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Influence of Combined Application of Inorganic N and P Fertilizers and Chicken Manure on Quality and Shelf-Life of Garlic (*Allium sativum* L.) Bulbs

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Abstract

Crop quality and shelf-life improvement with soil fertility maintenance requires a balanced application of inorganic and organic nutrient sources. Thus, a field experiment was conducted to investigate the effect of chicken manure (CM) combined with reduced levels of nitrogen and phosphorus fertilizers on garlic quality and shelf-life at Debre Zeit Agricultural Research Centre, Ethiopia, on two soil types (Andosols and Vertisols). The treatments consisted of factorial combinations of three levels of nitrogen (0, 46 and 92 kg N /ha), three levels of phosphorus (0, 20 and 40 kg P /ha) and three levels of chicken manure (0, 10 and 20 t CM /ha). The treatments were laid out in a randomized complete block design with three replications at each soil type. Results showed that the main effects of nitrogen, phosphorus, chicken manure and soil type had a positive and significant effect on the evaluated quality parameters in the experiments. The effect of the manure on shelf-life and qualities of garlic bulb were significantly higher in both soils than the mineral N and P fertilizers, but the highest quality of garlic bulb was recorded on Vertisols than on Andosols. The interactions of the applied fertilizers also significantly influenced the quality traits of garlic on both soils. Quality, shelf-life and mineral contents of garlic bulbs were significantly influenced by the interaction effect of fertilizers; the better values being obtained with the combined application of 46 kg N /ha, 20 kg P /ha and 20 t CM /ha on both soils. However, the highest bulb qualities were obtained in the combined application of 46 kg N, 20 kg P and 10 t CM /ha on Andosols. Thus, application of 10 or 20 t /ha CM resulted in a saving of 50% of the recommended levels of both inorganic N and P fertilizers, without reducing the bulb quality of garlic.

Keywords
Bulb quality
Inorganic fertilizer
Chicken manure
Shelf-life
Soil type

INTRODUCTION

From the different vegetable crops produced in the world, garlic (*Allium sativum* L.) is one of the important and ranked second of Allium crops next to common onion as it is produced for economic value, spices and medicinal purposes because of its particular flavor (Brewster, 1994; Fritsch and Friesen, 2002). Garlic is also one of the most widely used crops in Ethiopia. Its production is increasing from time to time, although many garlic producing farmers have limited knowledge of the different agronomic practices influencing both yield and quality of the crop (Getachew and Asfaw, 2000; FAO, 2003). In many areas, lack of available nutrients is frequently one of the limiting factors 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, indicating low N and P status of the soils (Berga et al., 1994; Yohannes, 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) 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 hectares in Ethiopia (Woldeab, 1987). Their poor physical properties such as poor drainage considerably

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restricted the productive potential of crops, which can be improved with organic matter amendments. Andosols (light gray and sandy loam) 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 of black heavy soils (Vertisols) to the red soils (Andosols) in the central highlands of Ethiopia. Despite its importance, the productivity of this crop is low mainly due to many agro-climatic factors and poor agronomic practices of which the growth of plants significantly influenced by poor fertilization (Liu et al., 2004). The use of chemical fertilizers alone might have resulted in a possible depletion of essential micronutrients thereby resulting in an overall reduction in total crop productivity. However, unless it is integrated with inorganic fertilizers, the use of farmyard manure alone may also not fully satisfy crop nutrient demand, especially in the year of application (Patel et al., 2009). Integrated plant nutrient management is a suitable strategy for overcoming the problem of soil fertility as the use of both sources of nutrient exhibits multiple effects, and synchronizes nutrient release and absorption by the plants (Palm et al., 1997). The importance of farmyard manure is being realized because of the high cost of commercial fertilizers and their long term adverse effect on soil chemical properties. Besides supplying macro- and micro-nutrients to the soil, farmyard manure also improves the physical and chemical properties of the soil (Negassa et al., 2001; Tirol-Padre et al., 2007). Animal manures are useful in improving the efficiency of fertilizer recovery, thereby resulting in higher crop yield (Gedam *et al.*, 2008). Nutrient contents in the plants also increase under integrated use of organic manures and chemical fertilizers. It is inferred that NPK contents in plant leaves and grains can be increased by integrating the nitrogen from organic and inorganic sources. Phosphorus, potassium, calcium, magnesium, copper, iron, zinc and manganese concentrations are become higher with organic manuring against mineral fertilizers. Moreover, contents of organic matter and concentrations of N, P, K and S in soil are enhanced with organic manuring (Sial et al., 2007).
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. It is also used to maintain the nutrient balance between the supplied nutrient and nutrient removed by plant, and to improve soil health and productivity on a sustainable basis (Sial et al., 2007). The use of organic manures like farmyard manure, vermicompost and poultry manure along with chemical fertilizers will reduce the cost of production and supplement the secondary and micronutrients to the crop (Barker, 1975). 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 indicated 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 FYM and 10-20 t/ ha cattle manure to sorghum and potato crops, respectively, without significantly affecting the optimum possible yield that can be obtained with the application of full doses of inorganic NP fertilizers alone. Joy et al. (2005) reported that the possibility of substituting up to 25% inorganic fertilizers with the application of 30 t/ ha FYM while still maintaining the highest rhizome yield and quality of black musli (*Carculigo orchioides*). Farmyard manure had also a long-term effect in that the following crop in sequential cropping also benefits from the application (Sidhu et al., 2007).

