Optimum rate of NPS fertilizer for economical production of irrigated onion (*Allium cepa* L) in Dembyia District of Amhara Region, Ethiopia

Muluneh Nigatu[1], Melkamu Alemayheu[2*], Amare H/Sillassie[3]
[1]Dembyia District Office of Agriculture, North Gondar Zone, Dembyia, Ethiopia
[2]College of Agriculture and Environmental Sciences, Bahir Dar University, Bahir Dar, Ethiopia
[3] International Water Management Institute (IWMI), Addis Ababa, Ethiopia

ABSTRACT

Onion is one of the most important vegetable crops grown under irrigation in Amhara Region. Application of fertilizer is an important input to increase yields of vegetables including onion where its rate mostly depends on the fertility status of the particular soil. The present study was initiated with the objective to identify the optimum rate of the newly introduced NPS fertilizer for maximum bulb yield of onion under irrigated smallholder farming system. The study was conducted in Dembyia District during the 2014/2015 irrigation season. Twelve NPS fertilizer rates were laid down on Randomized Complete Block Design (RCBD) with three replications to identify the optimum rates of NPS where maximum yield of Adama Red onion variety can be obtained. The results of the experiment revealed that most of the growth and yield parameters of onion were significantly affected by NPS fertilizer. The longest plant height (60.1 cm) was recorded when $N:P_2O_5:S$ was applied at the rate of 73.5:92:16.95 kg ha^{-1}, respectively. The longest (51.1cm) and widest (1.44 cm) onion leaves were recorded on plants where $N:P_2O_5:S$ was applied with 136.5:119.6:22 kg ha^{-1}. Onion plants supplied with 105:119.6:22 kg ha^{-1} $N:P_2O_5:S$ fertilizer rate gave the highest mean bulb weight (198.8 g), marketable yield (20.8 ha^{-1}) and total bulb yield (21.4 t ha^{-1}). Similarly, onion plants supplied with 105:119.6:22 kg ha^{-1} $N:P_2O_5:S$ fertilizer rate recorded the highest marginal rate of return followed by those onion plants supplied with 105: 92:16.95 kg ha^{-1}. Onion plants which were not supplied with NPS fertilizer showed generally lower growth and yield parameters. Application of NPS fertilizer at the rate of 105:119.6:22: kg ha^{-1} $N:P_2O_5:S$ can be recommended for economical production of onion in the study area.

Key words: Bulb yield, net benefit, NPS fertilizer, onion plant height, smallholder farmers

DOI: http://dx.doi.org/10.4314/ejst.v11i2.3

INTRODUCTION

Onion (*Allium cepa* L.) is the most widely cultivated species of the genus *Allium*. The crop belongs to the family *Alliaceae* (Hanelt, 1990). Onion is one of the cool season bulb vegetables produced throughout the world. The crop is grown in more than 130 countries in the world among which China and India are the largest producers followed by USA, the Netherlands, Egypt and Iran (FAOSTAT, 2014).

Onion is widely used as a condiment to enhance the flavor of food. Almost all spicy dishes contain onion, which is a rich source of several minerals and vitamins (Tindall, 1983; Raemaekers, 2001). Onion is also considerably important in the daily Ethiopian diet for the preparation of traditional foods where the bulbs and the lower section of

*Corresponding author: melkalem65@gmail.com

© This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/CC BY4.0).

the stems are used as a seasoning or a vegetable in stews. The onion leaves are also used as vegetables in other counties (Ministry of Agriculture and Rural Development (MoARD), 2005). Onion has also a long history in medicinal values in that its compounds have been reported to have a range of health benefits. The crop has, among others, anti-carcinogenic properties, anti-platelet and anti-thrombotic activities and antibiotic effects while it is also effective against the common cold, heart disease, diabetes, osteoporosis, and other diseases (Griffiths *et al.*, 2002).

Ethiopia has diversified agro-climatic conditions suitable for the production of a broad range of fruits and vegetables including onion. According to Lemma Dessalegn (2004) and Lemma Dessalegn *et al.* (2006), onion production is successful under mild climate without extremes of heat or cold and excessive rainfall in the country. It is predominantly produced as cash crop for local consumption and regional export market by smallholder farmers throughout the country (MoARD), 2005). The crop is mostly cultivated in high and mid-altitude with traditional production system (Lemma Dessalegn, 2004).

According to Central Statistic Agency (CSA) (2014), the average annual onion production in Ethiopia is about 230,745.2 tons with the productivity of about 9.5 t ha^{-1}, which is very low compared to the potentials the country has. The low level of vegetable production in general and that of onion is generally associated with such constraints as poor agronomic practices, shortage of seeds of improved varieties, diseases and insect pests, poor extension services, high costs of agricultural chemicals including fungicides, insecticides and fertilizers (Currah and Proctor, 1990, Melkamu Alemayehu *et al.*, 2015). Because of the expansion of irrigable areas, however, the production of vegetables including onion is likely to increase in the near future in the country (MoARD, 2005).

Crop plants including onion need various nutrients to sustain their growth and development. Because of its shallow root system, onion especially requires high level of soil fertility to support high yield. Although the fertilizer requirement depends on type of crops produced, fertility status of the soil, and the environmental conditions of the area, onion growers in Ethiopia including those in Dembyia District have been using blanket recommendation of 200 kg DAP (Diammonium sulfate) and 150 kg urea per hectare, which may not satisfy the nutrient requirements of onion plants. Therefore, the Ministry of Agriculture and Natural Resource (MoANR) has recently introduced a new NPS fertilizer, which contains N, P_2O_5 and S with the concentration of 19%, 38%, and 7%, respectively. According to MoANR (2013), DAP will be substituted with this new fertilizer in the near future. Its rate of application for onion production in Dembyia District is, however, not yet known. The main objective of the present study was, therefore, to evaluate the response of onion to the newly introduced NPS fertilizer in Dembia District of Amhara Region so as to contribute to horticultural development endeavors of the country in general and the Amhara Region in particular.

