1874-3315/19

Send Orders for Reprints to reprints@benthamscience.net

The Open Agriculture Journal

Content list available at: https://openagriculturejournal.com

CrossMark

RESEARCH ARTICLE

Economic Performance and Nutrient Use Efficiency of Onion (*Allium Cepa* L.) Under N, K and S Nutrient Combinations in Northern Ethiopia

Teklay Tesfay[1,*] and Selamawit Girmay[2]

[1]*Department of Plant Sciences, College of Agriculture, Aksum University Shire Campus, Aksum, Ethiopia*
[2]*Department of Agricultural Economics, College of Agriculture, Aksum University Shire Campus, Aksum, Ethiopia*

Abstract:

Background:

Nitrogen (N), potassium (K) and sulfur (S) nutrient elements play an important role in the growth and bulb yield of onion. However, imbalanced nutrient application leads onion producers to get lower onion bulb yield. Hence, the supply of adequate and balanced plant nutrients is important in order to achieve better nutrient utilization as well as proper growth and high yield.

Objective:

To evaluate the agronomic and economic performance as well as nutrient efficiency of onion in response to the combined application of nitrogen, potassium and sulfur nutrient levels.

Method:

The field experiment was conducted during 2016/17 to test agronomic, economic and nutrient use efficiency of eighteen treatment groups with the combination of three levels of N, three levels of K and two levels of S nutrient on onion using a randomized complete block design.

Results:

The combined application of N, K and S nutrient levels appreciably resulted in significant variation not only on growth and bulb yield of onion but also on the economic performance and nutrient use efficiencies. Increased growth and improved bulb yield of onion as well as better nutrient uptakes and recoveries were observed in plots treated with relatively higher NKS rates. However, enhanced Agronomic Efficiency (AE) and Partial Factor Productivity (PFP) were obtained from plots treated with no N and K nutrient applications.

Conclusion:

Higher growth, improved bulb yield and enhanced nutrient use efficiencies (nutrient concentrations, uptakes and recoveries) were obtained from onion plants cultivated using a relatively higher NKS nutrient level. However, from the economic point of view, onion production using combined application of 69 kg N ha^{-1} and 15 kg S ha^{-1} was the most profitable, irrespective of the K level.

Keywords: Onion growth, Bulb yield, Nutrient uptake, Nutrient concentration, AE, PFP, Apparent Nutrient Recovery (ANR).

Article History	Received: July 25, 2019	Revised: August 30, 2019	Accepted: October 12, 2019

1. INTRODUCTION

Onion (*Allium cepa* L.) is essentially produced by small-holder farmers as a source of income and it is believed to be more frequently consumed than any other vegetable crops in Ethiopia. Though it is an extremely important vegetable crop for internal consumption and income, the national average bulb yield of onion is very low, not more than 10 Mg ha^{-1} [1] compared to world average productivity, 19.1 Mg ha^{-1} [2]. Some of the reasons for the low bulb yield of onion are: Lack of high yielding varieties as well as poor management practices including improper fertilizer application. Because of its shallow root system, onion requires high level of soil fertility for high yield [3]. Many scholars reported that growth and bulb yield of onion responded positively to the combined application of NS [3, 4]; NK [5 - 7]; and NKS [8] nutrients at

* Address correspondence to this author at the Department of Plant Sciences, College of Agriculture, Aksum University Shire Campus, P. O. BOX: +251 314, Aksum, Ethiopia; Tel: +251 914 780666; E-mails: teklaytesfay62@gmail.com and teklaytesfay2007@gmail.com

different doses. One of the crucial reasons for the combined application of nutrients is for boosted bulb yield of onion. Moreover, the amount of nutrients exploited in the harvested portion of a crop depends on the yield and the concentration of the nutrients in the soil. Though nitrogen NKS are essential nutrient elements that play an important role for proper growth and higher bulb yield of onion in the study area, blanket recommendations of only 100 kg Urea and 100 kg DAP (Di Ammonium Phosphate) were used, as sources of N and P; respectively, with no K and S nutrient applications. This imbalanced nutrient application lead onion producers to get lower onion bulb yield. Although the supply of adequate and balanced plant nutrients is important in order to achieve better nutrient utilization as well as proper growth and high yield, little information is available regarding the NKS nutrient requirements of onion in Northern Ethiopia, particularly in the study area. Therefore, the present study was aimed to evaluate onion performance (agronomic and economic) and nutrient use efficiency as affected by the combined application of NKS nutrient levels.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

An experiment was conducted in Tahtay-Koraro district, Northern Ethiopia during 2016/17 under irrigation in the season to examine responses of onion to the combined applications of NKS nutrient levels sourced from mineral fertilizers. The experimental area is situated at 13°88’36” N latitude and 38°04’30” E longitude at an altitude of 1905 meters above sea level. The long term mean annual rainfall of the study area for the past 20 years (1997-2016) was 1050 mm with an average minimum and maximum temperature of 14.18°C and 27.7°C, respectively [9]. According to the modern climatic zone classifications of Ethiopia [10], the study area belongs to the cool sub-humid agro-climatic zone.

2.2. Experimental Design and Treatment Combinations

Optimum nutrient requirements of onion have been reported as 95 to 150kg N and 42 to 133kg ha^{-1} K [11 - 13] and 20-40kg S ha^{-1} [14] being mineral fertilizer sourced. Accordingly, onion variety ‘Neptune’ was used as a test crop in response to eighteen treatment groups with the combination of three levels of N (0, 69, 92 kg ha^{-1}), three levels of K (0, 45, 67 kg ha^{-1}), and two levels of S (0 and 15 kg ha^{-1}) using a randomized complete block design with three replications. Plot size of 2m x 2.1m (4.2m^2) was used with a distance of 0.5 m and 1m between plots and replications/blocks, respectively. Urea (46%N) was used for treatments allotted to N only. And for treatments that received N and S combinations, ammonium sulphate (21%N and 23% S) and urea were used. On the other hand, urea and potassium chloride (48.18%K) were applied to treatments that received combined N and K levels. Whereas, potassium chloride was used for the treatments allotted to K alone. For the combined application of K and S, potassium chloride and potassium sulphate (44.55%K, 18.8%S) were used. Sodium sulphate (22.6%S) was used for treatments which required only S. All these mineral fertilizers were applied in band ones after onion seedlings have been transplanted and established well, except urea, which was applied in parts, half was applied just after seedlings get established and the other half was applied 30 days after seedling establishment. The seedlings were transplanted after 48 days from sowing, at a spacing of 10 cm and 30 cm between plant and row, respectively. The crop water requirement (ETc) over the growing season was estimated from the crop coefficient (Kc) and potential evapotranspiration of the study area as *ETc=Kc*ETo;* and irrigation scheduling was estimated from climatic, soil and crop data using the CROPWAT software. Soil bunds were made around the edges of each plot to prevent nutrient movement across plots.

