Response of Onion (*Allium Cepa L.*) Growth and Yield to Different Combinations of N, P, S, Zn Fertilizers and Compost in Northern Ethiopia

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Abstract: ***Low soil fertility status is a limiting factor in northern Ethiopia in general and the study area in particular. To improve this problem and increase onion yield, balanced fertilization is a key important factor identified. However, use of correct type and rate of fertilizer applications are major problems in the study area. The objective of this research was, thus, to investigate the effect of three different combinations of N, P, S, Zn fertilizers and compost on yield and growth parameters of "Adama red" onion variety (Allium cepa L.). A field experiment was conducted at a farmer's field in Gumsalassa irrigation scheme in northern Ethiopia for the last two consecutive irrigation seasons (2012/2013 and 2013/2014). The experiment was laid out in randomized complete block design with three replications and five experimental plots (treated with N-P-S-Zn, N-P-S, N-P, compost and control) with unit plot size of 3m × 3.5 m = 10.5 m^2 and subjected to analysis of variance. Applied fertilizer rates were N=130, P=20, S=21, Zn=15 and Compost 12000 Kg he^{-1}. As a result, all combinations of fertilizers including compost gave significantly higher yield as compared to the control (P=0.05). On an average, the study revealed that a considerable response of onion to N-P-S-Zn fertilizers was observed with a maximum average yield of 25377.5 kg he^{-1}. Conversely, the minimum average yield (9810.5 kg he^{-1}) was observed in the control plot. Accordingly combinations of 130 kg N, 20kg P, 21kg S and 15kg Zn ha^{-1} could be recommended for better yield over others.***

Keywords: *Allium cepa*, bulb, compost, dry matter, fertilizer, growth, onion, yield

1. Introduction

Onions, shallots, garlic and leeks (most popular bulb crops) belong to the *Alliaceae* family characterized by a shallow root system which explains why fertilizers should be banded at 8-10 cm below the seed row (SOPIB, 2001). Thus, onion belongs to shallow rooted crops that are why it is preferable to split fertilizer application (before sowing or planting, at the fully expanded leaf stage, and just before bulb formation). High nutrient availability is important during bulb formation. Onion have distinctive flavor widely used in soups, meat dishes, salads, food dressing and sandwiches, medicinal purposes and is cooked alone as a vegetable. Its pungency is due to the presence of a volatile oil (*allyl propyl disulphide*) (Malik, 1994).

Onion (*Allium cepa* L.) is the main spices crop grown in Ethiopia. The annual production of onion in Ethiopia during 2012/2013 growing season was about 21,919 ton from 21,865 hectares of land (FDRECSA, 2013). In Gumsalasa irrigated fields of northern Ethiopia (the study area), onion is a major cash crop covering about ¼ of the total irrigated land. Intensive cropping, imbalanced fertilization, no use of fertilizers and less or no use of organic manures have resulted in depletion of soil fertility in the study area. Specifically, farmers of the area grow two to three crops in a same piece of land in a year without assessing how much fertilizer remains in the field for the next crop and how much would be applied to achieve higher yield in respect of benefits. Moreover, the farmers apply fertilizers based on blanket fertilizer application approach that make the soil heterogeneous causing declination of soil fertility in a long run. Consequently, nutrient statuses of the soils of the area have been decreasing steadily and currently the fertility status of soils are already depleted. However, there is enough scope to increase yield with balanced fertilization. Balanced fertilizer application is essential for the vegetative growth and, thus, for producing crops with top quality and high yields especially on soils that are cultivated continuously (Chintala *et al*., 2012a; 2012b). The requirement of fertilizers by the crop is also dependent on the residual effect of the applied fertilizer in the previous crop.

Onion being a cash crop, increment of yield with balanced fertilization is one of the most important factors. As a result the existing soil fertility status of the area is very important to recommend a balanced fertilizer dosage for a specific crop. As any location specific fertilizer recommendation is not available, this study was designed to find out optimum fertilizer dose for higher onion production in the study area by assessing the deficiency or sufficiency levels of N, P, S, and Zn nutrients in the field and evaluating the effect of combined application of N, P, S, and Zn fertilizers and compost on the yield and yield components of onion crop.

2. Materials and Methods

2.1 Area Description

The study area is located in the northern highlands of Ethiopia at Gumselassa irrigation scheme (13^{o}14′N and 39^{o}32′E) at an altitude of 1960 m.a.s.l. The scheme is situated about 4 km east of Adigudom town in the Tigray region. The area belongs to the "Weynadega" (characterized by an altitude of 1400-2600 m.a.s.l based on traditional classification) agro ecological zone. The rainfall in the study area is highly variable with space and time. It is in the range of 300-900 mm per year and uni-modal, with more than 85% of the rain falling within a period of four months from June to September. Drought periods of several weeks during the rainy season are also frequent (Mintesinot *et al*., 1999). The maximum and minimum average temperatures are 24.6 ^{o}C and 11.4 ^{o}C, respectively. The largest part of the area is dominated by arable lands having a gentle slope and encircled by a smaller area with steep sloping hills. About 61% of the area is covered with black clayey soils (Mintesinot *et al*., 1999; Table 2) having pH value ranging between 7.72 and 8.11 (Table 3).

