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Full Length Research Paper

Effects of Compost and Phosphorus Fertilizer Rate on the Yield and Yield Related Traits of Garlic at Bale Highlands, South Eastern Oromia

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Abstract

Field experiment has been conducted to determine the effects of compost and mineral Phosphorus fertilizer rate on the yield components and yield of Garlic at South eastern Ethiopia, Bale zone, Dinsho district. Compost was prepared at Sinana Agricultural Research centre compound from different crop residue and other waste materials. Experiment was done using RCBD experimental design with factorial arrangement. The treatments for this experiment were four rates of compost (0, 10, 20 and 30 ton/ha) and four rates of phosphorus fertilizer (0, 46, 69 and 92 kg/ha). There was 16 total numbers of treatments. Each treatment replicates three times. Yield related traits such as; plant height, number of cloves per bulb, average weight of bulb and total bulb yield were recorded and inserted to GenStat computer software. Analysis of variance showed that the main effects of both compost and phosphorus fertilizer on all yield traits and yield was significant. Additionally, interaction of compost and phosphorus fertilizer significantly affects all parameters. Accordingly, maximum plant height (46.11cm), maximum number of cloves (33.58), maximum average weight of bulb (23.56gm) and total bulb yield (70.74 Qt ha^{-1}) was obtained from the treatment received 20ton ha^{-1} of compost combined with 69kg ha^{-1} of phosphorus fertilizer. On the other hand the shortest plant (31.47cm), lowest number of cloves per bulb (24.03), the lowest weight of single bulb (13.94gm) and lowest total bulb yield (46.48 Qt ha^{-1}) was obtained from control plot. Moreover, partial budget analysis had been done to determine the profitability of treatments. As a result, the treatment supplied with 20ton ha^{-1} of compost combined with 46kg ha^{-1} of phosphorus fertilizer shows maximum marginal rate of return (8531.0%). To conclude, the treatment with maximum yield showed minimum marginal rate of return in relative to maximum marginal rate of return. Since major problem of local farmers is cost of fertilizer it is important to focus on cost benefit analysis result for recommendation. Consequently, 20ton ha^{-1} of compost without phosphorus fertilizer is recommended to be used by farmers to be profitable.

Key words: Bulb, Cloves, Compost, Garlic, Phosphorus

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Introduction

Garlic is an oldest cultivated herb botanically known as *Allium Sativum* and is a member of Alliaceae family (Sethi *et al.,* 2015). It is one of the most important bulb crop grown in Ethiopia. It was originated from central Asia. Garlic has a long tradition as a food and as a medicinal plant. Sumerians were mentioned as the first to utilize this crop (Asrat *et al.,* 2015). Therapeutic effects, routes of application and modes of preparation of garlic are very varied (Kreuter, 1997).

There are two types of Garlic; the hard neck (*Allium sativum var ophioscorodon*) and soft neck (*Allium sativum var sativum*) type. Hard neck varieties produce a flower stalk (scape), and are often termed as bolting or top setting varieties. Flowers if they are produced usually abort and form bulbils instead. This variety produce 4-12 cloves per plant before the bulb reaches marketable size. On the other hand soft neck varieties do not produce a flower stem. These are the most common varieties used for commercial cultivation due to minimal flower stalk and bulbils production which generally makes them more productive because energy goes to producing bulb while hard necks it is diverted to scape production. Soft neck varieties normally have a long shelf life than hard necks and store for up to six to eight months (Grieve, 2006).

Garlic is grown globally, but China is the largest producer of Garlic accounting for 75% of world output (Tadesse, 2015). In Ethiopia Garlic is the most widely cultivated *Allium* species next to Onion. It is widely cultivated around home gardens in this country. But nowadays, its production practiced in some large farms and exported to Europe, Middle East and North America (Diriba, 2016). Adet, Ambo, Debre-work, Sinana, Jimma and many other Ethiopian highlands produce a bulk of Garlic under small scale farmer sector. The average area covered by Garlic in Ethiopia was 15,381 ha and 1,386,643.07Quintals of Garlic were produced According to Ethiopian central statistical agency report in 2016/17 (CSA, 2016/17).