2.3. Soil and Plant Sample Collection and Analysis

As indicated in the reports by Lee *et al.* [15], onions have a shallow, sparsely branched root system with most roots in the top 30 cm of soil. Therefore, before the time of onion transplanting, two composite soil samples were taken at a depth of 0-15 cm and 15-30 cm from 17 sampling points to analyze the chemical and physical property of the experimental soil. Routine procedures described in the soil and plant laboratory manual by Sahlemedhin and Taye [16], were followed to determine the selected soil characteristics and plant tissue analysis. Ten randomly selected onion bulb samples were picked from each plot for the analysis of NKS nutrient content at full maturity (95 days after transplanting).

2.4. Agronomic Data Collection and Nutrient Use Efficiency (NUE) Determinations

The average reading of ten randomly selected onion plants from each plot was used for measuring plant height (cm), leaf number and leaf area (cm^2) at physiological maturity (65 days after transplanting), and the average values were computed for further analysis. Plant height (cm) of onion plants was measured from the soil surface to the top of the longest leaf using a ruler. Leaf area was measured using a non-destructive estimation method described by Corcoles *et al.* [17]. After onion was harvested and cured, (95 days after transplanting) mean fresh bulb weight (g) and horizontal bulb diameter (cm) of ten randomly selected bulbs were measured using electronic sensitive balance and a caliper, respectively. In addition to this, ten chopped onion bulb samples were dried in an oven at 72°C for 48 hours until a constant weight was obtained and average dry-bulb weight (g) was measured using the electronic sensitive balance. However, total bulb yield from a net plot size of 1.8 m^2 was measured in kilograms using a scaled balance and expressed in Mg ha^{-1}.

Nutrient Use Efficiency (NUE) of every treatment was analyzed using the following common NUE measurements and calculations written by Doberman [18].

$$\text{Partial Factor Productivity (PFP)} = \frac{bulb\ yield\ obtained}{nutrient\ applied}$$

$$\text{Nutrient uptake} = \frac{bulb\ yield\ X\ \%\ nutrient\ concentration\ in\ the\ bulb}{100}$$

$$\text{Agronomic Efficiency (AE)} = \frac{bulb\ yield\ of\ treatment - bulb\ yield\ of\ control}{amount\ of\ nutrient\ applied}$$

Apparent Nutrient Recovery (%ANR) =

$$\frac{nutrient\ yield\ of\ treatment - nutrient\ yield\ of\ control}{nutrient\ applied} \text{X } 100$$

2.5. Economic and Statistical Data Analysis

The partial budget analysis was carried out based on CIMMYT [19], to evaluate the economic performance of onion under combined application of NKS nutrient levels by estimating the varying costs and returns based on market prices for 2016. Gross returns, net returns and marginal rate of return were calculated using the following formulas.

*Gross return=bulb yield*price*

Net return=gross return-total varying cost

Marginal Rate of Return (MRR)= $\frac{\Delta\ gross\ return}{\Delta\ total\ variable\ cost}$

The varying fertilizer and labor costs were estimated based on the existing rate of fertilizer purchase and daily labor payment. Costs that do not vary among all treatments were excluded in the analysis. The Marginal Rate of Return (MRR) analysis was carried out on both dominated and non-dominated treatments in a stepwise manner. As suggested by most scholars, 100% minimum rate of return was considered as a guarantee for the farmers to accept or to reject alternative fertilization without a doubt.

The collected data on onion growth and yield parameters were subjected to the analysis of variance procedure with the help of SAS JMP-5 software. Treatment shows that separation was carried out using Tukey's HSD test at 1% probability level.

3. RESULTS

3.1. Soil: Physical and Chemical Properties of the Experimental Site

The physical and chemical property of the study site before onion seedling transplantion is displayed in Table **1**. Based on FAO/UNESCO [20], soil map, soil type of the experimental area was vertisol with a textural class of silt clay loam. Laboratory analysis of the experimental soil showed that the soil was non-saline with neutral pH and low organic content matter (Table **1**). Values of the soil parameters decreased across depths except, available K and pH level, which showed a relative increase with depth. Besides, the nutrient status of the experimental soil prior to the transplantion of onion seedlings was low in both soil depths, except the concentration of phosphorus which was rated as high according to Havlin *et al.* [21]. As a result, onion is expected to respond to NKS nutrient application doses.

3.2. Growth of Onion as Affected by NKS Nutrient Levels

The result presented in Table **2** shows that the growth parameters of onion were strongly affected by the combined application of NKS nutrient levels at 0.01 significance levels. Considerably higher onion plant height (57.06 cm) was recorded in plots treated with $N_{92}S_{15}K_{67}$. This result is closely followed by 56.57 cm and 56.13cm recorded from $N_{92}S_{15}K_{45}$ and $N_{92}S_{15}K_0$ treatments, respectively.

The result in Table **2** depicted that, the maximum number of leaves per plant were observed from the higher NS nutrient levels ($N_{92}S_{15}$) with low (K_0) to medium (K_{45}) K levels. Whereas, minimum number of leaves per plant (8.01) were observed in control treatment ($N_0\,S_0\,K_0$).

Similar to the plant height and leaf number, leaf area was higher (853.20 cm^2) in plots treated using $N_{92}S_{15}K_{67}$ while lower (307.10 cm^2) was recorded in the control treatment ($N_0\,S_0\,K_0$).

3.3. Bulb Yield and Yield Attributes of Onion as Affected by NKS Nutrient Levels

As indicated in Table **3**, onion bulb yield and yield-related parameters have notably been influenced by NKS nutrient levels at 1% probability level. Noticeably, a higher bulb diameter, 8.64 cm was recorded from plots treated with $N_{92}S_{15}K_{67}$ nutrient doses. This result is followed by 8.54 cm and 8.43 cm which were recorded from plots which received $N_{92}S_{15}K_{45}$ and $N_{92}S_{15}K_0$, respectively. Onion bulb diameter obtained from the application of $N_{92}S_{15}K_{67}$ nutrient levels was 117.09% higher than the bulb diameter measured from the control treatment. Besides, fresh and dry onion bulb weights were remarkably affected by the combined application of NKS nutrient levels (Table **3**). Higher fresh bulb weight (220.75 g) of onion per plant was recorded from plots treated with $N_{92}S_{15}K_{67}$ nutrient doses, non-significantly followed by 212.8 g, 206.43 g, and 195.78 g recorded from treatment with $N_{92}S_0K_{67}$ $N_{92}S_{15}K_0$ and $N_{92}S_{15}K_{45}$, respectively.

