Growth and yield of onion (*Allium cepa* L.) as affected by farmyard manure and nitrogen fertilizer application in Tahtay Koraro District, Northwestern Zone of Tigray, Ethiopia

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Abstract

A field experiment was carried out in Tahtay Koraro district of Northwestern zone of Tigray from October 2017 to April 2018, to assess the effect of organic and inorganic fertilizer on growth, yield and yield components of onion. The experiment consisted of four levels of FYM (Farmyard manure) as 0, 10, 20 and 30 t ha⁻¹ and four levels of inorganic N as 0, 34.5, 69 and 103.5 kg ha⁻¹ factorially arranged in RCB design with three replications. Analysis of variance revealed that the main effect of N, FYM as well as their interactions significantly ($P < 0.05$) influenced days to maturity, plant height, leaf number, leaf diameter, bulb diameter, neck diameter, average bulb weight, above ground dry biomass, marketable bulb yield and total bulb yield of onion. Similarly, main effects of N and FYM significantly ($P < 0.05$) affected leaf length, bulb length, unmarketable bulb yield and harvest index. The highest marketable bulb yield of 35.93 t ha⁻¹ and 34.72 t ha⁻¹ were obtained at combinations of 103.5 kg N ha⁻¹ + 30 t FYM ha⁻¹ and 103.5 kg N ha⁻¹ + 20 t FYM ha⁻¹ respectively. However, the lowest marketable bulb yield of 13.88 t ha⁻¹ was obtained from the unfertilized plot. Moreover, the highest marginal rate of return was obtained at combined application of 103.5 kg N ha⁻¹ and 10 t FYM ha⁻¹ and thus can be recommended for onion production in the study area.

Keywords Bulb yield · Inorganic fertilizer · Onion · Organic manure · Rate

Introduction

Onion (*Allium cepa* L.) is one of the most vital vegetables in the world (Shigyo and Kik 2008). It is commonly used as flavorings or as vegetables in stews and salads. It is one of the richest sources of flavonoids in the human diet which has been associated with a reduced risk of cancer, heart disease and diabetes. Globally, the area under onion production is increasing due to its high profitability per unit area and ease of production (FAO 2011).

In Ethiopia, onions grow in different agro-climatic regions mainly due to considerably increasing its importance in the daily diet of Ethiopians. It is also one of the most essential condiments, vegetable and cash crops in Ethiopia (Sara et al. 2015).

Onion production in Ethiopia is affected by different factors among which unbalanced fertilizer application, inappropriate fertilizer rate or lack of proper soil fertility management practices, limited awareness of growers on soil fertility management are the major ones (Gebretsadik and Dechassa 2016; Negasi et al. 2017). Continuous use of inorganic fertilizers and inappropriate soil fertility management practices are among the major factors limiting productivity of onion in Northwestern zone of Tigray (Yohannes et al. 2017). Farmers in the zone mostly use blanket recommendation of 200 kg ha⁻¹ DAP and 150 kg ha⁻¹ Urea for onion production. They rarely use organic manure for onion production on small scale in gardens and near their homestead (Yohannes et al. 2017).

Continuous use of inorganic fertilizers without supplementation with organic manure has often resulted in

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micronutrient deficiencies, imbalance soil physical and chemical properties and unsustainable crop production (Gupta et al. 1999; Yohannes et al. 2017). Decomposition of organic materials would provide additional nutrients to the growing medium, which may lead to higher uptake of nutrient by the crop and subsequently high yield (Shaheen et al. 2007).

Moreover, in Tahtay Koraro district of northwestern zone of tigray, there were no studies about combined application of organic and inorganic N on growth and yield of onion (Yohannes et al. 2017).

In view of this fact, a systematic investigation of the effect of inorganic N and locally available and affordable farmyard manure is paramount importance for improving yield (Kokobe et al. 2013; Tana and Wolde 2015; Yohannes et al. 2017). Therefore, the study was carried out to determine the response of onion to applied farmyard manure and inorganic N on growth, yield and yield components in Tahtay Koraro district of northwestern zone of Tigray, Ethiopia.

Materials and methods

Description of the study area

The experiment was carried out during 2017/2018 from late October to end of April using irrigation at May-Adrasha site in Tahtay Koraro district of Northwestern Zone of Tigray region. The district is located at 130 88' 36" to 140 08' 57" N latitude and 380 04' 30" to 380 17' 02" E longitudes at an altitude of 1902 m and 1917 m respectively (Teklay and Girmay 2015). The experimental site is situated at about 1040 km North of Addis Ababa (the country's capital) and 320 km Northwest of Mekelle (regional capital) respectively.

According to the agro-climatic classifications of Ethiopia, the climatic zone of the study area is generally sub-tropical with an extended dry period of nine to ten months. A maximum effective rainy season of 50 to 60 days with average annual rainfall of 885 mm. The area has average temperature of 20.92 °C with a mean maximum temperature of 30.97 °C in April and minimum temperature of 11.40 °C in January (Teklay and Girmay 2015). The soil texture of the district is sandy clay loam (Gebretsadik and Dechassa 2016). The major crops grown in the study area include onion (*Allium cepa* L.), tomato (*Solanum lycopersicum* L.), Teff (*Eragrostis tef*), maize (*Zea mays* L.), sorghum (*sorghum bicolor*), and finger millet (*Eleusine coracana*) (WTAO 2016).

Experimental materials

Bombay Red variety of onion was used as an experimental material for experiment. It was released by Melkasa Agricultural Research Center during 1980. The variety has a

characteristic of medium-red bulb color, erect leaf arrangement and flat globe bulb shape. It is an early maturing variety taking less than 120 days to reach maturity (EARO 2004; MoANRS 2011). Seeds were obtained from Shire-Maitsebri Agricultural Research Center. The inorganic and organic fertilizers used were N in the form of Urea ($\text{CO}(\text{NH}_2)_2$) (46% N) and animal dung were used in the experiment. Animal dung was collected and composted in a pit for five months to produce well decomposed FYM. The FYM was collected from Shire-endaselasie Agricultural, Technical, Vocational and Educational Training College. Recommended dose of 100 kg ha⁻¹ phosphorus in the form of TSP (Triple super phosphate) (46% P₂O₅) was applied uniformly to all plots at the time of planting.