Animal manures have been used for plant production effectively for centuries. Chicken manure has long been recognized as perhaps the most desirable of these fertilizers because of its high nitrogen content (Eliot, 2005; Ghanbarian et al., 2008). The chicken manure seems to be directly responsible in increasing crop yields of garlic either by accelerating the metabolic process by increasing cell permeability by hormone growth action or by a combination of all these processes (Islah, 2010). It supplies different nutrients and improves the 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, the present study was designed to assess the influence of integrated use of chicken manure and inorganic N and P fertilizers on quality and shelf-life of garlic bulbs under Andosols and Vertisols soil types in the mid altitude area of Debre Zeit, Ethiopia.

MATERIALS AND METHODS

Experimental site and materials

The experiment was conducted at Debre Zeit Agricultural Research Centre, which is found at 08°44"N latitude, 38°58"E longitude with an altitude of 1860 meters above sea level in central

Ethiopia on two major soil types of the area (Andosols and Vertisols) during the main rainy season of 2013. The area has a mean annual maximum and minimum temperatures of 27 °C and 10 °C respectively, with a sub-humid tropical climate type. It has a mean annual rainfall of about 888 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 past two consecutive cropping seasons. The physical and chemical properties of the experimental soils and chemical contents of the applied chicken manure were analyzed following their respective procedures 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.

Table 1. Selected 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)**	**C:N Ration**	**Organic matter (%)**	**EC (ds/ m)**	**pH (1:25 H_2O)**
Andosols	0.153	23.41	18.60	9.54	2.51	1.25	7.22
Vertisols	0.085	18.84	15.80	12.00	1.75	0.83	6.98
Chicken manure	3.57	53.31	25.91	9.35	51.23	3.10	8.19

	Exchangeable cations (cmol(+) /kg)				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

Source: Laboratory Analysis of the experimental soils at DZARC Soil Laboratory Unit

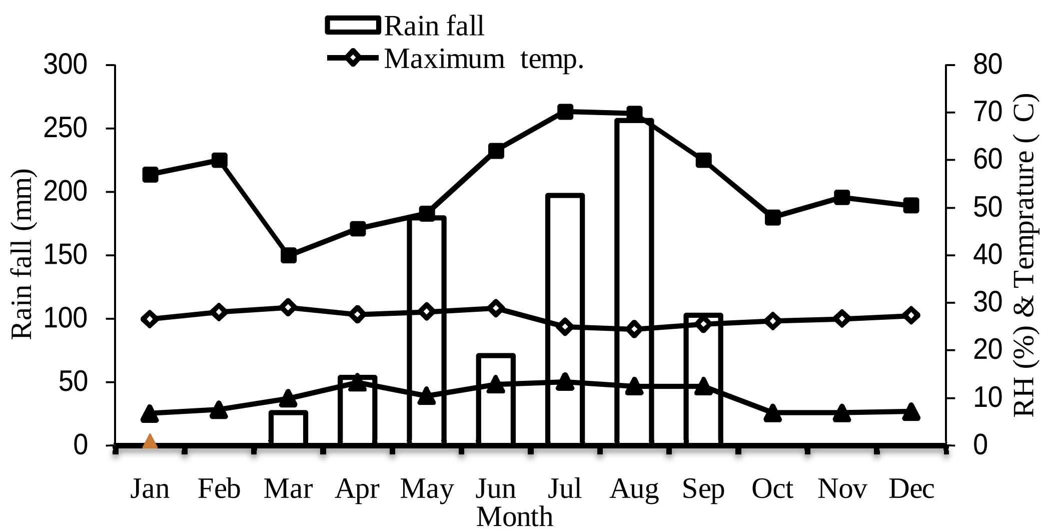

Figure 1. Monthly rainfall, mean relative humidity (RH), and maximum and minimum temperatures of the study area for the period 2012/13 crop season

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 at each site. The area of each plot was 3.6 m^2 (1.8 m x 2 m) with a spacing of 10 cm between plants and 30 cm between the rows. The plot consisted six rows with 20 plants per row, which comprised 120 plants per plot. A distance of 1 m between plots and 1.5 m between blocks was maintained.

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 size cloves were planted on ridges of about 20cm height at a depth of 4cm on Andosols and 2cm on Vertisols. Harvesting was done from the four central rows, leaving side rows to reduce border effect. Other crop management practices were carried out as per the recommendations of DZARC (Getachew and Asfaw, 2000).

In the first experiment, 92 kg/ha nitrogen and 40 kg/ha phosphorus were recommended for maximum yield and quality of garlic production on both Andosols and Vertisols; depending on the two nutrients interaction result (without sulphur). Consequently, for the 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 and 0, 20 and 40 kg P /ha on both soils; integrated with three levels of chicken manure (0, 10 and 20 t /ha). 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

Bulb quality parameters were determined following procedure of Bussard and Randle (1993) for pungency, and Waskar et al. (1999) for total soluble solid (TSS). Dry matter percentage was determined after harvest by weighing both fresh and oven dried bulb weights and multiplied by 100. Weight loss percentage of bulbs was calculated after three months of storage as differences between the initial and final weight divided by initial weight and multiplied by 100. Protein content of garlic bulb was determined in terms of the nitrogen concentration of garlic bulb (Nitrogen x 6.25) (AOAC, 1994).

Manure, soil, and plant tissue 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 and pH. Auger samples of 0-30 cm depth from both the experimental sites were taken before planting the cloves at random to represent the whole plot and then composited and divided into five representative 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 the respective procedures of Bouyoucos (1962) and Jackson (1967) (Table 1).

