved by 22.52% and 21.87%, respectively as compared to those produced on Andosols at the same rates (Table 7). Moreover, bulb diameter was significantly increased (4.11%) on Vertisols as compared to on Andosols, but there was no significant difference in bulb weight due to the effect of soil types.

The heaviest mean clove weight was produced when N-P-CM were co-applied at the rates of 92 kg N, 20 kg P and 20 t CM ha^{-1} on Andosols and at the rates of 46 kg N, 40 kg P and 20 t CM ha^{-1} on Vertisols, but the lightest clove weights were obtained from the non-fertilized plants on both soils. The largest mean clove weight in response to these two combinations was improved by 49% and 52% over their respective lowest mean clove weight produced on the control plot on both soils, respectively. However, the mean clove weight produced on Andosols was significantly higher by 5% as compared to that of Vertisols (Table 7).

Bulb yield

All the main and interaction effects of the applied N, P and CM significantly influenced garlic bulb yield on both soils (Tables 5 and 7). Wide range of variability in bulb yield due to applied fertilizers was observed on the two soils. It ranged from 5.13 t ha^{-1} (control) to 10.75 t ha^{-1} (46 kg N + 40 kg P + 20 t CM ha^{-1}) with a difference of 5.62 t ha^{-1} on Andosols; and ranged from 5.55 t ha^{-1} (control) to 13.28 t ha^{-1} (46 kg N + 20 kg P + 20 t CM ha^{-1}) with a difference of 7.73 t ha^{-1} on Vertisols (Table 7). There was a yield advantage of 110% and 139% between the highest and the lowest yields obtained from Andosols and Vertisols, respectively. Among the different interactions of applied fertilizers, combined application of the above rates of N, P and CM produced significantly higher bulb yields than any other factors or their combinations on both soils. Similarly, plants produced without nitrogen had lower bulb yields on both soils as compared to those which received N along with P and/or manure. Moreover, the highest bulb yield produced in response to combined application of 46 kg N, 40 kg P and 20 t CM ha^{-1} was in statistical parity with those produced with the combined application of 46 kg N, 20 kg P and 10 t CM ha^{-1} on Andosols. In addition, a combined application of 46 or 92 kg N ha^{-1} and 20 or 40 kg P ha^{-1} along with both 10 and 20 t CM ha^{-1} on Vertisols produced significantly higher bulb yields of garlic (Table 7).

Bulb yields produced on the two soils showed significant variation. Application of the best combination rates of N, P, and CM (46 kg N ha^{-1}, 20 kg P ha^{-1} and 20 t CM ha^{-1}) improved the bulb yield produced on Vertisols by 57% than the yield produced on Andosols (Table 7). Moreover, the mean bulb yield produced on Vertisols was increased by 21% than the mean bulb yield produced on Andosols (Table 7).

Economic Benefits

The economically viable treatment combination, partial budget, and dominance analysis followed by marginal and sensitivity analysis of cost-undominated treatments showed significant variation in response to the application of integrated organic and inorganic fertilizers (Tables 8 – 10). It was observed that performance of different fertilizers has increased the cost of economics of crop, gross and net returns, and benefit cost ratio (B: C). Partial budget analysis revealed that the highest gross return of Ethiopian Birr 134,810 ha^{-1} along with highest net return (124,383 Birr ha^{-1}) and benefit cost ratio of 12.93 were obtained from fertilizers combination of 46 kg N, 20 kg P and 10 t CM ha^{-1} on Andosols. Moreover, the respective values for Vertisols were 169,278 Birr ha^{-1}, 154,151 Birr ha^{-1} and 11.19, by the combined application of 46 kg N, 20 kg P and 20 t CM ha^{-1} (Table 8). Although the treatment 46 kg N, 40 kg P and 20 t CM ha^{-1} on Andosols gave the highest yield of garlic as well as gross and net returns, this treatment was not profitable because of high cost of investment and lower benefit cost ratio.

Dominance analysis showed that combined application of 46 kg N, 20 kg P and 10 t CM ha^{-1} on both soils gave the highest marginal rate of return than the other fertilizer treatments (Table 9). Sensitivity analysis, depending on the price fluctuation of both the inputs and bulb yield of garlic showed that the maximum marginal rate of return (MMR) of 1119.49% was obtained on Andosols when garlic plant was fertilized with 46 kg N, 20 kg P and 10 t CM ha^{-1}, whereas MRR of 985.95% was obtained when 46 kg N, 20 kg P and 20 t CM ha^{-1} combination was applied on Vertisols (Table 10). These two treatments on both soils produced higher yields, gross and net returns with best marginal rate of return and benefit cost ratios than the other fertilizer treatments.