Treatments and experimental design

The experiment consists of sixteen treatment combinations with four levels nitrogen (N) and four levels of farmyard manure (FYM). The treatments include 0, 10, 20 and 30 t ha⁻¹ FYM and 0, 34.5, 69 and 103.5 kg N ha⁻¹. Urea [$\text{CO}(\text{NH}_2)_2$] (46% N) and well decomposed FYM were used as a source of inorganic N and organic fertilizer. 69 kg N ha⁻¹ and 20 t ha⁻¹ FYM were the nationally recommended rates of fertilizers in Ethiopia (EARO 2004; MARC 2004).

Experimental procedure

A nursery bed of 10 m long and 1 m wide was marked out and cleared. The land was ploughed thoroughly and made into a fine tilth. Onion seed was sown at 10 cm distance between rows lightly covered with the soil and applied with 100 g Urea/5 m² and mulched with grass until seedlings emerge (EARO 2004). All proper agronomic practices were carried out until seedlings were transplanted to the main field (EARO 2004).

The experimental field was ploughed four times using oxen. Large size clods were broken-down to make the land to fine tilth, and the field was then marked out into blocks and plots. The spacing between blocks and plots were 1.5 and 1 m respectively. Experimental plots with a size of 1.20 m × 2 m (2.4 m²) were prepared and ridges were made with a spacing of 40 cm × 20 cm × 10 cm. There were six rows per plot each row having 20 plants with a total number of 120 plants with a net experimental area of 307.8 m². FYM was applied in to the experimental plots one month before planting during land preparation to facilitate decomposition (EARO 2004).

Vigorous, healthy, good-looking seedlings and nursery beds were selected for transplanting and the seedlings were irrigated one day before removing to facilitate uprooting. After 55 days, the seedlings were transplanted late in the afternoon to reduce the risk of desiccation and poor

establishments. Re-planting was done within one week after transplanting. Recommended dose of 100 kg ha^{-1} TSP (46% P_2O_5) was applied uniformly to all plots during transplanting. N was applied in two splits, one-half at planting, and the remaining half side-dressed at active stage of vegetative growth 45 days after transplanting.

The experiment was conducted under furrow irrigation method and the source was borehole water. The first irrigation was applied just after FYM was integrated in to the soil and then on an eight-day interval in order to decompose the FYM. The irrigation interval after transplanting was two times in a week for the first 4 weeks for better establishment and then extended to five days interval until 14 days remained to harvest. All other agronomic practices were applied uniformly for all plots (EARO 2004).

Data collection

Data on plant height, leaf number per plant, leaf length, leaf diameter, bulb diameter, neck diameter, average bulb fresh weight, above ground dry biomass were collected from ten randomly selected plants. However, days to maturity, marketable, unmarketable and total bulb yields were recorded per plot base. Plants in the central four rows were used for data collection, leaving aside plants in the border rows and those at the end of each row.

Days to maturity The number of days from seedling transplanting to a day at which more than 70% of the plants in a plot showed yellowing of leaves or attained physiological maturity.

Plant height (cm) was measured using a scale ruler from the ground level to the tip of the terminal leaves of ten randomly selected plants at the time maturity. The average of ten plants was used for statistical analysis.

Leaf number per plant The total number of leaves per plant was counted from ten randomly selected plants at maturity. The average of ten plants was used for statistical analysis.

Leaf length (cm) This was measured at physiological maturity from the sheath to tip of the leaf of ten plants using a ruler and the average of ten plants was used for statistical analysis.

Leaf diameter (cm) diameter of leaves at three different parts were measured from ten randomly selected plants using digital caliper and the average of ten plants was used for statistical analysis.

Bulb diameter (cm) The mean bulb diameter of ten sample bulbs was measured at the wider portion of matured bulbs at harvest using digital caliper. The average of ten plants was used for statistical analysis.

Neck diameter (cm) The average neck width of ten randomly selected mature bulbs were measured using digital

caliper and expressed in centimeter at harvest. The average of ten plants of bulbs were used for statistical analysis.

Average bulb weight (g) The average fresh weight of ten randomly taken mature bulbs were measured using sensitive balance and finally then expressed in grams. The average of ten plants was used for analysis.

Aboveground dry biomass (g) The above ground-biomass of ten plants were separated chopped and dried in an oven at 65°C until constant dry weight was attained and immediately weighed and recorded as aboveground dry biomass. The average of ten plants was used for statistical analysis.

Marketable bulb yield (t ha^{-1}) This referred to as the weight of healthy and marketable bulbs that range from 20 to 160 g in weight of bulbs from the net plot area at the time of harvesting.

Unmarketable bulb yield (t ha^{-1}) The total weight of unmarketable bulbs that are under sized ($< 20 \text{ g}$), diseased, decayed and bulbs from plants with physiological disorder such as thick neck and split were measured from a net plot at final harvest and expressed in t ha^{-1} .

Total bulb yield (t ha^{-1}) The total bulb yield was measured from the total harvest of the net plot as a sum weight of marketable and unmarketable bulb yields that were measured in kg per plot and finally converted into t ha^{-1} .

Harvest index (%) This was expressed as the ratio of total bulb fresh weight to the total biomass fresh weight at harvest maturity and expressed in percentage. Harvest index was calculated as total fresh bulb weight divided to total fresh biomass weight multiplied hundred.

Partial budget analysis

Partial budget analysis was calculated using the method described by CIMMYT (1988) to recognize economically smart combination of organic and inorganic fertilizer. Average marketable bulb yield from each plot was 10% adjusted (CIMMYT 1988). Cost of Urea (N) and FYM were taken as 15 ETB kg^{-1} and 500 ETB t^{-1} respectively. Labor cost of 70 ETB per man day $^{-1}$ was considered and two mandays for Urea and a ton of FYM for application were used. 14 ETB kg^{-1} was considered as selling price of onion at the local market during harvesting. Dominance analysis was done to select potentially profitable treatments and for each pair of undominated treatment, a percentage marginal rate of return (MRR) was calculated (CIMMYT 1988).

Soil and FYM sampling and analysis

Soil samples were collected before treatment application from a depth of 0–30 cm using diagonal pattern from the experimental site using auger. The collected samples were air dried, mixed and ground to pass through 2 mm sieve to remove large particles, debris, and stones. The samples were composited

to one sample and 2 kg working sample was obtained from the composite sample. The composite sample was packed in a polythene bag, labeled and taken to Mekelle Soil Testing Laboratory. Sample was analyzed for pH, organic carbon, and total N, available phosphorus and potassium, CEC, EC and soil texture using standard procedures. Total N was analyzed using wet oxidation procedure of Kjeldahl method (Bremner and Mulvaney 1982). Available P was analyzed using Olsen procedure (Olsen 1954) and CEC was analyzed using NH₄ acetate method (FAO 2008). FYM was analyzed for pH, total N, EC, and CEC.

