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Keywords: compound fertilizer, productivity, cropping season, economic benefits, garlic yield, soil type.

I. Introduction

Garlic is one of the main *Allium* vegetable crops known worldwide with respect to its production and economic value. It is used as a seasoning in many foods worldwide and without garlic; many of our popular dishes would lack the flavor and character that make them favorites. Garlic's volatile oil has many sulphur containing compounds that are responsible for the strong odor, its distinctive flavor and pungency as well as for its healthful benefits (Salomon, 2002). Moreover, it contains considerable amounts of different nutrients and vitamins (Maly *et al.*, 1998). Garlic has higher nutritive value than other bulb crops: 30–35% dry matter, 6–7% protein, and different minerals. Garlic also contains antibiotics *garlicin* and *allistatin*, a number of enzymes, amino acids, universal substances, including trace elements (Maly *et al.*, 1998). However, these quality attributes are depend on production and management practices on both field and after harvested.

Despite its importance, garlic yield and quality are affected by various biotic and abiotic stresses, among which low/excess mineral nutrition, irrigation schedule/rainfall are among the major ones (Jaleel *et al.*, 2007; Cheruth *et al.*, 2008). Garlic crop has a shallow root system and needs optimum and regular application of water and nutrients. Cropping season and soil moisture affect the growth and yield of garlic; low moisture conditions in the soil are conducive to poor productivity (Shock *et al.*, 1998), while excessive soil moisture results in wastage of irrigation water and nutrients leaching lead to rots and poor bulb quality. In dry cropping season, water is the most important limiting factor in agriculture and economic development issues. Water is an important factor in reducing yield and one way to increase crop yield is using irrigation water; thus, its application must be done efficiently to ensure profitability through maximizing yield, because as a natural resource it is either inadequate or irregular in most areas where onions production is prevalent (Muhammad *et al.*, 2011). With the adoption of new technology in intensive cropping with high yielding varieties, there is a considerable demand on soil for supply of nutrients. Fertilizer types also affect the productivity and quality of crops; poor bulb formation, undesirable crop quality and low nutritional quality result from inadequate levels of nitrogen, phosphorus and potassium application (Liu *et al.*, 2010).

Hence, considering garlic as one of the potential vegetable crop for consumption as well as for market, it is imperative to increase its productivity along with desirable quality and nutrients content through application of other sources of nutrients beyond Urea

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and Diammonium phosphate(DAP) that are most widely used in Ethiopia, in addition to other production and management practices like soil types and cropping seasons. The use of compound/blended fertilizers that contain various nutrients in one fertilizer product to obtain high yield and good quality garlic bulb is an important practice in today's garlic production on available land. Consequently, a study was undertaken with the objective of differentiating the suitable type and effect of comparing different compound fertilizers with various nutrients for garlic yield attributes and economic benefits under irrigation and rain-fed cropping conditions on both Andosols and Vertisols soil types.

II. Materials and Methods

a) Experimental Sites and Materials

The experimental areas were characterized by sub-humid tropical climate type with mean annual maximum and minimum temperatures of 28/26°C and 10.2/9.9°C, respectively; mean rainfall of 550/930mm and relative humidity of 52/62% during dry and rainy seasons, respectively. The experiment was conducted at the experimental farm of DebreZeit Agricultural Research Centre/DZARC/ ($08^0$44"N latitude, $38^0$58"E longitude, altitude of 1860 m.a.s.l) in central Ethiopia during both dry season using irrigation and rainy season under rain in the year 2013/14. The experiment was conducted on two major soil types: light grey soil(Andosols) with well-drained and good soil physical property; and black soil(Vertisols) with high water holding capacity, swelling and shrinking properties. 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 were analysed following the procedures of Jackson(1967). Thus, Vertisols experimental site showed surface soil texture of sandy-clay-loam which contained low organic matter (1.80 and 1.65%); low total N (0.058 and 0.071%), low available P (13.56 and 16.84ppm), medium available S (18.0 and 16.9mgkg^{-1}soil), medium K (1.15 and 1.23C.mol(+)/kg) and pH value of 7.17 and 7.08 during dry and rainy seasons, respectively. The Andosols experimental site with surface soil texture of sandy-loam was contained medium organic matter (2.56 and 2.34%), medium total N (0.127 and 0.113%), low available P (18.30 and 22.41ppm), low available S (15.8 and 19.7mgkg^{-1}soil), high K (2.22 and 2.04C.mol(+)/kg); and pH value of 7.66 and 7.38 during dry and rainy seasons, respectively when compared with that of Vertisols.

