African Journal of Agricultural Research Vol. 6(14), pp. 3252-3258, 18 July, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR10.1024
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Growth, bulb yield and quality of onion (*Allium cepa* L.) as influenced by nitrogen and phosphorus fertilization on vertisol I. growth attributes, biomass production and bulb yield

Y. Abdissa*, T. Tekalign and L. M. Pant

School of Plant Sciences, College of Agriculture and Environmental Sciences, Haramaya University, P. O. Box 138, Dire Dawa, Ethiopia.

Accepted 18 April, 2011

A field experiment was undertaken to study the effect of different levels of nitrogen (N) and phosphorus (P) fertilizers on the growth, biomass yield and fresh bulb yield of onion (*Allium cepa* L.) grown on vertisol of Shewa Robit, North east Ethiopia. Five rates of N (0, 69, 92, 115, 138 kg ha^{-1}) and five rates of P (0, 10, 20, 30, 40 kg ha^{-1}) were arranged in a Randomized Complete Block Design replicated three times. Nitrogen showed significant effects in all of the parameters studied, while P fertilization and its interaction with N did not. The proportion of bolters per plot decreased by about 11 and 22% in response to the application of 69 and 92 kg N ha^{-1}, respectively over the control. Regardless of the rate, N fertilization day extended days to physiological maturity by about 6 days over the control. Application of 69 kg N ha^{-1} increased plant height and leaf length by about 10 and 11.5%, respectively over the unfertilized check. Number of leaves increased by about 8% in response to the application of 92 kg N ha^{-1} over the control. Leaf diameter and bulb length were not influenced by N fertilization. Regardless of the rate of application, N fertilization increased bulb diameter and average bulb weight by about 12 and 21.5%, respectively over the control. Application of 69 kg N ha^{-1} increased the development of splitted bulbs by about 45%, average bulb weight by 24%, total dry biomass by 20%, harvest index by about 4%, total bulb yield by 18%, and marketable bulb yield by 17% over the control. Application of 69 kg N ha^{-1} enhanced the growth of onion plant and resulted in optimum fresh total and marketable bulb yield on the vertisol of Shewa Robit, North east Ethiopia. The lack of significant response in onion to P fertilization could be attributed to the presence of adequate amounts of available P (16.02 ppm) in the soil and hence P fertilization for onion production is not advisable.

Key words: Bulb diameter, bulb splitting, neck thickness, onion bolting, onion maturity.

INTRODUCTION

Nitrogen (N) and phosphorus (P) are often referred to as the primary macronutrients because of the probability of plants being deficient in these nutrients and because of the large quantities taken up by plants from the soil relative to other essential nutrients (Marschner, 1995). Nitrogen comprises 7% of total dry matter of plants and is a constituent of many fundamental cell components (Bungard et al., 1999). It is one of the most complex in behavior, occurring in soil, air and water in organic and inorganic forms. For this reason, it poses the most difficult problem in making fertilizer recommendations (Archer, 1988). Plant demand for N can be satisfied from a combination of soil and fertilizer to ensure optimum growth.

Three major essential plant nutrients, N, P and K were found increasingly in short supply in the soils of Eastern, Western and Southern Africa (Rao et al., 1998). Particularly N and P are deficient in many soils of tropical Africa (Richardson, 1968), which might also be true for many Ethiopian soils (Murphy, 1968). Phosphorus deficiency is one of the largest constraints to crop

*Corresponding author. E-mail: bubunafkot@yahoo.com. Tel: 00251-255530364. Fax: 00251-255530325.

production in many tropical soils, owing to low native content and high P immobilization within the soil (Fairhust et al., 1999). Accordingly, P fertilization is usually recommended in these soils. Phosphorus is essential for root development and when the availability is limited, plant growth is usually reduced. In onions, P deficiencies reduce root and leaf growth, bulb size and yield and can also delay maturation (Brewester, 1994). In soils that are moderately low in P, onion growth and yield can be enhanced by applied P. Onions are more susceptible to nutrient deficiencies than most crop plants because of their shallow and unbranched root system; hence they require and often respond well to addition of fertilizers (Brewester, 1994).

