

EFFECT OF FERTILIZER TYPES AND APPLICATION RATES ON ONION

(*Allium cepa* L.) PRODUCTIVITY IN KILOSA DISTRICT



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REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN
CROP SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE.**

MOROGORO, TANZANIA.

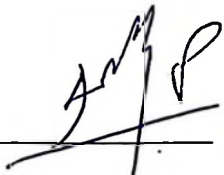
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ABSTRACT

Onion (*Allium cepa* L.) yield in Kilosa is said to be very low compared to the world production of about 22 t ha⁻¹. Poor crop husbandry including the use of unrecommended types and rates of fertilizers at incorrect time of application was found to be among the discrepancies facing onion production in the area. The purpose of this study was to establish and recommend the best combination and rate of N and P fertilizer sources for onion under Kilosa agroecological conditions. A field trial was conducted at Malolo village between September 2012 - January 2013 (dry season) and February 2013 - July 2013 (wet season). The experiment was laid out in split plot design with three replications. Two onion varieties namely; Red Bombay and Red Creole were used and assigned to the main plots. N and P fertilizer sources, each at the rates of 0, 50 and 100 kg N ha⁻¹ and 0, 40 and 50 kg P ha⁻¹, respectively were assigned to the subplots. Data were collected on vegetative growth, yield and bulb quality. They were then subjected to analysis of variance using GENSTAT 14th Edition at a difference declared significance of 5% level. Results showed significant differences between varieties in growth, yield and quality components. Red Bombay performed better in productivity in both dry and wet seasons compared with Red Creole. Wet season promoted better productivity than the dry spell. There was significant differences in yield between N and P sources at varying rates during the dry season, but insignificant during the wet season. Fertilizer combination of TSP and CAN at 50 kg P ha⁻¹ and 100 kg N ha⁻¹ respectively, is recommended as best for better productivity of onion plants under the Kilosa agroecological conditions.

DECLARATION

I, ASHRAF MOHAMED ASHRAF do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has neither been submitted nor concurrently being submitted for a degree award in any other University.

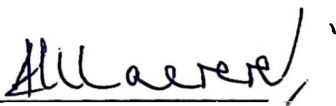


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DEDICATION

This work is dedicated to my parents the late Mohamed Dipak and Asha Mohamed Jiwa whose unfailing love and care they gave me has created the foundation for my education. This work solely, is the fruit of their hard work of raising me in good manners. To my lovely wife Naima Ramadhan Kapilima for her eagerness to take care of the family and encourage me during the master study. To my children Imran, Minaz, Abdulwaheed and Sureiya.

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LIST OF ABBREVIATIONS

ADP	Adenosine Diphosphate
AMP	Adenosine Monophosphate
Ca	Calcium
CAN	Calcium Ammonium Nitrate
CTAHR	College of Tropical Agriculture and Human Resources
cv	Cultivar
CV	Coefficient of Variation
DAP	Diammonium Phosphate
EC	Emulsifiable Concentrate
FAO	Food and Agriculture Organisation
IPNI	Intergrated Plant Nutrition Systems
L.S.D	Least Significant Difference
MAFC	Ministry of Agriculture and Cooperatives
OC	Organic Carbon
R	Fertilizer rate Combination
RB	Red Bombay
RC	Red Creole
SL	Sandy Loam
Temp.	Temperature
TSP	Triple Super Phosphate
TSS	Total Soluble Solids

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Onion (*Allium cepa* L.) is one of the most widely cultivated vegetables in the world. A global review of area and production of major vegetables shows that onion ranks second after tomato (FAO, 2003). It is a major source of income in many growing areas for rural families who sell their produce in local, regional and international markets (VECO-Tanzania, 2010). The crop is grown for its bulbs which are used daily in every home for seasoning and flavouring of foods. Onion is a valuable ingredient in the diet due to its content of sugars, vitamins and minerals (Ole *et al.*, 2004). Onion can be grown in a wide range of climatic conditions on any fertile, well drained, non crusting soil (INFONET – BIOVISION, 2013). The crop is probably cultivated in all countries of tropical Africa (Grubben and Denton, 2004).

Onion is produced almost all over Tanzania from the Northern and Southern highlands to the central plateau (VECO-Tanzania, 2010). The average yield for onion in Tanzania is 2.9 t ha⁻¹. This is very low compared to the world production which is about 22 t ha⁻¹ (FAO, 2010).

Several production constraints are responsible for such reduced bulb yield of which lack of specific fertilizer recommendation on the top list (Abdissa *et al.*, 2011). In many countries, fertilizer recommendation in onion is based on factors

such as previous cropping, soil type, fertility level and variety to be grown (Kalb, 2001). Onion is said to be a highly nutrient responsive crop (Ethel *et al.*, 2011). Based on a yield of 18 t ha⁻¹ of bulbs, onions remove an average of 66 and 11 kg of N and P, respectively (Kalb, 2001). Since a good production of onion needs fertile soil (Messiaen and Rouamba, 2004); therefore, a well balanced fertilizer application can be one of the most important management factors that contribute much to obtaining high and sustained crop productivity (Ghulam *et al.*, 2010). There are many fertilizer sources for the various nutrients needed by crops. Some are more economical than others and some supply more than one element (Hochmuth and Hanlon, 2000). Nutrients play a significant role in improving productivity of crops (Ahmad, 2009). Different levels of nutrients affect the yield and quality of the bulbs even within a variety. The essential nutrients especially, the primary macro nutrients; nitrogen, sulphur and phosphorus are necessary for plant growth, development and yield, particularly bulb formation, elongation, skin colour development and pungency (Abdul *et al.*, 2003).

The most commonly used N fertilizer sources in onion production in Tanzania are CAN and Urea (MAFC, 2002) whereas DAP (Muendo and Tschirley, 2004) and TSP are excellent sources of P (MAFC, 2007). However, information on appropriate fertilizer type and rate for onion production in Kilosa District is insufficient or sporadic (Msuya-Bengesi *et al.*, 2010). In view of this, the present experiment was undertaken to assess the effect of different N and P fertilizer sources and rates on growth, yield and quality of onion in the area.

1.2 Problem Statement and Justification of the Study

Onion is the major income generating horticultural crop in Kilosa. About 80% of farmers in the district are involved in onion production with experience ranging from 2 to 40 years in growing the crop (Msuya-Bengesi *et al.*, 2010). Despite of its importance, the yield of onion in Kilosa district (Table 1) is far less than the potential yield of 30 – 50 t ha⁻¹ in Tanzania (MAFC, 2002). Several factors are responsible for this discrepancy, including unawareness of the potential of the crop and lack of knowledge and skills on how to achieve this potential through correct general crop husbandry practices particularly on correct types and rates of fertilizers application (ECI-Africa, 2004). In the area the majority of farmers apply fertilizers without proper advice from Agricultural Officers (Isham, 2002). They do not know the correct dosage of fertilizers, when and how to apply for optimum onion production. Farmers in Kilosa apply DAP at the rate of 62.5 – 125 kg ha⁻¹ or no fertilizer is used in transplanting while CAN or Urea is applied at the rate of 250 – 375 and 500 - 750 kg ha⁻¹, respectively during vegetative growth (Msuya-Bengesi *et al.*, 2010).

According to Muendo and Tschirley (2004) the recommended rate of DAP on onion in Tanzania is 500 kg ha⁻¹ where as for TSP, Urea and CAN are 250, 100 and 200 kg ha⁻¹, respectively (MAFC, 2007). The quantity of fertilizer applied per unit area depends on farmer's income (Msuya-Bengesi *et al.*, 2010). Besides the general recommendations there is no information on the most appropriate type of fertilizer and rate of application for optimum production and quality of onion in Kilosa (Msuya-Bengesi *et al.*, 2010). In some studies, optimal fertilization on

onion was found to improve both yield and quality, for instance onion variety ‘Texas Grano’ was increased up to 80 t ha⁻¹ (Messiaen and Rouamba, 2004). Moreover, Sam (2007) reported that fertilizer had significant effect on growth of bulbs. Hence with improved knowledge on proper application of fertilizers, farmers in Kilosa can reduce the cost of production per unit area, increase yields and thus increase potential profitability (ECI-Africa, 2004).

Table 1: Onion yield in Kilosa

Yield tha ⁻¹	Variety		
	Red Bombay % Production	Red Creole % Production	Texas grano % Production
0.25 – 5	89.0	6.0	17.0
5.25 – 10	5.0	0.0	1.0
Above 10	0.0	0.0	0.0

Source: Msuya-Bengesi *et al.* (2010)

1.3 Objectives

1.3.1 Main objective

To establish and recommend the best combination and rate of N and P fertilizer sources for onion productivity under Kilosa agroecological conditions.

1.3.2 Specific objectives

- i. To evaluate the effect of different N and P fertilizer sources on growth and yield of onion
- ii. To assess the effect of different rates of N and P fertilizer sources on onion quality

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Botany of Onion

Onion is a biennial crop grown for bulb production and then for seed production in the second season (Hanelt, 1990). The leaves of the onion are hollow and emerge in two ranks at 180 degrees to each other. Onion leaves consist of two parts; one is the leaf base or sheath and the other is the blade. The leaf sheath is a hollow tube which encircles the apical meristem and encloses the shoot apex. The leaf blade is also a hollow tube that is closed at the tip (De Mason, 1990). The leaf sheathes and young leaf blades are formed in concentric rings called the pseudostem, which is distinguished from the true stem at the onion base (Hanelt, 1990). The primary root of the onion emerges from the seed, but it is short lived. The subsequent root system comes out from the stem base. The onion usually goes through a separate flowering season of growth to produce seed. The inflorescence occurs when the inflorescence axis is elongated from the shoot apical meristem. When elongation occurs, the true stem is extended through the leaf sheathes. The extended floral axis encloses the floral apex called the spathe (De Mason, 1990). The bulb or the edible part of the onion, consists of the vegetative stem axis and the leaf bases (Rubatzky and Yamaguchi, 1997).

2.2 Uses of Onion

Onions have wide uses in manufacture of soups, ketchups, onion flakes (dehydrated) and food seasoning besides being used as fleshy in salads and pickle. The smell and

pungency of onion is due to the essential oil known as “Allyl propyl disulphide”. Extracts of onion are used in the prevention of ‘atherosclerosis’ and ‘coronary heart disease’ as they can inhibit the aggregation of human blood platelets to form clots, which have the potential for arterial blocking. It is said to have effects on lowering blood sugar and lipid with good coagulation efficiency. The bulb is useful as diuretic and heart stimulant (Suresh, 2007).

2.3 Production Level

Onion is grown in at least 140 countries worldwide. The leading onion producing country is China, which produce 20.5 million tonnes/annum, followed by India and USA which produce 13.4 and 3.3 million tonnes/annum, respectively (FAO, 2010). Cultivation of onion in Tanzania is mainly practiced by smallholder farmers who produce the crop under both rain-fed and irrigated practices depending on the location and rainfall patterns. After harvesting bulbs are sun dried and packed in sacks with minimum grading. The harvested produces are then transported to local markets. Markets are unreliable with frequent price fluctuation and market loss (De Putter *et al.*, 2007).

2.4 Ecological Requirements for Onion Bulb Formation

The production of the bulb is controlled by day length. The critical daylength varies from 11 to 16 hours depending on variety. Therefore proper crop variety selection is essential, particularly in relation to the daylength requirements (FAO, 2013). The optimum rainfall requirement for onion yield is between 350 – 550 mm (AGL, 2002). Onions at the bulbing stage need a substantial amount of water, but

excessive moisture must be avoided during the growing season (INFONET – BIOVISION, 2013).

The optimum temperatures for plant development are between 13 and 24°C, although the range for seedling growth is narrow, between 20 and 25 °C. High temperatures favour bulbing and curing. In the tropics only short day or day neutral onion varieties will form bulbs. These thrive in warm to hot climates of 15 – 30 °C. If the temperature greatly exceeds that required for bulbing, maturity is hastened and bulbs do not grow to the maximum size, consequently lowering the yields (INFONET – BIOVISION, 2013). Onion can be grown on many soils but medium textured soils are preferred. Optimum pH is in the range of 6 to 7. The crop is sensitive to soil salinity, and a yield decrease from 0% to 100 % at varying levels of E_{Ce} from 1.2 mmhos/cm (optimum) to 7.5 mmhos/cm, respectively was observed (FAO, 2013).

2.5 Onion Growth and Development

The entire growth period for onion is between 100 and 140 days, this includes 30 to 35 days from germination to transplanting, 25 to 30 days in the vegetative period, 50 to 80 days for bulb enlargement and 25 to 30 days for maturity (AGL, 2002).

2.5.1 Vegetative growth

Onions are grown from seed, which at germination produces a single root and single hollow leaf (AGL, 2002). After the seedling is established, the young

onion plant enters the juvenile phase, where new foliage leaves and new shoot borne roots continue to be produced. For approximately every 2 weeks a new leaf grows inside the first leaf before growing out (AGL, 2002). New leaves are produced at the center of the plant and the late formed leaves are larger. This results in the earlier formed leaves being split open and discarded as the juvenile plant grows. During the adult vegetative phase, the stem thickens and increases in height such that each successive node is wider than the previous ones. Each new leaf blade is thicker than the previous leaf blade resulting in a change in the shape of the stem as the plant gets older. New roots are continuously produced throughout vegetative growth. Each successive group of roots is produced close to the shoot apex or root plate. This results in younger roots being produced above the level of older ones. As the stem diameter gets larger, roots are produced in rings in the stem and each successively produced ring has more roots (Doyle, 1993).

2.5.2 Bulb initiation and development

When day length becomes longer and the temperatures increase, onion plant forms bulb. During this process, morphological changes occur which result in preparing the onion plant for a resting state. These changes result from the mobilization of assimilates to the leaf bases to form the bulb (Doyle, 1993). Morphological changes that occur during bulb development include: 1) Initial enlargement of the bulb resulting from thickening of the bases of the foliage leaves, 2) As bulbing continues, the leaves developing near the center of the plant abort their blades, the bases of these leaves enlarge, and foliage growth ceases

(Rubatzky and Yamaguchi, 1997); 3) When the bulbs are mature, the outer (oldest) three to four leaf bases dry up and disappear or remain as papery coverings (Brewster, 1994).

2.6 Time of N and P Fertilizer Application on Onion

Time of application is an important aspect of fertilizer management practices as it affects fertilizer use efficiency. Response to fertilizers by crops can be affected by the time of application in relation to the stage of the crop growth and form of fertilizer applied (Abdoulaye and Sandes, 2005). Maximum use efficiency of nitrogen fertilizer is obtained for instance during vegetative growth to onion bulbing stage. This is the stage that permit maximum utilization of N fertilizer (Tisdale *et al.*, 1993). Generally, P is applied prior to planting since growing crops need P for growth and development (Jain and Shara, 1993). Since P has low mobility in the soil, they are always applied before or at planting (Hadwani and Gundalia, 2005).