Tseday(G-493) garlic cultivar was used with similar diameter and weight for the experiment on both soils under the two cropping seasons. Different compound fertilizers containing different nutrients were applied for the experiment viz., Diammonium phosphate/DAP/(18%N+20%P),Azofertil(30%N+25%S), D-coder(14%N+9%P+21%S+0.1%Zn) and Basic (9%N+6%P+22%K+ 10%CaO) compound fertilizers per 100 kgha^{-1}. However, the fertilizers were applied at the rate of 200 kgha^{-1} on two soils under both irrigation and rain-fed seasons for the experiments. The nitrogen amount in DAP fertilizer was adjusted to 92 kgha^{-1} using Urea.

b) Treatments and Experimental Design

The treatments were consisted of five different compound fertilizers which containing various nutrients; viz. Control/without fertilizer/, DAP, Azofertil, Basic and D-coder. DAP fertilizer, which regularly used by farmers, was applied as a check for comparison with the new compound fertilizers introduced from abroad. Randomized Complete Block Design was used in three replications on both soil types. The experimental plot area was 3.6m^2 (1.8mX2m) with spacing of 10cm, 30cm and 60cm between plants, single rows, double rows, respectively; maintaining 1m and 1.5m between plots and blocks distances, respectively. The plot size consisted of six rows with 20 plants/row. Treatments were assigned to each plot randomly. All the fertilizer treatments were applied during planting and all other cultural, crop production and management practices were carriedout uniformly to the plots on both soils under the two seasons following the areas' recommendations (Getachew and Asfaw, 2000).

c) Data Collected

Ten sample plants on each plot were randomly selected from the middle four rows at 90 days of planting and growth parameters like plant height(cm), leaf number per plant, neck diameter(mm) and leaf area index from ten sample plants were recorded. After matured, bulb and yield attributes like fresh bulbs weight(g), bulb diameter and length(cm), mean clove weight(g) (the ratio of total clove weight to total clove number per sampled bulbs), biological yield(g) (the summation of above and below ground yields), total bulb yield(t/ha), harvest index (the ratio of bulb yield to biological yield) of garlic were recorded. The economic benefits of bulb yield of garlic was calculated from the cost incurred that vary with each treatment and economic yields obtained depending on the average prices prevailed at the time of production was considered to calculate the gross return. The benefit to cost/B:C/ was obtained from the ratio of gross return to total input variable cost of cultivation to compare the performance of different treatments.

d) Data Analysis

The obtained data were subjected to statistical analysis of variance/ANOVA/ using SAS statistical software version 9.0 and mean separation was done using the Fisher's least significant differences at $P<0.05$

level of probability using the method described by Snedecor and Cochran (1980).

III. Results and Discussion

a) Effects of Fertilizers and Soils on Growth Attributes of Garlic

Application of different compound fertilizers significantly influenced garlic plant height under both irrigation and rain-fed production systems; but neck diameter and leaf area index/LAI/ were significantly affected only under rain-fed production. However, application of different types of fertilizers did not significantly influence leaf number(Table1). Plant height of garlic treated by different types of compound fertilizers was not showed significant variation from each other, except from the untreated/control/ plot using irrigation. However, highest plant height was recorded from garlic plants treated with D-coder fertilizer (200 $kgha^{-1}$) followed by those fertilized with Azofertil under rain-fed season, and lowest height was recorded from garlic produced on the control plot(Table1). Garlic neck diameter was significantly increased by Azofertil and D-coder fertilizers application than the others under rain-fed, and highest LAI was produced by D-coder application under rain-fed(Table1). These might be due to the response of the plants to the cumulative effect of the applied nutrients as indicated by their mean values, which revealed that the cumulative role of the nutrients available in the compound fertilizers on the plant development and growth. These results are inline with the result of Faten *et al.* (2010) who reported highest onion plant height and neck diameter due application of Sulphate of potash than Muriate of potash, which revealed that the positive cumulative effects of more than two nutrients available in the compound fertilizers than the fertilizer containing single/two elements on the growth of the crop.