At the time of harvest, bulb samples were collected, finely ground and oven dried at 65°C for 48 hours to determine the chemical composition of bulb tissues. Total N was determined using the modified micro Kjeldhal method (Cottenie et al., 1982) and P by colorimetric method using a spectrophotometer (Olsen et al., 1954).

Potassium content was measured using flame photometer method as described by Chapman and Pratt (1982). Sulphur content was determined turbidimetrically using a spectrophotometer method (Chesnin and Yien, 1951).

Statistical analysis

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 the 5 % level of probability.

RESULTS

Physical and chemical properties of the experimental soils

The physical and chemical properties of the soils have 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 was higher than that in Vertisols. In addition, according to the rating of Hazelton and Murphy (2007), the organic matter and N content of Andosols was low and that of Vertisols was very low. While, available P of both soils was categorized within low ranges rated by Holford and Cullis (1985) cited in Hazelton and Murphy (2007). In addition, the exchangeable K content of both soils was high, according to Hazelton and Murphy (2007). The sulphate-S content of both soils was low, according to the rating of Bashour (2001) cited in Bashour and Sayegh (2007), when it is between 10 and 20 mg/kg soil. The contents of organic matter, K, Na, Cu, Fe and Zn were higher in Andosols as compared to Vertisols. The analysis of the chicken manure used for the study as presented in Table 6.1 gave 3.57% of nitrogen, 53.31 ppm of available P, 2.55 cmol(+) /kg manure of exchangeable K, 25.91 mg/kg manure of sulphate-S and 51.23% of organic matter. The nutrient content of the manure was higher as compared with that of the soil; because of that, it was used through integrating with the reduced levels of both inorganic nitrogen and phosphorus fertilizers.

Bulb quality indices

The main effect of nitrogen, phosphorus and chicken manure, on both soil types, significantly ($P \leq 0.01$) influenced all quality parameters of the garlic crop, i.e., bulb dry matter, total soluble solid (TSS), pungency, protein content and weight loss of garlic bulb (Table 2). In addition, the interaction effect of N and P significantly affected bulb protein content and weight loss on both soils and pungency on Andosols, and the interaction of N and CM significantly affected bulb protein content of both soils, and pungency and weight loss on Andosols. Moreover, the interaction effect of P and CM significantly influenced both protein and pungency of bulbs on the two soils, and bulb weight loss on Vertisols. Furthermore, the three factors interaction effect of N x P x CM significantly influenced all quality parameters studied on both Andosols and Vertisols (Table 2).

Table 2. Mean square values for 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	NxPxCM
Dry matter	Andosols	67.94***	22.95*	196.70***	13.23ns	14.65ns	9.79ns	14.20*
	Vertisols	120.40***	172.16***	133.34***	5.23ns	11.66ns	18.32ns	9.31*
Protein	Andosols	117.36***	32.67**	52.82***	10.67*	9.29*	7.00*	5.69*
	Vertisols	163.53***	67.22***	82.49***	13.29**	6.44*	14.99**	6.88*
TSS	Andosols	12.57*	22.43***	33.08***	5.47ns	0.99ns	3.495ns	8.29**
	Vertisols	49.16***	24.17**	148.12***	1.71ns	2.68ns	4.63ns	8.54*
Pungency	Andosols	206.56***	16.02**	192.10***	13.48***	8.36**	23.89***	23.13***
	Vertisols	70.89***	34.61***	155.35***	4.32ns	1.06ns	12.18***	5.39**
Weight loss	Andosols	429.38***	148.93***	213.70***	43.76***	34.29**	14.24ns	15.49*
	Vertisols	229.78***	213.78***	289.83***	33.83*	19.10ns	66.74***	73.96***

Where, ns, indicate non-significant, and *, **, ***, indicate significant at 0.05, 0.01 and 0.001 level of probability, respectively

Combined application of 46 or 92 kg N /ha along with 40 kg P /ha and 20 t CM /ha produced highest dry matter contents of 34.34% and 36.61%, respectively on Vertisols (Table 3). The highest dry matter produced at these two combinations of fertilizers on Vertisols was improved by 53% and 29%, respectively as compared to those produced on Andosols. But, the applied fertilizers at the combined rates of 46 kg N /ha, 40 kg P and 10 t CM /ha produced bulbs contained highest dry matter (28.90%) on Andosols. Bulbs with lower dry matter were produced in the control plots of both soils. Higher percent of dry matter was produced on Vertisols as compared to Andosols at each fertilizer rate with significantly improved mean bulb dry matter by 25% on Vertisols than on Andosols (Table 3). The highest protein content of garlic bulb was produced by the combined application of 46 kg N, 20 kg P and 20 t CM /ha resulting in 24.79% and 22.51% protein on Andosols and Vertisols respectively (Table 3). In addition, garlic plants fertilized with combined rates of 46 kg N /ha, 40

Table 3. Interaction effect of inorganic N (kg /ha) and P (kg /ha) fertilizers, and chicken manure (CM) (t /ha) on bulb qualities of garlic on two soil types