Similar results were reported by Nigatu *et al.* [3], who recorded maximum bulb weight from the combined use of 105 kg N ha^{-1} and 22 kg ha^{-1} S. Fresh weight of onion bulb observed from $N_{92}S_{15}K_{67}$ was 282.91% higher than the control treatment. Similar to the bulb diameter and fresh weight of onion plants, maximum dry weight (44.70 g) of onion bulb per plant was recorded from plots treated with $N_{92}S_{15}K_{67}$ nutrient doses, which was 189.51% higher than the control treatment.

The data pertaining to Table **3** showed that the combined application of NKS nutrient levels strongly affected the bulb yield of onion. Increasing NKS nutrient doses significantly increased the total bulb yield of onion. Higher bulb yield of onion, 30.17, 29.11, 28.40 Mg ha^{-1} were recorded from the treatments that received $N_{69}S_{15}K_0$, $N_{69}S_{15}K_{45}$ and $N_{69}S_{15}K_{67}$, respectively with non-significant difference among them. Bulb yield of these treatments was enhanced by 302.6%, 291.98% and 284.86% over the control treatment. Likewise, higher bulb diameter, fresh bulb weight and dry weight were also observed from these treatments (Table **3**). This implies that bulb diameter and bulb weight were the direct contributors to the increase in total bulb yield.

3.4. Nutrient Use Efficiency of Onion Bulb

3.4.1. Nutrient Uptake and Concentration

Fig. (**1**) presents nitrogen (N), potassium (K) and sulfur (S) concentrations in onion bulb (**a-c**) and nutrient uptakes by onion bulb (**d-e**). The combined application of NKS nutrients at different levels significantly affected the nutrient content/ concentration and nutrient uptake of onion bulb at 0.01 significance level. Significantly higher N concentrations, 3.53% and 3.51% in the bulb yield of onion were recorded from $N_{92}S_{15}K_{67}$ and $N_{69}S_{15}K_{45}$ treatments, respectively (Fig. **1a**). Obviously, lower N concentration (2.64%) was recorded from the control treatment. Similarly, 1.32% and 1.30% of K concentration were obtained from an onion bulb treated with the combined nutrient levels of $N_{92}S_{15}K_{67}$ and $N_{92}S_{15}K_{45}$, respectively; which were 21.21% and 20% higher than the K concentration of onion bulb in the control treatment, respectively (Fig. **1b**). Maintaining application of 92 kg ha^{-1} N and 15 kg S ha^{-1}; increasing the application rates of K nutrient from 0 to 45 kg ha^{-1} and from 0 to 67 kg ha^{-1} increased K concentration of onion bulb by 11.29% and 16.67%, respectively. Similar to the N and K nutrient concentrations, S nutrient concentration in the bulb of onion was strongly influenced by combinations of NKS nutrient levels (Fig. **1c**).

In this study, relatively better S content (0.55%, 0.52, and 0.51%) in the bulb of onion was recorded from $N_{69}S_{15}K_{67}$, $N_{69}S_{15}K_0$ and $N_{69}S_{15}K_{45}$ treatments, respectively. This implies that the application of S nutrient in combination with N and K enhanced the uptake of S. This lower S content in the bulb yield of onion was recorded from the control treatment. Sulfur content in the bulb of onion was affected more by N and S nutrient application levels rather than by K.

Linear increase of nutrient uptake was obtained with increasing NKS nutrient levels as is indicated in Figs. (**1d-f**). The result presented in Fig. (**1d**) signifies that better N uptakes (106.58 kg ha^{-1} and 102.07 kg ha^{-1}) were recorded from $N_{92}S_{15}K_{45}$ and $N_{92}S_{15}K_{67}$ nutrient application rate, respectively. This result is followed by the uptake of 93.43 kg ha^{-1} N, which was recorded from $N_{92}S_{15}K_0$ nutrient levels. N uptake was lower (26.31 kg ha^{-1}) in the control treatment. Application on N in combination with K and/or S nutrients enhanced the N uptake of the onion bulb. Correspondingly, higher plant N uptake was recorded from combined N and S fertilization [4, 22, 23]. Comparable to N uptake, better K uptakes (39.73 kg ha^{-1} and 36.06 kg ha^{-1}) were recorded from $N_{92}S_{15}K_{45\text{-}67}$ nutrient application rates, closely followed by 34.36 kg ha^{-1}, which was observed from $N_{92}S_0K_{67}$ (Fig. **1e**). Lower K uptake was observed from the control treatment. This indicates that application of N and S nutrient combination facilitated the uptake of K by the onion bulb. Equivalent to N and K uptakes, higher (16.59 kg ha^{-1}) and lower (3.52 kg ha^{-1}) S uptakes were observed on plots treated with $N_{92}S_0K_{67}$ and $N_0S_0K_0$, respectively (Fig. **1f**). The application of 15 kg ha^{-1} S in combination with 92 kg N ha^{-1} and 67 kg K ha^{-1} increased S uptake by 292.59% rather than the sole application of S at 15 kg ha^{-1} rate.

3.4.2. Agronomic Efficiency (AE), Partial Factor Productivity (PFP) and Apparent Nutrient Recovery (ANR)

(Fig. **2**) presents the combined effect of NKS nutrient levels on AE and PFP. The combined application of NKS nutrient levels significantly affected AE and PFP at 1% probability level. Better AE (202.22 and 172.24 kg bulb per kg nutrient applied) were observed in plots treated with $N_0S_{15}K_0$ and $N_{92}S_{15}K_0$, respectively. Potassium nutrient application (without nitrogen and sulfur application) has a low effect on AE (Fig. **2**).

Similarly, the highest PFP (906.67 kg bulb per kg nutrient applied) was observed on plots treated with $N_0S_{15}K_0$ nutrient combinations at 1% probability level (Fig. **2**). This result is appreciably followed by plots treated with $N_{92}S_{15}K_0$ nutrient combinations, which attained 338.05 kg bulb per kg nutrient .

As the result depicted in (Fig. **3**), apparent nutrient recovery was significantly affected by NKS nutrient levels. The highest apparent nitrogen recovery, 71.24% was recorded from $N_{92}S_{15}K_{67}$ treated plots (Fig. **3a**). This result was non-significantly followed by 63.94% and 60.29% which were recorded from $N_{92}S_{15}K_{45}$ and $N_{92}S_{15}K_0$ treated plots, respectively. This indicates that irrespective of nitrogen and sulfur nutrient levels, decreasing potassium nutrient levels notably decreased apparent nitrogen recovery. Comparable to the apparent nitrogen recovery, the combined use of NKS nutrient levels extensively influenced apparent potassium recovery at 1% significance level (Fig. **3b**). The highest apparent potassium recovery (11.75%) was recorded from $N_{92}S_{15}K_{67}$ treatment followed by 9.33% and 8.97% which were recorded from $N_{92}S_{15}K_{45}$ and $N_{92}S_0K_{67}$ treatments, respectively. Lower appa-rent potassium recoveries were recorded from lower NKS nutrient levels.