Table 7. Interaction effect of nitrogen (N), phosphorus (P), and chicken manure (CM) on yield components and bulb yield of garlic on two soil types

Fertilizers			**Bulb weight (g)**		**Bulb diameter (cm)**		**Mean clove weight (g)**		**Bulb yield (t ha^{-1})**	
N (kgha^{-1})	**P (kgha^{-1})**	**CM (t ha^{-1})**	**Andosol s**	**Vertisols**	**Andosols**	**Vertisols**	**Andosol s**	**Vertisol s**	**Andosol s**	**Vertisols**
0	0	0	15.10^{mn}	12.95^{lm}	2.76^{h}	2.88^{l}	1.23^{ij}	1.17^{kl}	5.13^{n}	5.55^{m}
		10	17.48^{h-m}	13.63^{km}	3.11^{fg}	3.20^{gl}	1.48^{ch}	1.28^{ik}	6.02^{kl}	6.82^{jk}
		20	17.67^{g-l}	19.06^{fi}	3.09^{fh}	3.53^{eg}	1.51^{ch}	1.62^{bd}	5.96^{km}	7.13^{j}
	20	0	15.17^{mn}	11.70^{m}	3.03^{gh}	2.95^{kl}	1.45^{di}	1.18^{k}	5.67^{lm}	5.51^{m}
		10	17.31^{h-m}	21.82^{cf}	3.23^{fg}	3.33^{fj}	1.50^{ch}	1.61^{bd}	6.27^{k}	6.89^{jk}
		20	15.89^{k-n}	18.78^{gi}	3.05^{gh}	3.30^{fk}	1.53^{bg}	1.42^{fh}	5.49^{mn}	7.19^{j}
	40	0	14.55^{n}	13.47^{km}	3.07^{gh}	3.14^{hl}	1.41^{fj}	1.21^{jk}	5.53^{ln}	5.75^{lm}
		10	20.53^{c-f}	17.71^{ij}	3.36^{eg}	3.35^{fi}	1.49^{ch}	1.21^{jk}	6.25^{k}	6.39^{kl}
		20	19.96^{d-g}	18.69^{hi}	3.24^{fg}	3.31^{fk}	1.43^{fi}	1.36^{gi}	7.38^{ij}	6.95^{jk}
46	0	0	19.41^{d-h}	15.39^{jl}	3.16^{fg}	2.98^{jl}	1.62^{af}	1.44^{eh}	7.22^{ij}	8.96^{hi}
		10	16.45^{j-n}	20.63^{dh}	3.20^{fg}	3.38^{fh}	1.40^{fj}	1.33^{hj}	7.64^{gi}	10.30^{ef}
		20	19.48^{d-h}	25.17^{b}	3.20^{fg}	3.58^{df}	1.38^{gj}	1.61^{bd}	8.12^{fg}	10.74^{de}
	20	0	15.33^{l-n}	14.47^{km}	3.21^{fg}	3.01^{il}	1.20^{j}	1.17^{kl}	7.39^{ij}	8.56^{i}
		10	21.58^{b-d}	25.30^{ab}	3.92^{ac}	3.90^{cd}	1.66^{ad}	1.44^{eh}	10.57^{ab}	12.08^{bc}
		20	22.96^{bc}	28.13^{a}	3.75^{bd}	4.57^{a}	1.43^{ei}	1.52^{df}	8.44^{ef}	13.28^{a}
	40	0	16.41^{j-n}	15.81^{jk}	3.21^{fg}	3.18^{gl}	1.29^{hj}	1.19^{k}	7.38^{ij}	9.34^{gh}
		10	18.91^{e-i}	23.86^{bc}	4.08^{ab}	3.89^{ce}	1.74^{ab}	1.73^{ab}	10.11^{bc}	11.38^{cd}
		20	21.15^{b-e}	19.92^{di}	3.93^{ac}	4.28^{ab}	1.65^{ae}	1.78^{a}	10.75^{a}	11.63^{bc}
92	0	0	18.51^{f-j}	15.24^{jl}	3.10^{fh}	3.38^{fh}	1.53^{bg}	1.05^{l}	6.98^{j}	9.16^{hi}
		10	19.18^{d-h}	22.64^{bd}	3.36^{eg}	3.65^{df}	1.32^{gj}	1.29^{ik}	8.48^{ef}	9.92^{fg}
		20	18.00^{g-k}	19.03^{fi}	3.42^{df}	3.62^{df}	1.37^{gj}	1.46^{eg}	7.62^{hi}	9.67^{fh}
	20	0	16.56^{i-n}	19.55^{ei}	3.24^{fg}	3.29^{fk}	1.36^{gj}	1.46^{eg}	7.46^{hj}	9.29^{gh}
		10	18.10^{f-k}	21.57^{cg}	3.89^{ac}	4.13^{bc}	1.50^{ch}	1.59^{cd}	8.68^{e}	11.89^{bc}
		20	28.57^{a}	20.26^{di}	4.15^{a}	4.32^{ab}	1.83^{a}	1.66^{ac}	9.66^{cd}	12.17^{b}
	40	0	17.66^{g-l}	15.45^{jl}	3.35^{fg}	3.31^{fk}	1.50^{ch}	1.21^{jk}	8.47^{ef}	9.30^{gh}
		10	18.81^{e-j}	21.95^{ce}	3.69^{ce}	4.10^{bc}	1.52^{bg}	1.40^{fi}	7.94^{gh}	11.43^{cd}
		20	23.04^{b}	22.17^{ce}	4.21^{a}	4.32^{ab}	1.70^{ac}	1.56^{ce}	9.53^{d}	11.94^{bc}
Mean			18.66^{A}	19.05^{A}	3.41^{B}	3.55^{A}	1.48^{A}	1.41^{B}	7.64^{B}	9.23^{A}
CV(%)			8.00	9.10	6.10	6.30	9.20	5.40	3.90	4.80