MATERIALS AND METHODS

Description of the Study Area

Dembyia District is found in North Gondar Administration Zone of Amhara Region. It is located at the range of $37^0 3'27''$ to $37^0 29'1''$ E longitude and $12^0$11'2'' to $12^0$37'21'' N latitude. The district is comprised of 40 rural *Kebles* and five urban towns. The total population of the district is about 271,053, of which 42,746 households are engaged in agriculture (CSA, 2007). Dembyia District is bordered by Lake Tana, the biggest lake in Ethiopia, which indicates that the district is suitable for irrigated vegetable production including onion. According to Dembiya Woreda Rural Development and Agricultural Planning Office (DWRDAPO) (2014), about 25% of the cultivated land of Dembyia is irrigable. Moreover, the district receives annual mean rainfall of 1200 mm which falls mostly between the months of May and September. The annual mean minimum and maximum temperatures of the area are about 17^0C and 28^0C, respectively. The altitude of the district ranges from 1850 to 2200 meter above sea level, which is suitable for the production of a wide range of vegetables including onion, tomato, potato, cabbage, garlic, pepper and others (DWRDAPO, 2014). The altitude of the experimental site is 1853 meter above sea level while its soil, when analyzed from randomly taken composite sample before the experiment, was classified as heavy clay with a pH of 7.24, neutral in reaction. The CE, CEC, OMC, total N and available P contents of the composite soil sample were 0.06 ms cm^{-1}, 48.514 cmol (+) kg, 1.87%, 0.107% and 18.02 mg kg^{-1}, respectively. The total nitrogen content of the experimental soil was categorized as medium following Bremner and Mulvancy (1982). According to the classification made by Walkley and Black (1934) Olsen *et al.* (1954) and Black (1965), the experimental soil exhibited high available phosphorus and cation exchange capacity and low organic matter content. Generally, the laboratory analysis results proved that the soil was suitable for the production of onion.

Experimental Treatments and Design

The experiment was conducted in Jenda *Kebele* of Dembyia District during the 2014/15 irrigation season. A total of twelve NPS fertilizer rates (Table 1) were used in the present study which were determined based on the blanket recommendations of urea (150 kg ha^{-1}) and DAP (200 kg ha^{-1}) for onion production (EIAR, 2007). To determine the NPS fertilizer rates, 30% of the nutrients found in the blanket recommendations were added and subtracted and converted in terms of NPS fertilizer. The fertilizer rate used by the farmers was known by interviewing the onion producing farmers found in the area, and the average value was used in this study. NPS fertilizer was used mainly as the source of phosphorus and sulfur, while urea was used to compensate the nitrogen which was not covered by NPS fertilizer in the treatment. The treatments were arranged in Randomized Complete Block Design (RCBD) with three replications.

Management of the Experimental Plants

Onion variety of Adama Red was used as test crop in this study. The variety is well adapted and predominantly produced in the study area. The seedlings were raised on well prepared seedbed in nursery based on Lemma Dessalen and Shimeles Hailu (2003). Healthy and uniform seedlings at 3-4 leaf stage with the height of 12- 15 cm were transplanted into a well prepared experimental field. The planting of onion seedlings was done with double row (ridge) planting system at the spacing of 20 cm between rows and 10 cm between plants and 40 cm between double rows following Lemma Dessalegn and Shimeles Hailu (2003). The distances of 0.5 m between plots and one meter between replications were maintained to facilitate cultural practices. Each experimental plot was 5.4 m^2 in

Table 1: NPS fertilizer rates used in the study

Treatment	Rate of fertilizer ($N:P_2O_5:S$ kg ha^{-1})
T1	0:0:0
T2*	24.96:28.52:0
T3**	105:92:0
T4	73.5:64.4:11.86
T5	73.5:92:16.95
T6	73.5:119.6:22.0
T7	105:64.4:11.86
T8	105: 92:16.95
T9	105:119.6:22.0
T10	136.5:64.4:11.86
T11	136.5:92:16.95
T12	136.5:119.6:22.0

*Farmer`s practice (own result); **Blanket recommendation (EIAR, 2007)

size (1.8m x 3m) and accommodated five double rows with 16 plants in each row and 160 plants per plot.

The total amount of NPS, DAP and one third of urea were applied after the establishment of onion seedlings (ten days after transplanting). The other one third of urea was applied as side dressing 45 days after transplanting while the remaining one third was applied at the establishment of bulb, 60 days after transplanting. Experimental plots were regularly irrigated uniformly at 3-4 days' interval in the first developmental stages of onion plants. Later the irrigation interval was extended to 5-7 days depending on the weather condition. At the beginning of maturity, the irrigation interval was extended to 10 days until the attainment of 80% maturity of the onion plants. Hoeing of plants was done manually, and the experimental field was kept free of weed during the experimental period. The insecticide called "Profit 72% EC" at the rate of 0.75 l ha^{-1} was applied uniformly to all treatments to manage thrips (Ullah *et al*., 2010).

Data Collection and Analysis

Data on growth and tuber yield related parameters components of onion plants were measured and recorded timely from the net plot area of 3.52 m^2 using their respective standard procedures described below.

Growth parameters

Plant height (cm): Plant heights of ten randomly selected plants were measured from the soil surface to the top of the longest leaf using a ruler at physiological maturity, and the mean values were computed for further analysis.