2.7 Fertilizer Application Rates

Proper fertilizer application rates increase crop yields by correcting nutrient deficiencies. The optimum rate of fertilizer application to a crop is the rate that produces maximum economic return (Colwell, 1994). Fertilizer response is the function of a number of environmental factors which include availability in the soil of plant nutrients and available moisture within the rooting depth of a particular crop. Fertilizer application rates vary depending on various factors such as economic value of the crop, price of the fertilizer, nutrients available in the soil, ability

of the crop to absorb nutrients, moisture content of the soil and nutrient removal by crop and soil aeration (Abdoulaye and Sandes, 2005).

2.8 Effect of Fertilizer Sources and Rates on Onion

A wide variety of experiments of onion concerning fertilizer sources and treatment levels have been conducted worldwide (Gamiely *et al.*, 1991; Inal *et al.*, 2001; Sharma *et al.*, 2003; Singh *et al.*, 2002). Nandi *et al.* (2002) reported that growth and yield of onion were positively influenced by applying different doses of fertilizers. These researches are in agreement with the findings of Malkouti *et al.* (2002). The study on the growth and yield response of onion (*Allium cepa* L.) genotypes to different levels of fertilizers revealed that different levels of fertilizers influenced growth, yield components and yield of onion (Islam *et al.*, 2007). Nandi *et al.* (2002) indicated that growth and yield of onion were significantly influenced by irrigation and fertilizer levels.

2.8.1 Effect of N on growth, yield and quality of onion

N fertilizer sources have been investigated in several studies. It has been reported that irrigated onion plants benefited from application of 90 to 120 kg N ha⁻¹ compared to the unfertilized crops (Aklilu, 1997).

2.8.1.1 Effect of N on growth

Rizk (1997) reported that outcome of increasing N application generally increased growth parameters of the onion plant. However, Sorensen and Grevsen (2001) reported that too much nitrogen promoted excessive vegetative growth. Moreover N

rates from 125 to 150 kg ha⁻¹ have been reported in several studies as being adequate for onion growth (Sharma *et al.*, 2003; Singh and Singh, 2000). Shravan *et al.* (2004) recorded the optimum level of nitrogen for obtaining maximum growth of onion crop with treatments receiving 0, 50, 100 and 150 kg N ha⁻¹. The response of onion growth to different levels of nitrogen was shown by Arshad *et al.* (2007) to be significant on all growth parameters studied. Baloch *et al.* (1991) reported that the highest number of leaves per plant (17) was obtained with application rate in the range of 100 - 125 N kg ha⁻¹. However, the study conducted by Vachhani and Patel (1993) found that the number of leaves per plant was the highest with the application of 150 kg N ha⁻¹. Similarly, Kumar *et al.*, 1998; Singh and Chaure (1999) reported that the application of 150 kg N ha⁻¹ resulted to the maximum leaf length, number of leaves per plant, higher bulb weight and yield. Nandi and Nanda (1992) observed significant differences among fertilizers doses with respect to onion plant height by which the tallest plants were obtained with application of 90 kg N ha⁻¹. However, Jongatae *et al.* (2003) found the highest plant height of 73.2 cm at the rate of 180 kg N ha⁻¹. Jilani *et al.* (2004) reported that leaf length was highly significant at different levels of N in three different onion varieties. Whereas Abdissa *et al.* (2011) applied 69 kg N ha⁻¹ and found an increase in plant height and leaf length by 10 % and 11.5%, respectively over the control. Morsy *et al.* (2012) suggested that higher nitrogen level of 120 kg N ha⁻¹ achieved significant increase in plant height and number of leaves/plant as compared to lower rate of 90 kg N ha⁻¹.

2.8.1.2 Effect of N on yield

Shaikh *et al.* (1987) found that application of 90 kg N ha⁻¹ resulted to maximum yield of onion. The result was in agreement with Patel and Patel (1990) who reported significant increase in yield due to the increased nitrogen, although Maier *et al.* (1990) reported that N did not show any prominent effect on bulb dry matter content. Pandey and Ekpo (1991) reported a maximum bulb yield with 120 kg N ha⁻¹. Pandey *et al.* (1994) reported that application of nitrogen at rate of 80 kg ha⁻¹ gave higher yield than lower rates. However, Wiederfeld (1994) found no additional yield increase from applying N rates higher than 84 kg ha⁻¹. But Ali and Haque (1994) found the highest yield of 16 t ha⁻¹ with 100 kg N ha⁻¹ in Faridpur soil: Amin *et al.* (1995) reported that application of 100 kg N ha⁻¹ resulted in maximum bulb weight. Whereas Sadaria *et al.* (1997) reported that yield was highest with 100 kg N ha⁻¹. The observation was in agreement with experiment conducted by Kashi and Frodi (1998) who reported significant increase in bulb weight due to increased nitrogen levels. Kumar *et al.* (2001) also found that application of 120 kg N ha⁻¹ increased onion yield by 30%. There have been reports, however, of N rates as high as 200 kg ha⁻¹ resulting in significant yield increases over lower rates (Al - Moshileh, 2001). But Halvorson *et al.* (2002) in Colorado reported that nitrogen resulted in only small increase in bulb yield. Application of 60 kg N ha⁻¹ gave highest bulb yield in onion according to Cizauskas *et al.* (2003).

2.8.1.3 Effect of N on quality and storability

Khan *et al.* (2002) reported that onion bulb diameter was significantly affected by application of nitrogen. Yadav *et al.* (2003) found that N at 150 kg ha⁻¹ enhanced the

formation of bulbs with larger diameters. However, Woldetsadik *et al.* (2003) found that additional nitrogen to onion plants delayed bulb growth and development. Reddy and Reddy (2005) also observed an increase of bulb length in response to N fertilization. In a study by Abbey (2004), N fertilization was reported to significantly reduce onion bulb pyruvic acid concentration or pungency. On the other hand, the study conducted by Abdissa *et al.* (2011) revealed that the application of 69 kg N ha⁻¹ increased the proportion of splitted bulbs by 45% over the control. Dankhar and Singh (1991) and Bhalekar *et al.* (1987) showed that rotting of bulbs was increased with increase in N fertilization. Moreover, Singh and Dhankar (1995) found that increasing the rate of applied nitrogen from 50 to 150 kg ha⁻¹ led to significant increase in storage loss of onion during 4 to 5 months under ambient conditions. Moursy *et al.* (2007) showed that increasing the level of N fertilizer to 80 kg N ha⁻¹ resulted in about 8.5% increase in the TSS as compared to 40 kg N ha⁻¹. Whereas Hanna-Alla *et al.* (1991) suggested that increasing N levels up to 120 kg N ha⁻¹ decreased the percentage of TSS of mature bulbs of cv. Giza 20.

2.8.2 Effect of P on growth, yield and quality of onion

Researches from different parts of the world revealed that phosphorus nutrition greatly influenced growth and yield of onion. In soils that are moderately low in P, onion growth and yield can be enhanced in response to P fertilization. For instance, results of long term fertilizer trials on loamy sand soils in Germany have shown a strong response of onion to P fertilization in the range of 0 to 52 kg ha⁻¹ (Alt *et al.*, 1999).

2.8.2.1 Effect of P on growth

Greenwood *et al.* (2001) reported that P deficiency in onion resulted into reduced root and leaf growth. The optimum growth of onion was obtained with P application of 22 kg ha⁻¹, but even the higher levels gave a response with variety Pusa White Flat, which responded with optimum growth at 33 kg ha⁻¹ (Jha *et al.*, 2000).

A study in India in 1990 – 1991, suggested that P rates of 40 and 80 kg ha⁻¹ increased plant height and leaf number (Singh and Singh, 1999). In addition, evaluations of P rates of up to 98.2 kg ha⁻¹ showed no effect on growth of onions (Rodríguez *et al.*, 1999). Ajay *et al.* (2000) also reported that application of 75 kg P ha⁻¹ gave the best seedling survival. Whereas Pire *et al.* (2001) and Salo *et al.* (2002) reported significant effect of P on the growth of onion.

2.8.2.2 Effect of P on yield

Halder *et al.* (1998) recorded significant effects of P fertilizer on onion yield. Gupta and Gaffar (1990) obtained the highest yield (16.6 t ha⁻¹) with application of 54 kg P ha⁻¹. Woldetsadik (2003) in Ethiopia reported that phosphorus fertilization at the rate of 25 kg P ha⁻¹ increased yield of onion. In another study, rates of up to 160 kg P ha⁻¹ had no effect on total yield (Al - Moshileh, 2001).

2.8.2.3 Effect of P on quality and storability

Mangrio *et al.* (1987) suggested that highest dose of 44 kg P ha⁻¹ gave heavier bulb diameter. Singh *et al.* (1998) observed that increasing applications of P fertilizer from 25 to 100 kg ha⁻¹ resulted in loss of weight of stored onions.

Marschner (1995) also reported that P plays several keys of physiological processes including translocation of assimilates and photosynthetic products which ultimately results to increase of individual bulb weight in onion. The results obtained from Greenwood *et al.* (2001) suggested that P deficiency in onion would result into reduced bulb size.

2.8.3 Effect of N and P interaction on growth, yield and quality of onion

2.8.3.1 Effect of N and P interaction on growth

Aliyu *et al.* (2007) reported that N and P as well as their interaction significantly affected plant height, number of leaves per plant, percentage bolters and crop growth rate. The results obtained by Amin *et al.* (2007) showed that there was no significant difference of plant height due to different levels of N, P, K and S. Similar results were reported by Abdul *et al.* (2003) who reported that varieties, fertilizer levels and their interactions significantly affected plant height, leaf length and number of leaves per plant. Field experiments carried out by Fatma *et al.* (2012) revealed that all vegetative growth parameters significantly recorded highest values, when supplied with nitrogen and phosphorus at higher rates of 90 kg N ha⁻¹ and 45 kg P ha⁻¹, respectively. Stone (2000) reported that the application of Ammonium phosphate improved both growth and yields as compared with application of NH₄NO₃. On the other hand, Boyhan *et al.* (2002) found that additions of Diammonium Phosphate did not improve the quality of transplants. Al-madani *et al.* (2000) found that increasing the application of NPK fertilizers significantly increased the growth of onion.

2.8.3.2 Effect of N and P interaction on yield

Rahim *et al.* (1992) reported significant interaction of nitrogen and phosphorus on growth and yield of onion. Shamima and Hossain (2004) reported maximum yield of 37.6 t ha⁻¹ with application of N, P and S fertilizer sources. On the other hand another study conducted by Abdul *et al.* (2003) revealed significant effects of varieties, fertilizer levels and their interaction on yield per hectare. An experiment to determine the effect of N and P on yield and yield components of onion under different irrigation regimes revealed there was significant effect of Nitrogen application on yield components of onion compared to Phosphorous application (Negash and Weldekidan, 2010). A study to evaluate levels of N, P and K fertilizers and their effects on yield, graded yield, and leaf tissue nutrient status in short-day onions conducted in Georgia concluded that there was significant quadratic increase effect on yield after increasing N fertilizer from 0 to 336 kg ha⁻¹ whereas Phosphorus fertilizer rates from 0 to 147 kg ha⁻¹ had no effect on total yield (Bohyan, 2007). However, Gaviola *et al.* (1998) reported that the greatest total bulb yield of 34.5 t ha⁻¹ was obtained with 100 and 30 kg ha⁻¹ of N and P, respectively.

2.8.3.3 Effect of N and P interaction on quality and storability

An experiment to study the effect of different levels of N and P fertilizers on bulb quality and storability of onion grown on vertisol of Shewa Robit, North - East Ethiopia, revealed that N fertilization improved the pungency and reduced bulb dry matter content but were not significantly affected by P fertilization (Tekalign *et al.*, 2012). The study conducted by Fatma *et al.* (2012) revealed

significant interaction effects of nitrogen plus phosphorus and sulphur treatments on length of bulb and neck in the first season and bulb dimensions (length and diameter) in the second season. Mallangowda *et al.* (1995) reported maximum bulb diameter in onion with the application of N, P and K at 150, 50, 125 kg ha⁻¹, respectively. Whereas Patel and Vachani (1994) also suggested that onion bulb diameter increased with application of 150 kg N ha⁻¹ and 33 kg P ha⁻¹.

2.8.4 Effect of S on growth, yield and quality of onion

In recent years, there has been increased concern about the role of sulphur application as a soil amendment and as a factor of increasing fertilizer efficiency. Sulphur has a positive effect on onion and other crops (Bloem *et al.*, 2004). Sulphur has been found not only to increase bulb yield but also improved its quality, especially flavour and pungency (Jaggi and Dixit, 1999).

2.8.4.1 Effect of S on growth

Sulphur was found to be essential for building up amino acids and also for good vegetative growth, bulb development in onion (Anwar *et al.*, 2001). Nasreen *et al.* (2007) reported that addition of nitrogen and sulphur fertilizers exerted significant influence on the number of leaves/plant and plant height. While Jana and Jahangir (1992) indicated that the highest plant height of 48.62 cm and number of green leaves (9.14) were obtained with 30 kg S ha⁻¹. Mozumder *et al.* (2007) reported significant increases in plant height (41.8 cm), single bulb weight (41.4g) and fresh yield of 10.33 t ha⁻¹ with application of 24 kg S ha⁻¹. Two field experiments carried out at a farm in South Ghor area, Jordan, during 2004/2005 and 2005/2006 seasons

showed that increasing nitrogen and sulphur application rates significantly enhanced plant height, number of green leaves/plant and weight of plant at different stages of onion growth (Ahmad, 2009). Whereas Dabhi *et al.* (2004) reported that the highest plant height and number of green leaves were obtained by using sulphur. Thippeswamy (1993) studied the response of onion for four levels of sulphur (0, 20, 40 and 80 kg ha⁻¹) and recorded highest plant height of 53.69 cm and maximum number of leaves of 14.50 at 20 kg S ha⁻¹. Kumar and Singh (1995) reported that height of plant and length of leaves were significantly higher in sulphur sufficient plants compared to sulphur deficient plants.

2.8.4.2 Effect of S on yield

The effect of sulphur on yield of onion was reported by Nasreen *et al.* (2007). Similarly, El-Shafie and El-Gamaily (2002) reported that yield of onion bulbs increased by increment S rates of 0, 20 and 80 kg ha⁻¹. Jana and Jahangir (1992) indicated that the highest yield of 30.69 t ha⁻¹ was obtained at 30 kg S ha⁻¹. Sachdev *et al.* (1991) reported that highest yield of onion bulbs was obtained when 120 kg N ha⁻¹ was applied along with 40 kg S ha⁻¹ and it was at par with that obtained when 20 kg S ha⁻¹ was applied with 120 kg N ha⁻¹. However, the highest yield of 43.75 t ha⁻¹ was recorded in 40 kg S ha⁻¹ (Sumantrakar and Tiwari, 1993). Rajas *et al.* (1993) studied the effect of four levels of sulphur on the yield of onion cv. Pusa red and found that a dose of 80 kg S ha⁻¹ at 10 cm x 15 cm spacing produced the maximum yield of 28.11 t ha⁻¹ under dry and hot climate of Amaravathi, India. Anez *et al.* (1996) reported that sulphur application increased the average bulb yield from 28.36 t ha⁻¹ in control to 33.8 t ha⁻¹ when

S was applied at 30 kg ha⁻¹. Hamilton *et al.* (1997) reported that low sulphur availability significantly reduced the bulb weight. Nandi *et al.* (2002) indicated the highest yield with application of 150 kg N, 180 kg K and 60 kg S ha⁻¹. According to Abbey *et al.* (2002) the sulphur effects on the bulb dry matter was positive by increasing the sulphur rate.