The result in (Fig. **3c**) revealed that significantly higher apparent sulfur recoveries (46.43% and 40.02%) were recorded from $N_{92}S_{15}K_{67}$ and $N_{92}S_{15}K_{45}$ treatments, respectively. Increasing nitrogen and potassium nutrient levels have markedly increased apparent sulfur recovery. Apparent sulfur recovery was markedly influenced by the change in nitrogen level than the potassium level.

3.5. Economic Performance Analysis

The result of economic performance of the treatments analyzed using partial budget method (Table **4**) shows that higher Marginal Rate of Returns (MRR), 2258.01% and 2073.98% were recorded in $N_{92}S_{15}K_0$ and $N_{92}S_0K_0$ treated plots. However, net field incomes are different from profits because in the partial budget analysis, only variable costs are considered excluding the other production costs. Thus, based on the size of the net field incomes, it would be difficult to select the economically preferred treatment. For this reason, in order to compare each treatment, dominance analysis was performed based on the information on net field benefits and costs that vary (Table **5**).

Accordingly, the stepwise comparison (dominance analysis) between successive treatments (Table **5**) depicted that higher MRR, 61087.55%, 61721.14%, and 62354.74% were recorded from experimental plots treated with $N_{69}S_{15}K_{45}$, $N_{69}S_0K_0$, and $N_{69}S_{15}K_0$ nutrient combinations. The dominance analysis (Table **5**) showed that only twelve NKS nutrient combinations were not dominated while the six nutrient combinations are dominated treatments and they have no profit.

Therefore, considering the assumption of minimum acceptable MRR by farmers to be 100% to adopt new fertilizer combinations, onion production with 69 kg N ha^{-1} combined with or without K and S was acceptable. The dominance analysis result displayed in Table **5** revealed that the most profitable nutrient combinations are ranked as $N_{69}S_{15}K_0 > N_{69}S_0 K_0 > N_{69}S_{15}K_{45}$.

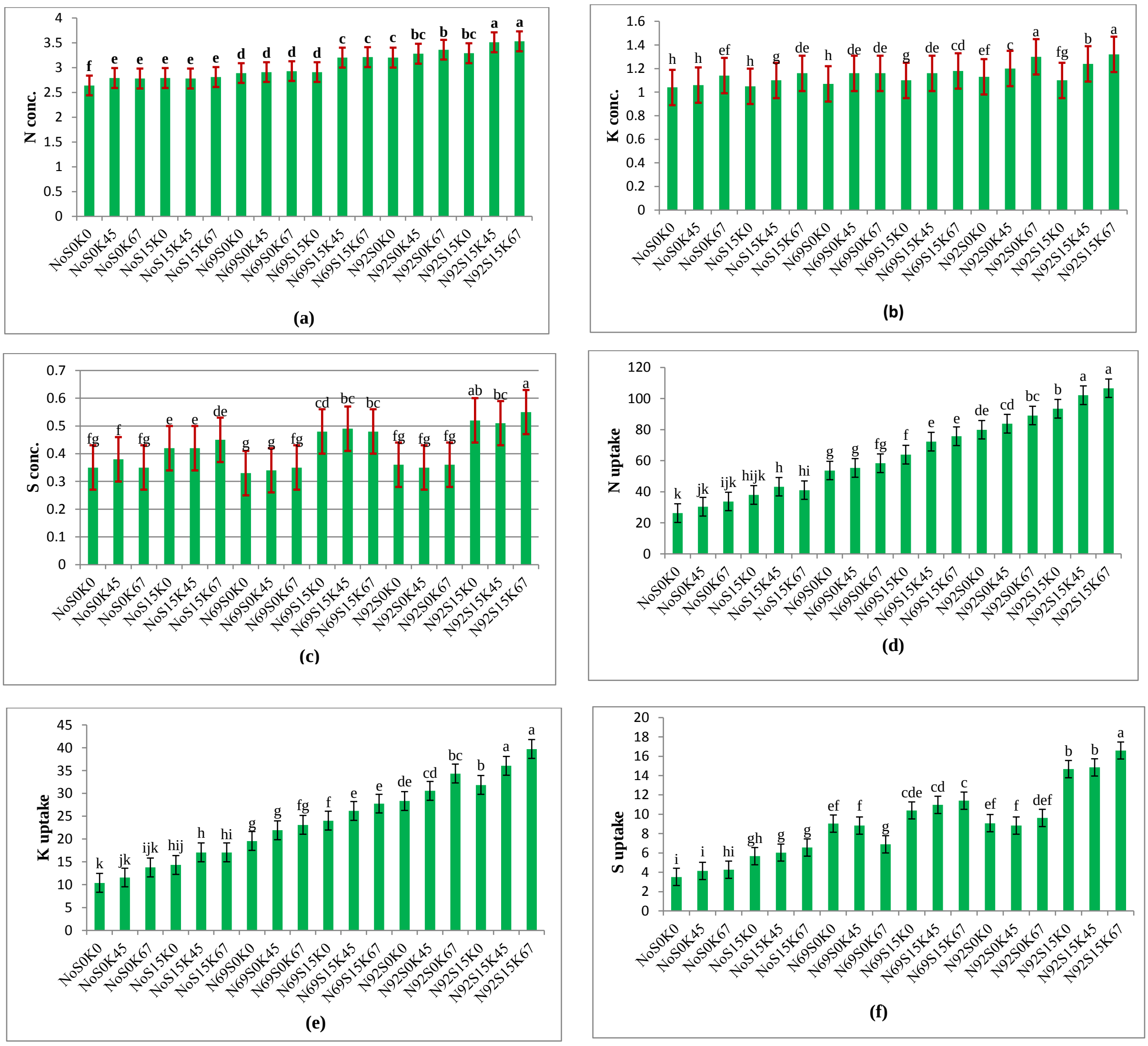

Fig. (1). Nutrient concentration (%) and uptakes (kg ha^{-1}) of onion bulb: Nitrogen concentration (**a**), Potassium concentration (**b**), Sulfur concentration (**c**), Nitrogen uptake (**d**), Potassium uptake (**e**), Sulfur uptake (**f**). Treatments (column) not connected by same letter for nutrient concentrations and uptakes are significantly different at the 0.01 level of probability. Vertical bars represent standard error of the mean.

Table 1. Soil characteristics of the experimental area before onion seedling transplantion.

Parameters	Soil Depth (cm)	
	0-15	**16-30**
Total N (%)	0.084	0.075
Available K (ppm)	33.2	38.4
Available S (ppm)	6.4	5.8
Available P (ppm)	16.8	12.7
OC (%)	0.81	0.71
OM (%)	1.4	1.22
pH (1:2.5 water)	6.67	6.8
EC (ds/m)	0.17	0.08

OC: organic carbon; OM: organic matter; EC: electronic conductivity.