Leaf length (cm): The lengths of five leaves of ten randomly selected plants at physiological maturity were measured from the point of their emergence using ruler, and the mean values were computed and used for further analysis.

Number of leaves per plant: Number of leaves of ten randomly selected plants per plot was counted at physiological maturity, and the mean values were computed for further analysis.

Leaf diameter (cm): The mid-diameter of the longest leaves of ten randomly selected plants was measured at physiological maturity using caliper, and the average mean diameters were used for further analysis.

Aboveground biomass (g/plant): The aboveground biomass of ten randomly selected plants were cut off and weighed at harvest, and average weights were computed and used for further analysis.

Dry weight of aboveground biomass (g/plant): Dry weights of ten randomly selected plants at harvest were measured using sensitive balance after drying them in oven for 24 hours at 65^{0}C, and the mean value per plant was computed and used for further analysis (Guesh Tekle, 2015).

80% days of maturity: The number of days elapsed from the time of planting up to the time when 80% of plants in the plot would become yellow, dry and collapse at the neck were counted, and then mean values were computed and used for further analysis (Guesh Tekle, 2015).

Bulb yield and yield related parameters

Bulb weight (g): The weight of ten randomly selected bulbs per plot was weighted with sensitive balance, and the mean bulb weights were computed and used for further analysis (Guesh Tekle, 2015).

Bulb length (cm): The lengths of ten randomly selected bulbs per plot were measured from the bottom to the top using caliper, and then mean values were computed for further analysis (Guesh Tekle, 2015).

Bulb diameter (cm): The mean sizes of the bulb at harvest from each plot were computed by measuring the diameters of ten randomly selected bulbs using caliper (Lemma Dessalegn and Shimeles Hailu, 2003).

Marketable bulb yield (t ha^{-1}): Bulbs which were free of mechanical, disease and insect pest damages, uniform in color and medium to large in size (20 - 160 g) were considered as marketable (Lemma Dessalen and Shimeles Hailu, 2003). The weight of such bulbs obtained from the net plot area was measured in kilogram using scaled balance and expressed as ton per hectare.

Unmarketable bulb yield (t ha^{-1}): According to Lemma Dessalen and Shimeles Hailu (2003) under (<20g) as well as over sized (>160g), misshaped, decayed, discolored, diseased and physiologically disordered bulbs are considered as unmarketable. The weight of such bulbs obtained from the net plot area was measured in kilogram using scaled balance and expressed as ton per hectare.

Total bulb yield (t/ha): Total yield of onion was obtained by adding marketable and unmarketable bulb yields (Guesh Tekle, 2015).

The collected growth and yield parameters of onion were subjected to analysis of variance (ANOVA) using SAS (Statistical Analysis System) version 9.1. Mean separation was carried out using Least Significant Difference (LSD) at 1% or 5% level of significance based on the results of variance analysis (Gomez and Gomez, 1984). Moreover, cost benefits and marginal rate of returns of the treatments were analyzed based on the technique described by CIMMYT (1988).

RESULTS AND DISCUSSION

Vegetative Growth of Onion as Influenced by NPS Fertilizer Rates

Plant height

The application of NPS fertilizer significantly increased the height of onion plants ($P \leq 0.05$). The longest onion plants (60.07 cm) were observed by the application of NPS fertilizer at the rate of 73.5:92:16.95 kg ha^{-1} N:P_2O_5:S (T5) which were statistically similar with those plants supplied with 105:119.6:22 (T9) and 136.5:119.6:22 (T12) kg ha^{-1} N:P_2O_5:S fertilizer rates (Table 2). Plants without NPS fertilizer (T1) were generally shorter than those plants supplied with NPS fertilizer. The increase in plant height was observed with the addition of nutrients required for the growth and development of onion plants. Onions are characterized as sulfur-loving plants (Bloem *et al*., 2004), so the increased heights of onion plants observed in the present study may be associated with the combined effect of nutrients in NPS fertilizer including sulfur. Another reason may be nitrogen, which, according to Bungard *et al*. (1999), is an important building block of amino acids and a crucial element in the formation of proteins required for growth and development of plants including onion.

Leaf length and diameter

The length and diameter of onion leaves were significantly ($P<0.05$) influenced by the application of different rates of NPS fertilizer. Generally, the length and diameter of onion leaves increased with increasing nitrogen levels (Table 2). The longest (51.07 cm) and the widest (1.44 cm) onion leaves were observed on onion plants which were fertilized with 136.5:119.6:22 kg ha^{-1} (T12), while the shortest (44.33 cm) and narrowest (1.33 cm) leaves were observed on the control onion plants.

The increase in length and diameter of onion leaves can be associated again with the fact that nitrogen is important for plant cell division and elongation (Brady, 1990; Marschner, 1995). Moreover, nitrogen plays significant role for the synthesis of chlorophyll, enzymes and proteins which are important for plant growth including onion. As noted before, nitrogen is the major constituent of proteins and its abundant presence tends to increase the size of the leaves, which brings about an increase in carbohydrate synthesis (Bungard *et al*, 1999). The results of this study is in agreement with Muhammad (2004) and Jilani (2004) who reported that the length and width of onion leaves increased with increased nitrogen rates.

Number of leaves per plant and aboveground biomass

The application of NPS fertilizer generally did not significantly ($P>0.05$) influence the number of onion leaves per plant. Nevertheless, the lowest number of leaves (12.60) was recorded on the control plants where no NPS fertilizer was applied (Table 2). These results disagree with previous findings such as Nasreen *et al.* (2007) and Vachhani and Patel (1993a). Nasreen *et al*. (2007) found that application of 120 kg ha^{-1} nitrogen significantly increased the number of onion leaves per plant. Similarly, Vachhani and Patel (1993a) reported that the number of onion leaves per plant was highest with the application of 150 kg ha^{-1} nitrogen. However further increase in nitrogen (160 kg ha^{-1}) tends to decrease the leaf number of onion (Nasreen *et al*., 2007).