Means followed by the same letter within a column are not significantly different from each other at 5% level of probability

Table 8. Effect of different levels of nitrogen, phosphorus and chicken manure on cost of production, adjusted yield, gross return, net return and benefit: cost ratio of garlic (var. Tseday) on both Andosols and Vertisols soil types

Fertilizers treatment			Total variable cost (Birr ha^{-1})		Adjusted yield (kg ha^{-1})		Gross return (Birr ha^{-1})		Net benefit (Birr ha^{-1})		Benefit cost ratio (B:C)		Remarks	
N	P	CM	Andosols	Vertisols	Andosols	Vertisols	Andosols	Vertisols	Andosols	Vertisols	Andosols	Vertisols	Andosols	Vertisols
0	0	0	4050	4381	4358	4714	65365	70712	61315	66330	16.14	16.14	UD	UD
		10	4807	5504	5113	5794	76695	86913	71889	81408	15.96	15.79	UD	UD
		20	4819	5870	5068	6060	76020	90899	71200	85029	15.77	15.49	D	UD
	20	0	5492	6635	4822	4772	72335	71579	66843	64943	13.17	10.79	UD	D
		10	6021	7762	5333	5857	79989	87852	73969	80089	13.29	11.32	UD	UD
		20	5456	8114	4667	6107	70002	91605	64545	83491	12.83	11.29	D	UD
	40	0	6389	8943	4701	4888	70516	73317	64126	64374	11.04	8.20	D	D
		10	7009	9563	5309	5427	79636	81405	72628	71842	11.36	8.51	D	D
		20	7957	10131	6270	5911	94052	88664	86096	78532	11.82	8.75	D	UD
46	0	0	6713	9281	6137	7619	92051	114287	85337	105006	13.71	12.31	UD	UD
		10	7104	10457	6498	8756	97465	131338	90362	120881	13.72	12.56	UD	UD
		20	7534	10925	6902	9132	103526	136977	95992	126053	13.74	12.54	UD	UD
	20	0	7858	11159	6282	7273	94223	109089	86364	97930	11.99	9.78	D	D
		10	10427	14059	8987	10265	134810	153977	124383	139918	12.93	10.95	UD	UD
		20	8795	15126	7172	11285	107580	169278	98785	154151	12.23	11.19	D	UD
	40	0	8863	13975	6276	7935	94137	119021	85275	105047	10.62	8.52	D	UD
		10	11074	15712	8596	9676	128941	145137	117867	129426	11.64	9.24	UD	D
		20	11632	16028	9138	9888	137062	148325	125431	132297	11.78	9.25	UD	UD
92	0	0	7531	11638	5930	7788	88948	116820	81417	105181	11.81	10.04	D	UD
		10	8770	12357	7204	8434	108056	126510	99286	114152	12.32	10.24	UD	UD
		20	8150	12277	6478	8220	97168	123297	89018	111019	11.92	10.04	UD	UD
	20	0	8922	13938	6339	7896	95094	118435	86172	104496	10.66	8.50	UD	D
		10	9943	16115	7379	10109	110683	151640	100740	135525	11.13	9.41	UD	UD
		20	10774	16452	8214	10345	123216	155168	112442	138716	11.44	9.43	UD	UD
	40	0	10731	16149	7199	7908	107988	118613	97257	102464	10.06	7.34	D	D
		10	10367	17946	6749	9713	101239	145690	90872	127744	9.77	8.12	D	UD
		20	11678	18470	8101	10149	121516	152235	109838	133765	10.41	8.24	D	D