Garlic has higher nutritive values than other bulb crops. It is rich in protein, phosphorus, potash, calcium, magnesium and carbohydrates. The fresh peeled garlic cloves contain 62% of moisture, 29% carbohydrates, 6.3% of protein, 1% of mineral matter, 0.8% of fiber, 0.1% fat, 1% total ash, 0.03% calcium, 0.31% phosphorus, 0.0001% iron, 0.4%mg/100g nicotinic acid and 13mg/100g vitamin C(Asrat *et al.,* 2015).

Despite the higher importance of the crop, its production and productivity is very low due to different problems. There many Biotic and Abiotic factors contributing for lower production of Garlic among which inappropriate agronomic practice especially fertilizer usage is the major problem (https://www.revolvy.com/topic/Dinsho%20(woreda). Fertilizer can be Organic and Inorganic. There is much information concerning fertilization of Inorganic fertilizer. However there is no sufficient information about the importance of Organic fertilizer usage. On the other hand Organic fertilizers are cheap to get since it can be prepared from different crop residue and locally available waste materials. Therefore, this experiment was done with the Objective of determining the optimum, economically important rate of phosphorous fertilizer and Compost for best Garlic production at Bale highland, Dinsho district.

Material and Method

Description of study area

This experiment was conducted at Dinsho district of Bale zone. Dinsho is one of highland Woredas of Bale zone. A survey of land shows that Dinsho has 33.1% arable land, 30.4% pasture, 30.2% forest and 29.8% was under annual crops. This woreda has latitude and longitude of $7^0$05'N $39^0$45E and an elevation of 3207m above sea level. Geographically Dinsho have average annual temperature of 14^0C and 55% of humidity (https://www.revolvy.com/topic/Dinsho%20). This district possesses bimodal Rain fall type which creates favorable condition to produce crops twice a Year. The maximum and minimum annual temperature of the district is 21 and 9^0C. The dominated soil type is pellic vertisols and slightly acidic (Kedir *et al.,* 2008).

Experimental Design and Treatments

The experiment was laid out by Randomized complete Block (RCBD) design with factorial arrangement. The treatments of the experiment were four levels compost (0, 10, 20 and 30 ton ha^{-1}) and four levels of phosphorus fertilizer in the form of TSP (0, 46, 69 and 92 kg h^{-1}).

Methods of Compost preparation

The compost for this experiment was prepared in Sinana agricultural research centre. The components of the compost were wood ash, pulse and cereal crops residue, different fresh leaves, Ruminant animals manure, soil and Water. The materials used for this compost preparation are digging hoe, shovel, fertilizer bags, hand lorry, axe, barchans and pigs. This compost was prepared in the hole having a size of 1mx1mx2m (lxwxh). Preparation was started in the month of November and stayed for five months up to the end of February. After all components of the compost was cooked well it is transported to the planting area.

Compost Application Methods

The prepared compost was taken to planting area and applied one month before planting in each row. Before application the sample of the compost was taken and analyzed in the soil laboratory. Accordingly some physico- chemical properties of this compost has been determined.

Soil Sampling and Analysis

One month later after compost application before planting soil sample was taken using Zigzag 'z' shape pattern. Sample was air dried and taken to laboratory for further investigation of soil status of experimental land. Accordingly soil physical properties (texture), soil chemical properties (phosphorus, total Nitrogen, potassium, Organic matter, Organic carbon, Cation Exchange capacity and pH) were determined at Sinana Agricultural Research centre soil Laboratory.

Methods of Planting and Fertilizer Application

One month later after Compost application Local variety of Garlic was planted with 20cm and 10cm spacing between rows and plants respectively. The first weeding and ridging was done after twenty days. The Experiment was followed up until harvesting. Phosphorus fertilizer in the form of TSP was also applied at planting with the proposed rate.