Moreover, fresh, and dry weights of the aboveground biomass of onion was not significantly (P>0.05) influenced by the application of different NPS fertilizer rates (Table 2). The highest fresh (51.83g) and dry (5.20g) weights of the aboveground biomass of onion plants were, however, recorded in T10 where 136.5:64.4:11.86 kg ha^{-1} N:P_2O_5:S fertilizer was applied. The lowest fresh (34g) and dry (2.96g) weights of the aboveground biomass were recorded from control plants. The results of the present study also disagree with the results of Nasreen *et al*. (2007) and El-Tantawy and El-Beik (2009) who found increased total biomass yields of onion with higher nitrogen application rates.

Days to 80% maturity

Maturity date of onion was highly significantly (P<0.01) influenced by the application of different rates of NPS fertilizer (Table 2). Onion plants supplied with NPS fertilizer at the rate of 136.5:119.6:22 kg ha^{-1} (T12) required 142 days to mature, while non-fertilized onion plants required 137 days to mature. This could be associated with the combined effect of nutrients including nitrogen found in the compound NPS fertilizer in extending the vegetative growth period of plants while delaying maturity. The results are in agreement with the findings of various researchers who observed extended vegetative growth of various vegetables including onion with higher rates of NPS fertilizers as well as of nitrogen (Yamasaki and Tanaka, 2005; Zelalem Ayichew *et al*., 2009; Abdissa Yadeta *et al*., 2011; Weldemariam Seifu *et al*., 2015; Demoz Kidanie, 2016; Mekides Mekashaw, 2016; Minwyelet Jemberie, 2017; Shege Getu *et al*., 2017; Melkamu Alemayehu and Minwyelet Jemberie, 2018). Similarly, Brewester (1994) and Sørensen and Grevsen (2001) observed that too much nitrogen promoted excessive vegetative growth and delayed maturity.

Table 2: Vegetative growth of onion as influenced by different NPS fertilizer rates

Treatments (N:P_2O_5:S kg ha^{-1})	PH	LL	LD	LN	FW	DW	DM
T1 (0:0:0)	50.30e	44.33d	1.33d	12.60	34.00	2.9	137.00f
T2 (24.96:28.52:0)	52.37de	45.60cd	1.43ab	13.20	44.33	3.96	137.33f
T3 (105:92:0)	55.03cd	48.40abc	1.43ab	14.03	39.00	3.53	137.33f
T4 (73.5:64.4:11.86)	55.73bcd	48.73abc	1.43ab	14.10	44.16	3.70	137.66ef
T5 (73.5:92:16.95)	60.07a	49.03ab	1.41abc	14.76	41.33	3.53	139.00cde
T6 (73.5:119.6:22)	55.37bcd	48.03abc	1.38bcd	12.63	42.16	3.93	138.00def
T7 (105:64.4:11.86)	53.47cde	46.70bcd	1.37cd	13.53	41.16	3.56	139.33cd
T8 (105:92:16.95)	55.37bcd	49.07ab	1.43ab	16.20	38.00	3.73	137.67ef
T9 (105:119.6:22)	57.10abc	50.07a	1.37cd	13.90	50.33	4.06	140.00bc
T10 (136.5:64.4:11.8)	56.07bcd	48.60abc	1.41abc	13.73	51.83	5.20	140.00bc
T11 (136.5:92:16.95)	54.30cd	47.80abc	1.40abc	13.76	46.16	3.86	141.33ab
T12 (136.5:119.6:22)	59.10ab	51.07a	1.44a	14.70	45.33	3.80	142.00a
CV (%)	4.11	4.12	2.27	12.60	22.53	16.82	0.66
SE±	1.23	1.10	0.02	1.02	5.02	0.29	0.42
Sign. Difference	*	*	*	ns	ns	ns	**

* = Significant at P≤0.05; ** = highly significant at P≤0.01; ns = not significant at P≤0.05; DF = degree of freedom; CV = coefficient of variation; PH = plant height (cm); LL = leave length (cm); LD = leave diameter (cm); LN = leave number; FW = fresh weight (g/plant); DW = dry weight (g/plant); DM = days to 80% maturity

Bulb Yield and Yield-Related Parameters of Onion as Influenced by NPS Fertilizer Rates

Bulb weight

Onion bulb weight was highly significantly ($P<0.01$) influenced by the application of different NPS fertilizer rates. That is, maximum bulb weight (198.83g) was obtained from onion plants supplied with 105:119.6:22 kg ha^{-1} N:P2 O5:S fertilizer rate (T9) which was about 50.1% bigger than the bulb weight obtained from non fertilized plants. The bulb weight obtained from T9 was, however, similar with those bulbs obtained from onion plants supplied with 136.5:119.6:22 kg ha^{-1} of $N:P_2O_5:S$ fertilizer rate (Table 3). The results of the current study are in agreement with the findings of Ahmed *et al*. (1988) where the application of sulfur up to 24 kg ha^{-1} significantly improved the weight of onion bulbs which was positively correlated with the onion yield as indicated in this study. Moreover, the results clearly reaffirm the validity of a previous finding: onion plants require sulfur for improved bulb yield (El-Shafie and El-Gamaily 2002).