2.2 Methods

The experiment was conducted in farmer's field for two consecutive irrigation seasons in 2012/2013 and 2013/2014 from December to May. The experimental plot was laid out in randomized complete block design with three replications and five treatment plots. A local improved onion variety called '*Adama red*' was used as planting material. The unit plot size was 3 m × 3.5 m = 10.5 m^2. The treatments consisted of three different combinations of N, P, S, and Zn (N-P, N-P-S and N-P-S-Zn) fertilizers assigned to three plots, fourth plot fertilized with compost and fifth plot was a control (Table 1).

Table 1: Fertilizer application rates

Treatments	Nutrient Dose (Kg he^{-1})				
	N	P	S	Zn	Compost
T_o	0	0	0	0	0
T_1	130	20	0	0	0
T_2	130	20	21	0	0
T_3	130	20	21	15	0
T_4	0	0	0	0	12,000

Note. T_o is control; T1 is nitrogen and phosphorous; T2 is nitrogen, phosphorous and sulphur; T3 is nitrogen, phosphorous sulphur and Zinc and T4 is compost

Two soil samples were randomly picked from each replication sites at a depth of 0-20 cm using auger to form a composite sample. The soil samples were air dried, crushed in a mortar and sieved through a 2 mm sieve. Chemical and physical soil analyses were done on the separates pass through 2mm mesh only. The pH of the soils was determined in 1:2.5 soil water suspensions using a glass electrode and the electrical conductivity of the soils was measured in saturated extract (Van Reeuwijk, 1992). Soil bulk densities were determined by analyzing the collected undisturbed soil samples following the core sampling method (Black, 1965). The Walkley and Black method was used to determine organic carbon content of the soils (Walkley & Black, 1934) and the organic matter content was obtained by multiplying the percent organic carbon by conversion factor of 1.724. Total nitrogen was analyzed using the Kjeldahll method as described in (Black, 1965). Available phosphorus was determined by Olsen method (Olsen & Dean, 1965). Available sulfur was determined using the KCl-40 test, where 0.25 M KCl was added to the soil and extracted at 40 ^{o}C temperature for three hours (Blair *et al*., 1991). Available zinc was determined after air-dried soils were extracted in 1% EDTA, the filtrate was aspirated into an air-acetylene flame of an atomic absorption spectrophotometer and the absorbance was recorded (Baker, 1974). The soil particle size distribution was determined using hydrometer method (Van Reeuwijk, 1992) and classified in to its soil class on the bases of particle size (Table 2). Fertilizer doses were calculated according to initial soil nutrient status of the experimental plots. The soil texture was determined as clay soil (Table 2). Soil pH was fairly alkaline, the total N status, available phosphorus, sulfur, and zinc were either at average or below the critical level and organic matter content of the soil was low (Table 3).

Table 2: Soil textural class of the study area according to USDA

Sample Code	*Soil Separate Value*			*Textural Class*
	%Sand	*%Silt*	*%Clay*	
Replication -1	17	21	62	clay
Replication -2	17	19	64	clay
Replication -3	21	21	58	clay

Note. USDA - United States Department of Agriculture.

The entire quantity of P, S, Zn with one half of N were applied as basal dose at the time of final land preparation and the remaining half of N was applied as top-dress at the fully expanded leaf stage, and just before bulb formation with side-dressing (Table 1). The sources of N, P, S, and Zn were urea, DAP, zinc-oxide and ammonium-sulfate, respectively. The 45 days old onion seedlings were transplanted in December, 2012/2013 and 2013/2014 consecutive irrigation seasons with a spacing of 20cm x 8cm between rows and plants respectively. All the management practices except the experimental variables were the same to all plots. Land was ploughed three times to prepare a favorable seedbed. The crop was harvested in 1st week of May 2013 and 2014 at maturity stage when most of the leaves dried up and bended over. Care was taken to avoid any kind of bulb injury during lifting. Data on plant parameters (plant height, total bulb weight, bulb diameter, fresh and dry matter weight of onion) were collected properly. The collected data at various growth stages in response to the applied combinations of fertilizer and compost were recorded and analyzed. The results were subjected to analysis of variance (ANOVA) using SAS statistical software version 9.0 and treatment effects were compared using the Fisher's Least Significant Differences test at 5% level of significance.