Data analysis

Collected data were subjected to analysis of variance (Two way ANOVA) using Gen Stat software version 16. Treatment means were separated using Fisher's Least Significant Difference (LSD) test at 5% probability level. Pearson's correlation was carried out to see the association between different parameters.

Results and discussion

The result of the physical and chemical analysis of experimental soil before planting had been depicted in Table 1. The textural class found to be clay loam with a particle size distribution of 40% sand, 38% silt and 22% clay (Hazelton and Murphy 2016). The pH value was 7.89, which is neutral according to the rating of (Bruce and Rayment 1982). The optimum pH for onion production ranges between 6 and 8 (Nikus and Mulugeta 2010). The total N of the experimental soil was 0.124%, which is medium according to Tekalign et al. (1991). Available phosphorus content of the soil was 59.85 ppm which is very high (Table 2) according to Olsen (1954). Olsen (1954) stated that the availability of phosphorus > 25, 18–25, 10–17, 5–9, and less than 5 mg kg⁻¹ are classified as very high, high, medium, low and very low respectively. The Cation exchange capacity of the soil was 67.769 meq/100 g, which is very high according to (Metson 1961; Landon 1991). Landon (1991) stated that CEC < 6, 6–12, 12–25, 25–40, and greater than 40 cmol (+) kg⁻¹ are grouped as very low, low, moderate, high and very high respectively. The soil organic carbon content was 1.873%, which is rated medium according to Maria and Yost (2006). Maria and Yost (2006) stated that organic carbon content of < 1.5, 1.5–2.5 and > 2.5% grouped as low, medium and high respectively. The soil also had EC value of 0.23, which is rated as low according to Mamo and Bekele (2014). In general, soils of the study area are good in their selected physico-chemical properties for onion cultivation except EC. The chemical composition of the FYM used for the experiment had total N, pH, CEC and EC of 0.575%,

Table 1 Physico-chemical characteristics of the experimental soil before treatment application and characteristics of FYM Source: Mekelle Soil Research Center and Soil Laboratory

Parameters	Result	
	Soil	FYM
Physic-chemical properties		
pH	7.89	6.7
Organic carbon (%)	1.87	
Cation exchange capacity (meq/100 g)	67.76	
Electrical conductivity (ms cm ⁻¹)	0.23	
Nutrient availability		
Total N (%)	0.12	0.4
Available P (ppm)	59.85	458
Available K (ppm)	71	
Particle size (%)		
Sand (%)	40%	
Silt (%)	38%	
Clay (%)	22%	
Textural class	Sandy Clay loam	

7.42, 29.278 meq/100 g and 0.38 ms cm⁻¹ respectively (Table 1).

Effect of Nitrogen and farmyard manure application on phenological and growth parameters of onion

Day to maturity

Days to maturity of onion significantly ($P < 0.01$) influenced by the main effect of N and FYM as well as their interaction effects (Table 2). The result showed that plants grown under nil application of fertilizer matured earlier (118.9 days) than the rest of the treatments although statistically similar with those treated with 10 t FYM ha⁻¹ + 0 kg N ha⁻¹. Furthermore, longer time of maturity of 129.7 days was observed with plots treated with 103.5 kg N ha⁻¹ + 30 t FYM ha⁻¹ (Table 2). The findings of the present study is in line with the reports of (Girma 2011; Negasi et al. 2017). Delayed maturity with increasing dose of fertilizer application might be attributed to the role that N and FYM play in promoting vegetative growth before start of bulb development.

Plant height

Main effects and their interactions had significantly affected ($P < 0.05$) plant height of onion (Table 2). Maximum plant height of 64.5 cm was obtained from the treatment combination of 103.5 kg N ha⁻¹ + 30 t FYM ha⁻¹ while the minimum (46.77 cm) was obtained at the control (Table 2). However, there was no statistically significant difference among the

Table 2 Effect of N and FYM rates on days to maturity, plant height, leaf number and leaf diameter of onion

Treatment combinations		Days to maturity	Plant height (cm)	Leaf number	Leaf diameter (cm)
FYM (t ha ⁻¹)	N (kg ha ⁻¹)				
0	0.0	118.9 e	46.77 e	9.20 g	0.790 e
10	0.0	119.3 e	53.00 cd	9.97 g	0.927 d
20	0.0	123.0 d	53.99 cd	11.05 f	0.973 d
30	0.0	123.0 d	54.00 cd	11.33 ef	1.067 c
0	34.5	125.0 c	59.07 b	12.00 ef	1.083 c
10	34.5	127.7 b	51.40 d	12.33 de	1.123 c
20	34.5	128.3 ab	57.67 bc	11.33 ef	1.127 c
30	34.5	128.7 ab	59.07 b	11.77 ef	1.130 c
0	69.0	128.3 ab	59.66 ab	13.33 cd	1.127 c
10	69.0	128.7 ab	60.06 ab	14.00 bc	1.137 c
20	69.0	129.0 ab	60.96 ab	13.33 cd	1.133 bc
30	69.0	129.3 ab	61.73 ab	14.33 bc	1.137 bc
0	103.5	128.3 ab	59.80 ab	14.67 ab	1.207 ab
10	103.5	129.3 ab	62.30 ab	15.00 ab	1.220 a
20	103.5	129.3 ab	62.32 ab	15.00 ab	1.233 a
30	103.5	129.7 a	64.50 a	15.67 a	1.257 a
F-test		**	**	*	**
LSD (5%)		1.48	4.42	1.07	0.07
CV (%)		1.0	4.0	3.5	2.1

Means with the same letter within a column are not significantly different at 5% probability levels, * and ** are significant at 5 and 1% probability level respectively

CV coefficient of variation

treatment combinations of 103.5 kg N ha⁻¹ + 30 t FYM ha⁻¹, 103.5 kg N ha⁻¹ + 20 t FYM ha⁻¹, 103.5 kg N ha⁻¹ + 10 t FYM ha⁻¹, 103.5 kg N ha⁻¹ + 0 FYM, 69 kg N ha⁻¹ + 30 t FYM ha⁻¹, 69 kg N ha⁻¹ + 20 t FYM ha⁻¹, 69 kg N ha⁻¹ + 10 t FYM ha⁻¹ and 69 kg N ha⁻¹ + 0 FYM. The result is in agreement with the findings of Kokobe et al. (2013), Negasi et al. (2017) and Yohannes et al. (2017). The increment in plant height in response to increased application of the fertilizers is attributable to the role the different nutrients play in the plant in terms of enhancing photosynthetic rate and cell division, elongation and vegetative growth.