Fertilizers			Bulb dry matter (%)		Protein (%)		TSS (^{0}Brix)		Pungency (µ.mol ml^{-1})		Weight loss (%)	
N	P	CM	Andosols	Vertisols	Andosols	Vertisols	Andosols	Vertisols	Andosols	Vertisols	Andosols	Vertisols
0	0	0	15.90^{m}	20.25^{j}	16.43^{lm}	13.36^{i}	23.37^{g}	25.87^{h}	6.99^{n}	6.71^{q}	22.61^{a}	29.97^{a}
		10	18.95^{i-m}	21.58^{ij}	17.22^{lm}	14.55^{hi}	30.47^{a-e}	30.03^{e-g}	10.59^{i-l}	9.04^{op}	21.83^{ab}	11.79^{e-i}
		20	20.09^{g-l}	25.26^{f-i}	18.03^{j-l}	14.75^{g-i}	29.57^{c-f}	32.27^{b-f}	12.59^{g-i}	12.24^{h-k}	13.75^{e-h}	15.26^{c-f}
	20	0	18.54^{j-m}	25.66^{f-i}	16.86^{lm}	13.95^{hi}	29.70^{c-f}	29.03^{f-h}	7.59^{mn}	9.31^{n-p}	17.45^{c-e}	18.35^{b-d}
		10	22.90^{c-h}	23.40^{g-j}	15.47^{m}	14.10^{hi}	29.13^{d-f}	30.27^{e-g}	8.33^{l-n}	12.91^{g-j}	13.81^{e-h}	10.51^{f-k}
		20	20.67^{f-l}	28.19^{c-f}	17.29^{k-m}	14.91^{g-i}	31.93^{a-c}	32.33^{b-f}	8.26^{l-n}	14.44^{d-g}	10.63^{h-k}	9.48^{g-l}
	40	0	22.44^{d-j}	25.14^{f-i}	16.46^{lm}	13.74^{hi}	30.37^{a-f}	29.13^{e-h}	9.46^{j-m}	8.78^{pq}	17.55^{b-e}	13.46^{d-h}
		10	22.50^{d-i}	28.36^{c-f}	18.62^{g-l}	14.88^{g-i}	30.37^{a-f}	32.13^{b-f}	14.33^{e-g}	11.64^{i-m}	18.37^{a-d}	19.24^{bc}
		20	21.51^{e-k}	30.74^{b-e}	20.98^{c-g}	21.27^{ab}	29.73^{c-f}	32.07^{c-f}	11.33^{h-j}	11.98^{h-k}	16.72^{c-e}	15.84^{c-e}
46	0	0	19.16^{h-m}	27.65^{c-g}	17.51^{k-m}	15.85^{e-i}	30.03^{a-f}	31.40^{d-f}	11.73^{h-j}	11.51^{j-m}	19.98^{a-c}	13.85^{d-g}
		10	23.57^{c-g}	29.27^{c-f}	18.22^{i-l}	16.01^{e-h}	29.67^{c-f}	32.17^{b-f}	15.26^{c-f}	11.31^{j-n}	12.05^{f-j}	12.29^{e-i}
		20	24.15^{b-f}	26.91^{d-h}	18.52^{h-l}	15.68^{e-i}	31.03^{a-e}	31.23^{d-f}	13.53^{f-h}	11.91^{h-k}	16.20^{c-f}	11.61^{e-i}
	20	0	20.99^{f-l}	25.53^{f-i}	16.94^{lm}	16.25^{e-h}	30.40^{a-f}	27.73^{gh}	9.39^{j-m}	9.71^{l-p}	15.32^{d-g}	17.53^{b-d}
		10	23.36^{c-g}	29.56^{c-f}	22.76^{a-d}	20.80^{ab}	32.43^{ab}	34.23^{a-d}	18.93^{a}	13.78^{e-i}	4.13^{m}	7.44^{i-l}
		20	23.93^{b-g}	31.13^{b-d}	24.79^{a}	22.51^{a}	32.57^{a}	35.93^{a}	18.39^{ab}	15.91^{a-e}	8.51^{i-l}	7.41^{i-l}
	40	0	17.29^{lm}	28.85^{c-f}	18.14^{j-l}	15.51^{f-i}	27.83^{f}	29.70^{e-g}	16.86^{a-d}	9.46^{m-p}	11.29^{g-k}	12.35^{e-i}
		10	28.90^{a}	31.85^{bc}	22.38^{b-e}	21.95^{a}	29.87^{b-f}	35.50^{ab}	17.93^{ab}	16.12^{a-d}	8.07^{j-m}	5.76^{kl}
		20	26.65^{a-c}	34.34^{ab}	23.14^{a-c}	20.65^{a-c}	31.33^{a-d}	36.27^{a}	16.86^{a-d}	17.32^{ab}	5.12^{lm}	6.54^{j-l}
92	0	0	20.60^{f-l}	22.99^{h-j}	20.57^{d-i}	17.20^{d-g}	28.53^{ef}	29.90^{e-g}	16.33^{b-e}	11.66^{i-l}	13.94^{e-h}	17.83^{b-d}
		10	22.24^{d-j}	28.94^{c-f}	19.66^{f-k}	17.95^{d-f}	29.83^{c-f}	32.23^{b-f}	14.66^{d-g}	13.19^{f-j}	7.40^{k-m}	21.95^{b}
		20	26.05^{a-d}	26.00^{f-i}	20.70^{d-h}	18.12^{c-e}	30.90^{a-e}	32.47^{b-e}	11.59^{h-j}	13.92^{e-h}	8.56^{i-l}	8.66^{h-l}
	20	0	18.91^{i-m}	26.33^{e-h}	20.12^{e-j}	19.14^{b-d}	30.67^{a-e}	30.77^{e-g}	8.93^{k-n}	11.19^{j-o}	12.42^{f-i}	15.43^{c-f}
		10	27.72^{ab}	28.24^{c-f}	24.11^{ab}	22.85^{a}	31.07^{a-e}	35.30^{a-c}	17.65^{ab}	15.32^{b-f}	7.67^{k-m}	8.45^{i-l}
		20	25.52^{a-d}	28.72^{c-f}	22.77^{a-d}	22.76^{a}	31.90^{a-c}	34.47^{a-d}	17.76^{ab}	17.66^{a}	6.17^{lm}	5.27^{l}
	40	0	18.16^{k-m}	25.94^{f-i}	21.04^{c-f}	17.24^{d-g}	29.77^{c-f}	29.43^{e-g}	9.46^{j-m}	10..66^{k-p}	11.07^{g-k}	8.47^{i-l}
		10	25.28^{a-e}	32.15^{a-c}	22.72^{a-d}	21.67^{ab}	31.67^{a-d}	35.03^{a-c}	17.46^{a-c}	16.79^{a-c}	5.98^{lm}	6.20^{j-l}
		20	23.96^{b-g}	36.61^{a}	22.40^{b-d}	21.89^{a}	31.03^{a-e}	34.57^{a-d}	18.46^{ab}	15.06^{c-g}	10.69^{h-k}	10.99^{e-j}
Mean			22.22	27.76	19.48	17.76	30.19	31.91	13.14	12.58	12.49	12.66
CV (%)			10.80	10.00	7.40	8.90	5.20	6.50	10.90	10.60	21.00	23.90