Soil types also significantly influenced the growth parameters of garlic plant during both dry and rainy seasons except LAI under dry season using irrigation(Table1). Plant heights under both dry and rainy seasons; and leaf number, neck diameter and LAI under rain-fed season were increased on Andosols grown garlic plants; but leaf number and neck diameter of garlic plant grown on Vertisols were higher than those grown on Andosols in dry season. These might be due to the soil characteristics to influence bulbs growth and nutrients mobility in addition to their availability as they influenced the growth of the whole plants. However, soils did not significantly influence the LAI produced during dry season using irrigation(Table1).

Table 1: Effects of different types of fertilizers and soils on growth indices of garlic under both dry season using irrigation and rainy cropping seasons of 2013/14

Treatments	Dry season(Irrigation)				Rainy season(Rain)			
	Plant height/cm/	Leaf number	Neck diameter/cm/	LAI	Plant height/cm/	Leaf number	Neck diameter/cm/	LAI
Fertilizer								
Control	50.22^{b}	12.00	7.02	0.970	47.65^{d}	11.75	9.12^{d}	1.945^{d}
DAP	53.98^{a}	11.67	7.03	1.063	51.33^{c}	11.78	10.48^{c}	2.107^{c}
Azofertil	54.47^{a}	11.67	7.22	0.993	55.65^{ab}	11.82	12.05^{a}	2.733^{b}
Basic	55.38^{a}	11.48	7.03	1.048	53.60^{bc}	11.35	11.12^{b}	2.237^{c}
D-coder	55.38^{a}	11.35	7.15	1.020	57.53^{a}	12.00	12.05^{a}	3.017^{a}
SE	1.46	0.41	0.211	0.07	0.58	0.187	0.259	0.051
LSD(0.05)	*	ns	ns	ns	*	ns	***	***
Soil								
Andosols	57.44^{a}	10.95^{b}	6.80^{b}	1.056	59.55^{a}	12.17^{a}	12.01^{a}	2.531^{a}
Vertisols	50.33^{b}	12.32^{a}	7.38^{a}	0.982	46.76^{b}	11.31^{b}	9.92^{b}	2.284^{b}
SE	0.93	0.26	0.134	0.044	0.37	0.119	0.164	0.032
LSD(0.05)	***	*	**	ns	***	**	***	**
CV(%)	4.34	9.94	7.33	16.80	3.29	3.93	5.80	5.21

SE-Standard error; LSD-Least Significant Differences; CV-Coefficient of Variation; DAP-Diammonium phosphate; LAI-Leaf Area Index; No–Number; ns-nonsignificant

b) Effect of Fertilizers and Soils on Yield and Yield Attributes of Garlic

The values of bulb attributes like fresh bulb weight, mean clove weight, bulb diameter and length were significantly($P \leq 0.01$) influenced by the fertilizer types applied during both dry- and rainy- seasons on both Andosols and Vertisols(Table2). Garlic cultivated without fertilizer application resulted in lowest bulb components under both seasons. Application of Azofertil (60kg N+50kg S ha^{-1}), Basic (18kg N+12kg P+44kg K+20kg CaO ha^{-1}) and D-coder (28kg N+18kg P+42kg S+0.2kg Zn ha^{-1}) compound fertilizers produced significantly higher bulbs as compared to DAP and control in both seasons. This indicated that availability of optimum nutrients with optimum moisture increased the growth of garlic height, number, length and width of leaves, in response to higher levels of fertilization(Diriba-Shiferaw *et al.*, 2013). All of which

might have increased dry matter production and allocation of assimilate to bulbs; resulting in an increased garlic weight of bulbs and cloves which are in agreement with the finding of Amin *et al.* (2007) who reported that application of 107kg N+72kg P+90kg K+33kg S ha^{-1} resulted in the highest growth and yield of onion over three consecutive cropping years. However, soil types significantly influenced bulb characteristics only during dry season production using irrigation; higher fresh bulb weight, mean clove weight, bulb diameter and length were produced on Andosols as compared to those produced on Vertisols(Table2). This might be due to moisture managements and better nutrients availability in Andosols before planting crop in addition to the externally applied as compared to Vertisols.