Where, D = Dominated and UD = Undominated benefits when arranged in an increasing order of the treatments cost; N = Nitrogen (kg ha^{-1}); P = Phosphorus (kg ha^{-1}); CM =Chicken manure (t ha^{-1})

Table 9. Marginal analysis of cost un-dominated fertilizers of nitrogen, phosphorus and chicken manure rates in response to bulb yield of garlic on Andosols and Vertisols

Andosols				**Vertisols**			
Fertilizer combinations (N:P:CM)	**Total cost that vary (Birr ha^{-1})**	**Net benefit (Birr ha^{-1})**	**MRR (%)**	**Fertilizer combinations (N:P:CM)**	**Total cost that vary (Birr ha^{-1})**	**Net benefit (Birr ha^{-1})**	**MRR (%)**
0:0:0	4050	61315	-	0:0:0	4381	66330	-
0:0:10	4807	71889	1396.83	0:0:10	5504	81408	1342.65
0:20:0	5492	66843	6383.33	0:0:20	5870	85029	989.34
0:20:10	6021	73969	1347.07	0:20:10	7762	80089	1343.92
46:0:0	6713	85337	6546.60	0:20:20	8114	83491	966.48
46:0:10	7104	90362	18667.37	46:0:0	9281	105006	12021.30
46:0:20	7534	95992	485833.33	0:40:20	10131	78532	1177.82
92:0:20	8150	89018	1513.99	46:0:10	10457	120881	12990.49
92:0:10	8770	99286	1656.13	46:0:20	10925	126053	1105.13
92:20:0	8922	86172	1520.34	92:0:0	11638	105181	1513.78
92:20:10	9943	100740	1426.84	92:0:20	12277	111019	913.62
46:20:10	10427	124383	55851.67	92:0:10	12357	114152	3916.25
92:20:20	10774	112442	35313.95	46:40:0	13975	105047	1489.19
46:40:10	11074	117867	1808.33	46:20:10	14059	139918	41513.10
46:40:20	11632	125431	1355.56	46:20:20	15126	154151	1333.93
				46:40:20	16028	132297	908.54
				92:20:10	16115	135525	3710.34
				92:20:20	16452	138716	11964.36
				92:40:20	18470	133765	1149.05

Table 10. Sensitivity analysis of garlic production after different practices based on a 15% rise in total cost and fall in garlic price of gross field benefit

Andosols				**Vertisols**			
Fertilizer combinations (N:P:CM)	**Total cost that vary (Birr ha^{-1})**	**Net benefit (Birr ha^{-1})**	**MRR (%)**	**Fertilizer combinations (N:P:CM)**	**Total cost that vary (Birr ha^{-1})**	**Net benefit (Birr ha^{-1})**	**MRR (%)**
0:0:0	4657.50	52117.75		0:0:0	5038.15	56380.50	
0:0:10	5528.05	61105.65	1032.44	0:0:10	6329.60	69196.80	992.40
0:20:10	6924.15	62873.65	126.64	0:0:20	6750.50	72274.65	731.25
46:0:0	7719.95	72536.45	1214.22	46:0:0	10673.15	89255.10	432.88
46:0:10	8169.60	76807.70	949.91	46:0:10	12025.55	102748.90	997.77
46:0:20	8664.10	81593.20	967.75	46:0:20	12563.75	107145.10	816.83
92:0:10	10085.50	84393.10	196.98	46:20:10	16167.85	118930.30	326.99
46:20:10	11991.05	105725.60	1119.49	46:20:20	17394.90	131028.40	985.95