Allium cepa as bulb onion and/or shallot is probably cultivated in all countries of tropical Africa including Ethiopia (Grubben and Denton, 2004). Onion is important in the daily Ethiopian diet and all the plant parts are edible, although the bulbs are widely used as a seasoning or a vegetable in various dishes. It is one of the most economically important olericultural products in the country. During 2006, the rainy season (Meher) about 16578.72 ha of lands were planted and more than 0.17 million tons of bulbs were obtained with an average yield of 10.6 tons/ha (CSA, 2006). Onion is one of the most important vegetable crops cultivated both under rainfed and irrigated condition in Kewet district of northeastern Ethiopia. According to CSA (2006) census report *A. cepa* L. is produced in 218.94 and 431.64 ha of land in main (Meher) and short (Belg) rainy seasons, respectively and the average yield of onion was 6.5 tons per ha which is far less than both from the national and world average yield of 10.5 and 13.4 tons per ha, respectively (CSA, 2006; FAO, 2006). A number of production constraints are responsible for such reduced bulb yield of which lack of specific fertilizer recommendation for the area is in the top list.

Currently, for the research and the extension activities in the district, the nationally recommended fertilizer rate of 92 kg N ha^{-1} is being used without considering P as a limiting nutrient. Hence, there is an urgent need to identify the optimum N and P level for better productivity of onion in the area. In view of the aforementioned, the study was carried out to determine the optimum level of N and P fertilizer for optimum yield of onion on vertisol of Shewa Robit and to assess leaf growth, biomass production and bulb yield under varying levels of N and P rates.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Shewa Robit Research Station of Debrebrehan Agricultural Research Center which is 125 km north east of Addis Ababa, Ethiopia. It is located at 11°55'N latitude and 37°20'E longitude at an altitude of 1380 m.a.s.l. The area has an average annual rainfall of 1007 mm, with short rain between March and April and long rain between June and September, and annual mean minimum and maximum temperature of 16.5 and 31^{0}C, respectively (BoA, 2000).

The field experiment was conducted on vertisols, which have clay texture with clay content of 56%, sand 10%, silt 34% and a pH value of 8.02. It has an organic matter content of 2.18%, total N of 0.15% and available P of 16.02 ppm. Additionally, the exchangeable K content was 1.89, Ca 37.60, Mg 7.20, and Cation Exchange Capacity 58.60 all expressed in Cmol kg^{-1} soil. Laboratory results of the soil analysis before planting indicates that the soil is heavy clay, basic in reaction with medium total nitrogen, normal available phosphorus, low organic matter, and high cation exchange capacity as well as exchangeable bases (Ca^{+2}, Mg^{+2}, and K^+).

Planting and agronomic practices

Bombay Red onion (*A. cepa* L.) variety, which is the dominant variety produced in the area, was used for the study. Seeds were sown in a nursery on a well prepared seed bed. When seedlings were at the 3- to 4- leaf stage or 12 to 15 cm height, they were transplanted in the experimental field. Planting was done on ridges of about 25 cm high, adopting the recommended spacing of 40 cm between water furrows, 20 cm between rows on the ridge and 10 cm between plants. The plot size was 4.2 x 3 m and a total of 30 plants were planted per row. A distance of 1 m was maintained between plots and 1 m between blocks. Each experimental plot had seven rows. All cultural practices were employed as per the regional recommendations.