2.8.4.3 Effect of S on quality and storability

Quareshi and Lawande (2004) showed that application of 75 kg S ha⁻¹ reduced the storage losses by 10 % (bulb weight basis). Jaggi (2003) reported storage losses such as percentage weight loss and percentage rotten bulbs to be significantly reduced by application of sulphur.

Attia (2001) found that application of 325 kg S ha⁻¹ consistently increased pungency. An experiment conducted during October 2003 to February 2005 at the Agricultural Research Station, Raikhali, Rangamati to investigate the effect of N, K and S on the yield and storability of transplanted onion showed that the application those nutrients significantly increased the length of bulb (4.49 cm) and diameter of bulb (3.85 cm) with the treatment of N₁₂₅ K₁₇₅ S₂₄ kg ha⁻¹ (Mozumder *et al.*, 2007). While, Jana and Jahangir (1992) reported the maximum bulb diameter of 6.13 cm due to application of 30 kg S ha⁻¹. Lancaster and Randle (2002) found that sulphur supply influenced bulb pungency and flavour intensity in *Allium* crops but had little effect on onion storage life (Forney *et al.*, 2010). Sulphur application significantly increased the uptake of N, P, K and S by onion plants when they received 45 kg S ha⁻¹ (Sankaran *et al.*, 2005). In contrast, Dabhi *et al.*

(2004) reported that the higher content and uptake of P, K, Mg, S, Zn and Cu in onion bulb were observed with 30 kg S ha⁻¹, followed by 20 kg S ha⁻¹. Sumantrakar and Tiwari (1993) reported that the best morphological characters of length, diameter, fresh weight, dry weight and volume of bulbs were obtained with CaSO₄ at 24 kg ha⁻¹. Nagaich *et al.* (1998) reported that increased levels of S significantly increased the diameter and length of bulbs on which the maximum values for all these parameters were observed with 60 kg S ha⁻¹. Randle and Bussard (1993) noticed that high sulphur influenced bulb pungency and concentrations. Moreover significant increases in bulb diameter, total soluble solids, pyruvic acid were observed with increasing levels of sulphur (Poornima, 2007).

The research conducted in farm and laboratory of SPII in Karaj, IRAN in 2010 on sulphur application rates effects on the yield and quality traits of onion, Red Rey and Qom White varieties, showed that varieties were significantly different in yield and pyruvic acid contents. Coolong *et al.* (2008) reported that increase in sulphur rates increased the bulb firmness. Ishtiaq *et al.* (2002) and Bybordi (2006) also indicated that the increase in sulphur increased the pyruvic acid.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

The experiment was carried out at Malolo village, Kilosa District, Morogoro Region in east central Tanzania between latitudes $5^{\circ} 55'$ and between $7^{\circ} 53'$ S and longitudes $36^{\circ} 30'$ and $37^{\circ} 30'$ E. The site lies at an altitude of 1 100 meters above sea level with average annual rainfall of 800-1 000 mm. The area experiences a mean annual temperature of 17°C (Min) - 29°C (Max). The area has sandy - loam soil. The first experiment was conducted during the dry season from 18 September, 2012 to 24 January, 2013 while the second experiment was conducted during the wet season between 2 February and 8 July, 2013.

3.2 Experimental Materials and Field Establishment

3.2.1 Experimental materials

3.2.1.1 Fertilizers

Four types of fertilizers at different rates; TSP and DAP (at transplanting), CAN and Urea (top dressing) were used. CAN contain 27% N, 10% Calcium and 0.4% Sulphur. It is a hygroscopic product that needs very low moisture to be absorbed by plants, hence it is effective in water stressed areas (MAFC, 2007). Urea contains 46% N. It should be applied only when it is possible either to incorporate it into the soil immediately after spreading to avoid evaporation losses of ammonia into the air or when rain is expected within a few hours following the application (FAO, 2000). TSP contains 46% P_2O_5 and 15% Calcium (IPNI, 2012) with no sulphur. It is applied



on plants grown in soils with low or average levels of Phosphorus (FAO, 2000). DAP contains 18% N and 47 % P. It also contains 2% Sulphur. Phosphorus in this fertilizer reacts more quickly than Phosphorus in other P fertilizer sources (CTAHR, 2012).

3.2.1.2 Onion varieties

Two commonly grown onion varieties; Red Bombay and Red creole were used. Red bombay is a small to medium sized, globe to flat shaped, purplish red with yield of between 30 – 40 t ha⁻¹(MAFC, 2002). Although seemingly more common in the market places, it takes longer to grow and has a shorter shelf life (ECI-Africa, 2004). Red creole is a medium to large, flat to round shaped, red coloured bulbs with yield ranging between 40 to 50 t ha⁻¹ (MAFC, 2002). It is preferred by farmers on grounds that it has good market and produces fewer splits (Msuya-Bengesii *et al.*, 2010). It grows faster and is more resistant to dry conditions. It also stores better and remains fresher longer (ECI-Africa, 2004).

3.2.2 Nursery establishment and management

Land was ploughed and harrowed by hand hoe followed by construction of seed beds each with size of 1 m width x 6 m length. Seed sowing on those beds was done by drilling at a spacing of 10 cm between drills. Watering of onion seedlings in nursery was done once per day (during early morning or late evening) or whenever the moisture of the soil became limited. Weeds were removed by hand pulling or by using garden hoe (forks) at an interval of 5 days to avoid competition for nutrients and harbouring of the pests in the nursery. The beds were wetted prior to weeding for

easy removal of weeds. Profecron^(R) EC insecticide was applied at the rate of 20 ml per 20 litres of water at interval of 15 days to control insect pests such as grasshoppers. Power 76^(R) WP fungicide was applied at a rate of 150 g per 20 litres of water at an interval of 15 days to control fungal diseases.

3.2.3 Experimental field

Soil samples were taken prior to the beginning of the experiment from 0 - 20 cm depth at 10 points per experimental replicate using a hand hoe and spade and then thoroughly mixed. The composite samples were air dried and ground through a 2 mm sieve. Samples for particle size analysis were sieved to pass through 0.5 mm sieves. The sieved samples were analyzed for pH in 1:2.5 soil to water ratio using the Coleman's pH meter (Yash, 1996). Organic carbon was determined by the Wakley and Black procedure (Nelson and Somers, 1992). Organic matter was estimated as organic carbon multiplied by 1.724. Total Nitrogen was determined by the micro Kjeldahl method (Bremner, 1965), while available P concentration was determined using the method developed by Olsen *et al.* (1954). Textural analysis was done using hydrometer method (Gee and Bauder, 1979). The analyses were done in the Soil Science laboratory at Sokoine University of Agriculture, Morogoro, Tanzania.

After soil sampling, the land was ploughed once using power tiller followed by harrowing and levelling after crushing the clods. The experimental plots were then laid out. Transplanting was done 45 days after sowing. During transplanting application of TSP and DAP each at the rates 0, 40 and 50 kg P ha⁻¹ was done

by broadcasting whereas CAN and Urea each at the rates of 0, 50 and 100 kg N ha⁻¹ were applied by broadcasting 4 weeks after transplanting as top dressing (MAFC, 2007).

3.3 Agronomic Practices

The experiment was conducted twice. The first experiment was conducted during the dry season from 18 September, 2012 to 24 January, 2013 (date of planting was 21 October, 2012) while the second experiment was conducted during the wet season between 2 February and 8 July, 2013 (date of planting was 4 April, 2013). During the dry season irrigation was done by flooding the experimental plots with water pumped from a nearby river. During the wet season irrigation was done whenever moisture of the soil became limited. Weeds were removed by hand pulling for broad leaved weeds or by using garden hoe for grasses and mexican poppy (*Argemone mexicana*) which were not easy to pull by hand. This was done at interval of 5 days. The beds were wetted prior to weeding for easy removal of weeds. Insect pests were managed as described under section 3.2.2. Earthing up was done immediately after the crop had started forming bulbs.

3.4 Experimental Layout and Design

The experiment was laid out in split plot design with three replications. Two onion varieties (Red Bombay and Red Creole) were assigned to the main plots. The subplots treatments contained fertilizer at the rates of 0, 50 and 100 kg N ha⁻¹ for each CAN and Urea and 0, 40 and 50 kg Pha⁻¹ for TSP and DAP, respectively.

The size of each plot was 2.0 m x 1.3 m giving an area of 2.6 m². The total experimental area including 0.5 m between plots and 1 m between replications was 581.1 m². A plant spacing of 20 cm x 10 cm was used (MAFC, 2007). There were 10 rows per plot and 13 plants per row which made 130 plants per plot.

3.5 Data Collection

3.5.1 Sampling area

For each experimental plot 10 plants within demarcated zone at the centre were randomly picked and tagged for recording of the various biometric data during crop growth. Edge rows in each plot were discarded from sampling to avoid border effects.

3.5.2 Crop growth parameters

Growth parameters including plant height, number of leaves plant⁻¹, length of leaf and diameter of leaf were recorded at an interval of two weeks from transplanting to 60 days (the time when the plants started to show signs of bulb formation).

3.5.2.1 Number of leaves per plant

This referred to the number of leaves formed by each plant. Number of fully opened leaves for the 10 tagged plants were counted and recorded. The mean number of leaves per plant in each treatment was then computed.

3.5.2.2 Length of the longest leaves

The length of the longest leaf for the 10 tagged plants was measured using a meter rule from the bulb neck to the tip of leaf when held vertically. The mean length of the leaves in each treatment was then computed and recorded.

3.5.2.3 Plant height

Height of the 10 tagged plants was measured using a meter rule from the ground level to the tip of the longest leaf by holding the plant vertically. The mean plant height (cm) in each treatment was calculated from recorded individual plant height.

3.5.2.4 The diameter of the longest leaves

The diameter of the longest leaf for the 10 tagged plants was measured using vernier calliper at the centre position of leaf when held horizontally. The mean width of leaves in each treatment was then computed and recorded.

3.5.3 Yield data

Data for yield was recorded after harvesting. The yield was measured based on the weight of bulbs in kg plot^{-1} and converted to t ha^{-1} .

3.5.4 Quality parameters

Quality of the onion bulbs for the different treatments was assessed based on the proportion of splitted bulbs percentage, bulb diameter, bulb length, neck thickness and pungency. These were determined after harvesting as follows:

3.5.4.1 Bulb splitting

The proportion of splitted bulbs was determined by counting the number of split bulbs and expressed as percentage of the total number of bulbs per plot.

3.5.4.2 Bulb diameter

This referred to the size of the bulbs at the widest point in the middle portion of the mature bulb. The diameter of 10 bulbs picked randomly after harvest from each treatment was measured using a vernier calliper. The average bulb diameter in centimetres was then computed and recorded.

3.5.4.3 Bulb length

The length of bulbs was measured from the base to neck of the bulb by using vernier calliper on 10 randomly picked bulbs after harvest. The average bulb length was then computed and recorded.

3.5.4.4 Neck thickness

This referred to the terminal position of the mature bulb. Neck thickness of 10 mature bulbs picked randomly after harvest from each treatment was measured using a vernier caliper. The average bulb neck thickness was then computed.

3.5.4.5 Pungency

Pungency was determined by using the taste panel method (Addington, 2012). 10 samples of onion bulbs from each plot were picked randomly after harvesting for odour assessment by three different groups of people. The groups were formed on

the basis of age and each group was consisted of 10 members at an equal ratio of males and females. The groups were as follows: group X; 13-20 years involving O-level students, group Y; 24 - 28 years of University students and group Z; different people of between 30 - 55 yrs. 25 Samples of each of the two onion variety from each were provided to each group for the assessment. Each member in the group was requested to fill in a structured questionnaire (Appendix 1).

3.6 Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using GENSTAT 14th Edition at a difference declared significance of 5% level. Descriptive statistics (mean, standard deviation and coefficient of variation) were generated using the GENSTAT procedures. Multiple means comparison was done by using Duncan GENSTAT tool at 5% level of significance. The statistical model for the split plot experimental design was:

$$X_{ijk} = X + M_i + B_j + d_{ij} + S_k + (MS)_{ik} + E_{ijk} \dots\dots\dots(1)$$

Where:

X = general mean common to all observations

M_i = main plot treatment effect (Onion varieties)

B_j = the block effect

d_{ij} = the main plot error (error a)

S_k = the sub plot treatment effect (Fertilizer type and rate combinations)

$(MS)_{ik}$ = the main plot and subplot interaction effect of a respective fertilizer rates with given N and P sources

E_{ijk} = subplot error (error b)

CHAPTER FOUR

4.0 RESULTS

4.1 Characteristics of the Soil at Experimental site

The physical and chemical properties of the soil from the experimental site at Malolo are presented in Table 2. Particle size analysis indicated that the soil had 18% clay, 7% silt and 75% sand. According to the soil classification system by FAO (1977) the soil textural class was Sandy loam.

The soil pH as determined in 1:2:5 soil:water suspension was 7.4. Landon (1991) categorised pH values as follows; very high (>8.5); high (7.5-8.5); medium (5.5-7.0) and low (<5.5). According to the above categorisation the pH of Malolo soil was rated as high.

On the basis of criteria given below; P values of <15 mg /kg, 15-50 mg /kg and >50 mg/kg were ranked as low, medium and high, respectively (Landon, 1991). Therefore according to this categorisation, available P in the soil was rated as medium (Table 2). Organic carbon contents in the soil was 1.34 (Table 2). This value in the study area rated as very low as it was less than 4% (Landon, 1991).

Pillai (2005) reported that N requirement is categorized as low, medium and high when the percentage total nitrogen values are less than 0.1, 0.1-0.2 and >0.2, respectively. Thus, according to the ranking above total N in the study area was low (Table 2). Exchangeable Ca⁺² values of 4cmol Ca /kg, 4-10 cmol Ca /kg and >10

cmol Ca /kg were ranked as low, medium and high, respectively (Landon, 1991). Thus, according to the above categorisation the exchangeable Ca level of Malolo soil was rated as medium (Table 2).

The Mg values of <0.2, 0.2-0.5 and >0.5 cmol/kg were ranked as low, medium and high, respectively while K values of 0.03-0.2, 0.2-0.4 and 0.4-0.8 cmol/kg were ranked as low, medium and high, respectively. Thus, the results of Mg and K values from Malolo reveal that the soil has medium Mg and K values (Landon, 1991).