Bulb length and diameter

The length and diameter of onion bulbs were not significantly ($P>0.05$) influenced by the application of different NPS fertilizer rates. However, an increasing trend in the length and diameter of onion bulbs was observed with increasing phosphorous and sulfur concentrations, especially at higher nitrogen levels (Table 3). In both parameters, bulbs obtained from non-fertilized onion plants were inferior. The results of this study are in agreement with those of Yadav *et al*. (2003) and Reddy and Reddy (2005) who found an increased onion bulb length in response to nitrogen fertilizers.

Bulb yields

Marketable bulb yield of onion was highly significantly ($P<0.01$) influenced by the application of NPS fertilizer rates. The highest marketable bulb yield 20.9 t ha^{-1} was obtained from onion plants applied with NPS fertilizer rate at the concentration of 105:119.6:22 kg ha^{-1} $N:P_2O_5:S$ (T9) followed by the application of 136.5:119.6:22 kg ha^{-1} $N:P_2O_5:S$ (Table 3). Similarly, higher total bulb yields were observed on onion plants in treatment T9, T12 and T11 with the mean values of 21.4, 20.8 and 20.2 t ha^{-1}, respectively, which were statistically similar to each other. Both marketable and total bulb yields obtained from onion plants without NPS fertilizer were the least in this study. The results of the present study generally show that the application of sulfur increases the yield of onion which is generally highly manifested with increased rates of phosphorous and sulfur.

The general increase in the yield of onion is obviously associated with the combined effects of plant nutrients (N, P and S) found in NPS fertilizer. Moreover, because onion is a sulfur-loving vegetable (Bloem *et al.*, 2004), the increased bulb yield of onion could be probably associated with the positive effect of sulfur contained in NPS fertilizer. According to Marschner (1995), application of sulfur containing fertilizer like NPS modifies soil pH, improves soil-water relation and increases the availability of plant nutrients like P, Fe, Mn and Zn, which may increase the bulb yield of onion. Furthermore, sulfur and nitrogen stimulate the enzymatic actions as well as chlorophyll formation, both of which promote the growth and development of plants and improve the yielding performance of onion plants (El-Shafie and El-Gamaily, 2002). Thus an adequate supply of nutrients to plants is associated with vigorous vegetative growth, resulting in higher productivity of crops including onion (Yadav *et al.*, 2003).

The results obtained in this study are in conformity with the findings of Ahmed et *al.* (1988) who reported that application of sulfur up to 24 kg ha^{-1} significantly improved the bulb weight and yields of onion. They further reported that non-application of sulfur especially in sulfur deficient soils resulted in restricted shoot growth, stiffed stem and woody and small sized bulbs, which meant low yield of onion. However, excessive sulfur may also increase onion pungency, which is probably undesirable for fresh market use (Cizauskas *et al.*, 2003). The results of the present study are also in agreement with Hansen and Hendrickson (2001) where marketable yield of onion increased with the application of nitrogen at the ranges of 60-150 kg ha^{-1}. Similarly, Singh *et al.* (1989) found the best onion bulb with the application of 120 kg ha^{-1} nitrogen. Similar results were also reported by Pandey and Ekpo (1991), Vachhanni and Patel (1993a), Vachhanni and Patel (1993b); Abdissa Yadeta *et al.* (2011) and Weldemariam Seifu *et al.* (2015). It is interesting to note that similar to the results of the present study, application of NPS fertilizer also increased the growth, and yield parameters of other vegetable crops like head cabbage, potato and garlic (Demoz Kidanie, 2016; Mekides Mekashaw, 2016; Minwyelet Jemberie 2017; Shege Getu *et al.*, 2017; Melkamu Alemayehu and Minwyelet Jemberie, 2018). In this regard, Shege Getu *et al.* (2017) reported improved vegetative growth, weight, diameter and length of garlic bulbs with increased application of NPS fertilizer.

Table 3: Bulb yield and yield-related parameters of onion as influenced by NPS fertilizer rates

Fertilizer rate ($N:P_2O_5:S$ Kg ha^{-1})	BW (g)	BL (cm)	BD (cm)	MBY (t ha^{-1})	UNMBY (t ha^{-1})	TBY (t ha^{-1})
T1 (0:0:0)	132.50i	6.63	6.44	10.385c	0.174b	10.559c
T2 (24.96:28.52:0)	153.47h	6.80	6.90	12.841c	0.466a	13.380c
T3 (105:92:0)	186.00e	6.87	6.66	18.850ab	0.459a	19.310ab
T4 (73.5:64.4:11.86)	178.00f	6.91	6.72	18.213ab	0.444a	18.658ab
T5 (73.5:92:16.95)	188.50e	6.80	6.87	18.442ab	0.449a	18.892ab
T6 (73.5:119.6:22)	174.50g	7.00	6.59	17.592b	0.429a	18.021b
T7 (105:64.4:11.86)	176.83fg	6.82	6.58	17.899ab	0.436a	18.335ab
T8 (105:92:16.95)	191.83cd	6.98	6.83	19.258ab	0.469a	19.727ab
T9 (105:119.6:22)	198.83a	7.15	6.87	20.888a	0.509a	21.398a
T10 (136.5:64.4:11.86)	188.83de	6.80	6.79	18,978ab	0.462a	19.441ab
T11 (136.5:92:16.95)	193.67bc	6.75	7.01	19.704ab	0.480a	20.185ab
T12 (136.5:119.6:22)	196.33ab	6.69	7.10	20.287ab	0.494a	20.781ab
CV (%)	0.10	4.79	4.95	1.00	1.30	0.99
SE±	0.90	0.16	0.21	1.10	0.035	1.11
Sign. Difference	**	ns	ns	**	**	**

* = Significant P≤0.05; ** = highly significant P≤0.01; ns = not significant at P≤0.05; DF = degree of freedom: CV = coefficient of variation; BW = bulb weight; BL = bulb length; BD = bulb diameter; MBY = marketable yield; UNMBY = unmarketable yield; TBY = total bulb yield