Treatments and experimental design

The experiment was conducted using irrigation during 2007/2008 production period. Transplanting was done end of September 2007 and harvesting was carried out end of January 2008. The treatments were factorial combination of five levels of N (0, 69, 92, 115 and 138 kg ha^{-1}) and five levels of P (0, 10, 20, 30 and 40 kg ha^{-1}). The treatment combinations were arranged in a Randomized Complete Block Design with three replications. The fertilizer sources were urea (46% N) and TripeSuperphosphate (20% P) for N and P, respectively. The full dose of P and half dose of N fertilizer were applied at transplanting and the remaining half dose of N was side-dressed 45 days after transplanting.

Data collection

Measurements on the following growth parameters and bulb characters were recorded at physiological maturity and harvesting time, respectively. Plant height was measured using ruler from the soil surface to the top of the longest mature leaf. Leaf number per plant refers to the total count of leaves per plant at maturity. The length of the longest leaf was measured with meter scale from the base to its apex. Leaf diameter refers to the maximum diameter of the longest leaf and neck thickness was measured at the narrowest point using vernier caliper. Bulb length and diameter refers to the height of the bulb and the average width at the widest point in the middle portion of the mature bulb measured using vernier caliper. Average bulb weight computed by weighing ten bulbs together and calculating the average. Total dry biomass was recorded as the weight of the bulb, above ground parts and roots at the time of maturity after drying at a temperature of 70°C in an oven to a constant weight. Harvest index is the ratio of dry bulb weight to total dry biomass yield per plant. The data set is the average of ten randomly taken plants in each experimental plot.

Measurements on the following parameters were recorded at the

Table 1. Effect of different rates of N and P on bolting, physiological maturity, plant height, number of leaves, leaf length and leaf diameter of onion grown on vertisol.

Nitrogen (Kg ha^{-1})	Bolting (%)	Days to physiological maturity	Plant height (cm)	Leaves per plant	Leaf length (cm)	Leaf diameter (cm)
0	4.15a	101.80b	51.55b	13.42b	42.75b	0.75a
69	3.68b	105.67a	56.89a	14.19b	47.67a	0.77a
92	3.25c	106.80a	56.52a	14.54a	47.59a	0.79a
115	3.08c	106.93a	56.87a	14.57a	48.41a	0.78a
138	3.07c	106.67a	57.65a	14.64a	48.83a	0.77a
F-test	*	*	*	*	*	NS
Phosphorus (Kg ha^{-1})						
0	3.32a	106.13a	56.37a	14.43a	47.42a	0.74a
10	3.57a	105.00a	55.91a	14.06a	47.27a	0.77a
20	3.32a	104.93a	56.01a	14.29a	47.13a	0.79a
30	3.49a	106.67a	55.39a	14.07a	46.63a	0.75a
40	3.55a	105.13a	55.81a	14.24a	46.80a	0.81a
F-test	NS	NS	NS	NS	NS	NS
SEM(±)	0.31	2.41	2.22	0.64	1.99	0.05

NS and *: non significant at P<0.05, significant at P>0.05, respectively. SEM: Standard error of the mean. Means with the same treatment and column sharing the same letters are not significantly different at P<0.05.

appropriate growth stage and computed as the mean of individual plots. Bolter plants per plot was the number of plants produced flower stalk and expressed in percentage in relation to total number of plants. Days to physiological maturity referred to the actual number of days from transplanting to a day at which more than 80% of the plants in a plot showed yellowing of leaves. Total bulb yield was computed based on the weight of matured bulbs yield per plot and converted in to hectare base and expressed in tones. Marketable bulb yield was determined after discarding bulbs smaller than 3 cm in diameter, splitted, thick necked, rotten and discolored. Split bulbs percentage was determined by counting the number of split bulbs per plot and expressed in percentage in reference to total number of normal bulbs per plot.

Statistical analysis

The data were subjected to analysis of variance using SAS (Statistical Analysis System) version 8.0. Mean separation was done using Least Significant Difference (LSD) at 5% probability level. Correlations between parameters were done when deemed applicable.