Table 3: Nutrient status of the initial soil

Soil parameters	Values			
	Replication -1	Replication -2	Replication -3	Average
pH (1:2.5 Soil-water)	8.11	8	7.72	7.94
Bulk density (g cm^{-3})	1.2	1.34	1.5	1.35
Organic matter (%)	2.07	2.6	2.49	2.39
Total N (%)	0.113	0.109	0.108	0.11
Available P (mg kg^{-1})	2.34	2.1	3.84	2.76
Available S (mg kg^{-1})	18.2	17.6	18.4	18.07
Available Zn (mg kg^{-1})	0.98	1.04	1.1	1.04

All data pertaining to growth yield and yield components were collected from 5 plants in each of the 15 experimental plots of onion. A random sampling was done from three central rows of the plot for determination of plant height.

After harvesting and curing, bulb yield and yield attributes (bulb weight per plot, bulb diameter, bulb fresh weight and dry matter weight) were recorded.

3. Results

3.1 Bulb Yield

Different combinations of nutrients and compost produced significant variations for bulb yield of onion (Table 4). The maximum bulb yield (25517 kg he^{-1} in 2012/2013 and 25238 kg he^{-1} in 2013/2014) was observed in T_3 and the minimum yield (9783 kg he^{-1} in 2012/2013 and 9838 kg he^{-1} in 2013/2014) was found in T_o (control). Mean yield of 21819 kg he^{-1} was obtained from T_2, whereas 21496.5 kg he^{-1} was found in T_1 and 16199 kg he^{-1} in T_4. The treatment T_3 performed as the highest yielder over control during the two consecutive irrigation seasons. On the other hand, T_2, T_1 and T_4 (compost) also increased the bulb yield over control. It can be concluded that the positive response of different combinations of nutrients and compost for onion production can be expressed by the following orders: (N, P, S, and Zn)> (N, P, and S)> (N and P)> (compost) as shown in Table 4.

Table 4: Yield of onion as affected by different combinations of nutrients of

Treatment	Bulb yield (kg he^{-1})		mean (kg he^{-1})
	2012/2013	2013/2014	
T_o	9783d	9838d	9810.5
T_1	21250b	21743b	21496.5
T_2	21733b	21905b	21819
T_3	25517a	25238a	25377.5
T_4	15417c	16981c	16199
CV%	2.52	4.45	

Note. he is hectare; T_o is control; T1 is nitrogen and phosphorous; T2 is nitrogen, phosphorous and sulphur; T3 is nitrogen, phosphorous, sulphur and Zinc and T4 is compost

3.2 Plant Height

Plant height was recorded 60 days after planting and it was observed that the effects of combined application of nutrients and compost was significant in the irrigation season 2013/2014 but not significant in 2012/2013 (Table 5). The plant height of onion was approximately same in 2012/2013. The tallest plants (37.86 cm in 2012/2013 and 64.27 cm in 2013/2014) were recorded in T_3 and the shortest (31.86 cm in 2012/2013 and 37.00 cm in 2013/2014) was in control, where as plant height was higher in T_2 and followed by T_1 and T_4.

3.3 Bulb Diameter

The highest value of bulb diameter (4.78 cm in 2012/2013 and 8.55 cm in 2013/2014) was recorded from the plots treated by T_3 though the treatments from T_o, T_1, T_2 and T4 were statistically similar in 2012/2013 (Table 5). The smallest diameter of bulb (4.24 cm in 2012/2013 and 5.23 cm in 2013/2014) was observed in T_o. Combinations of N, P, S, and Zn fertilizers played a positive role in the development of onion bulb diameter. Yet, the application of compost and combinations of N, P, and S to soils somehow increased the bulb diameter.

3.4 Bulb Fresh Weight

Application of different combinations of nutrients and compost significantly influenced the fresh weight of bulb of onion (Table 5). Though the observations were statistically similar in 2012/2013, the highest fresh weight of bulb (347.9 gm in 2012/2014 and 657.56 gm in 2013/2014) was found in T_3 and the second highest value was in T_2. The lowest value was recorded in T_o in the two seasons. The role of T_o to T_4 treatments showed similar response on fresh weight of bulb in the first season (2012/2013). It is indicated that application of N, P, S, and Zn fertilizers had positive effect on growth of onion bulb.

3.5 Bulb Dry Weight

The variations of dry weight of bulbs were highly significant by the application of different combinations of fertilizers in 2013/2014 season but statistically similar in 2012/2013 (Table 5). The present study revealed that maximum dry weight of bulb (60.49 gm in 2012/2013 and 140.17 gm in 2013/2014) was found in T_3 followed by T_2, T_1, and T_4.