Economically Optimum Rate of NPS Fertilizer for Onion Cultivation in the Study Area

The results of cost-benefit analysis related with application of different rates of NPS fertilizer are presented in Table 4. Generally, the benefits of NPS fertilizer application exceed the farmer`s traditional practice both in yield and return. The highest net benefit was obtained from onion plants supplied with NPS fertilizer at the rate of 105:119.6:22 kg ha^{-1} N:P2O5:S (T9) followed by the application of 136.5:119.6:22 kg ha^{-1} N:P2O5:S (T12) (Table 4). However, the highest marginal rate of returns was obtained from T9 followed by T8 with the application of 105:119.6:22 and 105: 92:16.95 $N:P_2O_5:S$ kg ha^{-1}, respectively (Table 5). The relative least marginal rates of returns were recorded from T10 and T5 with the values of 216.4% and 260.5%, respectively.

Table 4: Cost-benefit analysis of onion as influenced by NPS fertilizer rates in Dembyia District

Treatment (N:P2O5:S Kg ha^{-1})	Variable cost: Fertilizer cost per ha (Eth-birr) DAP	Urea	NPS	LC (Eth-Birr)	TVC (Eth-Birr)	Income: MBY (t/ ha)	GI (Birr)	GI – TVC (Net benefit in Eth-Birr)	Rank
T1 (0:0:0)	0.0	0.0	0.0	0.0	0.0	10.39	155,775.0	155,775.0	12
T2 (24.96:28.52:0)	972.8	351.1	0.0	350.0	1673.9	12.84	190,941.1	189267.2	11
T3 (105:92:0)	3,138.0	1,780.5	0.0	210.0	5,128.5	18.85	277,621.5	272,493.0	6
T4 (73.5:64.4: 11.86)	0.0	1,065.7	2,408.2	490.0	3,963.9	18.21	269,231.1	265,267.2	8
T5 (73.5:92:16.95)	0.0	709.6	3,440.3	560.0	4,709.9	18.44	271,920.1	267,210.2	7
T6 (73.5:119.6:22)	0.0	353.5	4,472.4	700.0	5,525.9	17.59	258,354.1	252,828.2	10
T7 (105:64.4:11.86)	0.0	1,878.6	2,408.2	560.0	4,846.8	17.90	263,638.2	258,791.4	9
T8 (105: 92:16.95)	0.0	1,522.5	3,440.3	630.0	5,592.8	19.26	283,277.2	277,684.4	4
T9 (105:119.6:22)	0.0	1,166.4	4472.4	700.0	6,338.8	20.89	306,981.2	300,642.4	1
T10 (136.5:64.4:11.86)	0.0	2,691.4	2,408.2	490.0	5,589.6	18.98	279,080.4	273,490.8	5
T11 (136.5:92:16.95)	0.0	2,335.3	3,440.3	560.0	6,335.6	19.70	289,224.4	282,888.8	3
T12 (136.5:119.6:22)	0.0	1,979.2	4,472.4	700.0	7,151.6	20.29	297,153.4	290,001.8	2

LC = labor cost; TVC = total variable cost; MBY = marketable bulb yield; GI = gross income; costs of NPS, DAP and urea were 14.04, 15.40 and 11.72 Eth-Birr kg^{-1}; price of onion = 15 Eth-Birr kg^{-1}, labor cost =70 Eth-Birr man-day^{-1}

Table 5: Onion marginal rate of return (MRR) as influenced by NPS fertilizer rates in Dembyia District

Treatments (N: P_2O_5:S kg ha^{-1})	Variable Cost	Net profit	MRR (%)	Rank
T1 (0:0:0)	0	155775	-	
T2 (24.96:28.52:0)	1673.88	189267.2	2000.87	4
T4 (73.5:64.4: 11.86)	3963.941	265267.2	3318.69	3
T5 (73.5:92:16.95)	4709.936	267210.2	260.46	7
T3 (105:92:0)	5128.5	272493	1262.13	5
T10 (136.5:64.4:11.86)	5589.614	273490.8	216.39	8
T8 (105: 92:16.95)	5592.773	277684.4	132752.17	2
T11 (136.5:92:16.95)	6335.609	282888.8	700.61	6
T9 (105:119.6:22)	6338.768	300642.4	562001.93	1

MRR = Marginal Rate of Return

CONCLUSION

The current study was initiated with the main objective of assessing the optimum rate of NPS fertilizer under irrigation for economical production of onion by smallholder farmers in Dembyia District of Ethiopia. It has been found that application of NPS fertilizer is necessary to improve the production and productivity of onion in irrigated farming system in the study area. The results revealed that almost all growth and yield parameters of onion were significantly affected by different rates of NPS fertilizer application. The application of NPS fertilizer at the rate of 105:119.6:22 kg ha^{-1} N:P_2O_5:S (T9) gave the highest marketable yield of onion (20.9 t ha^{-1}), though statistically similar results were also recorded from T12 (20.3 t ha^{-1}), T11 (19.7 t ha^{-1}) and T8 (19.3 t ha^{-1}). However, the highest marginal rate of return was obtained from T9. Therefore, application of NPS fertilizer at the rate of 105:119.6:22 kg ha^{-1} N:P_2O_5:S can be recommended for the production of onion in the study area as well as in other areas with similar agro-ecologies under irrigated production system. Furthermore, the study should be repeated at different locations and seasons to generalize the recommendation.

ACKNOWLEDGMENTS

This research was financed by Livestock and Irrigation Value-Chains for Ethiopian Smallholder (LIVES) project.