Table 2: Physical and chemical properties of soil in Malolo

Property	Results
Soil pH (in H ₂ O)	7.43
% Clay	18
% Silt	7
% Sand	75
Texture	SL
% N	0.13
% OC	1.34
% P	18.88
Ca ⁺² (cmol/kg)	8.68
Mg ⁺²	4.62
K ⁺	0.46

4.2 Effect of Season on Onion Growth, Yield and Quality

Figure 1 presents the weather data for the dry season. The maximum temperature experienced ranged from 29.7 °C to 33.5 °C while minimum temperature were 18.9 °C to 22.6 °C. September, October and November experienced hot conditions in the range of 29.7 to 30.4 °C. However, December was the hottest (33.5 °C). No rainfall

was received from September to the third week of November 2012. Weekly cumulative rainfall in the range of 29.9 mm and 45.3 mm were recorded during the fourth week of November to the fourth week of December 2012.

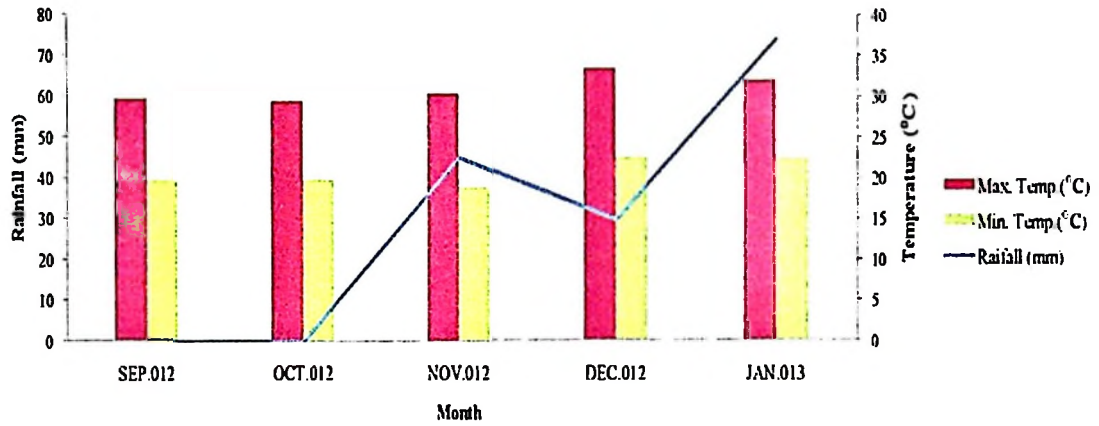


Figure 1: Minimum and maximum mean monthly temperature (°C) and cumulative rainfall (mm) during the dry season

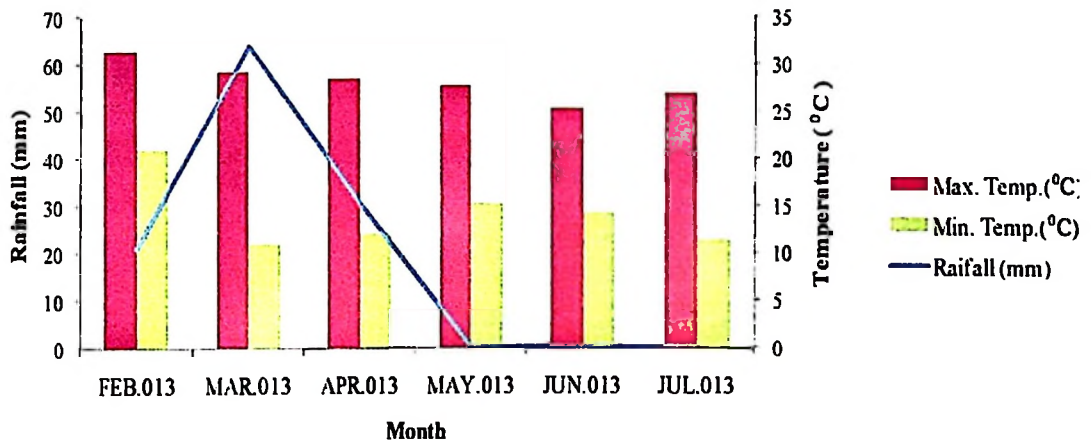


Figure 2: Minimum and maximum mean monthly temperature (°C) and cumulative rainfall (mm) during the wet season

In the wet season (Fig. 2), maximum temperatures ranged from 25.4 °C to 32 °C while minimum temperature were 11 °C to 22.5 °C. From first to fourth week of

January followed by the first and the third week of February were the hottest. The temperatures decreased from the fourth week of February (29.2 °C) to third week of June (25.4 °C). Weekly cumulative rain in the range of 21mm to 74.3 mm was received from January to April 2013. No or little rainfall (<10 mm) was recorded from the first week of May to July 2013. Comparison of dry and wet seasons show that, long periods of hot conditions were experienced in the dry season (>31 °C) than in the wet season (32 °C to 25.4 °C). Except for weekly cumulative rains of 45.3 mm and 29.9 mm in the fourth week of November and December, no rainfall was experienced during the rest of months in the dry season compared to a few weeks with little rain (<10 mm) in the wet season. All growth, yield and quality parameters were significantly ($p \leq 0.05$) different between the dry and wet seasons. The results indicate the wet season favoured better performance of plants interms of vegetative growth, yield and bulbs size (diameters and lengths) compared to the dry season. However, the wet season produced higher proportions of splitted, thicker necks and more pungent bulbs compared to the dry season (Table 3).

4.3 Effect of Variety on Onion Growth, Yield and Quality

4.3.1 Number and size of leaves

During the dry season, there was significant difference ($p < 0.05$) in the number and size of leaves between the studied onion varieties. Red Creole significantly ($p \leq 0.05$) produced more, longer and wider leaves (9.8, 42.73 cm and 0.94 cm, respectively) as compared to Red Bombay (number of leaves (8.8), length (38.15cm) and diameter (0.76 cm) (Table 4).

Table 3: Effect of season on growth, yield and bulb quality

Season	Nlp	L (cm)	D (cm)	Ph (cm)	Y (t/ha)	Sb (%)	Bd (cm)	Bl (cm)	Nt (cm)	Pu
Ds	9.31a	40.4a	0.8a	49.2a	7.7a	30a	4.3a	3.81a	1.52	2.3a
Ws	11.25b	44.91b	0.95b	54b	11.6b	43.5b	5.04b	4.99b	1.71	2.2b
F-Test	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01
CV (%)	20.4	10.4	22.8	10.6	43.1	39.8	15.8	13.8	16.5	18.5
SE±	2.1	4.4	0.21	5.5	4.2	14.6	0.74	0.61	0.27	0.42

Key: Nlp=Number of leaves per plant, L=Length of the longest leaf, D=Diameter of the longest leaf, Ph=Plant height, Y=Yield, Sb=Splitted bulbs, Bd=Bulb diameter, Bl=Bulb length, Nt=Neck thickness, Pu=Pungency, Ds=Dry season and Ws=Wet season

Table 4: Effect of variety on growth, yield and bulb quality during the dry season

	Nlp	L (cm)	D (cm)	Ph (cm)	Y (t/ha)	Sb (%)	Bd (cm)	Bl (cm)	Nt (cm)	Pu
RB	8.8a	38.2a	0.76a	49.2a	8.9b	28.2a	4.7b	4.1b	1.47a	2.4a
RC	9.8b	42.7b	0.94b	49.1a	6.5a	31.8b	4a	3.5a	1.58a	2.3a
F-Test	<0.001	<0.001	<0.001	0.93	<0.001	0.03	<0.001	<0.001	0.009	0.68
CV(%)	19.7	9.9	23.6	10.1	32.6	33.6	18.5	16	15.9	16.9
SE±	1.83	4	0.2	4.98	2.51	10.1	0.8	0.61	0.24	0.39

Key: Nlp=Number of leaves per plant, L=Length of the longest leaf, D=Diameter of the longest leaf, Ph=Plant height, Y=Yield, Sb=Splitted bulbs, Bd=Bulb diameter, Bl=Bulb length, Nt=Neck thickness, Pu=Pungency, RB=Red bombay and RC=Red creole.

However, during the wet season, Red Bombay generated significantly ($p \leq 0.05$) more (12.1), longer (46.54 cm) and wider (1.0 cm) leaves compared to those of Red Creole (10.4) leaves, (43.28 cm long) and (0.9 cm wide) (Table 5).

Table 5: Effect of variety on growth, yield and bulb quality during the wet season

	Nlp	L (cm)	D (cm)	Ph (cm)	Y (t/ha)	Sb (%)	Bd (cm)	Bl (cm)	Nt (cm)	Pu
RB	12.1b	46.5b	1b	57.4b	16.4b	39.1a	5.4b	5a	1.67a	2.1a
RC	10.4a	43.3a	0.9a	50.98a	6.8a	47.8b	4.6a	4.9a	1.77b	2.3b
F-Test	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	0.83	0.04	0,01
CV(%)	15.8	9	15.5	10.2	42	41.3	12.9	12.4	17.4	20
SE±	1.77	4	0.15	5.5	4.9	17.9	0.65	0.62	0.3	0.44

Key: Nlp=Number of leaves per plant, L=Length of the longest leaf, D=Diameter of the longest leaf, Ph=Plant height, Y=Yield, Sb=Splitting bulbs, Bd=Bulb diameter, Bl=Bulb length, Nt=Neck thickness, Pu=Pungency, RB=Red bombay and RC=Red creole.

4.3.2 Plant height

During the dry season, plant height between two onion varieties did not differ significantly ($p>0.05$). Red Creole plants had a mean height of 49.11 cm whereas Red Bombay had a mean height of 49.18 cm, which were statistically similar (Table 4). During the wet season, the height of plants differed significantly ($p\leq 0.05$) between the two varieties. Red Bombay variety produced the tallest plants (57.4 cm) while the shortest plants (50.98 cm) were recorded from Red Creole (Table 5).

4.3.3 Yield

The onion yield differed significantly ($p\leq 0.05$) between the two varieties during dry and wet season. During the dry season, Red Bombay produced the highest yield (8.93 t ha⁻¹) compared with that of Red Creole (6.46 t ha⁻¹) (Table 4). Similar results were obtained during the wet season as shown in the Table 5.

4.3.4 Bulb splitting

The proportion of splitted bulbs varied significantly ($p \leq 0.05$) between onion varieties during the dry season. Red Creole produced the highest proportion of splitted bulbs (31.77%) compared with that of Red Bombay (28.33%) (Table 4). Similar results were observed in the wet season as shown in Table 5.

4.3.5 Bulb diameter, length and neck thickness

Bulb diameter and Bulb length were significantly ($p \leq 0.05$) different between the onion varieties during the dry season. Red Bombay produced the widest and longest bulbs (4.69 cm and 4.08 cm, respectively) compared with those of Red Creole (3.98cm and 3.53cm, respectively) (Table 4). Similarly, during the wet season the variety Red Bombay produced the largest bulbs with mean diameter of 5.4 cm whereas the smaller bulbs (4.64) were recorded from Red Creole. However, the length of bulbs differed insignificantly ($p > 0.05$) between the onion varieties. The highest mean length (5.0 cm) was recorded from Red Bombay and the shortest length (4.98 cm) was obtained from Red Creole (Table 5).

Bulb neck thickness differed insignificantly ($p > 0.05$) between the two onion varieties during both dry and wet seasons. They had mean neck thickness of 1.47 cm and 1.57 cm for Red Bombay and Red Creole, respectively during the dry season (Table 4). On the other hand the bulb neck size of 1.67 cm and 1.77 cm for the Red Bombay and Red Creole respectively were recorded in the wet season. The variety Red Creole produced bulbs with relatively thicker neck than those produced by Red Bombay (Table 5).

4.3.6 Pungency

The level of pungency between the two onion varieties did not differ significantly ($p>0.05$) during the dry and wet seasons. During the dry season, the varieties recorded levels of pungency ranging from 2.3 (Red Creole) to 2.4 (Red Bombay) (Table 4). During the wet season, the highest level of pungency (2.1) was recorded from Red Bombay and the lowest (2.3) was recorded from Red Creole (Table 5).

4.4 Effect of P Fertilizer Sources on Onion Growth, Yield and Quality

4.4.1 Number and size of leaves

There was no significant ($p>0.05$) difference in number and size of leaves between P fertilizer sources in both dry and wet season. During the dry season, plants treated with DAP at 50 kg P ha⁻¹ generated the highest number of leaves per plant (9.8) similar to application of TSP at 50 kg P ha⁻¹ (9.7). On the other hand, plants treated with DAP at 40 kg P ha⁻¹ produced more leaves (8.8) compared to those treated with TSP at 40 kg P ha⁻¹ (7.8). The latter produced the lowest number of leaves per plant (Table 6). In the wet season, the control was observed to produce the highest number of leaves per plant (12) compared to fertilizer treated plants, whereas the lowest number of leaves (10) was obtained from TSP application at 40 kg P ha⁻¹ (Table 7).

Table 6: Effect of P fertilizer sources on growth, yield and bulb quality during the dry season

P sources	Nlp	L (cm)	D (cm)	Ph (cm)	Y (t/ha)	Sb (%)	Bd (cm)	Bl (cm)	Nt (cm)	Pu
DAP1	8.8a	43.19a	0.92ab	49.16a	10.4c	38.3d	4.45a	4.20a	1.47a	2a
DAP2	9.8a	40.71a	1b	50.41a	8.4bc	60.3e	4.43a	3.66a	1.53a	2a
NF	9.6a	38.4a	0.7a	47.5a	5.5a	1.7a	4.15a	4.03a	1.55a	2.3ab
TSP 1	7.8a	38.17a	0.99b	47.1a	8.8bc	12.7b	3.95a	4.06a	1.49a	2.5b
TSP2	9.7a	41.37a	0.76ab	49.79a	7.0ab	22.3c	4.18a	4.21a	1.62a	2a
F-Test	0.24	0.38	0.06	0.74	0.01	<0.001	0.8	0.59	0.8	0.05
CV(%)	18.5	12.2	23.6	10.2	28.1	26.9	19	16.2	16.8	15.8
SE±	1.69	4.94	0.21	4.99	2.31	7.3	0.81	0.66	0.26	0.34

Key: Nlp=Number of leaves per plant, L=Length of the longest leaf, D=Diameter of the longest leaf, Ph=Plant height, Y=Yield, Sb=Splitting bulbs, Bd=Bulb diameter, Bl=Bulb length, Nt=Neck thickness, Pu= Pungency, DAP 1(application rate of DAP at 40 kg P ha⁻¹), DAP 2 (application rate of DAP at 50 kg P ha⁻¹), TSP 1(application rate of TSP at 40 kg P ha⁻¹),TSP 2 (application rate of TSP at 50 kg P ha⁻¹) and NF=No fertilizer application (Absolute control)

In both dry and wet seasons, the length of the longest leaves differed insignificantly ($p \leq 0.05$) between P fertilizer sources. However, during the dry season, addition of DAP at 40 kg P ha⁻¹ resulted into the longest leaved plants (43.19 cm) compared to other fertilizer rates. The shortest leaved (38.17 cm) plants were obtained with application of TSP at 40 kg P ha⁻¹ (Table 6). A similar trend was recorded in the wet season (Table 7).