Table 2: Effects of different types of fertilizers and soils on bulb components of garlic under both dry and rainy cropping seasons of 2013/14

Treatments	Dry season(Irrigation)				Rainy season(Rain)			
	Fresh bulb weight(g)	Bulb diameter (cm)	Bulb length(cm)	Mean clove weight(g)	Fresh bulb weight(g)	Bulb diameter (cm)	Bulb length(cm)	Mean clove weight(g)
Fertilizer								
Control	23.30^{c}	3.34^{d}	2.44^{d}	1.54^{b}	19.05^{b}	14.51^{c}	2.37^{b}	0.94^{c}
DAP	32.32^{a}	4.29^{a}	3.60^{a}	1.70^{a}	25.46^{a}	19.32^{b}	2.61^{a}	1.14^{b}
Azofertil	31.85^{a}	4.10^{ab}	3.32^{b}	1.63^{ab}	28.20^{a}	21.99^{ab}	2.62^{a}	1.28^{a}
Basic	25.73^{b}	3.70^{c}	3.01^{c}	1.36^{c}	29.94^{a}	19.80^{b}	2.66^{a}	1.29^{a}
D-coder	31.39^{a}	4.04^{b}	3.20^{bc}	1.69^{a}	29.23^{a}	24.87^{a}	2.63^{a}	1.40^{a}
SE	0.64	0.075	0.084	0.042	1.58	0.086	0.065	0.043
LSD(0.05)	***	***	***	**	**	**	*	**
Soil								
Andosols	33.16^{a}	4.19^{a}	3.26^{a}	1.79^{a}	26.33	3.37	2.60	1.24
Vertisols	24.67^{b}	3.59^{b}	2.96^{b}	1.38^{b}	26.42	3.47	2.56	1.18
SE	0.40	0.048	0.053	0.026	1.00	0.054	0.041	0.027
LSD(0.05)	***	***	**	***	ns	ns	ns	ns
CV(%)	4.65	4.74	6.57	5.07	15.42	6.57	5.27	8.08

SE-Standard error; LSD-Least Significant Differences; CV-Coefficient of Variation; DAP-Diammonium phosphate; LAI-Leaf Area Index; ns-nonsignificant

Yield components and total bulb yield of garlic were also significantly($P \leq 0.01$) influenced by the applied fertilizers under the cropping seasons except harvest index/HI/ under rainy season (Table3). The highest biological yields were produced by application of DAP and D-coder fertilizer types at 200 $kgha^{-1}$ during dry-season using irrigation. However, under the rainy-season the highest biological yield was produced from garlic plants treated with D-coder without significant differences from those fertilized with Azofertil and Basic fertilizers. Lowest biological yields of garlic were obtained from those produced on the control plots in both seasons and from those fertilized with Basic and DAP fertilizers during dry and rainy seasons, respectively(Table3). Highest HI was produced in dry-season by D-coder application and lowest HI from garlic produced without fertilizer application(Table3); which was increased by 50% as compared to the lowest HI from control, and by 27% as compared to those produced with DAP application(standard check).

The highest bulb yield was produced in response to D-coder application in both dry and rainy seasons as compared to other fertilizer types, and lowest yield was produced from control plot in both seasons(Table3). The highest economic bulb yield produced by D-coder was increased by 47% and 61% over those produced on the control plot during dry and rainy seasons, respectively. Application of D-coder also increased bulb yield by 15% and 32% as compared to those fertilized by DAP during dry and rainy seasons, respectively(Table3). These results emphasized that the adequate soil moisture content along the growing period and applied nutrients encouraged vegetative growth of the plant, which cumulatively enhanced the development of large bulbs and yields. The results of this study are in agreement with the finding of AL-Abdulsalam and Hamaiel(2004) who reported significantly higher onion bulb weight with application of compound fertilizer containing 14%N:38%P:10%K nutrients. Morsy *et al.* (2012) also reported greatest values of onion bulb weight with 120 kgN+30 kgP+48 kgK ha^{-1} fertilization over two seasons. Halim and Ener (2001), Kumar *et al.* (2007) and Enciso *et al.* (2009) also found that irrigation highly affected the total bulb yield and yield components of onion. Similarly, Pejic *et al.* (2011) revealed that the highest yield and yield components of onion were produced by irrigation as compared to rain-fed cultivation.