Data collected

Plant height:-is length of plant from root to leaf. Sample five plants are selected and measured using measuring tape and the average is described as plant height in cm.

Number of cloves per Bulb:-is the amount of cloves counted by peeling randomly selected five plants and average is described as number of cloves per bulb.

Weight of Bulb (in gm):-is the average weight of single randomly selected sample bulb of the crop.

Total Yield (in Qt ha^{-1}):-is the weight of Garlic after dried and leaves and roots of the crop are removed.

Methods of Data Analysis

All data are collected inserted SAS statically data analysis software. On the other hand means are separated using LSD data separation method.

Partial Budget Analysis

Partial budget analysis has been done to determine the profitability of the treatments. Cost of inputs (seed, Nitrogen fertilizer, phosphorus fertilizer and compost) are assumed as total variable cost whereas income obtained from selling bulb is assumed as Total benefit of the treatments. On the other hand Yield was adjusted by 10% since the management of farmers can exert variation among the value. Accordingly MRR% was determined using the following formula.

$$\text{Marginal rate of return} = \frac{\text{The difference between sequential Net benefit}}{\text{The difference of respective Total variable cost}}$$

Result and Discussion

Soil physical and chemical properties before Planting

Before sowing, soil samples were taken randomly to a depth of 0 - 30 cm in a zigzag pattern to make one composite surface soil sample per block of the experimental field. The collected soil sample was composited to one sample and air dried, ground, and sieved using 2mm sieve, and 0.2 mm for organic matter. Then the composite soil sample was analyzed for the determination of soil texture, soil pH, organic carbon, total nitrogen, available phosphorus, and cation exchange capacity (CEC) analysis using standard laboratory procedures. Organic matter content was determined by the volumetric method (Walkley and Black, 1934). Total nitrogen was analyzed by Micro-Kjeldhal digestion method with

sulfuric acid (Jackson, 1962). The total number of exchangeable cations a soil can hold, cation exchange capacity (CEC), was measured after saturating the soil with 1N ammonium acetate (NH_4OAc) and displacing it with 1N NaOAc (Chapman,1965). Available phosphorus was determined by the Olsen's method using a spectrophotometer (Olsen *et al.,* 1954). Soil pH was measured in water at soil to water ratio of 1:2.5 (Van Reeuwijk, 1992). Soil texture analysis was performed by Bouyoucous hydrometer method (Bouyoucos, 1951).

Table 1. The status of Experimental Land before Planting at Dinsho district

Location	Soil physical properties			Soil chemical properties					
Dinsho	Sand (%)	Clay (%)	Silt (%)	pH(1:2.5 soil to water)	N (%)	P(ppm)	K^+ (Cmol kg^{-1})	OC (%)	CEC (Cmol Kag^{-1})
	48	22	30	6.04	0.4	0.153	0.47	2.67	26.13
Textural class: Sandy									

Key:-N; Total Nitrogen, available phosphorus, K^+; available potassium, , OC; Organic carbon, CEC; Cation Exchange capacity, pH; Power of hydrogen

Status of Compost during Application

Sample of compost prepared for this experiment has been taken to Laboratory to determine its physical and chemical properties using the same procedure as soil. As a result the following values were determined.

Table 2. Status of compost Physico-chemical properties during application

Compost physical properties			Compost Chemical properties					
Sand (%)	Clay (%)	Silt (%)	pH(1:2.5 soil to water)	N (%)	P(ppm)	K^+(Cmol kg^{-1})	OC (%)	CEC (Cmol Kag^{-1})
54	35	11	7.24	0.46	0.172	0.15	2.29	34.12
Textural class: Sandy								

Key:-N; Total Nitrogen, P_2O_5; available phosphorus, K^+;available potassium, OM; Organic matter, OC; Organic carbon, CEC; Cation Exchange capacity, pH; Power of hydrogen

Growth traits influenced by fertilizer rate

Organic and In-organic fertilizers have effects on the yield related traits of Garlic as it was investigated by different researchers all over the world. These Yield related traits of Garlic such as Plant height, Number of cloves per bulb and weight of bulb are selected for this experiment and the effects of compost and mineral phosphorus fertilizer on them is discussed below.