During the dry season, the diameter of the longest leaves differed significantly ($p \leq 0.05$) between P fertilizer sources. The addition of either DAP at 50 kg P ha⁻¹ or TSP at 40 kg P ha⁻¹ to the soil produced widest leaved plants (1.0 cm) while

thinnest plants (0.7 cm) were recorded with the control treatments (Table 6). In the wet season, the diameter of leaves was not significantly ($p>0.05$) different between P fertilizer sources. However, application of TSP at 40 kg P ha⁻¹ produced wider leaves (1.1 cm) almost similar to those with DAP at 50 kg P ha⁻¹ and 40 kg P ha⁻¹ (0.98 cm and 0.95 cm, respectively). The lowest leaves diameter (0.92 cm) was obtained in the control (Table 7).

Table 7: Effect of P fertilizer sources on growth, yield bulb quality during the wet season

P sources	Nlp	L (cm)	D (cm)	Ph (cm)	Y (t/ha)	Sb (%)	Bd (cm)	Bl (cm)	Nt (cm)	Pu
DAP1	10.7a	46.05a	0.95a	55.12a	14.13a	47.67b	4.85a	5.28a	1.66a	2.2a
DAP2	11.2a	45.04a	0.98a	54.03a	12.15a	98.33c	4.97a	4.88a	1.83a	2.2a
NF	11.7a	43.45a	0.92a	53.36a	9.62a	11.83a	4.96a	5.11a	1.76a	2.3a
TSP 1	10.3a	43.32a	1.13a	52.14a	11.8a	21.83ab	4.8a	5.13a	1.74a	2.3a
TSP2	11.2a	45.77a	0.92a	55.7a	10.42a	33ab	4.95a	5.32a	1.76a	2.2a
F-Test	0.85	0.65	0.44	0.81	0.46	<0.001	0.99	0.813	0.9	0.95
CV(%)	19.6	8.8	22.9	10.2	37.8	54.3	13.4	13.1	17	24
SE±	2.15	3.95	0.22	5.51	4.4	23.1	0.66	0.67	0.3	0.53

Key: Nlp=Number of leaves per plant, L=Length of the longest leaf, D= Diameter of the longest leaf, Ph=Plant height, Y=Yield, Sb=Splitting bulbs, Bd=Bulb diameter, Bl=Bulb length, Nt= Neck thickness, Pu=Pungency, DAP 1(application rate of DAP at 40 kg P ha⁻¹), DAP 2 (application rate of DAP at 50 kg P ha⁻¹), TSP 1(application rate of TSP at 40 kg P ha⁻¹), TSP 2(application rate of TSP at 50 kg P ha⁻¹) and NF=No fertilizer application (Absolute control)

4.4.2 Plant height

The height of onion plants did not vary significantly ($p>0.05$) between P fertilizer sources in both dry and wet seasons. However, during the dry season, application of DAP at 50 kg P ha⁻¹ produced the tallest plants (50.41 cm) which was at par with

application of TSP at 50kg P ha⁻¹ (49.8 cm). The shortest plants (47.10 cm) were obtained when TSP was applied at 40 kg P ha⁻¹ (47.5 cm) (Table 6). During the wet season, application of TSP at 50 kg P ha⁻¹ produced the tallest plants (55.70 cm) compared with the other rates whereas the shortest plants were obtained with TSP at 40 kg P ha⁻¹ (52.14 cm) (Table 7). In the wet season plants treated with DAP at 40kg P ha⁻¹ were taller (55 cm) than treated with DAP at 50 kg P ha⁻¹ (54 cm) (Table 7).

4.4.3 Yield

During the dry season, the yield was significantly ($p \leq 0.05$) different between P fertilizer sources. The application of DAP at 40 kg P ha⁻¹ produced the highest yield (10.4 t ha⁻¹) compared with yields obtained from other fertilizer rates (8.4kg P ha⁻¹). The lowest yield (5.5 t ha⁻¹) was obtained from the control (Table 6). Moreover, application of TSP at 40 kg ha⁻¹ produced higher yields (8.8 t ha⁻¹) compared to yield obtained when the same type of fertilizer was applied at 50 kg P ha⁻¹ (8.4 t ha⁻¹) (Table 6). Similar results were obtained during the wet season. However, during the season insignificant ($p > 0.05$) differences in yield due to P fertilizer sources were recorded (Table 7).

4.4.4 Bulb splitting

In the dry season, the proportion of bulb splits formed varied significantly ($p \leq 0.05$) between P fertilizer sources. The application of DAP at 50 kg P ha⁻¹ produced the highest proportion (60.3%) of splitted bulbs while the control treatment produced the lowest proportion (1.67%) (Table 6). Moreover, application of DAP at 40 kg P ha⁻¹ produced the highest proportion (38.3%) of splitted bulbs compared with the

application of TSP at 50kg P ha⁻¹ and 40kg P ha⁻¹ (22.3% and 12.7%, respectively). Similar results on the formation of bulb splits were observed during the wet season (Table 7).

4.4.5 Bulb diameter, length and neck thickness

In both the dry and wet seasons, the bulb diameter did not differ significantly ($p>0.05$) between P fertilizer sources. In the former season, plants fertilized with DAP at 40 kg P ha⁻¹ produced the widest bulbs (4.5 cm) whereas the thinnest bulbs (3.95 cm) were recorded from plants treated with TSP at 40 kg P ha⁻¹ (Table 6). It was also noticed that application of DAP at 50 kg P ha⁻¹ produced higher bulb diameter (4.4cm) compared to TSP at 50 kg P ha⁻¹ (4.2cm) (Table 6). This was true during the wet season, however, the application of DAP at 50 kg P ha⁻¹ produced widest bulbs (4.97 cm) which was at par with TSP at 50 kg P ha⁻¹ (4.95 cm). Furthermore, DAP applied at 40 kg P ha⁻¹ produced wider bulbs (4.9 cm) compared with TSP applied at the same rate (4.8 cm) (Table 7).

Bulb length did not differ significantly ($p>0.05$) between P fertilizer sources in the dry or wet season. However, in the dry season, application of TSP at 50 kg P ha⁻¹ and DAP at 40 kg P ha⁻¹ produced the longest bulbs (4.2 cm) while the shortest bulbs (3.7 cm) was recorded from onion plants treated with DAP at 50 kg P ha⁻¹ (Table 6). Similar results were obtained in the wet season (Table 7).

During the dry season, bulb neck thickness did not differ significantly ($p>0.05$) between P fertilizer sources although, addition of TSP at 50 kg P ha⁻¹ produced the

thickest bulb necks (1.62 cm) while the thinnest bulb necks (1.49 cm) were recorded from application of TSP at 40 kg P ha⁻¹ (Table 6). The study also showed that application of DAP at 50 kg P ha⁻¹ led to bulbs with thicker necks (1.53 cm), which were statistically similar to DAP at 40 kg P ha⁻¹ (1.47) (Table 6). These results are in line with the results obtained in the wet season.

However, application of DAP at 50 kg P ha⁻¹ produced bulbs with thicker neck (1.83 cm) than necks (1.66 cm) produced from onions treated with DAP at 40 kg P ha⁻¹ while application of TSP at 50 kg P ha⁻¹ produced larger bulb necks (1.8 cm) than the application of TSP at 40 kg P ha⁻¹ (1.7 cm) (Table 7).

4.4.6 Pungency

The degree of pungency differed significantly ($p \leq 0.05$) between P fertilizer sources in the dry season. The study showed that plants which received TSP at 50 kg P ha⁻¹ had the highest pungency which was numerically the same and statistically similar to DAP at 40 and 50 kg P ha⁻¹ (2.0) whereas the lowest pungency (2.5) was obtained from application of TSP at 40 kg P ha⁻¹ (Table 6). The results of pungency for DAP and TSP were also similar in the wet season (Table 7).

4.5 Effect of N Fertilizer Sources on Onion Growth, Yield and Quality

4.5.1 Number and size of leaves

The results showed no significant differences ($p > 0.05$) in number of leaves per plant treated with different N fertilizer sources in dry and wet seasons. However, in the dry season, those plants fertilized with Urea at 100 kg N ha⁻¹ generated the highest

number of leaves (9.7) while Urea at 50 kg N ha⁻¹ produced the lowest number of leaves per plant (8.5). Moreover, addition of CAN at 50 kg N ha⁻¹ to the soil resulted in plants with the highest number of leaves (9.2) compared to the same type of fertilizer at 100 kg N ha⁻¹ (8.8) (Table 8). These results are similar to those of the wet season. However, application of Urea and CAN at the same rate of 50 kg N ha⁻¹ exclusively produced the same number of leaves per plant (11.2) (Table 9).

Table 8: Effect of N fertilizer sources on growth, yield and bulb quality of during the dry season

N sources	Nlp	L (cm)	D (cm)	Ph (cm)	Y (t/ha)	Sb (%)	Bd (cm)	Bl (cm)	Nt (cm)	Pu
CAN1	9.17a	41.7bc	0.55a	50.66a	8.13bc	3.67ab	4.37a	3.92b	1.60a	2a
CAN2	8.83a	36.4a	0.7ab	45.29a	4.63a	5.67ab	4.03a	3.80ab	1.40a	2a
NF	9.67a	38.4ab	0.83b	47.5a	5.46ab	1.67a	4.15a	4.03b	1.55a	2.3a
UREA1	8.5a	41.1bc	0.85b	47.94a	6.29abc	9.17b	3.50a	3.29a	1.40a	2.2a
UREA2	9.7a	42.2c	0.88b	49.29a	8.46c	17.17c	4.43a	3.27a	1.52a	2a
F-Test	0.84	0.005	0.02	0.54	0.03	<0.001	0.34	0.024	0.21	0.23
CV(%)	23.3	6.9	23.5	11.5	34.3	63	20.2	12.9	11.7	14.2
SE±	2.14	2.77	0.18	5.52	2.3	4.7	0.83	0.47	0.18	0.3

Key: Nlp=Number of leaves per plant, L=Length of the longest leaf, D=Diameter of the longest leaf, Ph=Plant height, Y=Yield, Sb=Splitted bulbs, Bd=Bulb diameter, Bl=Bulb length, Nt=Neck thickness, Pu=Pungency, CAN 1(application rate of CAN at 50 kg N ha⁻¹), CAN 2 (application rate of CAN at 100 kg N ha⁻¹), UREA 1 (application rate of Urea at 50 kg N ha⁻¹), UREA 2 (application rate of Urea at 100 kg N ha⁻¹) and NF=No fertilizer application (Absolute control)

The length of leaves did not differ significantly ($p>0.05$) between N fertilizer sources in the dry season. Application of Urea at 100 kg N ha⁻¹ produced longest leaved plants (42.18 cm) while application of 100 kg N ha⁻¹ in the form of CAN produced

the shortest leaved plants (36.4 cm) (Table 8). The study in the wet season also indicated similar results as shown in the Table 9.

Table 9: Effect of N fertilizers sources on growth, yield and bulb quality during the wet season

N sources	Nlp	L (cm)	D (cm)	Ph (cm)	Y (t/ha)	Sb (%)	Bd (cm)	Bl (cm)	Nt (cm)	Pu
CAN1	11.2a	46.1a	0.98a	55.38a	12.31a	13.5ab	5.13a	5.03a	1.76a	1.8a
CAN2	10.7a	42.03a	0.83a	51.41a	8.53a	16ab	4.77a	4.94a	1.56a	2a
NF	11.7a	43.45a	0.92a	53.36a	9.62a	11.83a	4.96a	5.11a	1.76a	2.3a
UREA1	11.2a	45.1a	0.97a	52.9a	10.35a	19.17b	4.67a	4.61a	1.6a	2.2a
UREA2	11.8a	46.36a	1.02a	54.89a	12.6a	25.33c	5.2a	4.81a	1.8a	2a
F-Test	0.94	0.381	0.54	0.613	0.613	<0.001	0.43	0.5	0.553	0.394
CV(%)	23	9.6	20.8	48.6	48.6	28.4	11.4	10.7	17.8	21.8
SE±	2.3	4.3	0.196	5.2	5.2	4.9	0.56	0.52	0.303	0.45

Key: Nlp=Number of leaves per plant, L=Length of the longest leaf, D=Diameter of the longest leaf, Ph=Plant height, Y=Yield, Sb=Splitting bulbs, Bd=Bulb diameter, Bl=Bulb length, Nt=Neck thickness, Pu=Pungency, CAN 1(application rate of CAN at 50 kg N ha⁻¹), CAN 2 (application rate of CAN at 100 kg N ha⁻¹), UREA 1(application rate of 50 kg N ha⁻¹), UREA 2 (application rate of TSP at 100 kg N ha⁻¹) and NF=No fertilizer application (Absolute control)

During the dry season, the diameter of leaves differed significantly ($p \leq 0.05$) between N fertilizer sources. The application of N in the form of Urea at 100 kg N ha⁻¹ produced the widest leaves (0.88 cm) statistically similar to application of CAN and Urea at the same rate of 50 kg N ha⁻¹ exclusively (0.85 cm and 0.83 cm, respectively) while N in form of CAN at 100 kg N ha⁻¹ produced the minimum leaves diameter (0.55 cm) (Table 8). Similar results were also observed in the wet season (Table 9).

4.5.2 Plant height

There was no significant difference ($p>0.05$) in height of onion plants between N fertilizer sources in dry and wet season. However, application of CAN at 50 kg N ha⁻¹ during the dry season produced the tallest plants (50.66 cm) whereas application of CAN at 100 kg N ha⁻¹ produced the shortest plant (45.29 cm). Moreover, application of Urea at 100 kg N ha⁻¹ produced taller plants (49.3 cm) statistically similar to Urea at 50 kg N ha⁻¹ (Table 8). These results on plant height are in line with those obtained during the wet season (Table 9).

4.5.3 Yield

During the dry season, onion yield differed significantly ($p\leq 0.05$) between N fertilizer sources. The application of Urea at 100 kg N ha⁻¹ produced the highest yield (8.5 t ha⁻¹) at par with the application of CAN at the rate of 50 kg N ha⁻¹. The lowest yield (4.63 t ha⁻¹) was obtained when N was applied in form of CAN at 100 kg N ha⁻¹ (Table 8). In the wet season, yield did not differ significantly ($p>0.05$) between N fertilizer sources. However, the results indicate that an application of Urea at 100 kg N ha⁻¹ produced higher yield (12.60 t ha⁻¹) than the yield (8.5 t ha⁻¹) which was produced from application of CAN at 100 kg N ha⁻¹ (Table 9). The study also showed that the application of CAN at 50 kg N ha⁻¹ produced higher yield than application of Urea at 50 kg N ha⁻¹ (Table 9).