Table 2. Onion growth parameters as affected by nitrogen, potassium and sulfur nutrient levels.

Nutrient Levels (Treatments)	Plant Height (cm)	Nº of Leaves Per Plant	Leaf Area (cm^2)
$N_0 S_0 K_0$ (control)	40.96^{l}	8.01^{g}	307.10^{m}
$N_0 S_0 K_{45}$	40.41^{lm}	7.98^{g}	313.48^{m}
$N_0 S_0 K_{67}$	39.94^{m}	8.21^{g}	352.39^{lm}
$N_0 S_{15} K_0$	42.95^{k}	9.36^{f}	403.29^{klm}
$N_0 S_{15} K_{45}$	43.39^{k}	9.44^{f}	424.71^{jkl}
$N_0 S_{15} K_{67}$	44.39^{j}	9.55^{f}	454.76^{ijk}
$N_{69} S_0 K_0$	46.84^{i}	10.94^{e}	495.00^{hij}
$N_{69} S_0 K_{45}$	47.34^{i}	11^{e}	515.96^{ghi}
$N_{69} S_0 K_{67}$	48.34^{h}	11.12^{e}	544.93^{fgh}
$N_{69} S_{15} K_0$	51.09^{g}	12.56^{d}	599.02^{efg}
$N_{69} S_{15} K_{45}$	51.63^{fg}	12.58^{d}	618.92^{def}
$N_{69} S_{15} K_{67}$	52.30^{ef}	12.76^{d}	651.50^{cde}
$N_{92} S_0 K_0$	53.00^{de}	13.27^{c}	695.02^{cd}
$N_{92} S_0 K_{45}$	53.46^{cd}	13.34^{c}	717.98^{c}
$N_{92} S_0 K_{67}$	54.14^{c}	13.46^{c}	$731.82b^{c}$
$N_{92} S_{15} K_0$	56.13^{b}	14.59^{ab}	$738.53b^{c}$
$N_{92} S_{15} K_{45}$	56.57^{b}	14.70^{a}	819.09^{b}
$N_{92} S_{15} K_{67}$	57.06^{a}	14.14^{b}	853.20^{a}
CV	11.67	1.96	9.84
Significance level	**	**	**

Treatments not connected by the same letter for a growth or yield parameter are significantly different at 99% probability level.
** stands significant at P<0.01.

Table 3. Onion yield parameters as affected by nitrogen, potassium and sulfur nutrient levels.

Nutrient Levels (Treatments)	Bulb Diameter (cm)	Fresh Bulb Weight (g)	Dry Bulb Weight (g)	Total Bulb Yield (Mg ha^{-1})
$N_0 S_0 K_0$ (control)	3.98^{m}	57.65^{l}	15.44^{h}	9.97^{k}
$N_0 S_0 K_{45}$	4.05^{m}	59.54^{l}	15.79^{h}	10.90^{k}
$N_0 S_0 K_{67}$	4.23^{lm}	69.75^{kl}	17.15^{gh}	12.10^{jk}
$N_0 S_{15} K_0$	4.80^{klm}	84.53^{jkl}	18.18^{gh}	13.60^{ij}
$N_0 S_{15} K_{45}$	5.68^{jkl}	89.51^{jkl}	19.04^{gh}	15.50^{i}
$N_0 S_{15} K_{67}$	5.02^{kl}	98.13^{ijk}	20.65^{g}	14.72^{ij}
$N_{69} S_0 K_0$	5.78^{ijk}	120.27^{hij}	26.37^{f}	18.31^{h}
$N_{69} S_0 K_{45}$	5.88^{hij}	126.12^{ghi}	27.35^{f}	18.90^{h}
$N_{69} S_0 K_{67}$	6.1^{ghij}	135.59^{fgh}	28.76^{f}	$19.90g^{h}$
$N_{69} S_{15} K_0$	6.6^{fghi}	156.27^{efg}	34.67^{e}	21.80^{fg}
$N_{69} S_{15} K_{45}$	6.72^{fgh}	157.82^{efg}	35.71^{de}	22.53^{ef}
$N_{69} S_{15} K_{67}$	6.85^{efg}	166.04^{def}	37.11^{de}	23.60^{def}
$N_{92} S_0 K_0$	7.57^{def}	175.28^{cde}	36.92^{de}	25.00^{cde}
$N_{92} S_0 K_{45}$	6.68^{cde}	180.85^{bcde}	37.92^{cde}	25.51^{cd}
$N_{92} S_0 K_{67}$	7.82^{bcd}	212.8^{ab}	39.32^{bcd}	26.50^{bc}
$N_{92} S_{15} K_0$	8.43^{bc}	206.43^{abc}	42.30^{abc}	28.40^{ab}
$N_{92} S_{15} K_{45}$	8.54^{b}	195.78^{abcd}	43.22^{ab}	29.11^{ab}
$N_{92} S_{15} K_{67}$	8.64^{a}	220.75^{a}	44.70^{a}	30.17^{a}
CV	4/24	8.60	7.71	5.87
Significance level	**	**	**	**

Treatments not connected by the same letter for a growth or yield parameter are significantly different at 99% probability level.
** stands significant at P<0.01.

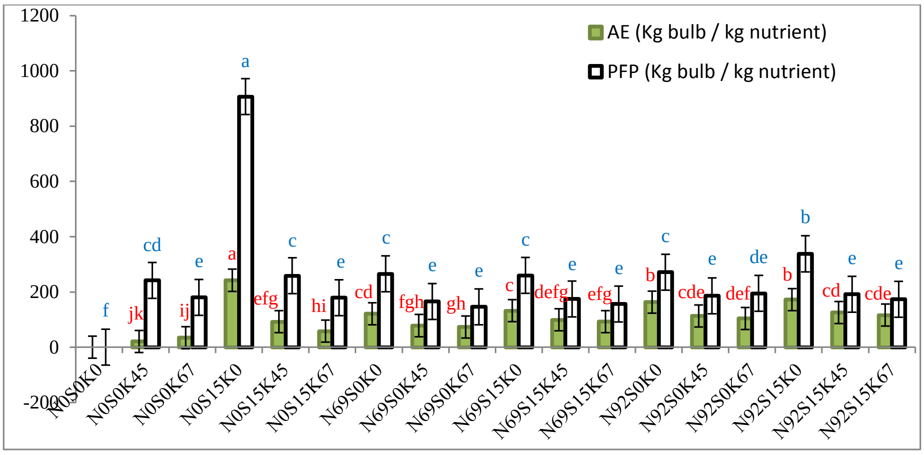

Fig. (2). Agronomic efficiency (Kg bulb / kg nutrient) and partial factor productivity (Kg bulb / kg nutrient). Treatments (columns) not connected by the same letter for AE and PFP are significantly different at the 0.01 level of probability. Vertical bars represent standard error of the mean.