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

kg P /ha and 10 t CM /ha; 92 kg N, 20 kg P and 10 t CM /ha; 92 kg N, 20 kg P and 20 t CM /ha; and 92 kg N, 40 kg P and 20 t CM /ha resulted in 21.95%, 22.85%, 22.76% and 21.89% protein respectively on Vertisols. The lowest protein content bulb was produced in the control plots of both soils. In contrast to dry matter content, protein content of bulbs was significantly increased by 10% on Andosols as compared to those produced on Vertisols (Table 3).

The various interaction effects of nitrogen, phosphorus and chicken manure were found to be significant with respect to total soluble solid (TSS) in all the treatment combinations on both soils. Consequently, the highest total soluble solid (32.57% and 35.93% on Andosols and Vertisols, respectively) were recorded from bulbs fertilized with a combination of 46 kg N, 20 kg P and 20 t CM /ha. In addition, a combined application of 46 kg N, 40 kg P and 20 t CM /ha produced highest TSS on Vertisols, which is in statistical parity with the former combination of the same soil. The combined application of the three fertilizers significantly increased the bulb TSS on both soils. On the other hand, bulbs with the lowest TSS were produced in the control plots on both soils. Application of integrated fertilizers improved TSS of bulbs on Vertisols as compared to those produced on Andosols (Table 3).

Significant differences in the pungency of garlic bulbs were recorded with the application of varying levels of nitrogen, phosphorus and chicken manure interaction (Table 3). The pyruvate content of garlic bulb was increased from 6.99 µmol /ml (control) to 18.93 µmol /ml with the application of 46 kg N, 20 kg P and 10 t CM /ha on Andosols, and from 6.71 µmol /ml (control) to 17.66 µmol /ml with the application of 92 kg N, 20 kg P and 20 t CM /ha on Vertisols. However, the bulbs contained higher pyruvates were produced on Andosols when 46 kg N /ha and 20 kg P /ha was combined with both 10 and 20 t CM /ha which significantly improved by 37% and 15%, respectively as compared to the pyruvate content of bulbs produced on Vertisols. Application of these three fertilizers together increased bulb pungency over the control by 171 and 163% on Andosols and Vertisols, respectively. Like protein content, pungency of bulbs showed a slight increase on Andosols as compared to on Vertisols (Table 3).

The applied fertilizers during growth in both soil fields significantly influenced weight losses of garlic bulbs in storage (Table 3). The largest bulb weight loss (22.61 and 29.97%) was recorded from bulbs of the plants grown on unfertilized plots on Andosols and Vertisols, respectively. Generally, more weights of bulbs were reduced within three months of storage time due to the absence of one or two nutrients during growth of the crop. However, the plots received both inorganic N and P fertilizers in addition to chicken manure at optimum rates had lower losses of bulb weights in the storage. The minimum bulb weight loss was measured in garlic produced by a combined application of 46 kg N, 20 kg P and 10 t CM /ha on Andosols (4.13 %) and 92 kg N, 20 kg P and 20 t CM /ha on Vertisols (5.27 %). At these combined rates of the fertilizers the weight losses of bulbs were reduced by 447% and 468% on Andosols and Vertisols, respectively as compared to the highest bulb weight losses recorded. The bulb weight loss in storage did not show significant variation due to the soil types on which the crop was produced (Table 3).

Relationships between bulb quality parameters

Correlation coefficient values (r) computed to display the relationships between and within main bulb quality attributes of garlic showed apparent relationship on both soil types (Table 4). The result of correlation analysis on both Andosols and Vertisols indicated that bulb quality parameters had a positive and significant ($P \leq 0.01$) correlation with each other except negatively correlated with bulb weight loss. Bulb weight loss of garlic in storage was negatively correlated with all other bulb quality attributes on both soils. There were also significant and positive correlations between dry matter, pungency, TSS and protein contents of the garlic bulb on both soil types (Table 4).

Table 4. Correlation coefficient for the bulb quality attributes considered on Andosols and Vertisols

Parameters	Soil	TSS	Pung	Protein	WL
DM	Andosols	0.454***	0.570***	0.558***	-0.456***
	Vertisols	0.619***	0.553***	0.560***	-0.393**
TSS	Andosols		0.378**	0.444***	-0.440***
	Vertisols		0.719***	0.633***	-0.530***
Pungency	Andosols			0.724***	-0.570***
	Vertisols			0.714***	-0.636***
Protein	Andosols				-0.593***
	Vertisols				-0.529***

Where no asterisk indicates non-significant; and * and **, indicate significant difference at 5% and 1%, levels of probability, respectively. DM=Dry matter (%); TSS = Total soluble solid; Pung =Pungency; Protein=Protein (%); WL =Weight loss (%).