4.5.4 Bulb splitting

The proportion of bulb splitting varied significantly ($p\leq 0.05$) between N fertilizer sources in the dry season. Those plants fertilized with Urea at 100 kg ha⁻¹ were found

to produce the highest proportion (17.2%) of bulb splitting than plants fertilized with the same source at 50 kg N ha⁻¹ (9.2%). No fertilizer treated plants was found to produce the lowest proportion (1.67%) (Table 8). The results also indicated that application CAN to the soil at 100kg N ha⁻¹ produced higher proportion of splits (5.7%) compared when the same type of fertilizer was applied at 50kg N ha⁻¹ (3.8%) (Table 8). The proportion of bulb splits formed during the wet season were similar to those formed during the dry season (Table 9).

4.5.5 Bulb diameter, length and neck thickness

In the dry season, bulb diameter was not significantly ($p>0.05$) different between N fertilizer sources. However, the application of Urea at 100 kg N ha⁻¹ produced the maximum bulb diameter (4.4 cm) while the minimum bulb diameter (3.5 cm) was obtained from application of Urea at 50 kg N ha⁻¹ (Table 8). The results also showed that application of CAN at 50 kg N ha⁻¹ led to plants with wider bulbs (4.37 cm) than plants fertilized with the same source of fertilizer at 100 kg N ha⁻¹ (4.0 cm) (Table 8). The experiment in the wet season recorded similar results (Table 9).

Plants treated with different N fertilizer sources showed insignificant variation ($p>0.05$) of bulb length in dry season. However, the longest bulbs (4.0 cm) were produced from the control plants were at par with the application of CAN at 100 and 50 kg N ha⁻¹ (3.8 cm and 3.9 cm, respectively). The shortest bulb length (3.3 cm) was obtained from fertilization of Urea at 100 kg N ha⁻¹ (Table 8). Similar results were observed during the wet season (Table 9). Bulb neck thickness differed insignificantly ($p>0.05$) between plants treated with different N fertilizer sources.

However, application of CAN at 50 kg N ha⁻¹ produced the thickest bulb neck (1.6 cm) whereas the narrowest bulb neck (1.4 cm) was recorded in bulbs from onion plants which were treated with CAN at 100 kg N ha⁻¹. Moreover, application of Urea at 100 kg N ha⁻¹ produced larger neck (1.5) compared to the application of Urea at 50 kg N ha⁻¹ (1.4) (Table 8). Similar results were observed in the wet season (Table 9).

4.5.6 Pungency

During the dry season, the level of pungency was not significantly ($p>0.05$) different between N fertilizer sources. However, the application of CAN at 50 kg N ha⁻¹ produced the highest pungency (2.0) statistically similar to the application of CAN and Urea at 100 kg N ha⁻¹. The lowest pungency (2.3) was obtained from the absolute control onion plants at par with application of Urea at 50 kg N ha⁻¹ (2.2) (Table 8). Similar results were recorded during the wet season. However, the application of the same rate of CAN and Urea at 100 kg N ha⁻¹ exclusively produced similar level of pungency (2.0) (Table 9).

4.6 Effect of N and P Fertilizer Sources Combination on Growth, Yield and Quality of Onion

4.6.1 Number of leaves per plant

During the dry season, significant ($p\leq 0.05$) variation in the number of leaves was observed in plants treated with P and N fertilizer sources combination at varying rates. Fertilization of 40 kg P ha⁻¹ in form TSP combined with 50 and 100 kg N ha⁻¹ as CAN and 50 kg N ha⁻¹ as Urea exclusive of each other gave similar number of

leaves per plant (8.7). However, relatively many leaves per plant were produced when TSP at 40 kg P ha⁻¹ and Urea at 100 kg N ha⁻¹ were applied (10.8) (Table 10).

Application of 50 kg P ha⁻¹ in form of TSP combined with N from Urea and CAN also had significant ($p \leq 0.05$) effect on the number of leaves per plant. Plants treated with TSP at 50 kg P ha⁻¹ and CAN at 50 and 100 kg N ha⁻¹ applied independently of each combination produce statistically similar number of leaves per plant (8.8 and 9.3 respectively). However, TSP at 50 kg P ha⁻¹ and Urea at 50 kg N ha⁻¹ produced relatively higher number of leaves (8.2) compared to the leaves produced (7.7) when the same rate of P was combined with Urea at 100 kg N ha⁻¹ (Table 10).

DAP at 40 kg P ha⁻¹ and CAN at 50 kg N ha⁻¹ produced statistically the same number of leaves (9) compared to when the same P source and rate was combined with CAN at 100 kg N ha⁻¹ which produced 9.5 leaves per plant. This was also true when the same source and rate of P was combined with Urea at 100 kg N ha⁻¹. However, Urea at 50 kg N ha⁻¹ combined with DAP at 40 kg P ha⁻¹ produced the largest number of leaves per plant (10.5) (Table 10).

Application of DAP at 50 kg P ha⁻¹ combined with CAN at 50 kg N ha⁻¹ produced more leaves per plant (11) compared to the number of leaves produced per plant (10) when the same P source and rate was combined with CAN at 100 kg N ha⁻¹. The number of leaves was statistically similar to the number of leaves per plant (10.8) produced when the same source and rate of P was combined with Urea at 100 kg N ha⁻¹. However, the results showed that combining DAP at 50 kg P ha⁻¹ with Urea at

50 kg N ha⁻¹ produced relatively few leaves per plant (9.2) (Table 10). Similar results were also observed during the wet season. However, there was no significant ($p>0.05$) variation in number of leaves per plant with application of P and N fertilizer sources in combination at varying rates.

Table 10: Effect of N and P fertilizer sources combination on growth yield and bulb quality during the dry season

N+P combinations	Nlp	L (cm)	D (cm)	Ph (cm)	Y (t/ha)	Sb(%)	Bd (cm)	Bl (cm)	Nt (cm)	Pu
40kg, P, TSP+50 kg,N,CAN	8.667abc	37.36ab	0.75a	44.07a	5.25abc	15a	4.017a	3.548a	1.465bc	2.333ab
40kg, P, TSP+100 kg,N,CAN	8.667abc	39.44cd	0.8ab	46.49ab	5.833cd	14.67a	4.517ab	3.448a	1.498cd	2.333ab
40kg, P, TSP+50 kg,N, UREA	8.667abc	33.92a	0.8083ab	45.33ab	6.292cde	17.33a	4.175ab	3.338a	1.465bc	2.5bc
40kg, P, TSP+100 kg,N, UREA	10.833d	40.5cde	0.875ab	48.87abc	7.312defg	17.83a	3.767a	3.914ab	1.365ab	2.5bc
50kg, P, TSP+50 kg,N,CAN	8.833abc	37.12ab	0.75a	46.78ab	6.56cdef	19.33a	4.8ab	4.393c	1.515cd	2.333ab
50kg, P, TSP+100 kg,N,CAN	9.333abc	40.34cde	0.85ab	49.15abc	11.854i	23a	4.633ab	4.043ab	1.498cd	2.333ab
50kg, P, TSP+50 kg,N, UREA	8.167ab	38.98cd	0.725a	47.29ab	3.688a	28.83a	4.625ab	3.543a	1.598cd	3d
50kg, P, TSP+100 kg,N, UREA	7.667a	45.73f	0.8833ab	53.1cd	6.188cde	29a	3.833a	4.074ab	1.465abc	2.333ab
40kg, P, DAP+50 kg,N,CAN	9abc	40.66cde	0.8333ab	50.57bcd	5a	51.33b	3.8a	3.703ab	1.148a	2a
40kg, P, DAP100 kg,N,CAN	9.5abc	38.95cd	0.8ab	48.29abc	8.25eigh	47.83b	4.833ab	3.98ab	1.565cd	2.667bcd
40kg, P, DAP+50 kg,N, UREA	10.5cd	45.29f	1.1333d	54.76d	9.292gh	53.33b	5.1c	4.035ab	1.732d	2.5bc
40kg, P, DAP+100 kg,N, UREA	9.833abc	44.15ef	0.95abc	50.69bcd	8.688fgh	55.83b	4.55ab	4.129ab	1.598cd	2.833cd
50kg, P, DAP+50 kg,N,CAN	11d	40.66cde	0.95abc	53.06cd	9.625h	54.33b	4.383ab	3.913ab	1.682cd	3d
50kg, P, TSP+100 kg,N,CAN	10abc	41.52de	1.0333cd	50.56bcd	8.667fgh	45.33b	4.85ab	3.822ab	1.615cd	2.333ab
50kg, P, DAP+50 kg,N, UREA	9.167abc	42.48def	0.85ab	53.23cd	9.062gh	55b	4.4ab	3.543a	1.698cd	2a
50kg, P, DAP+100 kg,N, UREA	10.833d	40.79cde	0.75a	49.28abc	13.25i	51b	4.617ab	3.348a	1.598cd	2.333ab
F-Test	0.04	<0.001	0.03	<0.001	<0.001	<0.001	0.3	0.08	0.03	<0.001
CV (%)	14.4	7.1	22.7	8.2	21.9	30.7	20.2	15.4	16.2	19
SE _t	0.35	2.9	0.2	4.1	1.71	11.1	0.9	0.59	0.25	1.8

Nlp=Number of leaves per plant, L=Length of the longest leaf, D=Diameter of the longest leaf, Ph=Plant height, Y=Yield, Sb=Splitting bulbs,

Bd=Bulb diameter, Bl=Bulb length, Nt=Neck thickness and Pu=Pungency.

In the wet season, application of 50 kg P ha⁻¹ in form of TSP combined with 50 kg N ha⁻¹ from CAN produced similar number of leaves per plant when the same amount of P combined with CAN at 100 kg N ha⁻¹ applied (10.7) (Table 11).

4.6.2 Length of the longest leaves

The results indicated that the length of leaves differed significantly ($p \leq 0.05$) with P and N fertilizer sources combination in the dry season. Application of TSP at 40 kg P ha⁻¹ with CAN at 50 and 100 kg N ha⁻¹ produced longer leaves (37.36 and 39.44 cm, respectively) than combining the same source of P with Urea at 50 kg N ha⁻¹ (33.92 cm). Fertilization with TSP and CAN at 50 kg P ha⁻¹ and 50 kg N ha⁻¹, respectively, produced the shortest leaved plants (37.12 cm) than those with length of 40.34 cm produced when the same P source and rate was combined with CAN at 100 kg N ha⁻¹. However, combining TSP at 50 kg P ha⁻¹ and Urea at 100 kg N ha⁻¹ produced longer leaves (45.73 cm) than when the same P was combined with urea at 50 kg N ha⁻¹ (Table 10).

Plants fertilized with DAP and CAN at 40 kg P ha⁻¹ and 50 kg N ha⁻¹, respectively, produced longer leaves (40.66 cm) than when the same amount of DAP was combined with CAN at 100 kg N ha⁻¹. Moreover, application of the same amount of DAP and Urea at 50 kg N ha⁻¹ to onion plants resulted into relatively longer leaves (45.29 cm) than when the same amount of DAP was combined with Urea at 100 kg N ha⁻¹ (44.15 cm) (Table 10). Application of DAP and CAN at 50 kg P ha⁻¹ and 50 kg N ha⁻¹, respectively, produced relatively shorter leaved plants (40.66 cm) than the same amount of DAP combined with CAN at 100 kg N ha⁻¹ (41.52 cm).

The results also shows that application of the same amount of DAP and Urea at 50 kg N ha⁻¹ produced longer leaved plants (42.48 cm) than those treated with the same amount of DAP combined with Urea at 100 kg N ha⁻¹ (40.79 cm) (Table 10). The study in the wet season indicated similar results. However, the length of leaves did not differ significantly ($p>0.05$) with P and N fertilizer source combinations (Table 11).

4.6.3 Diameter of the longest leaves

The results in the dry season showed that the diameter of the longest leaves differed significantly ($p\leq 0.05$) between P and N fertilizer rate combinations. The study results showed that plants treated with TSP and CAN at 40 kg P ha⁻¹ and 100 kg N ha⁻¹ produced wider leaves (0.8 cm) than the same source of P with CAN at 50 kg N ha⁻¹. The latter combination produced the thinnest leaves (0.75cm). Furthermore, the results showed that the use of TSP at 40 kg P ha⁻¹ and Urea at 100 kg N ha⁻¹ produced wider leaves (0.88 cm) than (0.8 cm) than when the same amount of TSP was used with Urea at 50 kg N ha⁻¹ (Table 10).

The results also showed that plants supplied with 50 kg P ha⁻¹ and 100 kg N ha⁻¹ from TSP and CAN respectively, produced wider leaves (0.85cm) than those treated with 50 kg P ha⁻¹ and 50 kg N ha⁻¹ of TSP and CAN combinations (Table 10). On the other hand, TSP at 50 kg P ha⁻¹ and Urea at 100 kg N ha⁻¹ produced wider leaves (0.88 cm) than those produced (0.73 cm) when the same P source combined with Urea at 50 kg N ha⁻¹ (Table 10). The combination of DAP and CAN at 40 kg P ha⁻¹ and 50 kg N ha⁻¹, respectively, produced wider leaves (0.83 cm) than those produced

(0.8 cm) when the same amount of DAP combined with CAN at 100 kg N ha⁻¹. In addition, combination of the same amount of DAP and Urea at 50 kg N ha⁻¹ produced larger diameter (1.13 cm) than that (0.95 cm) produced when DAP was combined with Urea at 100 kg N ha⁻¹ (Table 10). Fertilization of DAP and CAN at 50 kg P ha⁻¹ and 100 kg N ha⁻¹, respectively, produced larger diameter (1.03 cm) than when the same amount of DAP was combined with CAN at 50 kg N ha⁻¹ (0.95 cm). The study results also show that plant treated with DAP 50 kg P ha⁻¹ and Urea at 50 kg N ha⁻¹ produced wider leaves (0.85 cm) than (0.75 cm) produced when the same amount of DAP was combined with Urea at 100 kg N ha⁻¹ (Table 10). The results of leaf diameter in the wet season were similar to those obtained in dry season. However, they did not differ significantly ($p>0.05$) between P and N fertilizer rate combinations. In the wet season, application of TSP and CAN at 40 kg P ha⁻¹ and 50 kg N ha⁻¹ produced slightly wider leaves (0.92 cm) than combining the same source of P with CAN at 100 kg N ha⁻¹ (0.9 cm) (Table 11).

4.6.4 Plant height

The height of onion plants differed significantly ($p\leq 0.05$) between P and N fertilizer rate combinations in the dry season, fertilization of TSP at 40 kg P ha⁻¹ and CAN at 100 kg N ha⁻¹ was observed to produce longer plants (46.49 cm) than combining the same source of P with CAN at 50 kg N ha⁻¹. The latter combination produced the shortest onion plants (44.07 cm). Moreover, combining TSP at 40 kg P ha⁻¹ and Urea at 100 kg N ha⁻¹ produced taller plant (48.87 cm) than those (45.33 cm) produced under combination of the same amount of TSP with Urea at 50 kg N ha⁻¹ (Table 10). Plants treated with TSP at 50 kg P ha⁻¹ and CAN 100 kg N ha⁻¹ were

found to be taller (49.15 cm) than those fertilized with 50 kg P ha⁻¹ and 50 kg N ha⁻¹ of TSP and CAN combination (46.78 cm). On other hand, the same TSP combined with Urea at 100 kg N ha⁻¹ produced taller onion plants (53.1 cm) compared to (47.29 cm) plants that received the same P source combined with Urea at 50 kg N ha⁻¹ (Table 10).