Leaf number

The main effects as well as their interaction effects had significantly ($P < 0.05$) affected leaf number of onion (Table 2). The highest number of leaves per plant of 15.67 was obtained at interactions of 103.5 kg N ha⁻¹ + 30 t FYM ha⁻¹ while the lowest (9.20) was observed at the control of both factors (Table 2). However, statistically significant differences were not observed between treatment combination of 103.5 kg N ha⁻¹ + 30 t FYM ha⁻¹ and treatment combinations of 103.5 kg N ha⁻¹ + 20 t FYM ha⁻¹, 103.5 kg N ha⁻¹ + 10 t FYM ha⁻¹ and 103.5 kg N ha⁻¹ + 0 t

FYM ha⁻¹ (Table 2). Corroborating findings were reported by Kokobe et al. (2013) who revealed that the highest number of leaves per plant of 15.44 at treatment combinations of 150 kg N ha⁻¹ and 45 t FYM ha⁻¹ while the control treatment gave the lowest. Jeyakumar et al. (2007) also reported similar findings. The increase in leaf number in response to the increased application of fertilizers might be due to the role of the different nutrient elements such as N and phosphorus plays in root and shoot growth and development and formation of phosphoproteins and phospho-lipids that encourage meristematic activity of plants, resulting in increased number of leaves per plant (Bagali et al. 2012).

Leaf diameter

Table 2 revealed that main effects of N and FYM as well as their interaction effects had significantly ($P < 0.05$) influenced leaf diameter of onion. Treatment combinations of 103.5 kg N ha⁻¹ + 30 t FYM ha⁻¹ gave the highest leaf diameter of 1.26 cm while the control gave the lowest width 0.79 cm. However, statistically significant difference was not observed between treatment combination of 103.5 kg N ha⁻¹ + 30 t FYM ha⁻¹ and 103.5 kg N ha⁻¹ + 20 t FYM ha⁻¹, 103.5 kg N ha⁻¹ + 10 t FYM ha⁻¹ and

103.5 kg N ha⁻¹ + 0 FYM (Table 2). In accord with the findings, Negasi et al. (2017) indicated that the highest doses of the combined fertilizers of 138 kg N, 184 kg P₂O₅ and 40 t FYM ha⁻¹ resulted in the maximum leaf diameter of onion. The increment in leaf diameter with increased application of N and FYM was attributed to the enhancing effect of N, P and on cell division and elongation and thus improved vegetative growth.

Leaf length

There was a significant ($P < 0.05$) effect of N and FYM on leaf length of onion while their interaction effects did not (Table 3). Nitrogen application at a rate of 103.5 kg ha⁻¹ gave the highest leaf length of 54.21 cm although statistically similar with application of 69 kg N ha⁻¹ which gave 52.17 cm. However, nil nitrogen application gave the shortest length of 39.36 cm (Table 3). Messele (2016) reported similar findings where significant increase in vegetative growth parameters of onion with increasing N supply from zero to 50 kg N ha⁻¹. Maximum rate of N showed the highest increment in mean leaf length and leaf number (Kokobe et al. 2013). This might be attributed to the stimulative effect of N on vegetative growth, as it involves in production and use of carbohydrate through photosynthesis and metabolism (Jeyakumar et al. 2007).

Accordingly, the highest leaf length of 51.28 cm was observed at application of 30 t ha⁻¹ FYM while the shortest (45.72 cm) was observed at the control of FYM application (Table 3). This result is in line with the findings of

Kokobe et al. (2013) who indicated that leaf length per plant increased by about 28% with application of FYM compared with the control which gave (33.60 cm). Moreover, increasing levels of applied manures significantly increased growth parameters (Zakari et al. 2014). Availability of higher quantity of nutrients, improvement in the physical properties of soil and increased activity of microbes with higher levels of organics might have helped in increasing vegetative growth (Bagali et al. 2012).

Effect of Nitrogen and farmyard manure application on bulb yield and bulb characters of onion

Neck thickness

Main effects of N and FYM as well as their interaction effects had significantly ($P < 0.05$) affected neck thickness of onion (Table 4). Combined application of 103.5 kg N ha⁻¹ + 30 t FYM ha⁻¹ gave the highest neck thickness of 1.99 cm although statistically at par with the treatment combination of 103.5 kg N ha⁻¹ + 30 with FYM ha⁻¹, 103.5 kg N ha⁻¹ + 20 t FYM ha⁻¹ and 103.5 kg N ha⁻¹ + 10 t FYM ha⁻¹. The lowest neck thickness of 0.78 cm, was obtained at the control of the two fertilizers and statistically at par with that obtained at combinations of nil N and 10, 20 and 30 t ha⁻¹ and interaction of nil FYM with 34.5 N (Table 4). In conformity, Yohannes et al. (2017) reported that neck thickness is one of the important parameters which is highly significantly influenced by the combined application of organic and inorganic fertilizers. However, Negasi et al. (2017) reported contrasting findings. Comfortable plant growth with respect to plant height, number of leaves per plant and leaf area per plant could be attributed to increased rate of photosynthesis and assimilation in plant tissues.