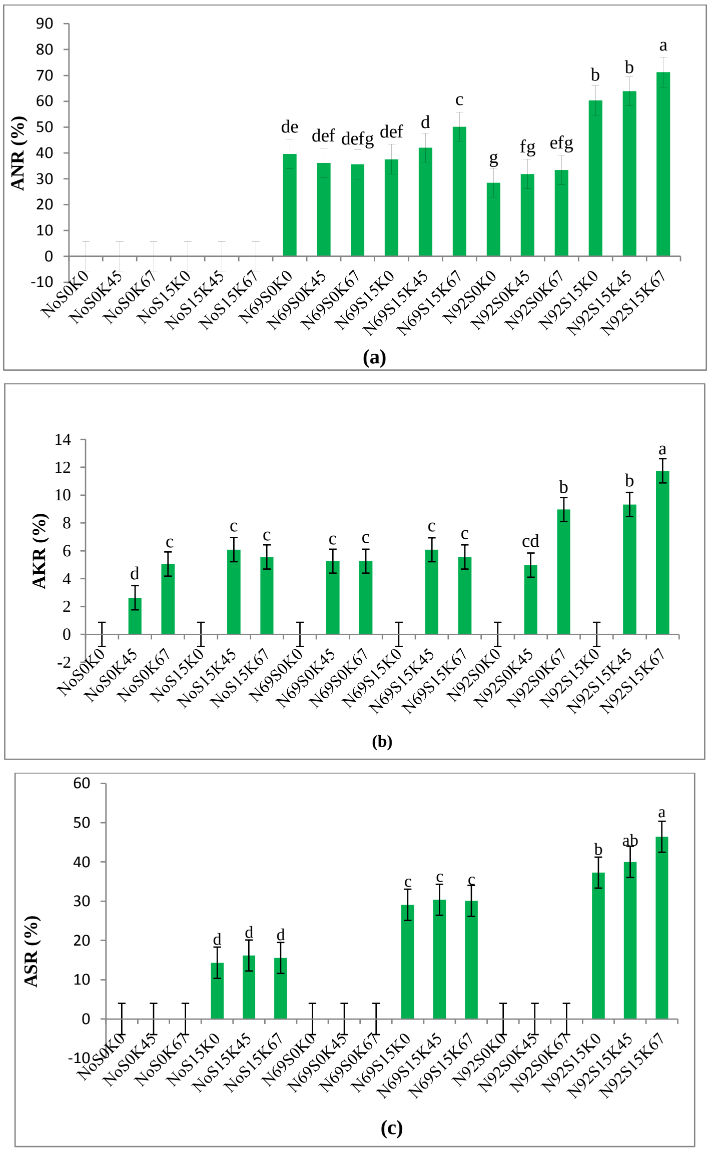

Fig. (3). Apparent nutrient recovery (%) of nitrogen (**a**), potassium (**b**) and sulfur (**c**). Treatments (columns) not connected by the same letter for apparent recovery of N, K and S are significantly different at the 0.01 level of probability. Vertical bars represent standard error of the mean.

Table 4. Marginal Rate of Return (MRR) analysis in comparison with control treatment ($N_oS_0K_0$).

Nutrient Levels (Treatments)	Returns and Costs in USD				
	Gross Return	Total Varying Cost	Net Return	Net Income Over Control	MRR (%)
$N_0S_0K_0$ (control)	4609.71	0.00	460.97	-	-
$N_oS_0K_{45}$	4930.62	454.68	4475.93	4014.96	883.03
$N_oS_0K_{67}$	5390.29	526.95	4863.33	4402.36	835.43
$N_oS_{15}K_0$	6027.75	410.27	5617.49	5156.52	1256.87
$N_oS_{15}K_{45}$	6461.41	482.54	5978.87	5517.89	1143.51
$N_oS_{15}K_{67}$	6838.68	554.81	6283.87	5822.90	1049.53
$N_{69}S_0K_0$	7892.45	459.47	7432.98	6972.01	1517.39
$N_{69}S_0K_{45}$	8196.01	531.75	7664.26	7203.29	1354.65
$N_{69}S_0K_{67}$	8642.67	604.02	8038.65	7577.68	1254.54
$N_{69}S_{15}K_0$	9453.60	487.33	8966.27	8505.30	1745.28
$N_{69}S_{15}K_{45}$	9770.16	559.60	9210.56	8749.59	1563.53
$N_{69}S_{15}K_{67}$	10234.17	631.88	9602.29	9141.32	1446.69
$N_{92}S_0K_0$	10784.91	474.89	10310.02	9849.05	2073.98
$N_{92}S_0K_{45}$	11058.11	547.16	10510.95	10049.98	1836.76
$N_{92}S_0K_{67}$	11491.76	619.43	10872.33	10411.36	1680.79
$N_{92}S_{15}K_0$	12315.70	502.74	11812.95	11351.98	2258.01
$N_{92}S_{15}K_{45}$	12619.25	575.02	12044.24	11583.27	2014.42
$N_{92}S_{15}K_{67}$	13083.26	647.29	12435.97	11975.00	1850.02

Table 5. Dominance analysis.

Treatments	Returns and Costs in USD				
	Gross Return	Total Varying Cost	Net Return	Net Income Over Control	Marginal Rate of Return (%)
$N_0S_0K_0$	4609.71	-	460.97	-	-
$N_0S_{15}K_0$	6027.75	410.27	5617.49	5156.52	1256.87
$N_0S_0K_{45}$	4930.62	454.68	4475.93	4014.96	**-2570.17**
$N_{69}S_0K_0$	7892.45	459.47	7432.98	6972.01	61721.14
$N_{92}S_0K_0$	10784.91	474.89	10310.02	9849.05	18666.53
$N_0S_{15}K_{45}$	6461.41	482.54	5978.87	5517.89	**-56587.25**
$N_{69}S_{15}K_0$	9453.60	487.33	8966.27	8505.30	62354.74
$N_{92}S_{15}K_0$	12315.70	502.74	11812.95	11351.98	18469.58
$N_0S_0K_{67}$	5390.29	526.95	4863.33	4402.36	**-28703.67**
$N_{69}S_0K_{45}$	8196.01	531.75	7664.26	7203.29	58462.64
$N_{92}S_0K_{45}$	11058.11	547.16	10510.95	10049.98	18469.58
$N_0S_{15}K_{67}$	6838.68	554.81	6283.87	5822.90	**-55227.48**
$N_{69}S_{15}K_{45}$	9770.16	559.60	9210.56	8749.59	61087.55
$N_{69}S_{15}K_{45}$	12619.25	575.02	12044.24	11583.27	18385.17
$N_{45}S_0K_{67}$	8642.67	604.02	8038.65	7577.68	**-13811.12**
$N_{92}S_0K_{67}$	11491.76	619.43	10872.33	10411.36	18385.17
$N_{69}S_{15}K_{67}$	10234.17	631.88	9602.29	9141.32	**-10205.23**
$N_{92}S_{15}K_{67}$	13083.26	647.29	12435.97	11975.00	18385.17