RESULTS AND DISCUSSION

Bolting and physiological maturity

Nitrogen fertilization significantly reduced bolting in onion while P and its interaction with N had no effect (Table 1). The proportion of bolters per plot decreased by about 11 and 22% in response to the application of 69 and 92 kg N ha^{-1}, respectively over the control. This could be associated with the effect of N in extending the vegetative growth period of plants while delaying flowering. This is in agreement with the finding of Yamasaki and Tanaka (2005) in *Allium fistulosum* L. who found that low nitrogen promoted bolting in onion plants exposed to low temperature for 35 days. Bolting in bulb crop is triggered in response to exposure to conditions such as sufficient low temperature or limited N supply which induce flowers to emerge before bulb are adequately grown to suppress flower initiation.

Generally, significantly higher bolting percentage was observed on the control plants than the fertilized plants, which may be linked to limitation of N and the cool growing periods from planting October to harvesting in January. Nitrogen fertilization significantly extended days to the number of days required for the onion crop to attain physiological maturity while P did not (Table 1). Regardless of the rate, N fertilization day extended physiological maturity by about 6 days over the unfertilized treatment (102 days). This could be due to the fact that N fertilization extended the vegetative growth period of plants; as a result it delayed maturity. This is in agreement with Brewester (1994) and Sørensen and Grevsen (2001) who reported that too much nitrogen promoted excessive vegetative growth and delayed maturity.

Plant height and number of leaves per plant

Application of N fertilizer significantly increased plant height in onion while P fertilization and its interaction with N did not (Table 1). Application of 69 kg N ha^{-1} increased plant height by about 10% compared to the control (51.55 cm) although further N application did not cause further significant change. The increase in height could be attributed to its involvement as building blocks in the synthesis of amino acids, as they link together and form proteins and make up metabolic processes required for plant growth. Bungard et al. (1999) stated that N is a constituent of many fundamental cell components and it plays a vital role in all living tissues of the plant. No other element has such an effect on promoting vigorous plant growth. This result is in agreement with Rizk (1997) who reported that increasing N application generally increased growth parameters of onion plant.

Similarly, N fertilization significantly influenced number of leaves produced by onion plant while P had no effect (Table 1). Number of leaves increased by about 8% in response to the application of 92 kg N ha^{-1} over the control. This could be attributed to the increase in the vegetative growth of the onion plants through its effect in the synthesis of the different components of protein required for leaf development. Similar results were reported by Nasreen et al. (2007) who found that application of 120 kg N ha^{-1} significantly increased the number of leaves per plant and further increased N supply to 160 kg ha^{-1} tended to decrease it. Vachhani and Patel (1993a) also found that number of leaves per plant was the highest with the application of 150 kg N ha^{-1}.

Leaf length and diameter

Without affecting leaf diameter, N fertilization significantly increased leaf length in onion (Table 1). However, leaf length and leaf diameter were not significantly influenced by P fertilization and did not interact with N. Although the onion plant did not respond for further increase in N supply, application of 69 kg N ha^{-1} increased leaf length by about 11.5% as compared to the control (42.75 cm). The positive effect of N on leaf length may be due to its role on chlorophyll, enzymes and proteins synthesis. The result is in agreement with Bungard et al. (1999) who reported that N is the major constituent of proteins and the presence of abundant protein tends to increase the size of the leaves and ultimately increase carbohydrate synthesis. Similarly, Jilani (2004) reported that application of 200 kg N ha^{-1} significantly enhanced the length of onion leaves.

Neck thickness and split bulbs

Nitrogen and P fertilization and their interaction did not significantly affect the formation of thick-necked bulbs (Table 2). This could be due to the minimal direct effect of fertilization in the formation of thick-neck bulb. In agreement with this speculation, Brewester (1987) reported that neck-thickness is a physiological disorder that is influenced by seasons, sites and cultivars, not by fertility. In contrast, Jilani (2004) reported that application of N at 200 kg ha^{-1} increased the number of thick-necked bulbs. Application of N significantly increased the number of splitted bulbs in onion (Table 2).