REFERENCES

AbdissaYadeta, Tekalign Tadesse and Pant, L.M. (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. *African Journal of Agricultural Research* **6(14)**: 3252-3258.

Ahmed, M.K., Aditya, D.K and Siddique, M.A. (1988). Effects of nitrogen and sulfur application on the growth and yield of onion cv. Faridpur Bhatti. *Bangladesh Horticulture* **16(1)**: 36-41.

Black, C.A. (1965). Determination of exchangeable Ca, Mg, Na, K, Mn and effective cation exchange capacity in soil. Methods of soil analysis 9. American Society of Agronomy, Madison, Wisconsin.

Bloem, E., Haneklaus, S and Schnug, E. (2004). Influence of nitrogen and sulfur fertilization on the alliin content of onions and garlic**.** *Journal of Plant Nutrition* **27**: 1827-1839.

Brady, N.C. (1990). The nature and properties of soils. 10th Edition, Collier-Macmillan, New York.

Bremner, J. M and Mulvancy, C.S. (1982). Total nitrogen. In: Methods of soil analysis, Part two, Chemical and microbiological properties, 2nd edition, pp 595-624, (Black, C.A., ed.)**,** American Society of Agronomy Inc. Madison, Wisconsin.

Brewster, J.L. (1994). Onions and other vegetable Alliums. CAB publishing. UK. 321.

Bungard, R.A., Wingler, A., Morton, J.D and Andrews, M. (1999). Ammonium can stimulate nitrate and nitrite reductase in the absence of nitrate in *Clematis vitalba*. *Plant Cell and Environment* **22 (7)**: 859-866.

CIMMYT (1988). From agronomic data to farmer recommendations: An economic training manual. Completely revised Edition, Mexico. http://apps.cimmyt.org/ (accessed September 2017).

Cizauskas, A., Viskelis, P., Dris, R and Oladele. O.I. (2003). Influence of nitrogen rates on onion yield, quality and storability. *Moor Journal of Agricultural Research* **4(1)**: 85-89.

CSA (2007). Population and housing census of Ethiopia, Summery and statistical report. Central Statistics Agency. http://www.csa.gov.et/ (accessed August 2016).

CSA (2014). Area and production of major crops, agricultural sample survey. Central Statistical Authority, Addis Ababa, Ethiopia. http://www.csa.gov.et/ (accessed November 2016).

Currah, L. and Proctor, F.J. (1990). Onion in tropical regions. Bulletin 35, National Resources Institute. Chatham, U.K. 151.

Demoz Kidanie. (2016). Assessment of production practices and effect of NPS rates on yield and yield components of head cabbage (*Brassica oleracea* var. *capitata*) under irrigation conditions in Lay Armachio District, Amhara Region, Ethiopia. M.Sc. thesis, Bahir Dar University, Bahir Dar, Ethiopia.

DWRDAPO (2014). Annual report on agricultural outputs and livestock, Dembiya Woreda Rural Development and Agricultural Planning Office, Dembiya, Ethiopia. 13.

El-Shafie, F.S and El-Gamaily, E.E. (2002). Effect of organic manure, sulfur and microelements on growth, bulb yield, storability and chemical composition of onion plants. *Minufiya Journal of Agricultural Research* **27(2)**: 407-424.

El-Tantawy, E.M and El-Beik, A.K. (2009). Relationship between growth, yield and storability of onion (*Allium cepa* L.) with fertilization of nitrogen, sulfur and copper under calcareous conditions. *Research Journal of Agriculture and Biological Science* **5(4)**: 361-171.

EIAR (2007). Crop technologies guideline. Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia**.** 173.

FAOSTAT (2014). Food and Agriculture. Data of the United Nations Organization. http://www.fao.org/faostat/en/#home (accessed April 2016).

Gomez, K.A and Gomez, A.A. (1984). Statistical procedures for agricultural research. 2nd Edition, an International Rice Research Institute Book, Wiley-Inter science Publication, John Wiley & Sons, New York. 390.

Griffiths, G., Trueman, L., Crowther, T., Thomas, B and Smith, B. (2002). Onions: A global benefit to health. *Phytotherapy Research* ***16*(7)**: 603-15. http://www.ncbi.nlm.nih.gov/pubmed/12410539.

Guesh Tekle. (2015). Growth, yield, and quality of onion (*Allium cepa* L.) as influenced by intra-row spacing and nitrogen fertilizer levels in central zone of Tigray, Northern Ethiopia. M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.

Hanelt, P. (1990). Taxonomy, evolution and history. In: Onion and allied crops, Vol. 1, Botany, Physiology and Genetics, pp. 1-26, (Rabinowitch, H.D. and Brewster, J.L., eds.), CRC Press, Boca Raton, Florida.

Hansen, S.L and Henriksen, K. (2001). Increasing the dry matter production in bulb onions (*Allium cepa* L.). *Denmark Department Fruit, Vegetable Food Science* **2**: 147-152.

Jilani, M.S. (2004). Studies on the management strategies for bulb and seed production of different cultivars of onion (*Allium cepa* L.). PhD Thesis, Gomal University, Pakistan.

Lemma Dessalegn. (2004). Onion production pamphlet (Amharic version). EARO, Melkassa Research Center, Addis Ababa, Ethiopia.

Lemma Dessalegn and Shimelis Aklilu. (2003). Research experience in onion production, Research Report No 55, Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia.

Lemma Dessalegn, Shimeles Aklilu, Selamawit Ketema and Chimdo Anchela. (2006). The vegetable seed sector in Ethiopia: Current status and future prospects, pp 103-109. In: Proceedings of the Inaugural and 3rd National Horticultural Workshop of Ethiopian Horticulture Science Society, Addis Ababa, Ethiopia.