Values in bold indicate dominated treatment

4. DISCUSSION

Onion plant height, leaf number and leaf area were strongly affected by the combined applications of NKS nutrient levels (Table **2**). A similar result was also reported by Nasreen *et al.* [4] and Nigatu *et al.* [3]. Significantly shorter plant height, minimum number of leaves and lower leaf area of onion were recorded from plots treated with lower NS nutrient levels, despite K nutrient dose. On the other hand, superior onion growth performance was observed under the combinations of higher nutrient levels. Despite the K nutrient level, any changes in N and S nutrient levels significantly affected growth (plant height, number of leaves per plant and leaf area) and yield performance of onion. The mean height of onion treated with $N_{92}S_{15}K_{67}$ nutrient levels was 28.22% superior than the height of onion plants in the control treatment ($N_0S_0K_0$). Similarly, onion plants cultivated under $N_{92}S_{15}K_{67}$, $N_{92}S_{15}K_{45}$ and $N_{92}S_{15}K_0$ nutrient levels were 45.35%, 45.51% and 45.10% higher in leaf number than the control treatment, respectively. Increasing K nutrient level from 45 kg ha^{-1} to 67 kg ha^{-1} at higher NS nutrient application levels (92 kg ha^{-1} N and 15 kg ha^{-1} S) decreased leaf number in onion plants by 3.96%. Conversely, at lower NS nutrient levels, changing K nutrient levels had no significant effect on leaf number of onion (Table **2**). Furthermore, at the lower doses of N and/or S nutrients, K nutrient has a low effect on onion leaf area.

In the present study, increasing the application of NKS nutrient levels increased onion bulb diameter, bulb weight and total bulb yield (Table **3**). Higher bulb diameter, fresh bulb weight and dry bulb weights of onion were recorded from $N_{92}S_{15}K_{67}$, $N_{92}S_{15}K_{45}$ and $N_{92}S_{15}K_{0,}$ ranked in decreasing order. However, at relatively lower rates of N and/or S nutrient levels (below 92 kg ha^{-1} N and/or 15 kg ha^{-1} S), onion bulb yield and yield-related parameters showed a low response to K application levels. This implies that onion plants need relatively more N and S, than K. Moreover, the present study showed that onion bulb yield has strong response to higher N and S levels than K nutrient, indicating that the combination of maximum level of N (92 kg ha^{-1}) and S (15 kg ha^{-1}) had improved the productivity of onion, irrespective of K nutrient dose which appears to be weakly associated. These results are further supported by the literatures [3 - 5]. Onion growth and bulb yield increased by linearly increasing NKS nutrient application rates at higher than 0 kg ha^{-1} (Tables **2** and **3**). The results of this study are in agreement with Nigatu *et al.* [3] and Nasreen *et al.* [4].

Noticeably higher concentrations of N (3.53% and 3.51%) and K (1.32% and 1.30%) in the bulb yield of onion were recorded from $N_{92}S_{15}K_{67}$ and $N_{69}S_{15}K_{45}$ treatments with a non-significant difference between them, respectively. Whereas, enhanced S concentration (0.55%, 0.52% and 0.51%) were observed from $N_{92}S_{15}K_{67}$, $N_{92}S_{15}K_0$ and $N_{69}S_{15}K_{45}$ treatments with the insignificant differences among them, respectively. Mishu *et al.* [14] recorded maximum sulfur content (0.49%) of onion bulb at 40 kg S ha^{-1} followed by 0.45% at 20 kg S ha^{-1} application level. As indicated in Figs. (**1d-f**), combined and increased application of NKS nutrient levels linearly increased the nutrient uptake of the onion bulb. The findings of Habtegebrial, Singh [23] and Nasreen *et al.* [4] confirmed that significantly higher plant N uptake was recorded due to the combined N and S fertilization. Obviously, lower NKS nutrient concentrations and uptakes in the bulb of onion were recorded from the control treatment.

The result depicted in Fig. (**2**) showed that appreciably highest AE (242.22 kg bulb per kg nutrient applied) and PFP (906.67 kg bulb per kg nutrient applied) were observed on plots treated with no NK nutrient combinations ($N_0S_{15}K_0$). The mean AE in plots treated with $N_0S_{15}K_0$ was 28.89% and 54.55% higher than the next ranked treatments, $N_{92}S_{15}K_0$ and $N_{69}S_{15}K_0$, respectively. This implies that the influence of sulfur nutrient on AE was greater than that of nitrogen. On the other hand, the average AE in $N_0S_{15}K_0$ was 162.65% and 318.13% higher than in $N_0S_{15}K_{45}$ and $N_0S_{15}K_{67}$ treated plots, respectively. At 0 kg ha^{-1}N and 15 kg ha^{-1}S levels, AE decreased with increasing potassium nutrient level from 45 kg ha^{-1} to 67 kg ha^{-1}. At higher nitrogen and potassium nutrient levels ($N_{92}S_{15}$), increasing potassium nutrient levels from zero to 45 kg ha^{-1} and from zero to 67 kg ha^{-1} decreased PFP by 26.89% and 32.56%, respectively. This implies that AE is less affected by potassium nutrient application.

Onion production with the combined application of NKS nutrient at different levels significantly influenced apparent nutrient recovery (Fig. **3**). Better N, S and K recovery were recorded from the experimental plots treated with $N_{92}S_{15}K_{67}$ (Fig. **3**) which might be probably due to the presence of one or more nutrient combinations that can facilitate the uptake of one or the other nutrient. Habtegebrial and Singh [24] reported that S application along with N improves the N use efficiency by 28%. Cassman *et al.* [25] also reported that N recovery from mineral fertilizers is about 33- 50%. However, in the present study, maximum apparent N recovery was 71.24% higher than the cited reports.

Despite K and S nutrient levels, better MRR was observed at a high nitrogen level (92 kg ha^{-1} N). Comparable results were also reported by Nigatu *et al.* [3], who obtained higher MRR at 105 kg ha^{-1} N and 16.95 kg ha^{-1} S. However, based on the dominance analysis, higher MRR, 62354.74% was recorded from $N_{69}S_{15}K_0$ nutrient combination. This entails that, by applying 69kg ha^{-1} N combined with 15 kg ha^{-1} S, farmers can recover 1 USD plus an extra 623.55 USD ha^{-1} in a net benefit for each 1 USD ha^{-1} on average.