The formation of splitted bulb was not significantly influenced by P fertilization and its interaction with N. Nitrogen fertilization at a rate of 69 kg ha^{-1} increased the development of splitted bulbs by about 45% over the check plot. However, further increase in the rate did not bring significant increase except at the highest rate that caused 57% splitted bulb formation over the control. Steer (1980) reported that bulb splitting as a result of multiple growing points is under genetic control with shallots being at the extreme in this respect. Growth in high temperatures and short days increases lateral shoot production in some cultivars (Steer, 1980).

Bulb diameter and length

Nitrogen fertilization significantly increased bulb diameter without affecting bulb length (Table 2). Phosphorus fertilization and its interaction with N did not significantly influence either bulb diameter or length. Regardless of the rate, N fertilization increased bulb diameter by about 12% in reference to the control (6.44 cm), which may be linked to the increase in dry matter production and allocation to the bulb. This was in agreement with Nasreen et al. (2007) who reported a significant increase in the diameter of bulbs due to the application of N up to 120 kg ha^{-1}. Similar results also reported by Yadav et al. (2003) who found that N at 150 kg ha^{-1}, enhanced the formation of bulbs with larger diameters. Although N fertilization did not affect bulb length in this study, there are findings disclosing an increased bulb length in response to N fertilization (Yadav et al., 2003; Reddy et al., 2005).

Mean bulb weight

Nitrogen significantly increased the average bulb weight of Bombay Red onion cultivar (Table 2). Mean bulb

Table 2. Effect of different rates of N and P on neck thickness, split bulbs percentage, bulb diameter, bulb length and bulb average weight of onion grown on vertisol.

Nitrogen (Kg ha^{-1})	Neck thickness (cm)	Split bulbs (%)	Bulb diameter (cm)	Bulb length (cm)	Average bulb weight (g)
0	1.37a	1.26c	6.44b	4.96a	112.79b
69	1.07a	1.83b	7.12a	5.12a	141.58a
92	1.78a	1.80b	7.19a	5.01a	144.00a
115	1.15a	1.90b	7.15a	4.93a	144.91a
138	1.14a	2.20a	7.33a	4.99a	144.14a
F-test	NS	*	*	NS	*
Phosphorus (Kg ha^{-2})					
0	1.16a	1.77a	6.95a	4.96a	133.94a
10	1.12a	1.76a	7.11a	5.12a	142.21a
20	1.41a	1.74a	7.05a	5.01a	139.34a
30	1.09a	1.91a	7.08a	4.93a	135.44a
40	1.14a	1.81a	7.04a	4.99a	136.50a
F-test	NS	NS	NS	NS	NS
SEM (±)	0.22	0.21	0.29	0.18	4.55

NS and *: non significant at P< 0.05, significant at P>0.05, respectively. SEM: Standard error of the mean. Means with the same treatment and column sharing the same letters are not significantly different at P<0.05.

weight increased by about 26% in response to application 69 kg N ha^{-1} as compared to the control; although further application did not bring significant change. Mean bulb weight improvement in response to N could be attributed to the increase in plant height, number of leaves produced, leaf length, and extended physiological maturity in response to the fertilization all might have increased assimilate production and allocation to the bulbs.

Mean bulb weight was strongly and positively correlated with plant height (r = 0.81**), number of leaves (r = 0.64**), leaf length (r = 0.78**), and days to physiological maturity (r = 0.76**). Onion bulb size can be increased by application of N during the growing period (Rice et al., 1993). In the present study, mean bulb weight was positively and strongly correlated with bulb length (r = 0.86**) and diameter (r = 0.96**) signifying that N fertilization increased bulb weight by improving both parameters. Reiley and Shry (1979) reported that of the three major plant nutrients, N exerted the most noticeable effects on plants, since it is required in large quantity by most crops. The initial soil test result proved the presence of medium amounts of N (total N of 0.15%), which justifies the application of additional N to enhance plant growth and crop productivity.