Where, MRR = Marginal rate of return. MRR less than 100% was omitted from sensitivity analysis of garlic production

Note: Cost of TSP = 11.50 Birr kg^{-1}; cost of Urea = 10.00 Birr kg^{-1}; cost of chicken manure = 5.00 Birr kg^{-1}; Fertilizer application = 120.00 Birr 100 kg^{-1} ha^{-1}; cost of harvesting and marketing (cleaning, curing and topping, packing) = 2 person per day at Birr 35.00 per person; packing and its material = 4.00 Birr per 100 kg; transportation = 5.00 Birr 100 kg^{-1}. At the time of dispatch, the price of 1kg garlic ranged from 10-25 Birr and the average (15 Birr kg^{-1}) was used for the calculations. Yield was adjusted by 15% reduction to compromise with the yield produced by farmers.

Discussion

The physical and chemical analysis result showed that, the Andosols and Vertisols have low organic matter content, which is below the rate (3.74%) reported by Roy *et al*. (2006), indicating that low potential of the soils to supply N to plants since organic matter can be used as an index of N availability. Also according to Landon (1991) rating, the experimental soils had lower N, P, S and organic matter. Such findings further signified that the soils required external application of the certain nutrients according to recommendation for the crops grown. Moreover, according to the classification limit set by Marx (1996), the soils had low available P. The low P content of the soils is probably attributed to high P fixing capacity and nutrient mining by the crop from the soil (Negassa *et al*., 2001). This confirmed the findings of Voncir *et al*. (2007) who reported that soil reaction has a great influence on the availability of plant nutrients, which is generally highest between pH 6.0 and 7.5. These properties indicated that the experimental soil had some limitations with regard to its use for crop production. The result of the chicken manure analysis revealed higher content of nitrogen and other nutrients and low cost which encouraged the use of chicken manure for successful growth and yield of garlic through integration with the reduced levels of inorganic fertilizers.

It was observed that the application of organic and inorganic fertilizers in sole had a great influence on the vegetative growth of garlic viz., plant height, neck diameter and leaf area index. The increase in vegetative parameters of garlic due to application of chicken manure or N and P levels may be attributed to availability of more nutrients; especially N. Nitrogen enhances number and dimensions of leaves due to its simulative effect on cell division and enlargement. It also enhances protein synthesis leading to building up of carbohydrates and increases in leaf area and other plant growth characters as also revealed by Mandal *et al*. (1992) that in turn enhanced dry matter accumulation (Rupp and Hubner, 1995). Similarly, availability of more P plays a pivotal role in metabolic processes and it is the main constituent of energy compounds, nucleic acids, phospholipids and co-enzymes. Phosphorus also has favorable effects on root development and formation of carbohydrates. The reason behind the increment in vegetative growth and yield characters due to application of chicken manure might be that the addition of organic fertilizer led to the increase in growth and yield components as a result of the relationship in improving the feed treatment in the root radius from the feed elements, the improvement of soil structure and the increment of some benefit lives in the soil which leads to the improvement of growth and yield character (Gupta and Rathore, 1995). Masarirambi *et al*. (2010) also reported significantly higher plant height, leaf number and leaf area index of red lettuce due to application of chicken manure than bounce back compost, cattle manure and inorganic fertilizers.