CONCLUSION

Higher growth, bulb yield, and nutrient use efficiency were recorded when an onion is cultivated using $N_{92}S_{15}K_{67}$ nutrient combination. An increasing trend in growth, bulb yield and yield-related parameters of onion was observed with increasing NKS nutrient concentrations, especially at higher nitrogen and sulfur levels. Application of NKS nutrient combinations enhanced nutrient concentration nutrient uptake of the onion bulb. Superior AE and PFP were observed in plots treated with $N_0S_{15}K_0$. Unlike the AE and PFP, better nutrient content, nutrient uptake and apparent nutrient recoveries were recorded from the combined nutrient application at higher levels ($N_{92}S_{15}K_{67}$), whereas inferior nutrient utilization efficiencies were observed on the control treatment ($N_0S_0K_0$). The low response of the control treatment in almost all the parameters can be attributed to the low fertility status of the experimental soil. The present study reveals that the combined application of NSK at a ratio of 92:15:00-67 kg ha^{-1} is an adequate dose for proper growth and yield performance of onion. Conversely, there have been various reports, of NKS nutrient levels as high as this dose showing significant yield increase. However, from the economic point of view, onion production using 69 kg N ha^{-1} and 15 kg S ha^{-1} nutrient combinations was the most profitable, irrespective of the K level.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No animals/humans were used for studies that are the basis of this research.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

FUNDING

None.

CONFLICT OF INTEREST

The author declares no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

REFERENCES

[1] CSA (Central Statistics Agency). Area and production of major cropsAgricultural sample survey 2016/2017, private peasant holdings, Meher season, Statistical Bulletin 532, Addis Ababa. 2017.

[2] FAOSTAT. World food and agricultural organization statistical year book. 2014.

[3] Nigatu M, Alemayheu M and H/Sillassie A. Optimum rate of NPS fertilizer for economical production of irrigated onion (Allium cepa L) in Dembyia District of Amhara Region, Ethiopia. Ethiopian Journal of Science and Technology 2018; 11(2): 113-27.

[4] Nasreen S, Haque M, Hossain M, Farid A. Nutrient uptake and yield of onion as influenced by nitrogen and sulphur fertilization. Bangladesh J Agric Res 2007; 32(3): 413-20. [http://dx.doi.org/10.3329/bjar.v32i3.543]

[5] Kumar A, Singh R, Chchillar R. Influence of nitrogen and potassium application on growth, yield and nutrient uptake by onion (*Allium cepa*). Indian J Agron 2001; 46: 742-6.

[6] Akhtar M, Bashir K, Khan M, Khoklar K. Effect of potash application on yield of different varieties of onion (*Allium cepa* L.). Asian J Plant Sci 2002; 1: 324-5. [http://dx.doi.org/10.3923/ajps.2002.324.325]

[7] Mohanty B, Das J. Response of rabi onion cv. Nasik Red to nitrogen and potassium fertilization. Vegetable Science 2001; 28: 40-2.

[8] Mozumder S, Moniruzzaman M, Halim G. 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 2007; 5(1&2): 58-63.

[9] ENMA. Ethiopia National Meteorology and Statistics Agency, Mekelle branch. 2018.

[10] Alemneh D. Integrated natural resources management to enhance food security: The case for community-based approaches in Ethiopia. Rome, Italy: Food and Agriculture Organization of the United Nations 2003.

[11] Amin MR, Hasan MK, Naher Q, Hossain MA, Noor ZU. Response of onion to NPKS fertilizers in low ganges flood plain soil. Intl J Sustain Crop Prod 2007; 2: 11-4.

[12] Ghaffoor A, Jilani MS, Khaliq G, Waseem K. Effect of different NPK levels on the growth and yield of three onion (Allium cepa L.) varieties. Asian J Plant Sci 2003; 2: 342-6. [http://dx.doi.org/10.3923/ajps.2003.342.346]

[13] Singh RP, Jam NK, Poonia BL. Response of Kharif onion to nitrogen, phosphorus and potash in eastern plains of Rajasthan. Indian J Agric Sci 2000; 70: 871-2.

[14] Mishu HM, Ahmed F, Rafii MY, Golam F, Abdul Latif M. Effect of sulphur on growth, yield and yield attributes in onion (Allium cepa L.). Aust J Crop Sci 2013; 7(9): 1416-22.

[15] Lee J, Moon J, Kim H, Ha I, Lee S. Reduced nitrogen, phosphorus, and potassium rates for intermediate-day onion in paddy soil with incorporated rice straw plus manure. HortScience 2011; 46(3): 470-4. [http://dx.doi.org/10.21273/HORTSCI.46.3.470]

[16] Sahlemedhin S, Taye B. (Eds.) Procedure for soil and plant analysis: National Soil Research Center, Ethiopia Agricultural Research Organization. Technical paper No 74; Addis Ababa, Ethiopia2000.

[17] Córcoles JI, Domínguez A, Moreno MA, Ortega JF, De Juan JA. A non-destructive method for estimating onion leaf area. Ir J Agric Food Res 2015; 54(1): 17-30. [http://dx.doi.org/10.1515/ijafr-2015-0002]

[18] Dobermann A. Nutrient use efficiency – measurement and management. IFA International Workshop on Fertilizer Best Management Practices. Brussels, Belgium. 2007; pp. 1-28.

[19] CIMMYT. From agronomic data to farmer recommendations: An economics training manual (completely revised edition). CIMMYT, Mexico, DF. 1988; pp. 9-38.

[20] FAO/UNESCO. Soil map of the world, Africa. Paris: UNESCO 1977; Vol. 6.

[21] Havlin J, Beaton J, Tisdale S, Nelson W. Soil fertility and fertilizers: An introduction to nutrient management. 7th ed. New Jersey: Prentice Hall 2005.

[22] Bloem E, Haneklaus S, Schnug E. Influence of nitrogen and sulfur fertilization on the alliin content of onions and garlic. J Plant Nutr 2004; 27: 1827-39. [http://dx.doi.org/10.1081/PLN-200026433]

[23] Habtegebrial K, Singh BR. Effects of timing of nitrogen and sulphur fertilizers on yield, nitrogen, and sulphur contents of tef (*Eragrostis tef* (Zucc.) Trotter). Nutr Cycl Agroecosyst 2006; 75: 213-22. [http://dx.doi.org/10.1007/s10705-006-9028-8]

[24] Habtegebrial K, Singh BR. Response of wheat cultivar to Nitrogen and Sulfur for crop yield, Nitrogen Use Efficiency, and Protein quality in semiarid Region. J Plant Nutr 2009; 32: 1768-87. [http://dx.doi.org/10.1080/01904160903152616]

[25] Cassman KG, Dobermann A, Walters DT. Agroecosystems, nitrogen-use efficiency, and nitrogen management. Ambio 2002; 31(2): 132-40. [http://dx.doi.org/10.1579/0044-7447-31.2.132] [PMID: 12078002]

© 2019 Tesfay and Girmay

This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Public License (CC-BY 4.0), a copy of which is available at: (https://creativecommons.org/licenses/by/4.0/legalcode). This license permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.