Bulb diameter

There was a significant ($P < 0.05$) effect of the factors and their interactions on bulb diameter of onion (Table 4). Application of N fertilizer at the rate of 103.5 kg ha⁻¹ interacted with 30 t ha⁻¹ FYM gave the highest (6.587 cm) bulb diameter of onion while the lowest of 3.01 cm and 3.49 cm were obtained from the control of both fertilizers and combinations of 0 kg N ha⁻¹ + 10 t FYM ha⁻¹ respectively (Table 4). Statistically significant differences were not observed among the treatments treated with combinations of 103.5 kg N ha⁻¹ + 30 t FYM ha⁻¹ and 103.5 kg N ha⁻¹ + 20 t FYM ha⁻¹ as well as 103.5 kg N ha⁻¹ + 20 t FYM ha⁻¹, 103.5 kg N ha⁻¹ + 10 t FYM ha⁻¹ and 69 kg N ha⁻¹ + 30 t FYM ha⁻¹ (Table 4). This result was in line with the findings of Negasi et al. (2017)

Table 3 Effects of N and FYM on leaf length of onion

N (kg ha ⁻¹)	Leaf length (cm)
0.0	39.36 c
34.5	47.52 b
69.0	52.17 a
103.5	54.21 a
F-test	**
FYM (t ha ⁻¹)	
0	45.72 c
10	47.31 bc
20	48.95 ab
30	51.28 a
F-test	**
LSD	2.47
CV (%)	5.2

Means with the same letter(s) within a column are not significantly different at 5% level of significance, ** indicates significance at 1% probability level
CV coefficient of variation

Table 4 Effect of N and FYM on bulb diameter, neck thickness, average bulb weight, above ground dry biomass, marketable and total bulb yield of onion

Treatment combinations							
FYM (t ha ⁻¹)	N (kg ha ⁻¹)	BD (cm)	NT (cm)	ABW (g)	AGDB (g)	MBY (t ha ⁻¹)	TBY (t ha ⁻¹)
0	0.0	3.010 i	0.780 f	43.60 i	3.540 e	13.88 i	18.67 g
10	0.0	3.497 hi	0.790 f	47.20 i	3.557 e	15.97 hi	20.00 fg
20	0.0	3.817 gh	0.800 f	57.00 h	4.300 d	16.70 gh	20.67 efg
30	0.0	3.819 gh	0.800 f	65.00 g	4.400 d	17.70 gh	21.33 ef
0	34.5	4.263 fg	0.880 ef	70.00 f	4.400 d	18.70 fg	22.37 ef
10	34.5	4.237 fg	1.080 de	80.00 e	4.807 c	20.93 f	23.13 e
20	34.5	4.433 ef	1.133 d	90.00 d	5.033 c	23.70 e	25.97 d
30	34.5	4.733 ef	1.140 d	95.00 c	5.067 c	25.77 e	28.00 d
0	69.0	4.313 efg	1.207 cd	98.00 bc	5.661 b	23.79 e	26.57 d
10	69.0	4.870 de	1.300 cd	96.00 bc	5.733 b	28.83 d	31.00 c
20	69.0	5.387 cd	1.300 cd	98.00 bc	5.767 b	30.64 cd	32.67 bc
30	69.0	5.877 bc	1.597 b	105.67 a	5.833 b	32.35 bc	34.00 ab
0	103.5	4.317 efg	1.433 bc	99.67 b	5.833 b	24.28 e	27.27 d
10	103.5	5.637 bc	1.980 a	106.00 a	6.200 a	32.74 bc	34.70 ab
20	103.5	6.063 ab	1.987 a	107.87 a	6.220 a	34.72 ab	36.33 a
30	103.5	6.587 a	1.993 a	109.50 a	6.267 a	35.93 a	37.33 a
F test		*	*	**	**	**	**
LSD		0.54	0.21	3.69	0.26	2.05	2.19
CV (%)		6.4	4.3	1.7	6.7	5.4	1.0

Means with the same letter(s) within a column are not significantly different at 5% level of probability, * and ** indicates significance at 5 and 1% probability level

CV coefficient variation, BD bulb diameter, NT neck diameter, ABW average bulb weight, AGDB above ground dry biomass, MBY marketable bulb yield, TBY total bulb yield

who indicated interactions of FYM and NP increased bulb diameter of onion. Yohannes et al. (2017), indicated the interaction effects of organic and inorganic N fertilizers can increase bulb diameter of onion. It could be attributed to the fact that increasing major elements particularly N level through organic manure might have accelerated the synthesis of chlorophyll and amino acids this resulting to more translocation of photosynthesis from leaves to bulb and causing enhancement bulb weight and diameter (Shedeed et al. 2014; Tana and Wolde 2015).

Average bulb weight

Main effect of N and FYM as well as their interaction effects significantly ($P < 0.05$) affected average bulb weight of onion (Table 4). Maximum bulb weight of 109.50 gm was obtained from the treatment treated with combinations of 103.5 kg N ha⁻¹ + 30 t FYM ha⁻¹ although statistically similar with interactions of 103.5 kg N ha⁻¹ + 30 t FYM ha⁻¹ and 103.5 kg N ha⁻¹ + 20 t FYM ha⁻¹. However, minimum bulb weight of 43.6 gm was obtained at the control treatment of both fertilizers and is in statistical similar with treatment combinations of 0 kg N ha⁻¹ + 10 t FYM ha⁻¹ (Table 4). Application of

103.5 kg N ha⁻¹ + 30 t FYM ha⁻¹ increased bulb weight of onion by about 65.9 g as compared to the control (Table 4). The result is in agreement with the findings of Kokobe et al. (2013) who reported that interaction effects of N and FYM significantly affected bulb weight of onion. Moreover, integrated use of organic and chemical fertilizers increased bulb weight by about 8.1–12.2% over control (Jayathilake et al. 2002). The increase in bulb weight could be attributed to the increase in plant height, number of leaves produced and leaf length in response to the highest rate of N (Shedeed et al. 2014). Similarly, Pearson's correlation also indicates that average bulb weight was positively and significantly ($p < 0.05$) correlated with days to maturity ($r = 0.907^{**}$), plant height ($r = 0.75^{**}$), leaf number ($r = 0.873^{**}$), leaf length ($r = 0.713^{**}$), leaf diameter ($r = 0.89^{**}$), bulb length ($r = 0.65^{**}$), bulb diameter ($r = 0.813^{**}$), total bulb yield ($r = 0.895^{**}$) and above ground dry biomass ($r = 0.936^{**}$) of onion.

Above ground dry biomass

Aboveground dry biomass of onion had significantly ($P < 0.05$) influenced by the main effects of N, FYM

and their interaction effects (Table 4). Combined application of $103.5 \text{ kg N ha}^{-1} + 30 \text{ t FYM ha}^{-1}$ gave the highest aboveground dry biomass of 6.27 g while the control treatment gave the lowest (3.54 g) above ground dry biomass (Table 4). However, statistically significant difference were not observed among the interaction of treatment combinations of $103.5 \text{ kg N ha}^{-1} + 30 \text{ t FYM ha}^{-1}$, $103.5 \text{ kg N ha}^{-1} + 20 \text{ t FYM ha}^{-1}$ and $103.5 \text{ kg N ha}^{-1} + 10 \text{ t FYM ha}^{-1}$ (Table 4). In addition, statistically significant difference were not observed between nil application of both fertilizers and treatment combinations of $0 \text{ kg N ha}^{-1} + 10 \text{ t FYM ha}^{-1}$ (Table 4). Application of $103.5 \text{ kg N ha}^{-1} + 30 \text{ t FYM ha}^{-1}$ increased aboveground dry biomass of onion by about 2.73 g as compared to the control. Similar findings were reported by many authors (Girma 2011; Nasreen et al. 2007).