Table 5. Mean square values for nutrient concentrations of garlic bulb affected by the main and interaction effects of nitrogen (N), phosphorus (P) and chicken manure (CM) on two soils

Factors	d.f.	Mean square of bulb nutrient concentrations (%)							
		Nitrogen		Phosphorus		Potassium		Sulphur	
		A	V	A	V	A	V	A	V
N	2	3.01***	4.19***	0.061***	0.036**	7.26***	2.98***	2.18***	4.02***
P	2	0.84**	1.72***	0.067***	0.074***	3.29***	3.99***	1.46***	2.58***
CM	2	1.35***	2.11***	0.014**	0.013*	7.36***	3.09***	1.75***	3.93***
N x P	4	0.27*	0.34**	0.046***	0.053***	0.73***	0.73***	0.18*	0.45**
N x CM	4	0.24*	0.17*	0.015***	0.008ns	0.39***	0.44**	0.09ns	0.17ns
P x CM	4	0.18*	0.38**	0.013***	0.026**	0.44***	0.23**	0.152*	0.17ns
N x P x CM	8	0.15*	0.18*	0.014***	0.013**	0.48***	0.27**	0.154*	0.20*
Error	52	0.054	0.063	0.0011	0.005	0.026	0.106	0.045	0.130
CV (%)		7.58	7.50	10.40	16.98	8.10	9.72	22.74	20.38

Where, *, ** and *** shows significant difference at P = 0.05, 0.01 and 0.001, respectively; ns = non-significant; d.f. = degrees of freedom; TSS = Total soluble solid; A = Andosols; V = Vertisols

Bulb tissue nutrient concentrations

The main and two factor interaction effects of applied nitrogen, phosphorus and chicken manure (CM) significantly influenced the concentration of N, P, K, and S in garlic bulb on both Andosols and Vertisols. Only the interaction effect of N and CM did not show significant effect on phosphorus concentration in bulb harvested from Vertisols and sulphur concentration of bulb harvested from both soils, and the interaction effect of P and CM on sulphur concentration on Vertisols. Moreover, N, P, K and S concentrations of bulb were significantly ($P \leq 0.05$) influenced by the three factors interaction effect of the fertilizers (Table 5).

Results showed that bulb N and P concentrations were significantly increased in plants that received a combination of 46 kg N /ha, 20 kg P /ha and 20 t CM /ha. Bulb tissue K and S concentrations were significantly increased in garlic plants fertilized with a combination of 92 kg N /ha, 20 kg P /ha and 20 t CM /ha over the other fertilizer treatments on both soils (Table 6). In addition, nitrogen concentration in the bulb was significantly increased by a combined application of 92 kg N /ha, 20 kg P /ha and 10 or 20 at CM /ha on both soils, and the lowest was recorded from the plants grown without fertilizer application at all on Vertisols or when the plant fertilized with 0 kg N, 20 kg P and 10 t CM /ha on Andosols. The lowest P concentration in bulbs was recorded in response to the combined application of 92 kg N, 0 kg P and 20 t CM /ha and 46 kg N, 0 kg P and 20 t CM /ha on Andosols and Vertisols respectively (Table 6). Similarly, the lowest K and S concentrations were obtained from plants produced without any fertilizer application. On the other, in the case of no applied N, P or CM fertilizer or in their combinations, the concentration of N, P, K and S in the garlic bulb was significantly low.

Soil type also significantly influenced the nutrients (N, K and S) content of garlic bulb. Generally, garlic bulbs with 11% higher in N concentration were produced on Andosols than on Vertisols while bulbs with 36% and 50% higher in K and S concentrations, respectively were produced on Vertisols as compared to Andosols. However, the P concentration of garlic bulb was not significantly differed due to the effect of soil type (Table 6).

Table 6. The interaction effect of nitrogen (kg /ha), phosphorus (kg /ha) and chicken manure (t /ha) on nutrient concentrations (%) of garlic bulb grown on Andosols and Vertisols