Total and marketable bulb yield

The analysis of variance indicated that N significantly improved both total and marketable bulb yield of onion as presented in Table 3. Application of N at a rate of 69 kg ha^{-1} improved the total and marketable bulb yield by about 5.74 and 4.06 ton, respectively as compared to the controls. However, in both cases further increase did not bring significant effect suggesting 69 kg ha^{-1} is the optimum rate to obtain the highest marketable and total bulb yield of onion at Shewa Robit on vertisol. This positive response may be due to the role of N in promoting the growth of onion plant.

In agreement with the current finding, application of 60 kg N ha^{-1} gave highest bulb yield of onion according to Cizauskas et al. (2003). On the sandy loam soil in a semi arid region, in the central rift valley of Ethiopia, irrigated onion plants benefited from application of 90 to120 kg ha^{-1} N compared to the unfertilized crops (Aklilu, 1997). Different researchers reported bulb yield improvement in response to N fertilization (Singh et al., 1989; Patel and Patel, 1990; Pandey and Ekpo, 1991; Vachhani and Patel, 1993b; Patel and Vachhani, 1994). There are reports indicating that different plant growth characters (plant height and bulb diameter) are known to increase the yield of onion (Nasreen et al., 2007).

In the same manner, it was observed that leaf length was positively correlated with total (r = 0.52**) and marketable (r = 0.46**) fresh bulb yields; leaf diameter was positively correlated with total (r = 0.24) and marketable (r = 0.36*) bulb yields. This association indicates that an increased photosynthetic area in response to N fertilization had substantially contributed to enhance onion productivity that could be through the production of more assimilates. Similar results were also reported by Nasreen et al. (2007). Bulb diameter has also strong and positive correlation (r = 0.33**) with the total

Table 3. The influence of different rates of N and P on fresh and dry bulb yield, total dry biomass and harvest index of onion grown on vertisol.

Nitrogen (Kg ha^{-1})	Fresh bulb yield (tons ha^{-1})		Dry bulb yield (tons ha^{-1})	Total dry biomass (tons ha^{-1})	Harvest index
	Total	Marketable			
0	32.13b	24.30b	5.10b	6.23b	0.82b
69	37.87a	28.36a	6.33a	7.49a	0.85a
92	37.71a	29.37a	6.35a	7.57a	0.84a
115	36.60a	27.39a	6.53a	7.61a	0.86a
138	36.99a	28.04a	6.41a	7.56a	0.85a
F-test	*	*	*	*	*
Phosphorus (Kg ha^{-1})					
0	37.10a	28.31a	6.11a	7.37a	0.84a
10	36.61a	27.24a	6.23a	7.27a	0.85a
20	37.14a	28.26a	6.29a	7.45a	0.84a
30	35.66a	26.52a	6.05a	7.19a	0.85a
40	34.79a	27.15a	6.04a	7.19a	0.84a
F-test	NS	NS	NS	NS	NS
SEM (±)	3.390	2.280	0.688	0.779	0.017
CV (%)	15.73	14.34	19.41	18.53	3.69

NS and *: non significant at $P< 0.05$, significant at $P>0.05$, respectively. SEM: Standard error of the mean. Means with the same treatment and column sharing the same letters are not significantly different at $P< 0.05$.

bulb yield of onion suggesting that the increased individual bulb size is fundamental to maximize onion productivity per unit area.