Table 5: Yield parameters of onion as affected by different fertilizer combinations and compost

Treatment	Plant Height (cm)			bulb Diameter (cm)			Fresh Weight (gm.)			Dry Weight (gm.)	
	2012/2013	2013/2014		2012/2013	2013/2014		2012/2013	2013/2014		2012/2013	2013/2014
T_o	31.86a	37.00e		4.24a	5.23e		333.01a	366.37d		50.46a	54.120c
T_1	33.80a	45.13d		4.40a	6.49d		335.99a	591.48b		58.18a	108.59b
T_2	34.93a	53.00b		4.60a	7.57b		336.76a	622.97a		58.30a	124.71a
T_3	37.86a	64.27a		4.78a	8.55a		347.91a	657.56b		60.49a	140.17b
T_4	32.53a	51.87c		4.47a	7.01c		333.65a	529.59c		51.4a	101.65b
CV (%)	19.78	2.78		21.63	4.22		50.68	3.29		52.49	24.27

Note. T_o is control; T1 is nitrogen and phosphorous; T2 is nitrogen, phosphorous and sulfur; T3 is nitrogen, phosphorous sulfur and Zinc and T4 is compost; cm is centimeter and gm is gram

4. Discussion

Bulb weight is an important yield contributing character for onion. From the review of the results the variance analysis of the treatments showed that the effect of fertilizers on the analyzed bulb yield was highly significant (Table 3). Bulb yield of onion was increased significantly over the control while the maximum yield was obtained in plots fertilized with N, P, S, and Zn fertilizers at the rate of N=130, P=20, and S=21, Zn=15kg he^{-1}(Table 1). Onion yield increment could be due to the fact that nitrogen supply to the plant increases the rate of metabolism where more carbohydrate is synthesized, which increases the bulb weight and thus increases total yield. The results of Amin *et al.* (1995) are of primary importance in this regard who reported that 100 kg Nhe^{-1}resulted in maximum yield. Maurya and Lal (1975) reported that application of Zn at 1, 2 and 3 ppm increased the yield and bulb quality significantly. The results of fresh weight of bulbs are in agreement with the findings of Satbir *et al.* (1989). They stated that fresh weight of bulb significantly increased by using Zn and B. Gamelli EL. et al. (2000) narrated that dry weight of bulb was significantly increased by applying Zn, where similar contribution of Zn was also observed in this experiment.

Significant difference of plant height was observed as affected by different combinations of nutrient elements and compost (Table 5). Diameter of bulb under different combinations of nutrients was not identical. Thus, the results revealed that maximum plant height and bulb diameter were observed in plots treated with N, P, S, and Zn over others (Table 5) while minimum plant height was recorded in plots received no treatment (control).The reason for this may be zinc involves in auxin metabolism in vegetative growth that increases leaf length. Tisdale *et al.* (1985) reported that zinc is involved in auxin metabolism and other enzymatic reactions that increase leaf length. It may be due to collective effect of nitrogen and zinc that stimulate plant growth and thus increases leaf length. According to Aujla and Madan (1992), N application and closer row spacing influence the girth of bulb of onion. Average weight of single bulb increased over control in response to different nutrient elements and that was reflected in the yield. Maximum mean dry weight was observed in plots fertilized with N, P, S, and Zn over the others (Table 5).

In general, the yield response of onion to N, P, S, and Zn fertilizers were relatively higher over the others (Table.5). In this regard, the result may be due to the role of nitrogen on chlorophyll, enzymes and proteins synthesis and the role of phosphorus on root growth development, phosphoproteins and phospho-lipids formation. The role of moderate dose of Sulfur was found responsive that diameter and weight of bulbs were significantly improved with the application of S up to 24 kg he^{-1} (Ahmed *et al.*, 1988). Balasubramonium *et al.* (1979) studied that the added S had positive effect in increasing the yield of onion but a reduction in yield with very high dose of S was also reported. With regard to the contribution of zinc to the yield increment of onion, the results are in conformity with Mukesh *et al.* (1997) who reported that the high fresh onion yield was achieved on plots treated only with zinc at a rate of 10 kg Zn he^{-1}. The results of Sliman *et al.* (1999) and Mukesh *et al.* (2000) are also in close conformity in this regard.

5. Conclusion

The experiment was carried out to investigate the effect of different combinations of fertilizers and compost on yield and growth parameters of onion. Different combinations of nutrients played important roles on growth, yield and yield attributes. Results of the experiment revealed that almost all the yield and yield parameter studied were significantly affected by different combinations of N, P, S, and Zn fertilizers and compost. Maximum yield was obtained from plots that received combined fertilizers of N, P, S, and Zn. Therefore, combined application of nitrogen, phosphorous, sulfur, and zinc together at the rate of 130, 20, 21 and 15 kg he^{-1}, respectively is found to be the most suitable combination and dose for maximum growth and yield of onion and suggested for farmer's use in the field. Likewise, further study is still needed to analyze the economic feasibility of fertilizer application.

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