Fertilizers			Nutrient concentration (%)							
N	P	CM	Nitrogen		Phosphorus		Potassium		Sulphur	
			Andosols	Vertisols	Andosols	Vertisols	Andosols	Vertisols	Andosols	Vertisols
0	0	0	2.63^{kl}	2.14^{i}	0.272^{b}	0.283^{bd}	0.54^{q}	0.73^{i}	0.23^{j}	0.36^{i}
		10	2.75^{kl}	2.33^{gi}	0.269^{b}	0.288^{bd}	0.98^{k-n}	1.67^{h}	0.60^{g-i}	0.99^{ei}
		20	2.88^{i-k}	2.36^{fi}	0.290^{b}	0.269^{bd}	0.82^{m-p}	1.96^{fh}	0.55^{g-j}	0.83^{fi}
	20	0	2.70^{kl}	2.23^{hi}	0.292^{b}	0.242^{d}	0.75^{n-q}	1.54^{h}	0.55^{g-j}	0.80^{gi}
		10	2.47^{l}	2.26^{hi}	0.297^{b}	0.307^{bd}	1.58^{hi}	2.04^{eh}	0.54^{h-j}	1.10^{ei}
		20	2.77^{j-l}	2.39^{fi}	0.298^{b}	0.270^{bd}	0.89^{l-o}	2.05^{eh}	0.56^{g-j}	0.84^{fi}
	40	0	2.63^{kl}	2.20^{hi}	0.288^{b}	0.349^{bd}	0.70^{o-q}	1.71^{h}	0.51^{ij}	0.67^{hi}
		10	2.98^{f-k}	2.38^{fi}	0.272^{b}	0.275^{bd}	1.26^{jk}	1.82^{gh}	0.75^{g-i}	1.27^{ch}
		20	3.36^{b-e}	3.40^{ab}	0.282^{b}	0.258^{bd}	1.93^{g}	3.15^{ab}	1.19^{d-f}	1.56^{ch}
46	0	0	2.80^{j-l}	2.54^{ei}	0.286^{b}	0.267^{bd}	0.73^{n-q}	1.74^{h}	0.58^{g-j}	0.98^{ei}
		10	2.91^{h-j}	2.56^{ei}	0.282^{b}	0.268^{bd}	1.31^{ij}	1.63^{h}	0.74^{g-i}	1.25^{ci}
		20	2.96^{g-k}	2.51^{ei}	0.298^{b}	0.237^{d}	0.61^{pq}	1.58^{h}	0.69^{g-i}	1.61^{bg}
	20	0	2.71^{kl}	2.60^{eh}	0.281^{b}	0.279^{bd}	1.08^{j-m}	1.82^{gh}	0.64^{g-i}	1.25^{ci}
		10	3.64^{a-c}	3.33^{ac}	0.640^{a}	0.616^{a}	2.05^{fg}	2.33^{cg}	1.42^{a-d}	2.10^{ad}
		20	3.97^{a}	3.60^{a}	0.626^{a}	0.604^{a}	2.88^{ab}	2.74^{bc}	1.60^{a-c}	2.15^{ac}
	40	0	2.90^{i-k}	2.48^{ei}	0.283^{b}	0.346^{bd}	1.07^{j-m}	2.32^{cg}	0.86^{f-i}	1.13^{ei}
		10	3.58^{a-d}	3.51^{a}	0.291^{b}	0.273^{bd}	2.58^{cd}	2.49^{cf}	1.19^{d-f}	1.71^{af}
		20	3.70^{ab}	3.30^{ac}	0.283^{b}	0.309^{bd}	2.28^{ef}	2.60^{cd}	1.25^{c-e}	2.04^{ad}
92	0	0	3.29^{c-h}	2.75^{dg}	0.273^{b}	0.253^{bd}	1.11^{j-l}	1.69^{h}	0.73^{g-i}	0.94^{fi}
		10	3.15^{e-j}	2.87^{de}	0.273^{b}	0.248^{cd}	2.22^{ef}	2.50^{ce}	0.88^{f-h}	1.28^{ch}
		20	3.31^{c-g}	2.90^{ce}	0.266^{b}	0.268^{bd}	2.32^{d-f}	2.04^{eh}	0.90^{e-g}	1.02^{ei}
	20	0	3.22^{d-i}	3.06^{bd}	0.295^{b}	0.302^{bd}	1.59^{h}	2.54^{ce}	0.69^{g-i}	1.20^{di}
		10	3.86^{a}	3.66^{a}	0.292^{b}	0.363^{bd}	2.40^{c-e}	3.32^{a}	1.70^{ab}	2.48^{ab}
		20	3.64^{a-c}	3.64^{a}	0.272^{b}	0.336^{bd}	3.02^{a}	3.40^{a}	1.76^{a}	2.59^{a}
	40	0	3.37^{b-e}	2.76^{df}	0.268^{b}	0.339^{bd}	1.29^{j}	2.07^{dh}	0.89^{f-h}	1.11^{ei}
		10	3.64^{a-c}	3.47^{ab}	0.304^{b}	0.400^{b}	2.22^{ef}	2.48^{cf}	1.50^{a-d}	2.10^{ad}
		20	3.58^{a-d}	3.50^{a}	0.258^{b}	0.391^{bc}	2.61^{bc}	2.59^{cd}	1.41^{b-d}	1.86^{ae}
Mean			3.16	2.84	0.31	0.32	1.58	2.17	0.92	1.38
LSD (5%)			0.381	0.413	0.049	0.115	0.263	0.533	0.346	0.591
CV (%)			7.58	7.50	10.40	16.98	8.10	9.72	22.74	20.38

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

DISCUSSION

The physical and chemical analysis of the experimental fields 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 the low potential of the soils to supply N to plants since organic matter can be used as an index of N availability. Furthermore, according to Landon (1991), these experimental soils have low N, P, S and low organic matter. Such findings further signified that the soils required external application of the certain nutrients according to the requirement of the crops. Moreover, according to the classification limit set by Marx et al. (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 (Wakene et al., 2002). 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 in 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 application of organic and inorganic fertilizers in sole had a great influence on the qualities and shelf-life of garlic bulbs. Garlic bulb qualities and nutrient content were significantly improved by the combined application of 46 or 92 kg N /ha, 20 or 40 kg P /ha and 10 or 20 t CM /ha on both Andosols and Vertisols. The best economical combination rates of 46 kg N, 20 kg P and 20 t CM /ha resulted in 50%, 25%, 39% and 163% on Andosols and 54%, 23%, 39% and 137% on Vertisols of dry matter, protein, TSS and pungency contents of garlic bulb improvements respectively as compared to the bulb qualities obtained in the control plots. This might be because of chicken manure supplementation with the inorganic N and P, which can improve the soil characteristics and make nutrients available for uptake by the plants. Similar to the present result Dhotre (2009) found the highest (19.42 %) dry matter content in bulbs due to application of vermicompost. Chicken manure is used to supply both S and K, which are important for onions, as they have attributed to favorable effect on protein synthesis, carbohydrate metabolism and ultimately stored food material of onion (Mahmoud, 1999; El-Bassiony, 2006). Applying chicken manure to an onion field prior to cultivation was reported to give higher nutrient uptake than mineral fertilizer, animal manure and untreated soil (Thornton et al., 1997; Halvorson et al., 2002).