Marschner, H. (1995). Mineral nutrition of higher plants. 2nd edition, Academic Press, London. 889.

Mekides Mekashaw. (2016). Assessment of farmer's production practices and effects of different rates of NPS fertilizer on yield and yield components of potato (*Solanum tuberosum* L) variety under irrigated farming system in Dessie Zuria District, Amhara Region, Ethiopia. M.Sc. Thesis, Bahir Dar University, Ethiopia.

Melkamu Alemayehu, Fentahun Tesafa, Solomon Bizuayehu and Belayneh Ayele. (2015). Amhara Region horticultural development strategy (2015-2020), AgroBIG and ANRS BoA, Bahir Dar, Ethiopia. 127.

Melkamu Alemayehu and Minwyelet Jemberie. (2018). Optimum rates of NPS fertilizer application for economically profitable production of potato varieties at Koga Irrigation Scheme, Northwestern Ethiopia. *Cogent Food and Agriculture* **4**: 1439663. https://doi.org/10.1080/23311932.2018.1439663.

Ministry of Agriculture and Natural Resource. (2013). Ethiopia is transitioning into the implementation of soil test based fertilizer use system. www.moa.gov.et/documents/93087/.../be8d5386-e5fb-4ca3-8ff0-d295bc603e70.

Ministry of Agriculture and Rural Development (2005). Irrigation development package manual (Amharic version). Ministry of Agriculture and Rural Development, Addis Ababa, Ethiopia.

Minwyelet Jemberie. (2017). Effects of NPS fertilizer rate and irrigation frequency determination method on the growth and tuber yield of potato (*Solanum tuberosum* L) in Koga Irrigation Scheme, Northwestern Ethiopia. M.Sc. Thesis, Bahir Dar University, Bahir Dar, Ethiopia.

Muhammad, S.J. (2004). Studies on the management strategies for bulb and seed production of different cultivars of onions (*Allium cepa* L.). PhD Thesis, Gomal University, Deraismil Khan, Pakistan.

Nasreen, S., Haque, M.M., Hossain, M.A and Farid, A.T.M. (2007). Nutrient uptake and yield of onion as influenced by nitrogen and sulfur fertilization. *Bangladesh Journal of Agricultural Research* **32**: 413-420.

Olsen, S.R., Cole, C.V., Watanabe, F.S and Deen, L.A. (1954). Estimation of available P in soils by extraction with sodium bicarbonate. USDA. *Circ* **939**: 1-19.

Pandey, U.C and Ekpo, U. (1991). Response of nitrogen on growth and yield of onion (*Allium cepa* L.) in Maiduguri region of Borno State, Nigeria. Research and Development Reporter **8**: 5-9.

Raemaekers, H.R. (2001). *Crop Production in Tropical Africa*. DGIC , Ministry of Foreign affairs, External Trade and International Co-operation, Brussels, Belgium. 455.

Reddy K.C and Reddy K.M. (2005). Differential levels of vermicompost and nitrogen on growth and yield in onion (*Allium cepa* L.) Radish (*Raphanus sativus* L.) cropping system. *Journal of Research ANGRAU* **33(1)**: 11-17.

Shege Getu, Melkamu Alemayehu, Amare Hailesilassie and Yigzaw Dessalegn. (2017). Economic and agronomic optimum rates of NPS fertilizer for irrigated garlic (*Allium sativum* L) production in the highlands of Ethiopia. *Cogent Food & Agriculture* **3**: http://doi.org/10.1080/23311932.2017.1333666

Singh, T., Singh, S.B and Singh, B.N. (1989). Effect of nitrogen, potassium and green manuring on growth and yield of rainy season onion. *Narendra Development Journal of Agricultural Research* **4**: 57-60.

Sorensen, J.N and Grevsen, K. (2001). Sprouting in bulb onions (*Allium cepa* L.) as influenced by nitrogen and water stress. *Journal of Horticultural Sciences and Biotechnology* **76**: 501-506.

Tindall, H.D. (1983). Vegetables in the tropics. New Delhi, India. CBS Publishers and Distributors. 533.

Ullah, F. Mulk, M. Farid, A. Saeed, Q.M and Sattar, S. (2010). Population dynamics and chemical control of onion Thrips (*Thrips tabaci*, Lindemann). *Pakistan Journal of Zoology* **42(4)**: 401-406.

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

Vachhani, M.U and Patel, Z.O. (1993b). Effect of nitrogen, phosphorus and potash on bulb yield and quality of onion (*Allium cepa*). *Indian Journal of Agronomy* **3**: 333-334.

Walkley, A and Black, C.A. (1934). Determination of organic matter in the soil by chronic acid digestion. *Soil Science* 63: 251-264.

Weldemariam Seifu, Kebede Weldetsadik and Wassu Mohammed. (2015). Growth parameters of onion (*Allium cepa* L. var. cepa) as affected by nitrogen fertilizer rates and intra-row spacing under irrigation in Gode, South-Eastern Ethiopia. *Agriculture, Forestry and Fisheries* **4(6)**: 239-245.

Yadav, R.L., Sen, N.L and Yadav, B.L. (2003). Response of onion to nitrogen and potassium fertilization under semi-arid condition of Rajasthan. *Indian Journal of Horticulture* **60(2)**: 176-178.

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

Zelalem Ayichew, Tekalign Tsegaw and Nigussie Dessacha. (2009). Response of potato (*Solanum tuberosum* L.) to different rates of nitrogen and phosphorus fertilization on vertisols at Debre Berhan, in the central highlands of Ethiopia. *African Journal of Plant Science* **3**(2): 016-024.