Dry bulb yield, total dry biomass and harvest index

Nitrogen fertilization significantly affected bulb dry weight, total dry biomass yield and harvest index of onion (Table 3). Bulb dry weight, total dry biomass yield and harvest index increased by about 24, 20, and 3.6%, respectively over the respective checks in response to the application of 69 kg N ha^{-1}. These characters showed a tendency to increase with N up to 115 kg ha^{-1} and then decline. The observed bulb dry weight as well as total biomass yield improvement could be attributed to an increased photosynthetic area in response to N fertilization that enhanced assimilate production and partitioning to the bulbs. Similar result was also reported by Anwar et al. (2001) for onion. Harvest index was significantly and positively correlated with dry bulb yield (0.92**) and total dry biomass (0.86**) indicating that N improved harvest index in onion by increasing both bulb dry weight and total biomass yield.

In general, bolting percentage, days to physiological maturity, onion plant height, leaves number, length and diameter, fresh total and marketable bulb yield, dry bulb yield, total dry biomass and harvest index of onion were not significantly affected by P fertilization. The lack of significant response could be attributed to the presence of adequate amounts of available P in the soil for normal growth of the crop. This was supported with soil analysis before planting that indicated the presence of adequate amount of available P (16.02 ppm) in soils of the experimental site. Besides, the pH of the soil was 8.02 which supports better uptake of available P from the soil. In soils that are moderately low in P, onion growth and yield can be enhanced in response to P fertilization (Alt et al., 1999).

For instance, results of long term fertilizer trials on loamy sand soils in Germany have shown a strong response of onion to P fertilization in the range of 0 to 52 kg ha^{-1} (Alt et al., 1999). From the current investigation, an application rate for N of 69 kg ha^{-1} enhanced the growth of onions and resulted in optimum fresh total and marketable bulb yield on the vertisol of Shewa Robit, northeast Ethiopia. This rate is lower than the current nationally recommended rate of 92 kg N ha^{-1}. The application of P fertilizer is not advisable as the soil has adequate level for normal onion plant performance.

ACKNOWLEDGEMENT

Authors acknowledge the effort of Late Professor L.M. Pant who passed away while the manuscript was being prepared for publication.

REFERENCES

Aklilu L (1997). Onion research and production in Ethiopia. Acta Hortic., 433: 95-97.

Alt D, Ladebusch H, Melzer O (1999). Long-term trial with increasing amounts of phosphorus, potassium and magnesium applied to vegetable crops. Acta Hortic., 506: 29-36.

Anwar MN, Sarker JU, Rahman M, Islam MA, Begum M (2001). Response of onion to nitrogen, phosphorus, potassium, sulphur and zinc. Bangladesh J. Environ. Sci., 7: 68-72.

Archer J (1988). Crop Nutrition and Fertilizer Use. Second Edition. Farming Press Ltd. Wharfedaale Road, Ipswich, Suffolle.

BoA (Bureau of Agriculture) (2000). Kewet Woreda Agriculture Development Office, Annual report.

Brewester JL (1987). The effect of temperature on the rate of sprout growth and development within stored onion Bulbs. Ann. App. Biol., 111: 463-465.

Brewester JL (1994). Onions and other vegetable *Alliums*. CAB International, Wallingford, UK, p. 236.

Bungard RA, Wingler A, Morton JD, Andrews M (1999). Ammonium can stimulate nitrate and nitrite reductase in the absence of nitrate in Clematis vitalba. Plant Cell Environ., 22: 859-866.

Cizauskas A, Viskelis P, Dris R, Oladele OI (2003). Influence of nitrogen rates on onion yield, quality and storability. Moor J. Agric. Res., 4(1): 85-89.

CSA (Central Statistical Agency) (2006). Agriculture sample survey. Central Statistical Agency, Addis Ababa, Ethiopia, Bulletin, 1: 361.

Fairhust T, Lefroy R, Mutert E, Batijes N (1999). The importance, distribution and causes of phosphorus deficiency as a constraint to crop production in the tropics. Agrofor. Forum, 9: 2-8.

FAO (2006). Production year book. Food and Agriculture Organization of the United Nation, Rome, Italy.

Grubben JH, Denton DA (2004). Plant resources of tropical Africa. PROTA Foundation, Wageningen; Back huys, Leiden; CTA, Wageningen.