The availability of lower amount of nutrients in Vertisols before the external fertilizer applied led the crop to use higher rates of N and chicken manure supplemented to produce more dry matter in bulbs that made the bulbs led to reduce bulb weight loss during storage. However, garlic bulbs produced without nitrogen with either phosphorus or chicken manure or both showed an increased bulb weight loss during storage on both soils as protein and dry matter contents of bulbs were low. Nitrogen and P have a relationship to bulb dry matter production as a result of this, as one level increased the other become decreased to produce higher dry matter on the soils. Similar to the result obtained on Vertisols, Gebrehaweria (2007) found significantly the highest dry matter in garlic bulb with application of 120 kg N /ha along with 30 and 60 kg P /ha. The present results are also in agreement with the findings of Hossain et al. (2007) who found significantly increased dry matter of garlic bulb with increased fertilizations of N and P.

The bulb weight losses were reduced by 447% and 303% in response to a combined application of 46 kg N, 20 kg P and 10 t CM /ha on both Andosols and Vertisols, respectively. This could be attributed to the positive effect of optimum nutrient application on the dry matter production and nutrient uptake as compared to those produced by the lower rates (control) that reduced the plant photoassimilates production. Moreover, higher rates of the fertilizers may have been caused a greater increase of bulbs weight and water uptake that led to more weight losses in storage. The post-harvest handling and storage losses in garlic are around 10-20%, and the shelf-life in garlic bulb is attributed to genotypes, cultural practices, pre-harvest treatments and proper production and storage environment factors (Lawande, 2004).

Application of integrated N, P and CM significantly increased N, P, K and S concentrations in garlic bulbs in both soils, which might be attributed to better supply of nutrients throughout the crop growing period by the inorganic manure. Generally, higher N concentration was produced on Andosols than Vertisols while significantly higher K and S concentrations in garlic bulbs were produced on Vertisols as compared to Andosols. These might be due to nitrogen deficiency in the Vertisols as compared to Andosols before planting the crop. Also might be attributed to the inefficient utilization of the N element at a deficient level of nutrients in the soil and externally unfertilized plots. The use of organic manure along with inorganic fertilizers enhanced the fertilizer use efficiency of the crop (Muneshwar et al., 2001; Nevens and Reheul, 2003). Adeinyan and Ojeniyi (2003) recorded similar results in maize; they recorded an increase in nutrient uptake by maize plant with applying chicken manure. Moreover, applying of organic manure was reported to increase the uptake of N, P, K, Ca, and Mg contents in the soil and, therefore, organic manure are considered to be a good source for soil fertility (Nyathi and Campbell, 1995; Adenyian and Ojeniyi, 2003).

The positive correlation of garlic bulb quality attributes with each other except negatively with bulb weight loss indicated that the application of both inorganic fertilizers and chicken manure significantly influenced the growth, yields, quality, and chemical contents of the bulb. In addition, the negative correlation of weight loss of bulbs with the other bulb quality attributes indicated that high nutrient uptake led to low bulb quality and high bulb weight loss, which in turn decrease the shelf life of bulb. Dry matter, pungency, TSS and protein contents of garlic bulb had positive and significant correlation with each other as also suggested by

Freeman and Mossadeghi (1970), Nasreen and Hossain (2004) on onion bulb. It has also been noted that enzymatically formed pyruvic acid correlate positively with bulb S content, suggesting that S influences the uptake of other nutrients (N, P and K) to increase different flavor and non-flavor compounds of garlic. Higher uptake of sulphur leads to better growth, development besides increasing the synthesis of volatile sulphur compounds leading to increased production of pyruvate content (pungency) of the crop, which signified the direct relationship between the availability of sulphur and garlic pungency and other bulb quality attributes. Thippeswamy (1993) also observed a similar result in onion, as fertilization of the crop with sulphur fertilizer significantly improved the pungency of the bulbs.

CONCLUSION

Chicken manure combined with reduced levels of inorganic N and P fertilizers increased the quality and nutrient concentrations of garlic bulbs with better shelf-life than NP fertilizers alone used in the experiments. The quality attributes of the crop showed a significant and positive correlation between them, except bulb weight loss on both soils. The integrated application of 10 or 20 t/ ha chicken manure along with 46 kg N /ha and 20 kg P /ha increased garlic production and productivity both on Andosols and Vertisols of Debre Zeit area compared to application of NP. Integrating chicken manure into the cropping system substantially reduced the N and P requirement by 50% for optimum quality and shelf-life of garlic in both soils without significantly reducing the quality of the crop on Andosols, but improving the quality of the crop on Vertisols as compared to the NP levels used in the experiment. Therefore, depending on the nutrient status of a soil, farmers in the study area could apply a combination of 46 kg N /ha + 20 kg P /ha + 10 t CM /ha on Andosols and 46 kg N /ha + 20 kg P /ha + 20 t CM /ha on Vertisols to attain maximum productivity of the crop.

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