Marketable bulb yield

Marketable bulb yield significantly ($P < 0.05$) affected by the main effects of N and FYM and their interactions (Table 4). Maximum marketable bulb yield of 35.93 t ha^{-1} was obtained from the treatment combinations of $103.5 \text{ kg N ha}^{-1} + 30 \text{ t FYM ha}^{-1}$ although statistically similar with treatment combinations of $103.5 \text{ kg N ha}^{-1} + 20 \text{ t FYM ha}^{-1}$. Moreover, the minimum marketable bulb yield of 13.88 t ha^{-1} was obtained at the control treatment of both fertilizers and is statistically at par with interactions of treatment combinations of $0 \text{ kg N ha}^{-1} + 10 \text{ t FYM ha}^{-1}$ and $0 \text{ kg N ha}^{-1} + 20 \text{ t FYM ha}^{-1}$ (Table 4). Application of $103.5 \text{ kg N ha}^{-1} + 30 \text{ t FYM ha}^{-1}$ increased marketable bulb yield by 22.05 t ha^{-1} as compared to the control application of both fertilizers (Table 4). This result was in conformity with the findings of Bagali et al. (2012) who reported that higher levels of inorganic and organic fertilizers resulted in higher bulb yields of onion. The increment in marketable bulb yield could be due to the application of N which attributed to the increment in vegetative growth and increased production of assimilate leading to increment in bulb diameter and average bulb weight (Girma 2011; Khan et al. 2002; Nasreen et al. 2007). Moreover, correlation analysis indicated that marketable bulb yield was significantly ($p < 0.05$) and positively correlated with leaf diameter ($r = 0.77^{**}$), leaf length ($r = 0.79^{**}$), leaf number ($r = 0.82^{**}$), average bulb weight ($r = 0.91^{**}$), bulb diameter ($r = 0.92^{**}$), and bulb length ($r = 0.65^{**}$) and above ground dry biomass weight ($r = 0.84^{**}$) of onion.

Total bulb yield

Total bulb yield of onion had significantly ($P < 0.05$) affected by the factors and their interactions (Table 4). Total bulb yield was highest (37.33 t ha^{-1}) treatment combinations of $103.5 \text{ kg N ha}^{-1} + 30 \text{ t FYM ha}^{-1}$ and is statistically similar with total bulb yield obtained at treatment combinations of $103.5 \text{ kg N ha}^{-1} + 20 \text{ t FYM ha}^{-1}$, $103.5 \text{ kg N ha}^{-1} + 10 \text{ t FYM ha}^{-1}$ and $69 \text{ kg N ha}^{-1} + 30 \text{ t FYM ha}^{-1}$. However, the lowest (18.67 t ha^{-1}) total bulb yield was obtained from nil application of both fertilizers although statistically at par with treatment combinations of nil application of N and 10 as well as 20 t FYM ha⁻¹ (Table 4). Corroborating result was reported by Kokobe et al. (2013) who indicated a highest (36.85 t ha^{-1}) bulb yield of onion was obtained at combined application of 100 kg N ha^{-1} and 45 t FYM ha^{-1} . Similarly, reported higher bulb yield of onion at application of 180 kg N ha^{-1} and 24 t FYM ha^{-1} (Bashir and Qureshi 2014). The lowest total bulb yield in the nil application of both fertilizers might be due to the fact that plots were deficient of the essential plant nutrients of N and FYM. The findings in the present study could be due to the activities of N and FYM in promoting physiological and metabolic processes in plant which improved dry matter production and accumulation. Moreover, the beneficial effect of organic manures on yield might be due to additional supply of plant nutrients and improved physical and biological properties of soil (Datt et al. 2003).

Bulb length

Bulb length of onion had significantly ($P < 0.05$) affected by the main effects of Nitrogen and FYM but not their interactions (Table 5). The highest bulb length of 6.11 cm was obtained at application of $103.5 \text{ kg N ha}^{-1}$ although statistically at par with application of 69 kg N ha^{-1} . However, the lowest bulb length of 4.48 cm was observed at the application of nil nitrogen. Similarly, application of 30 t FYM ha^{-1} gave the highest bulb length of 5.82 cm which was statistically similar with application 20 t FYM ha^{-1} (Table 5). Corroborating findings were reported where highest bulb length of onion was obtained at application of 138 kg N ha^{-1} (Gessesew 2015). Increment in leaf number and length which increases assimilate production and allocation to the bulbs might have increased bulb length of onion (Jayathilake et al. 2002).

Table 5 Effect of N and FYM on bulb length, unmarketable bulb yield and harvest index of onion

N (kg ha ⁻¹)	BL (cm)	UMBY (t ha ⁻¹)	HI (%)
0.0	4.482 c	4.105 a	66.14 c
34.5	5.506 b	2.592 b	73.60 b
69.0	5.880 a	2.157 c	77.58 a
103.5	6.111 a	1.990 c	79.64 a
F-test	**	**	**
FYM (t ha ⁻¹)			
0	4.999 c	3.555 a	70.94 b
10	5.441 b	2.590 b	73.01 b
20	5.717 ab	2.468 b	75.93 a
30	5.822 a	2.230 b	77.08 a
F-test	**	**	**
LSD	0.33	0.39	2.23
CV (%)	14.3	17.6	4.6

Means with the same letter within a column are not statistically significant at 5% level of probability, ** indicates significance at 1% probability level

CV coefficient of variation, BL bulb length, UMBY unmarketable bulb yield, HI Harvest Index

Harvest index

N and FYM had significantly ($P < 0.05$) influenced harvest index of onion while interaction of N and FYM did not

(Table 5). Highest harvest index of 79.64% was obtained at the application of N at 103.5 kg ha⁻¹ although statistically at par with application of N rate at the rate of 69 kg ha⁻¹ which gave 77.58% harvest index (Table 5). On the other hand, the lowest harvest index of 66.14% was observed at nil application of N (Table 5). The findings were consistent with the reports of Gebretsadik and Dechassa (2016) who indicated that application of N at 150 kg N ha⁻¹ recorded the highest harvest index of 77.64% which increased harvest index by about 6% compared with the control. Similarly, highest harvest index of 86% was obtained in response to increased rate of N application (Abdissa et al. 2011). On the other hand, application FYM significantly affected harvesting index of onion where the highest (77.1%) was obtained at application of 30 t ha⁻¹ and is statistically similar with application of 20 t ha⁻¹. However, the lowest harvest index of 70.94% was obtained at the control and is statistically similar with application of 10 t ha⁻¹ (Table 5). Similar findings were reported by Girma (2011) who indicated that application of FYM from 0 to 20 t ha⁻¹ increased harvest index by about 9%.