Application of D-coder fertilizer improved bulb yields of garlic more than other fertilizer types. The increment in vegetative growth and dry weight of plant organs by combined N,P,S,Zn application may be

attributed to the direct effect of nutrients in improving plant metabolism, increasing photosynthetic rate and free amino acids, which led to an increase in yield and quality characters (El-Kader *et al*., 2007). The interaction of N with P and K application also increased production of large dry matter and bulb weights of the crop that increased the total bulb yield. Similarly, Morsy *et al*. (2012) obtained higher yield and quality attributes of onion by applying 120kg N+24kg P+48kg K ha^{-1} combination in two seasons; and Coolong and Randle (2008) revealed that, application of Ammonium sulphate improved bulb yield and mineral uptake of onion than other fertilizer types.

Soil types also showed significant variation on economic bulb yield during both dry and rainy seasons; however, biological yield and HI was showed significant variations only during dry season due to soil type(Table3). Both biological yield and HI was higher on Andosols as compared to those produced on Vertisols during dry season using irrigation; improving by 36.6% and 20%, respectively. The economic bulb yield was significantly increased on Andosols compared to on Vertisols during both dry and rainy seasons. Bulb yield produced on Andosols was improved by 31.75% during dry season and by 9.52% in rain-fed as compared to yield produced on Vertisols(Table3). These might have been due to the controlled watering of the crop through irrigation which improved the economic bulb yield through improving uptake of nutrients from the Andosols. This revealed that application of optimum amounts of nutrients along with the nutrients available in the soils increased the production of dry matter as well as the total bulb yield of garlic which increased crop nutrients uptake in both seasons on the soils (Diriba-Shiferaw *et al*., 2013).

Table 3: Effects of different types of fertilizers and soils on yield and yield indices of garlic under dry and rainy cropping seasons of 2013/14

Treatments	Dry season(Irrigation)			Rainy season(Rain)		
	Biological yield(g)	HI	Bulb yield(t/ha)	Biological yield(g)	HI	Bulb yield(t/ha)
Fertilizer						
Control	32.68^{c}	0.56^{d}	8.16^{d}	22.10^{c}	0.88	5.33^{d}
DAP	50.06^{a}	0.66^{c}	10.45^{bc}	28.76^{b}	0.91	6.48^{c}
Azofertil	41.88^{b}	0.77^{b}	10.89^{b}	33.40^{ab}	0.86	7.40^{b}
Basic	34.62^{c}	0.74^{b}	9.61^{c}	32.12^{ab}	0.95	7.42^{b}
D-coder	49.26^{a}	0.84^{a}	12.00^{a}	34.53^{a}	0.85	8.59^{a}
SE	1.15	0.021	0.298	1.620	0.051	0.301
LSD(0.05)	**	***	**	**	ns	**
Soil						
Andosols	48.15^{a}	0.78^{a}	11.62^{a}	31.17	0.85	7.36^{a}
Vertisols	35.25^{b}	0.65^{b}	8.82^{b}	29.20	0.93	6.72^{b}
SE	0.72	0.013	0.189	1.025	0.033	0.191
LSD(0.05)	**	***	***	ns	ns	*
CV(%)	8.10	6.64	7.55	14.82	15.28	10.50

SE-Standard error; LSD-Least Significant Differences; CV-Coefficient of Variation; DAP-Diammonium phosphate; HI-Harvest Index; ns-nonsignificant