Plant height

The main effects of phosphorus fertilizer rate on Plant height of Garlic were significant. Accordingly, the mean value of plant height ranges from 31.61cm to 44.3cm. The plot with longest plant was received 20ton ha^{-1} of compost whereas the minimum plant height is recorded for control plot. Increasing the level of compost from 0-20 ton ha^{-1} increases plant height though, plant height decreases at the top level of compost. On the other hand the main effects of phosphorus fertilizer on plant height is highly significant at ($p<0.01$). Accordingly, increasing the level of phosphorus fertilizer up to 69kg ha^{-1} increases plant height while it shows declination at 92kg ha^{-1}. As a result plant height ranges from 31.5cm to 45.11cm at Dinsho (Table 3). The maximum height of plant was investigated on the treatment received 69kg ha^{-1} of fertilizer where the minimum plant height was obtained from control plot. Furthermore, the interaction effects of compost and phosphorus fertilizer rate on plant height of Garlic was significant. Consequently, the longest plant height of the crop recorded for the treatment received 20ton ha^{-1} of compost combined with 69kg ha^{-1} of phosphorus fertilizer at Dinsho. This result supports the finding reported by Neerendra (2016) where maximum plant height was obtained by applying higher dose of Farm yard Manure and minimum plant height was obtained from control plot. Similar result was also reported by Shafeek *et al.* (2016) where increasing the level of compost with humic acid increases plant height up to 62cm. Moreover, the finding reported from experiment conducted at northern Ethiopia also showed significant effect of phosphorus fertilizer on plant height of Garlic (Shafeek *et al.,* 2016).

Table 3. The interaction effects of Compost and phosphorus fertilizer rate on plant height of Garlic (in cm)

Compost rate in ton ha^{-1}	Phosphorus fertilizer rate in kg ha^{-1}				
	0	46	69	92	Mean
0	31.47^{no}	36.54^{ij}	44.82^{ab}	35.93^{jk}	37.2
10	40.80^{de}	43.39^{abc}	45.79^{a}	39.23^{efgh}	42.3
20	38.32^{hi}	40.7^{ef}	46.11^{a}	41.51^{cd}	41.7
30	32.43^{n}	35.37^{jkl}	40.15^{efg}	35.17^{jklm}	35.8
LSD at (5%)					2.51
CV					17.54%

Key; LSD: Least Significant difference, CV: Coefficient of Variance

Yield Traits Influenced Fertilizer Fate

Number of cloves per bulb

Analysis of variance shows that the interaction effects of compost and mineral phosphorus fertilizer on number of cloves per bulb is significant at ($p<0.05$). Accordingly the mean value of number of capsule per bulb ranges from 24.03-33.58. The maximum number of cloves per Bulb was recorded for the treatment received 20ton ha^{-1} of compost combined with 69kg ha^{-1} of phosphorus fertilizer. However, minimum number of cloves per bulb is investigated from control plot. On the other hand, the main effects of compost and mineral phosphorus fertilizer rate on this trait was significant at ($p<0.05$). Increasing compost rate up to 20ton h^{-1} increases number of cloves, where it showed slight declination above the mentioned level. Similarly, increasing the levels of phosphorus fertilizer, increase number of cloves per bulb.

The Result is in agreement with the finding reported by Hassan A. Hassan from Egypt where number of cloves reported were lower than that of recorded in this experiment (Hassan, 2015). Similar finding was also reported by Hamma I. from Nigeria (Hamma *et al.,* 2015. On the other hand Alemu Dagwale also reported significant effects of phosphorus fertilizer on number cloves per bulb, but lower number of cloves (Alemu, 2014). This may due to the variation among varieties' genetic yield potential and environmental factors.