Economic analysis

Partial budget analysis revealed that the highest benefit of 430, 131.5 ETbirr was obtained at treatment combinations of 103.5 kg ha⁻¹ N and 30 t ha⁻¹ FYM (Table 6). Dominance

Table 6 Partial budget and marginal rate of return analysis

Treatment combination (N kg ha ⁻¹ + FYM t ha ⁻¹)	TMBY (t ha ⁻¹)	ATMBY (t ha ⁻¹)	GB (birr ha ⁻¹)	TVC (birr)	NB (birr)	D/UD	MINB (birr)	MIVC (birr)	MRR (%)
0+0	13.88	12.492	174,888	0	174,888	0	0	0	0
34.5+0	18.70	16.83	235,620	1125	234,495	UD	59,607	1125	5298
69+0	23.79	21.41	299,740	2250	297,490	UD	62,995	1125	5599
103.5+0	24.28	21.85	305,900	3375	302,525	UD	5035	1125	447
0+10	15.97	14.373	201,222	6405.5	194,816.5	D			
34.5+10	20.93	18.84	263,760	7530.5	256,229.5	D			
69+10	28.83	25.95	363,300	8655.5	354,644.5	UD	52,119.5	1125	4632
103.5+10	32.74	29.46	412,440	9780.5	402,664.5	UD	48,020	5280.5	909
0+20	16.70	15.03	210,420	12,811	197,609	D			
34.5+20	23.70	21.33	298,620	13,936	284,684	D			
69+20	30.64	27.576	386,064	15,061	371,003	D			
103.5+20	34.72	31.25	437,500	16,186	421,314	UD	18,649.5	1125	1657
0+30	17.70	15.93	223,020	19,216.5	203,803.5	D			
34.5+30	25.77	23.19	324,660	20,341.5	304,318.5	D			
69+30	32.35	29.1	407,400	21,466.5	385,933.5	D			
103.5+30	35.93	32.337	452,718	22,591.5	430,131.5	UD	8817.5	6405.5	137

N Nitrogen, FYM farmyard manure, D dominated, UD undominated, TMBY total marketable bulb yield, ATMBY adjusted total marketable yield, GB gross benefit, TVC total variable cost, NB net benefit, MINB marginal increase in net benefit, MIVC marginal increase in variable cost, MRR marginal rate of return

analysis indicated that treatment combinations of 34.5 kg N ha⁻¹ + 0 FYM, 69 kg ha⁻¹ N + 0 FYM, 103.5 kg ha⁻¹ N + 0 FYM, 69 kg ha⁻¹ N + 10 t ha⁻¹ FYM, 103.5 kg ha⁻¹ N + 10 t ha⁻¹ FYM, 103.5 kg ha⁻¹ N + 20 t ha⁻¹ FYM and 103.5 kg ha⁻¹ N + 30 t ha⁻¹ FYM became undominated while the rest were dominated and rejected from analysis of marginal rate of return (MRR) which indicated that increased total cost of those dominated treatments did not increase the net benefit proportionally, benefit were lower than the lowest total cost. Based on marginal rate return analysis all the undominated treatment combinations found to be economically viable as MRR is above 100%. However, in view of bulb yield, economic feasibility as well as sustainable use of the resource base, application of 103.5 kg N ha⁻¹ + 10 t FYM ha⁻¹ can be considered as viable option for onion bulb production in the study area (Table 6). Ouedrago et al. (2001) suggested that integrated use of inorganic and biofertilizers should be opted for maximizing economic yield and to improve soil health. Mozumder et al. (2007) indicated that onion can successfully and profitably be cultivated by applying 165 kg N, 174 kg K₂O and 30 kg S along with 10 t ha⁻¹ cow dung and 75 kg P₂O₅ in the eastern hilly areas of Bangladesh.

Conclusion

The findings of the experiment revealed that application of farmyard manure and inorganic N as well as their interactions significantly affected phenological, growth, yield and yield attributes of onion. Combined application of 103.5 kg N ha⁻¹ + 30 t FYM ha⁻¹ gave the highest marketable bulb yield of onion although statistically at par with 103.5 kg N ha⁻¹ + 20 t FYM ha⁻¹. However, marketable bulb yield was lowest at the control treatment. Moreover, economic analysis indicated that application of sole N at 69 kg ha⁻¹ gave the highest marginal rate return of 55.99% however, considering sustainability of the resource, yield and economic feasibility application of 103.5 kg N ha⁻¹ + 10 t FYM ha⁻¹ can be used as an alternative option for onion production in the study area.