Jilani MS (2004). Studies on the management strategies for bulb & seed production of different cultivars of onion (*Allium cepa* L.). PhD thesis, Gomal University, Dera Ismail Khan.

Marschner H (1995). Mineral Nutrition of Higher Plants, 2nd ed. Academic press. London, p. 196.

Murphy HF (1968). A Report on Fertility Status of Some Soils of Ethiopia. HSIU/College of Agric. Alemaya. Experiment Station. Bull. No. 44.

Nasreen S, Haque MM, Hossain MA, Farid ATM (2007). Nutrient uptake and yield of onion as influenced by nitrogen and sulphur fertilization. Bangladesh J. Agric. Res., 32(3): 413-420.

Pandey UC, Ekpo U (1991). Response of nitrogen on growth and yield of onion (*Allium Cepa* L.) in Maiduguri region of Borno State, Nigeria. Res. Dev. Reporter, 8(1): 5-9.

Patel IJ, Patel AT (1990). Effect of nitrogen and phosphorus levels on growth and yield of onion. (*Allium cepa* L.) cultivar Pusa Red Res. Gujarat Agric. Univ., 15: 1-5.

Patel ZG, Vachhani MU (1994). Effect of N P K fertilization on the yield and quality of onion. Hort. J., 7(1): 75-77.

Rao MR, Niag A, Kwcsiga F, Duguma, B, Frazel S, Jama B, Buresh R (1998). Soil Fertility Replenishment in Sub-Saharan Africa. *In*: Londoen D (ed.) Agro forestry Today. No. 2. International Center for Research in Agroforestry (ICRAF), UK, 10: 2-5.

Reddy KC, Reddy KM (2005). Differential levels of vermicompost and nitrogen on growth and yield in onion (*Allium cepa* L.) - radish (*Raphanus sativus* L.) cropping system. J. Res. ANGRAU, 33(1): 11-17.

Reiley HE, Shry CLJ (1979). Introductory Horticulture. Delmar Publisher. Albany, New York.

Rice RP, Rice LW, Tindall HD (1993). Fruit and vegetable production in warm climates. The Macmillan press Ltd. London and Basingstoke.

Richardson HL (1968). The Use of Fertilizers: The Soil Resources of Tropical Africa. Moss RP (ed.). Cambridge University Press, p. 138.

Rizk FA (1997). Productivity of onion plant (*Allium cepa*, L.) as affected by method of planting and NPK application. Egyptian J. Hort., 24(2): 219-238.

Singh T, Singh SB, Singh BN (1989). Effect of nitrogen, potassium and green manuring on growth and yield of rainy season onion (*Allium cepa*, L.). Narendra Deva J. Agric. Res., 4(1): 57-60.

Sorensen JN, Grevsen K (20010. Sprouting in bulb onions (*Allium cepa* L.) as influenced by nitrogen and water stress. J. Hort. Sci. Biotech., 76: 501-506.

Steer BT (1980). The bulbing response to day length and temperature of some Australian cultivars of onion (*Allium cepa* L.). Aust. J. Agri. Res., 31: 511-518.

Vachhani MU, Patel ZG (1993a). Growth and yield of onion (*Allium cepa*, L.) as influenced by levels of nitrogen, phosphorus and potash under South Gujarat conditions. Progressive Hort., 25(3): 166-167.

Vachhani, MU, Patel ZO (1993b). Effect of nitrogen, phosphorus and potash on bulb yield and quality of onion (*Allium cepa)*. Indian J. Agro., 3: 333-334.

Yadav RL, Sen NL, Yadav BL (2003). Response of onion to nitrogen and potassium fertilization under semi-arid condition. Indian J. Hort., 60(2): 176-178.

Yamasaki A, Tanaka K (2005). Effect of nitrogen on bolting of bunching onion (*Allium fistulosum* L). Hort. Res. (Japan), 4(1): 51-54.