Table 4. Interaction effects of compost and mineral Phosphorus fertilizer on number of cloves per bulb of Garlic

Compost rate in ton ha^{-1}	Phosphorus fertilizer rate in kg ha^{-1}				
	0	46	69	92	Mean
0	24.03^{m}	25.32^{jkl}	25.82^{jk}	26.46^{ij}	25.408
10	27.28^{efghi}	27.87^{fg}	28.74^{efgh}	28.96^{ef}	28.213
20	31.41^{b}	29.31^{de}	33.58^{a}	30.98^{bd}	31.320
30	33.35^{ab}	32.52^{ab}	33.14^{abc}	31.35^{bc}	32.590
Mean	29.02	29.9	30.32	29.44	
LSD at (5%)					1.15
CV					12.56%

Key; LSD: Least Significant difference, CV: Coefficient of Variance

Weight of Bulb

Interaction effects of Compost and phosphorus fertilizer on single weight of bulb was significant at ($p<0.05$). Accordingly increasing rate of compost across with phosphorus fertilizer increases weight of single bulb. The mean value of single bulb weight ranges from 13.94gm to 23.56gm where, the maximum weight of bulb recorded for treatment received 20ton ha^{-1} of compost combined with 69kg ha^{-1} of mineral phosphorus fertilizer. Increasing compost rate increases weight of bulb in similar manner with phosphorus fertilizer. However, the level of compost beyond 20ton ha^{-1} and phosphorus fertilizer above 69kg ha^{-1} decreases the weight of bulb. In fact increasing supplementation of nutrient above the optimum level enhances the crop to emphasis on vegetative growth rather than storing food in their bulb.

This result is consistent with the finding reported by Alemu whom reported as phosphorus fertilizer and vermi compost shows significant effects on weight of single bulb (Hamma *et al.,* 2015). Abraha Gebre kiros also reported the significant effects of phosphorus fertilizer on weight of bulb and obtained maximum weight of bulb (61.93gm) by applying nitrogen, phosphorus, sulfur and zinc in combination (Shafeek *et al.,* 2016).

Table 5. Interaction effects of compost and Mineral phosphorus fertilizer on weight of bulb (in gm)

Compost rate in ton ha^{-1}	Phosphorus fertilizer rate in kg ha^{-1}				
	0	46	69	92	Mean
0	13.94^{j}	16.99^{efgh}	18.44^{bcdef}	16.42^{fghi}	16.45
10	17.98^{efg}	19.07^{bcde}	21.55^{abc}	19.98^{bcd}	19.65
20	20.05^{bc}	22.14^{abcd}	23.56^{a}	22.16^{ab}	21.98
30	21.56^{abcd}	21.52^{abc}	20.39^{b}	22.88^{ab}	21.59
Mean	18.38	19.93	20.98	20.36	
LSD at (5%)					2.97
CV					20.57%

Key; LSD: Least Significant difference, CV: Coefficient of Variance

Total Bulb Yield

Total bulb yield was significantly affected by compost and mineral phosphorus fertilizer rate at ($p<0.05$). 20tonha^{-1} of compost combined with 69kg ha^{-1} of phosphorus fertilizer gives maximum bulb yield while control gives minimum amount of bulb yield. The mean value of bulb yield ranges from 46.48 Qt ha^{-1} to 70.74 Qt ha$^{-1.}$ On the other hand, the main effects of compost and mineral phosphorus fertilizer on bulb yield of Garlic was also significant at ($p<0.05$). Accordingly increasing level of compost increases the yield of bulb. The result is consistent with the finding reported by Alemu who reported 79.6 Qt ha^{-1} of bulb yield by applying 92kg ha^{-1} of phosphorus fertilizer (Hassan, 2015). Hassan A. also reported significant effects of compost on total Bulb yield of Garlic (Hamma *et al.,* 2015).