Addition of DAP at 40 kg P ha⁻¹ and CAN at 50 kg N ha⁻¹ to the soil resulted in taller plants (50.57 cm) than when the same amount of DAP was combined with CAN at 100 kg N ha⁻¹ (48.29 cm). The results also showed that plants which received DAP at 40 kg P ha⁻¹ and Urea at 50 kg N ha⁻¹ were taller (54.76 cm) than those supplied with the same amount of P in DAP combined with Urea at 100 kg N ha⁻¹ (50.69 cm) (Table 10). On the other hand, application of DAP and CAN at 50 kg P ha⁻¹ and 50 kg N ha⁻¹, respectively, produced taller plants (53.06 cm) compared to when the same amount of DAP was combined with CAN at 100 kg N ha⁻¹ (50.56 cm). Moreover, plants treated with DAP at 50 kg P ha⁻¹ and Urea at 50 kg N ha⁻¹ were taller (53.2 cm) compared to plants supplied with the same amount of DAP and Urea at 100 kg N ha⁻¹ (49.28 cm) (Table 10). Similar results were observed during the wet season. However, the height of onion plants did not differ significantly ($p>0.05$) between P and N fertilizer rate combinations. In the wet season, application of DAP and CAN at 40 kg P ha⁻¹ and 100 kg N ha⁻¹, respectively, produced taller plant (54.9 cm) than the plant height (54.1 cm) produced when the same amount of DAP was combined with CAN at 50 kg N ha⁻¹ (Table 11).

4.6.5 Yield

Yield differed significantly ($p \leq 0.05$) between the fertilizer rates combinations. The application of TSP and CAN at 40 kg P ha⁻¹ and 100 kg N ha⁻¹ produced higher yield (5.83 t ha⁻¹) than combining the same source of P with CAN at 50 kg N ha⁻¹. The latter combination produced the lowest yield (5.25 t ha⁻¹). Also, combination of TSP at 40 kg P ha⁻¹ and Urea at 100 kg N ha⁻¹ was observed to give higher yield (7.31 t ha⁻¹) than when the same amount of TSP combined with Urea at 50 kg N ha⁻¹ (6.56 t ha⁻¹) (Table 10).

The study also shows that, plants treated with TSP and CAN at 50 kg P ha⁻¹ and 100 kg N ha⁻¹, respectively, produced higher yield (11.85 t ha⁻¹) than plants which received the same amount of P and 50 kg N ha⁻¹ from CAN (6.56 t ha⁻¹). On the other hand, treatment of TSP at 50 kg P ha⁻¹ and Urea at 100 kg N ha⁻¹ produced higher yield (6.18 t ha⁻¹) than the yield obtained when the same P source was combined with Urea at 50 kg N ha⁻¹ (3.68 t ha⁻¹) (Table 10).

Treatments of 40 kg P ha⁻¹ in the form of DAP and 100 kg N ha⁻¹ of CAN to the plants was found to produce higher yield (8.25 t ha⁻¹) than when the same amount of DAP was combined with CAN at 50 kg N ha⁻¹ (5 t ha⁻¹). Moreover, combination of the same amount of DAP and Urea at 50 kg N ha⁻¹ produced higher yield (9.29 t ha⁻¹) than the yield obtained when the same amount of P in DAP was combined with Urea at 100 kg N ha⁻¹ (8.68 t ha⁻¹) (Table 10). Application of DAP and CAN at 50 kg P ha⁻¹ and 50 kg N ha⁻¹, respectively, produced higher yield (9.63 t ha⁻¹) than the yield (8.67 t ha⁻¹) obtained when the same amount of DAP was combined with CAN at

100 kg N ha⁻¹. Furthermore, combination of the same amount of DAP and Urea at 100 kg N ha⁻¹ gave higher yield (13.25 t ha⁻¹) than the yield (9.06 t ha⁻¹) produced when the same amount of DAP was combined with Urea at 50 kg N ha⁻¹ (Table 10). Similar results were obtained during the wet season. However, the yield did not vary significantly ($p>0.05$) between the N and P fertilizer rates combinations (Table 11).

4.6.6 Bulb splitting

The proportion of splits differed significantly ($p<0.05$) between N and P fertilizer combinations in both dry and wet season. In the former season, the treatments of TSP and CAN at 40 kg P ha⁻¹ and 50 kg N ha⁻¹, respectively produced bulbs with larger (15%) proportion of splits than those formed by combining the same source of P with CAN at 100 kg N ha⁻¹ (14.67%). Moreover, combining TSP at 40 kg P ha⁻¹ and Urea at 100 kg N ha⁻¹ gave slightly higher (17.83%) proportion of splitting than with the same amount of TSP combined with Urea at 50 kg N ha⁻¹ (17.33%) (Table 10).

Plants fertilized with, TSP and CAN at 50 kg P ha⁻¹ and 100 kg N ha⁻¹, respectively, produced higher proportion (23%) of bulb splitting than those obtained with a combination of the same amount of P with 50 kg N ha⁻¹ from CAN (19.33%) . On the other hand, when the same TSP was combined with Urea at 100 kg N ha⁻¹ gave higher proportion (29%) of splitting than the proportion (28.83%) obtained when the same P source was combined with Urea at 50 kg N ha⁻¹ (Table 10). Higher proportion of bulb splitting was observed to be produced by plants which received DAP at 40 kg P ha⁻¹ and CAN at 50 kg N ha⁻¹ (51.33%) than when 40 kg P ha⁻¹ of DAP was combined with CAN at 100 kg N ha⁻¹ (47.83%). In addition, combination

of the same amount of DAP and Urea at 100 kg N ha⁻¹ induced higher proportion (55.83%) of bulb splitting than the proportion (53.33%) obtained when DAP was combined with Urea at 50 kg N ha⁻¹ (Table 10).

Furthermore, application of DAP and CAN at 50 kg P ha⁻¹ and 50 kg N ha⁻¹, respectively, gave higher proportion (54.33%) of bulb splitting than the proportion (45.33%) of bulb splits formed when the same amount of DAP was combined with CAN at 100 kg N ha⁻¹. In addition, combination of the same amount of DAP and Urea at 50 kg N ha⁻¹ gave higher proportion (55%) of bulb splitting than the proportion (51%) obtained when the same amount of DAP was combined with Urea at 100 kg N ha⁻¹ (Table 10). As for the P in form of TSP, statistical similarity was also unveiled in the proportion of bulb splitting by application of P in form of DAP combined with different rates of CAN and Urea (Table 10). The experiment conducted in the wet season obtained similar results. However, the combination of DAP at 40 kg P ha⁻¹ and Urea at 50 kg N ha⁻¹ gave higher proportion (70.7 %) of bulb splitting than the proportion obtained when the same amount of DAP was combined with Urea at 100 kg N ha⁻¹ (67.3%). Furthermore, application of DAP and CAN at 50 kg P ha⁻¹ and 100 kg N ha⁻¹ respectively, gave higher proportion (91.5%) of bulb splitting than the proportion of bulb splits formed when the same amount of DAP was combined with CAN at 50 kg N ha⁻¹ (72%) (Table 11).

Table 11: Effect of N and P fertilizer sources combinations on growth, yield and bulb quality during the wet season

N+P combinations	Nlp	L (cm)	D (cm)	Ph (cm)	Y (t/ha)	Sb (%)	Bd (cm)	Bl (cm)	Nt (cm)	Pu
40kg, P, TSP+50 kg, N, CAN	11.17ab	42.01a	0.9167a	50.46a	9.49ab	26.5a	4.483a	4.82a	1.637a	2a
40kg, P, TSP+100 kg, N, CAN	11ab	43.8ab	0.9a	52.34ab	10.42ab	25.83a	5.11ab	4.677a	1.693a	2.333ab
40kg, P, TSP+50 kg, N, UREA	11.17ab	42.22a	0.9a	51.05ab	10.32ab	27.17a	5.06ab	4.877a	1.59a	2.333ab
40kg, P, TSP+100 kg, N, UREA	11.67ab	44.64ab	0.95a	54.04ab	12.69ab	29.67a	4.92a	5.183a	1.56a	2.333ab
50kg, P, TSP+50 kg, N, CAN	10.67ab	42.25a	0.8667a	51.93ab	11.92ab	30.83a	5.367ab	5.373a	1.693a	2.333ab
50kg, P, TSP+100 kg, N, CAN	10.67ab	45.14ab	0.95a	53.44ab	14.39ab	33.33ab	5.217ab	5.097a	1.643a	2.167ab
50kg, P, TSP+50 kg, N, UREA	10.5ab	42.84ab	0.8667a	51.95ab	8.33a	40abc	4.933a	4.637a	1.843a	2.667b
50kg, P, TSP+100 kg, N, UREA	9.83a	48.53b	0.9667a	58.51b	10.58ab	40.5abc	4.767a	5.07a	1.587a	2a
40kg, P, DAP+50 kg, N, CAN	10.83ab	44.79ab	0.95a	54.11ab	9.62ab	60.67cd	4.627a	4.94a	1.533a	2.167ab
40kg, P, DAP100 kg, N, CAN	11ab	44.62ab	0.9167a	54.9ab	12.66ab	55.83bcd	5.237ab	5.07a	1.687a	2.333ab
40kg, P, DAP+50 kg, N, UREA	12.5ab	48.28b	1.0667a	58.66b	13.08ab	70.67de	5.913c	5.117a	1.803a	2.167ab
40kg, P, DAP+100 kg, N, UREA	11.83ab	46.5ab	0.9667a	55.82ab	12.53ab	67.33d	5.167ab	5.327a	1.73a	2.333ab
50kg, P, DAP+50 kg, N, CAN	12.83b	45.86ab	0.9833a	56.61ab	12.82ab	71.5de	5.19ab	5.01a	1.91a	2.667b
50kg, P, TSP+100 kg, N, CAN	12.33ab	45.97ab	1.0167a	55.08ab	11.41ab	91.5e	5.37ab	5.053a	1.83a	2.167ab
50kg, P, DAP+50 kg, N, UREA	11.33ab	46.67ab	0.95a	55.9ab	12.5ab	64.33d	5.05ab	4.643a	1.89a	2a
50kg, P, DAP+100 kg, N, UREA	12.17ab	45.51ab	0.9167a	54.74ab	15.77b	64d	5.227ab	4.75a	1.84a	2.167ab
F-Test	0.53	0.17	0.95	0.35	0.52	<0.001	0.22	0.64	0.41	0.3
CV (%)	18.2	9.3	20.00	10.4	41.1	36.2	13.9	12.3	16.9	19.6
SE±	2.1	4.2	0.61	5.63	4.9	18.1	0.71	0.61	0.29	0.4

Key: Nlp=Number of leaves per plant, L=Length of the longest leaf, D=Diameter of the longest leaf, Ph=Plant height, Y=Yield, Sb=Splitted bulbs,

Bd=Bulb diameter, Bl=Bulb length, Nl=Neck thickness and Pu=Pungency.

4.6.7 Bulb diameter

The results indicate that the diameter of the bulbs did not differ significantly ($p>0.05$) between P and N fertilizers. The application of TSP and CAN at 40 kg P ha⁻¹ and 100 kg N ha⁻¹ produced larger bulb diameter (4.52 cm) than the diameter of bulbs (4.02 cm) formed by combining the same source of P with CAN at 50 kg N ha⁻¹ but they were statistically similar. Furthermore, combining TSP at 40 kg P ha⁻¹ and Urea at 50 kg N ha⁻¹ gave larger bulb diameter (4.18 cm) than the diameter of the bulb (3.77 cm) formed in combination of the same amount of TSP with Urea at 100 kg N ha⁻¹ (Table 10).

Fertilization of TSP with CAN at 50 kg P ha⁻¹ and 50 kg N ha⁻¹, respectively, produced larger bulb diameter (4.8 cm) than the bulb diameter (3.77 cm) obtained with combination of the same amount of P with 100 kg N ha⁻¹ from CAN. On the other hand, when the same TSP was combined with Urea at 50 kg N ha⁻¹ produced bulbs with larger diameter (4.8 cm) than the diameter of bulb (4.63 cm) obtained when the same P source was combined with Urea at 100 kg N ha⁻¹ (Table 10).

Plants supplied with 40 kg P ha⁻¹ of DAP and 100 kg N ha⁻¹ CAN produced larger bulb diameter (4.83 cm) than the diameter of bulbs (3.8 cm) formed by combining the same source of P with CAN at 50 kg N ha⁻¹. In addition, combining DAP at 40 kg P ha⁻¹ and Urea at 50 kg N ha⁻¹ gave larger bulb diameter (5.1 cm) than the diameter of the bulb (4.55 cm) formed in combination of the same amount of DAP with Urea at 100 kg N ha⁻¹ (Table 10). Treatment of DAP with CAN at 50 kg P ha⁻¹ and 100 kg N ha⁻¹, respectively to onion plants resulted to larger bulb diameter (4.85 cm) than

the bulb diameter (4.38 cm) obtained at a combination of the same amount of P with 100 kg N ha⁻¹ from CAN. On the other hand, when the same DAP was combined with Urea at 100 kg N ha⁻¹ produced bulbs with larger diameter (4.62 cm) than the diameter of bulb (4.4 cm) obtained when the same P source was combined with Urea at 50 kg N ha⁻¹ (Table 10). Similar results were obtained during the wet season (Table 11).

4.6.8 Bulb length

The length of onion bulbs did not differ significantly ($p>0.05$) between P and N fertilizers in both dry and wet season (Table 10 and 11). The application of TSP and CAN at 40 kg P ha⁻¹ and 50 kg N ha⁻¹ produced longer bulb (3.54 cm) than the length of bulb (3.44 cm) formed by combining the same source of P with CAN at 100 kg N ha⁻¹. Furthermore, combining TSP at 40 kg P ha⁻¹ and Urea at 100 kg N ha⁻¹ gave longer bulb (3.91 cm) than the length of the bulb (3.33 cm) formed in combination of the same amount of TSP with Urea at 50 kg N ha⁻¹ (Table 10).