c) Economic Benefits of Compound Fertilizers

The different types of fertilizers applied on different soils both during dry and rainy seasons were found significant with respect to gross and net returns. The higher gross and net returns were found with application of D-coder, Azofertil and Basic fertilizers respectively on Andosols during dry season using irrigation and on Vertisols under rainy season than DAP and control. However, the significantly highest gross and net returns were obtained from Andosols treated with D-coder, Basic and Azofertil fertilizers respectively during the rainy season; but highest gross and net returns were due to DAP which followed by D-coder and Azofertil fertilizers on Vertisols during dry season. The highest net return was found in plot fertilized with D-coder on Andosols during dry season and lowest from control plot on Vertisols during rainy season(Figure 1). Fertilizers, seasons and soils showed significant differences with respect to benefit to cost (B:C) ratio. D-coder fertilizer applied on Andosols in both seasons and on Vertisols during rainy season showed significant benefit than other fertilizers types on both soils because of its higher yield produced in terms of cost incurred during production. Whereas, among the fertilizer types applied on Vertisols during dry season, highest B:C ratio was recorded with application of DAP followed by D-coder and Azofertil, and lowest B:C due to Basic fertilizer. Lowest B:C ratio was observed when garlic was grown without any fertilizer on both soils during the two seasons except on Vertisols during dry season, because of Basic treated produced low yield interms of higher cost incurred during the production season(Figure2). This might be also due to the higher yield as a result of nutrients uptake and dry matter

production using elements available in compound fertilizers plus the nutrients in Andosols soil and availability of optimum moisture during rainy season. However, application of fertilizers to Vertisols did not produce significant benefit to cost ratio during both seasons, which might be due to lower amount of nutrients available in the soil before the external fertilizers applied. Kale (2010) also found higher gross and net returns with higher yields of onion with the application of Sulphate of potash and Ammonium sulphate but lower B:C than the other N and K fertilizer sources, single nutrient containing fertilizer type.

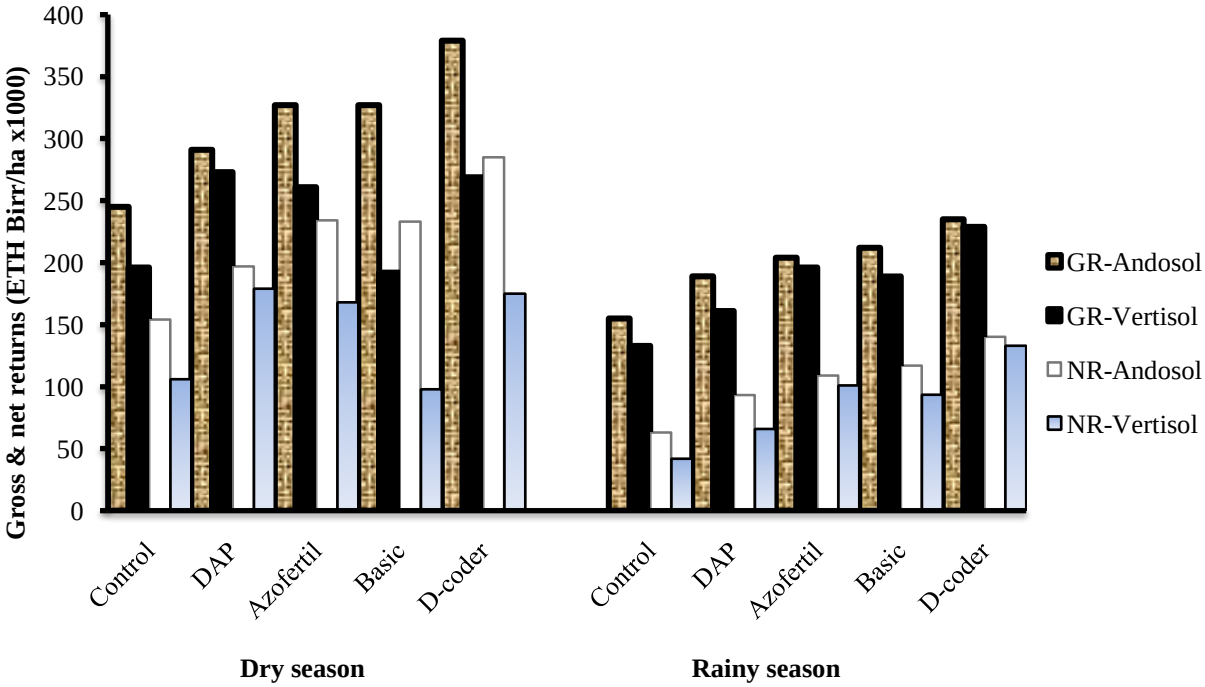

Figure 1: Gross return(GR) and Net return(NR) of garlic as influenced by fertilizer types on Andosols and Vertisols during dry and rainy cropping seasons of 2013/14