Table 6. Total bulb yield of Garlic (in Qt ha^{-1}) as influenced by interaction of compost and phosphorus fertilizer rate

Compost rate in ton ha^{-1}	**Phosphorus fertilizer rate in kg ha^{-1}**				
	0	46	69	92	Mean
0	46.48^{jklmn}	48.37^{ghijklm}	52.68^{ghijk}	51.47^{ghijkl}	49.75
10	55.00^{defgh}	56.42^{cdefg}	59.49^{bcd}	54.32^{defghi}	56.31
20	59.81^{bc}	66.38^{ab}	70.74^{a}	60.31^{b}	64.31
30	58.52^{bcdef}	59.48^{bcde}	68.45^{ab}	53.89^{ghij}	60.09
Mean	54.95	57.66	62.84	55.00	
LSD at (5%)					8.9
CV					20.57%

Key; LSD: Least Significant difference, CV: Coefficient of Variance

Partial Budget Analysis

Partial budget analysis has been done to determine the profitability of treatments. Accordingly yield was adjusted by 10% and Total variable cost, Gross benefit, Net benefit and Marginal rate of return was calculated and treatments were compared within each other depending on their Marginal rate of return. Treatments were arranged in descending order based on total variable cost. Total variable cost was calculated by adding cost of compost and mineral phosphorus fertilizer in the form of TSP. The analysis of partial budget showed that the treatment received 20ton ha^{-1} of compost combined without phosphorus fertilizer has high marginal rate of return (8531%), followed by the treatment supplied with 20ton ha^{-1} of compost combined with 46kgha^{-1} of phosphorus fertilizer (6993.8%).

Table 7. Partial budget analysis result in ETB

Treatments		Yield in Qt ha^{-1}		Cost of compost	Cost of TSP	Total variable cost	Gross benefit	Net benefit	MRR%
Comp	TSP	Unadjusted yield	Adjusted yield						
0	0	46.48	41.83	0	0	0	146412	146412	2583.8
10	0	55	49.5	1000	0	1000	173250	172250	1415.2
20	0	59.81	53.83	2000	0	2000	188401.5	186401.5	8531
20	46	66.38	59.74	2000	3000	5000	209097	204097	6993.8
20	69	70.74	63.67	2000	4500	6500	222831	216331	2583.8

Key: Comp: compost, TSP:-Triple super phosphate, ETB: Ethiopian Birr, MRR: Marginal rate of Return

Conclusion

Garlic has been produced in Ethiopia for long period of time. In similar way it is also cultivated in Bale zone by small land holding farmers with and without fertilizer. Some of the farmers do not use fertilizers because of high cost of fertilizer. Therefore, it was important to find profitable alternative fertilizer like Farm yard manure, compost and animal manure. This was the objective of this experiment. Field Experiment had been conducted to determine the effects of compost and mineral phosphorus fertilizer on yield related parameters as well as yield. All data of yield traits such as plant height, number of cloves per bulb, weight of bulb and total bulb yield were collected inserted to GenStat computer software.

Analysis of variance indicates that all parameters significantly respond to compost and mineral phosphorus fertilizer rate. Accordingly, maximum plant height, maximum number of cloves per bulb, maximum average weight of bulb and maximum total bulb yield was obtained by applying 20ton ha^{-1} of compost with 69kg ha^{-1} of phosphorus fertilizer. On the other hand minimum plant height, minimum number of cloves per bulb, minimum average weight of bulb and minimum total bulb yield was obtained from control plot.

On the other hand partial budget analysis has been done to determine the profitability of candidate treatments. Accordingly the treatment received 20ton ha^{-1} of compost combined with 46kg ha^{-1} of phosphorus fertilizer showed maximum marginal rate of return, followed by the treatment supplied with 20ton ha^{-1} of compost combined with 69kg ha^{-1} of mineral phosphorus fertilizer rate.

To conclude, it is obvious that, the treatments with higher yield comparing to others are always recommended to use by farmers. However, it is important to determine the profitability of the treatment. Since the problem of our farmers is cost of fertilizer our recommendation would focus on cost benefit analysis. Accordingly, farmers will be recommended to use 20ton ha^{-1} of compost in combination with 46kg ha^{-1} of phosphorus fertilizer which means 100kg of TSP fertilizer to be profitable.

Conflict of Interests

The authors have not declared any conflict of interests.

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