Significant increase in weight of cloves, and diameter and length of bulbs contributed to increase in weight of bulbs per plant by the cumulative effects of both the organic and inorganic fertilizers. These yield components were significantly improved with application of 46 kg N, 20 kg P and 10 or 20 t CM ha^{-1} either in sole or in combination over the other rates on both soils. Higher bulb weight and diameter was recorded in the plots received chicken manure with chemical fertilizer as compared to chemical fertilizers alone which might be due to low bulk density, better aggregation and continuous supply of nutrients in manure treated plots, which might be due to higher soil organic matter, nitrogen and other nutrients content in Andosols than that in Vertisols. This might also be due to application of chicken manure with N and P fertilizers that improved soil structure and nutrients content of Vertisols supplementing its lower nutrients content, improved the vegetative growth, and accelerated the photosynthates in storage organs of bulbs (Sharma, 1992). According to the report of Yafan and Barker (2004), the presence of organic matter in both compost and animal manures improves soil physical properties such as aggregation, soil aeration and lower bulk density, insisting surface crust, increased water retention and supply plant nutrients. These might be the case why the bulb weight and diameter of garlic increased on Vertisols by 22.52% and 21.87%, respectively in response to the combined application of 46 kg N, 20 kg P and 20 t CM ha^{-1} as compared to those produced on Andosols with the same rates. The positive effect of organic fertilizers added to soil may also be attributed to stimulating the activity of bacteria, which promotes the availability of N, P and other nutrients in the soil and enhances nutrients absorption by the crop roots (Bertand and Cleyetmarel, 2008). Organic matters supplied by manures not only increase the water holding capacity of the soil but also the portion of water and nutrients available for plant growth, yield and quality, and improve physical properties of soil (Sial *et al*., 2007). Similarly, Bababe *et al*. (1998) showed that organic manure is a supplier of N, P and K in the soil, which also increases the phosphate solublising bacteria in the rhizosphere.

The beneficial effect of organic manure in combination with chemical fertilizers at the combined rates of 46 kg N and 20 kg P ha^{-1} along with both 10 and 20 t CM ha^{-1} in producing higher bulb yield and economic returns of garlic on both soils might be due to the additional supply of plant nutrients as well as improvement in overall physical, chemical and biological properties of soil (Datt *et al*., 2003). It could also be attributed to the fact that after decomposition and mineralization the applied manure supplies more available nutrients directly to plant and supports solubilizing micro-organisms which has positive effect on nutrients uptake. Sharma *et al*. (2003) and Sharma *et al*. (2009) have noted similar improvement in yield of onion due to integrated use of vermicompost and FYM with chemical fertilizer. The highest bulb yields obtained in the availability of manure at both levels with N and P over the low nutrients contained soil (Vertisols) might be attributed to the improving soil structure and soil nutrients of the manure to increase bulb weight and better nutrients uptake leading to higher bulb yield. Similarly, Melaku (2010) obtained the highest total bulb yield of onion with combined application of 80 kg N, 40 kg P and 20 t FYM ha^{-1} and 80 kg N, 20 kg P and 20 t FYM ha^{-1} fertilizers. Teklu *et al*. (2004) reported that application of 61 kg N, 31 kg P and 2 t FYM ha^{-1} produced the highest bulb yield of shallot. Wondimu (2009) also obtained significant interaction of N and FYM on onion bulb yield at 25 kg ha^{-1} and 8 t ha^{-1} combinations. Garlic is a heavy feeder plant and it gives good response to the organic manure as it improves both growth and yields of garlic with chicken fertilizer application through supplying N, Zn, Fe, Mn to the crop (Adewale *et al*., 2011).

Variation in nutrient content of soil and uptake amount by the plant might be the cause for variation in growth and yield, which was clearly observed in plant height, neck diameter and leaf area index per plant. For the maximum production of bulb yield of the crop, maximum LAI is usually necessary and dry matter increases rapidly with larger LAI; it is found to show significant positive correlation with the total bulb yield production and crop growth rate (Reddy, 2004). Akoun (2004) and Gambo *et al*. (2008) also confirmed that manure increases the nutrient status of a soil, which leads to increase in yield of the crop. Also El-Magd *et al*. (2012) reported that the highest garlic yield was produced when chicken manure as compared to those fertilized with farmyard manure, sheep manure, compost and mineral NPK fertilizers fertilized garlic plant over two seasons.

Conclusion

Chicken manure combined with reduced levels of inorganic N and P fertilizers increased plant growth and yields of bulb with good economic benefit of garlic than NP fertilizer alone. The integrated application of 10 or 20 t ha^{-1} chicken manure along with 46 kg N ha^{-1} and 20 kg P ha^{-1} fertilizers increased garlic production and productivity both on Andosols and Vertisols of Debrezeit area compared to a single application of NP fertilizer. Integrating chicken manure into the cropping system substantially reduced the nitrogen and phosphorus requirement (by 50%) for optimum yield and economic return of garlic grown on both Andosols and Vertisols without reducing growth and yield of the crop than the levels used in the previous experiments. Therefore, farmers in the study area could apply 46 kg N ha^{-1} + 20 kg P ha^{-1} + 10/20 kg CM ha^{-1} combinations to attain maximum productivity of the crop for enhanced household income and better livelihoods.

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