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References

- Abdissa Y, Tekalign T, Pant L (2011) Growth, bulb yield and quality of onion (*Allium cepa* L.) as influenced by nitrogen and phosphorus fertilization on vertisol I. Growth attribute biomass production and bulb yield. Afr J Agric Res 6(14):3252–3258
- Bagali AN, Patil HB, Chimmad VP, Patil PL, Patil RV (2012) Effect of inorganics and organics on growth and yield of onion (*Allium cepa* L.). Karnataka J Agric Sci 25(1):112–115
- Bashir U, Qureshi F (2014) Effect of nitrogen and farmyard manure on yield, nutrient content and quality of potato (*Solanum tuberosum* L.). Int J Biol Life sci 2(3):786–791
- Bremner JM, Mulvancy CS (1982) Chemical and microbiological properties. In: Page AL (ed) Methods of soil analysis, part two, 2nd edn. American Society of Agronomy, Madison, pp 595–624
- Bruce RC, Rayment GE (1982) Analytical methods and interpretations used by the Agricultural Chemistry Branch for soil and land use surveys. Queens land Department of Primary Industries Bulletin QB82004
- CIMMYT (1988) From agronomic data to farmer recommendations: an economics training manual. Completely revised edition. Mexico, DF
- Datt N, Sharma RP, Sharma GD (2003) Effect of supplementary use of farmyard manure along with chemical fertilizers on productivity and nutrient up-take by vegetable pea (*Pisum sativum* var *arvense*) and buildup of soil fertility in Lahaul valley of Himachal Pradesh. Indian J Agric Sci 73:266–268
- EARO (Ethiopian Agricultural Research Organization) (2004) Directory of released crop varieties and their management. Addis Ababa, Ethiopia
- FAO (Food and Agriculture Organization of the United Nations) (2008) FAO fertilizer and plant nutrition bulletin: guide to laboratory establishment for plant nutrient analysis. FAO, Rome, p 203
- FAO (Food and Agriculture Organization) (2011) Food and Agricultural Organization of the United Nations, Rome, Italy. <https://faostat.fao.org/site/567/default.aspx>. Accessed on 3 Apr 2016
- Gebretsadik K, Dechassa N (2016) Agronomic and economic evaluation of nitrogen fertilizer rates and intra row spacing on growth and bulb yield of onion (*Allium cepa* L.) under rainfall condition. Environment 6(21):1–10
- Gessew WS (2015) Onion (*Allium cepa* Var. *Cepa* L.) bulb traits as affected by nitrogen fertilizer rates and intra-row spacing under irrigation in Gode, South-Eastern Ethiopia. J Hort 2(4):1–6
- Girma Z (2011) Response of onion (*Allium cepa* L. Var. *Cepa*) to organic and inorganic fertilizers at gode, South-Eastern Ethiopia. Doctoral dissertation, School of Graduate Studies, Haramaya University, Ethiopia
- Hazelton P, Murphy B (2016) Interpreting soil test results: what do all the numbers mean? CSIRO Publishing, Clayton
- Jayatilake PKS, Reddy IP, Srihari D, Neeraja G, Ravinder R (2002) Effect of nutrient management on growth, yield and yield attributes of rabi onion (*Allium cepa* L.). Veg Sci 29:184–185
- Khan H, Iqbal M, Ghaffoor A, Waseem K (2002) Effect of various plants spacing and different nitrogen levels on the growth and yield of onion. J Biol Sci 2:545–547
- Kokobe WY, Derbew B, Adugna D (2013) Effect of farmyard manure and nitrogen fertilizer rates on growth, yield and yield components

- of onion (*Allium cepa* L.) at Jimma, Southwest Ethiopia. Asian J Plant Sci 12:228–234
- Landon JR (1991) Tropical soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics
- Mamo T, Bekele T (2014) Soil fertility status and fertilizer recommendation atlas for Tigray Regional State, Ethiopia. Ministry of Agriculture and Ethiopian Agricultural Transformation Agency, Addis Abeba
- MARC (Melkassa Agricultural Research Center) (2004) Progress report for 1995–2003 EARO Ethiopia
- Maria RM, Yost R (2006) A survey of soil fertility status of four agro-ecological zones of Mozambique. Soil Science 171(11):902–914
- Messele B (2016) Effects of Nitrogen and Phosphorus rates on growth, yield, and quality of onion (*Allium cepa* L.) At Menschen Für Menschen Demonstration Site, Harar, Ethiopia. Agric Res Tech 1(3):555–563
- Metson AJ (1961) Methods of chemical analysis for soil survey samples. Soil Bureau Bulletin No. 12, New Zealand Department of Scientific and Industrial Research, pp 168–175
- MoANRS (Ministry of Agriculture and Natural Resources) (2011) Irrigation agronomy. Addis Ababa, Ethiopia, pp 140
- Mozumder SN, Moniruzzamanand M, Halim GMA (2007) Effect of N, K and S on the yield and storability of transplanted onion (*Allium cepa* L.) in the hilly region. J Agric Rural Dev 5(1 & 2):58–63
- Negasi T, Nigussie D, Kebede W, Lemma D, Abuhay T (2017) Effect of Integrated Nitrogen, Phosphorus, and Farmyard manure on post-harvest quality and storability of onion (*Allium Cepa* L.). J Postharvest Technol 5(4):25–37
- Nikus O, Mulugeta F (2010) Onion seed production techniques. A manual for extension agents and seed producers. FAO. Crop Diversification & Marketing Development Project, Asella
- Olsen SR (1954) Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. Circ. 939. U.S. Dep. Agric., Washington, DC
- Ouedrago E, Mando A, Zombre NP (2001) Use of compost to improve properties and crop productivity under low input agricultural system in West Africa. Agric Ecosyst Environ 84:259–266
- Shaheen A, Fatma M, Rizk A, Singer SM (2007) Growing onion plants without chemical fertilization. Res J Agric Biol Sci 3(2):95–104
- Shedeed SI, El-Sayed SAA, Bash DMA (2014) Effectiveness of bio-fertilizers with organic matter on the growth, yield and nutrient content of Onion (*Allium cepa* L.) plants. Eur Intl J Sci Technol 3(9):115–122
- Shigyo M, Kik C (2008) Handbook of plant breeding, vol 2. Springer, New York
- Tana T, Wolde ST (2015) Different rates of nitrogen fertilizer and farmyard manure at Bore, Southern Ethiopia. Ph.D. Dissertation, Haramaya University, Ethiopia
- Tekalign T, Haque I, Aduayi EA (1991) Soil, plant, water, fertilizer, animal manure and compost analysis. Working document, (13)
- Teklay T, Girmay G (2015) Impact of mixed fertilizer applications under different planting methods and seed rates on yield, yield components and nutrient use efficiency of Tef [*Eragrostis tef* (Zucc.) Trotter]. J Bio Agric Healthc 5:2224–3208
- WTAO (WoredaTahtaykoraro Agriculture and Rural Development Office) (2016) Document fourth quarter of annually report. Unpublished
- Yohannes GK, Kebede W, Arvind C, Fikreyohannes G (2017) Effect of integrated nutrient management on growth, bulb yield and storability of onion (*Allium cepa* L.) under irrigation at Selekeleka, Northern Ethiopia. Int J Life Sci 5(2):151–160
- Zakari SM, Miko S, Aliyu BS (2014) Effect of different types and levels of organic manures on yield and yield components of garlic (*Allium sativum* L.) at Kadawa, Kano, Nigeria. Bayero J Pure Appl Sci 7(1):121–126

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