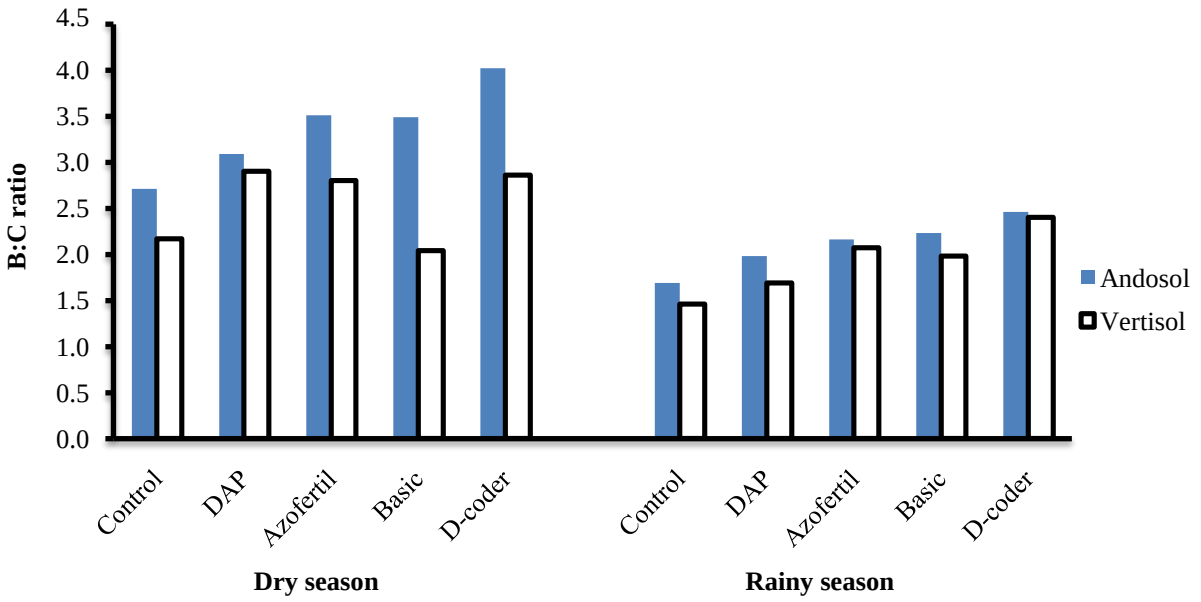

Figure 2: Effect of fertilizer types on B:C of garlic on Andosols and Vertisols during dry and rainy cropping seasons of 2013/14

Note: At the time of dispatch 1kg of garlic costs Birr 25-35 and average taken was 30Birr/kg during both seasons; consequently, production yields were adjusted by 10% reduction to compensate with those produced by farmers.

IV. Conclusions and Recommendations

Garlic plant showed differential responses to the different types of compound fertilizers on both Andosols and Vertisols under both dry and rainy seasons. The morphological characters like plant height, neck diameter and leaf area index were significantly influenced by the application of different compound fertilizers and soil types under different production seasons. Yield and yield components and economic returns of the crop were also significantly increased by the application of different compound fertilizers in dry-season cultivation using irrigation than under rainy season on both soils. But, significantly superior response of garlic, as observed by vegetative growth, yields and economic benefits of the crop, was obtained when garlic was planted in the dry-season using irrigation on Andosols with the fertilization of D-coder fertilizer at 200 $kgha^{-1}$ which supplied 28kg N+18kg P+42kg S+0.2kg Zn ha^{-1} followed by Azofertil fertilizer at 200 $kgha^{-1}$ which supplied 60kg N+50kg S ha^{-1}. Thus, it could be concluded that application of D-coder fertilizer containing 28kg N+18kg P+42kg S+0.2kg Zn ha^{-1} nutrients and Azofertil fertilizer containing 60kg N+50kg S ha^{-1} nutrients are better to substitute the locally recommended DAP fertilizer (92kg N+40kg P ha^{-1}) for better productivity of garlic over the other fertilizer types under both dry season using irrigation and rainy season on both Andosols and Vertisols soil types of the area and the like.

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