Application of TSP with CAN at 50 kg P ha⁻¹ and 50 kg N ha⁻¹, respectively, produced significantly ($p<0.05$) longer bulbs (4.39 cm) than bulbs (length=4.04 cm) obtained at a combination of the same amount of P with 100 kg N ha⁻¹ from CAN. On the other hand, when the same TSP was combined with Urea at 100 kg N ha⁻¹ produced longer bulbs (4.07 cm) than the length of bulbs (3.54 cm) obtained when the same P source was combined with Urea at 50 kg N ha⁻¹ (Table 10). Plants treated with DAP and CAN at 40 kg P ha⁻¹ and 100 kg N ha⁻¹ produced longer bulbs (3.98 cm) than the length of bulbs (3.7 cm) formed by combining the same source of

P with CAN at 50 kg N ha⁻¹. Also, combining DAP at 40 kg P ha⁻¹ and Urea at 100 kg N ha⁻¹ gave longer bulb (4.13 cm) than the length of the bulb (4.04 cm) formed in combination of the same amount of DAP with Urea at 50 kg N ha⁻¹ (Table 10).

Treatment of DAP at 50 kg P ha⁻¹ and CAN at 50 kg N ha⁻¹ produced longer bulbs (3.91 cm) than those formed when 50 kg P ha⁻¹ of DAP and 100 kg N ha⁻¹ from CAN was applied (3.82 cm). On the other hand, when the same DAP was combined with Urea at 50 kg N ha⁻¹ produced longer bulbs (3.54 cm) than the length of bulbs (3.34 cm) obtained when the same P source was combined with Urea at 100 kg N ha⁻¹ (Table 10).

Similar results were observed during the wet season. However, the combination of DAP with CAN at 50 kg P ha⁻¹ and 100 kg N ha⁻¹, respectively, produced slightly longer bulbs (5.1 cm) than the length of bulbs (5.0 cm) obtained at a combination of the same amount of P with 50 kg N ha⁻¹ from CAN. On the other hand, when the same DAP was combined with Urea at 100 kg N ha⁻¹ produced longer bulbs (4.75 cm) than the length of bulbs (4.64 cm) obtained when the same P source was combined with Urea at 50 kg N ha⁻¹ (Table 11).

4.6.9 Bulb neck thickness

The bulbs necks thickness differed significantly ($p \leq 0.05$) between the fertilizer rate combinations. Plants fertilized with TSP and CAN at 40 kg P ha⁻¹ and 100 kg N ha⁻¹ produced thicker bulb necks (1.49 cm) than those plants received same source of P combined with CAN at 50 kg N ha⁻¹ (1.47 cm). A combination of TSP at 40 kg P ha⁻¹

and Urea at 50 kg N ha⁻¹ gave thicker bulb necks (1.47 cm) than the bulb necks (1.37 cm) formed in combination of the same amount of TSP with Urea at 100 kg N ha⁻¹ (Table 10). Plants supplied with 50 kg P ha⁻¹ of TSP and 50 kg N ha⁻¹ produced thicker bulb necks (1.52 cm) than those received 50 kg P ha⁻¹ of TSP and 100 kg N ha⁻¹ from CAN (1.49 cm). On the other hand, when the same TSP was combined with Urea at 50 kg N ha⁻¹ produced thicker bulb necks (1.59 cm) than the bulb necks (1.47cm) obtained when the same P source was combined with Urea at 100 kg N ha⁻¹ (Table 10).

Plants treated with 40 kg P ha⁻¹ of DAP and 100 kg N ha⁻¹ of CAN produced thicker bulb necks (1.57 cm) than those formed from combination of the same source of P with CAN at 50 kg N ha⁻¹ (1.14cm). Also, combining DAP at 40 kg P ha⁻¹ and Urea at 50 kg N ha⁻¹ gave thicker bulb necks (1.73 cm) than those (1.59 cm) formed in combination of the same amount of DAP with Urea at 100 kg N ha⁻¹ (Table 10).

Fertilization of DAP with CAN at 50 kg P ha⁻¹ and 50 kg N ha⁻¹, respectively, produced thicker bulb neck (1.68cm) than the bulb neck (1.62 cm) obtained at a combination of the same amount of P with 100 kg N ha⁻¹ from CAN. On the other hand, when the same DAP was combined with Urea at 50 kg N ha⁻¹ produced thicker bulb neck (1.69 cm) than the bulb neck (1.59 cm) obtained when the same P source was combined with Urea at 100 kg N ha⁻¹ (Table 10). Similar results were observed during the wet season. However, the bulb neck thickness did not differ significantly ($p>0.05$) between the fertilizer rate combinations (Table 11).

4.6.10 Pungency

The extent of pungency was significantly ($p \leq 0.05$) different between fertilizer rate combinations. The results indicated that combining TSP at 40 kg P ha⁻¹ with CAN at 50 and 100 kg N ha⁻¹ at any possible combination produced the same level of pungency (2.3). In addition, a combination of 40 kg P ha⁻¹ of TSP with Urea at 50 and 100 kg N ha⁻¹ gave similar level of pungency (2.5) (Table 10). In addition the combination of TSP and CAN at 50 kg P ha⁻¹ and 50 kg N ha⁻¹ statistically produced the similar results with application of TSP at the same rate combined with CAN at 100 kg N ha⁻¹ (2.3). On the other hand, when the same TSP combined with Urea at 100 kg N ha⁻¹ gave higher pungency (2.3) than the pungency (3.0) obtained when the same P source was combined with Urea at 50 kg N ha⁻¹ (Table 10).

The application of DAP and CAN at 40 kg P ha⁻¹ and 50 kg N ha⁻¹ gave relatively higher pungency (2.0) than the pungency (2.7) produced by combining the same source of P with CAN at 100 kg N ha⁻¹. In addition, combining DAP at 40 kg P ha⁻¹ and Urea at 50 kg N ha⁻¹ gave higher pungency (2.5) than the pungency (2.8) obtained in combination of the same amount of DAP with Urea at 100 kg N ha⁻¹ (Table 10).

The combination of DAP with CAN at 50 kg P ha⁻¹ and 50 kg N ha⁻¹, respectively, gave higher pungency (2.3) than the pungency (3.0) obtained at a combination of the same amount of P with 100 kg N ha⁻¹ from CAN. On the other hand, when the same DAP was combined with Urea at 50 kg N ha⁻¹ gave higher pungency (2.0) than the pungency (2.3) obtained when the same P source was combined with Urea at 100 kg

N ha⁻¹ (Table 10). The extent of pungency results obtained in the wet season did not vary from those during the dry season, however the results in the latter season were not significantly ($p>0.05$) different between N and P fertilizer combinations. Also, the results indicate that combining TSP at 40 kg P ha⁻¹ with CAN at 100 kg N ha⁻¹ produced lower pungency (2.3) than when the same rate of TSP combined with 50 kg N ha⁻¹ of CAN (2.0). Moreover, the combination of DAP with CAN at 50 kg P ha⁻¹ and 100 kg N ha⁻¹, respectively, gave higher pungency (2.2) than the pungency (2.7) obtained at a combination of the same amount of P with 50 kg N ha⁻¹ from CAN. On the other hand, when the same DAP was combined with Urea at 50 kg N ha⁻¹ gave higher pungency (2.0) than the pungency (2.2) obtained when the same P source was combined with Urea at 100 kg N ha⁻¹ (Table 11).

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of Season on Growth, Yield and Quality of Onion

The results indicate that better vegetative growth and high yield were obtained during the wet season compared to the dry season. This suggests that onion growth and yield are favoured by adequate moisture regimes. Bagali *et al.* (2012) reported significant vegetative growth caused by shorter interval with higher level of irrigation. The same author observed that higher level of irrigation replaces the water lost through evapotranspiration (consumptive use) and thereby maintains soil moisture at root zone thus ensuring adequate soil water throughout the crop growth period. Mermoud *et al.* (2005) showed that irrigation frequency plays an important role on yield of the onion crop.

Findings on the effects of dry condition to the expansion of bulbs and hence variation in bulb diameter has been reported in other studies. For example, Muhammad *et al.* (2011) found significant increase in bulb diameter at short irrigation intervals of 3 and 6 days as opposed to 9 and 12 days interval. This trend could be linked to adequate supply of the photosynthetic raw material (water) for metabolic processes, which controls most of plant physiological processes including bulb development.

Similar findings were obtained by Caser and Amer (2005) who reported that watering treatments significantly increased bulb size and yield. Kadayifci *et al.* (2005) reported that bulb and dry matter production were highly dependent on

appropriate water supply. Results showed that bulbs with highest proportion of splitting were produced during the wet season compare to the dry season. Similarly, Metwally (2011) and Caser and Amer (2005) reported the increase of bulb splitting percentage under wet condition. Data taken in the study indicate that wet season produced thicker bulbs necks compared to the bulbs produced in dry season. Al-Moshileh (2007) and Bagali *et al.* (2012) showed that higher level of water resulted in significant thicker necks.

The results show that most pungent onions were produced during the wet season while dry season produced onion bulbs with low pungency. However, Randall *et al.* (1999) reported that higher growing temperatures increase pungency for which twice as much pungency may be expected when the temperature at bulbing is 32.2 °C than when it is 10° C. Low pungency in the dry season may be attributed to the rainfall condition during the fourth week of November to December 2012, the period when the crop was at bulb stage. Adequate soil moisture can contribute to lower dry matter content, diluting concentrations of flavour precursors and resulting in a milder onion (Randall *et al.*, 1999).

5.2 Effect of Variety on Growth, Yield and Quality of Onion

The results have revealed better vegetative growth, yield and bulb quality performance of Red Bombay compared to Red Creole in both dry and wet season. The difference in the performance between these varieties was attributed largely to their different genetic composition with respect to environmental adaptation. Similarly, Jilani and Ghaffoor (2003) reported that cultivars of the same species

grown under the same environment often yield differently. Moreover, Akhtar *et al.* (2002) reported the difference in yield between varieties was attributed to their genetic variability. In agreement with the present study, Kahsay *et al.* (2013) reported significant difference between onion varieties by which the highest yield was recorded from Red Bombay. Although yield performance of Red Creole obtained in this study was lower compared to the yield (11.6 t ha⁻¹) obtained by Msuya *et al.* (2005). This could be attributed to difference in growing environmental conditions between these studies.

The high proportion of splitted bulbs and large bulb neck thickness in Red creole as opposed to the Red Bombay could be attributed to varietal characteristic in the formation of splits. These results are in agreement with Steer (1980) who reported that bulb splitting was obtained as result of multiple growing points under genetic control. Brewster (1987) pointed out that neck-thickness is a physiological disorder that is influenced by seasons, sites and cultivars. The results of bulb neck thickness and splitted bulbs correspond to the findings obtained by Msuya *et al.* (2005) who reported that Red Creole had comparatively high degree of thick necks and bulb splittings.

The pungency of bulbs between Red bombay and Red creole did not vary significantly. The study also revealed that bulb pungency could be affected by other factors such fertilizer applications or environmental conditions including moisture conditions of the soil rather than the effect of variety (Randall *et al.*, 1999).

5.3 Effect of P Fertilizer Sources on Growth, Yield and Quality of Onion

5.3.1 Effect of P fertilizer sources on growth and yield

During the dry season large number of leaves formed by application of DAP or TSP at 50 kg P ha⁻¹ could be attributed to the significance of P in the formation of leaves (Aliyu *et al.*, 2012). Similar findings were also reported by Boyhan *et al.* (2007) that application of 40 and 80kg P ha⁻¹ increased vegetative growth characteristics of onion including plant height and leaf number. During the wet season, the non fertilized control was found to produce the maximum number of leaves per plant as compared to other application rates. These results revealed no effect of fertilizer on the formation of leaves during the wet season. This could be attributed to the P-binding effect, which led to less number of leaves, since P is required in fast formation in the early stages of plant growth (CTAHR, 2007). Similar results was obtained by Rodríguez *et al.* (1999) who reported that the P rates up to 98.2 kg·ha⁻¹ did not show any effect on growth of onions.

Similar results on the influence of P fertilizer sources were observed in dry and wet season by which application of DAP at 40 kg P ha⁻¹ or TSP at 50 kg P ha⁻¹ produced the longest leaves and tallest plants compared to other rates. The increment in vegetative parameters due to the addition of N and P may be attributed to the significance of these nutrients in growth of plants. Nitrogen constituents many fundamental cell components (Bungard *et al.*, 1999) while Phosphorus is a vital component of nucleic acids (DNA and RNA), energy molecules (AMP, ADP and ATP) and phospholipids (Brewester, 1994). These correspond to the findings obtained by Fatma *et al.* (2012) who reported that higher level of N and P fertilizers

significantly increased plant vegetative growth. However, onion plants in the study did not respond to the excess N from DAP (at 50 kg P ha⁻¹). Similarly, Nasreen *et al.* (2007) reported that application of 120 kg N ha⁻¹ significantly increased vegetative growth although further increase in the level of nitrogen (160 kg ha⁻¹) led to its decrease.

The application of TSP at 40 kg P ha⁻¹ had been found to produce the widest leaves in both dry and wet season. These indicate that P from TSP play significant role in the expansion of leaves diameter rather than N contained in DAP. This could be attributed to the fact that N plays several roles in the growth of plant particularly in the formation of meristematic tissues rather than expansion of leaves (Bungard *et al.*, 1999). Similarly, Abdissa *et al.* (2011) concluded that leaves diameters were not influenced by N fertilization rates.

The variation of yields with sources and rates of P in both seasons provides information that these have significant impact on the yield components. The findings of the present study suggest that application of 40 kg P ha⁻¹ as DAP or TSP improve yield by far compared with other rates from DAP and TSP. These correspond to Al-Moshileh (2001) who reported that higher rates of P application (160 kg P ha⁻¹) have not been shown to affect onion yield in all cases. Similarly, Jha *et al.* (2000) and Sharma *et al.* (2003) obtained optimum yield at 33 kg P ha⁻¹.

5.3.2 Effect of P fertilizer sources on quality

The higher effect of DAP over TSP in causing bulb splitting was attributed to N in DAP rather than P in DAP and TSP fertilizers. This suggests that the formation of

split bulb was not significantly influenced by P fertilization (Abdissa *et al.*, 2011). These findings are in line with the results obtained by Al-Fraihat (2009) who reported that the formation of split bulb was significantly enhanced by the increase of N.

Application of DAP at any level produced bigger bulbs compared to application of TSP. This could be attributed to nutrients N contained in DAP which enhance the increase of bulb diameter rather than P alone in TSP. Similar findings were obtained by Jongatae *et al.* (2003) who found that the highest values of bulb diameter were obtained at rates of 240 kg N ha⁻¹. Bulb length is highly influenced by P in DAP or TSP rather than N-P in DAP. Moreover any excess amount of N-P interaction in DAP has got no effect on the increase of the bulb length. Similarly Abdissa *et al.* (2011) reported that interaction of N and P did not influence bulb length.

Similar results during dry and wet season on the effect of P fertilizer sources on bulb necks suggest that the application of TSP at any rate produced the maximum bulb necks compared to DAP. This indicate that the amount of P in TSP is superior over N or P present in DAP in the formation of bulb neck. However, Jilani (2004) reported that application of N significantly influenced the increase of bulb neck thickness. In this study thinnest necks obtained from application of DAP may be caused by the loss of N through the leaching process caused by rainfall occurred during vegetative growth stage. Application of P in form of DAP at any rate induced relatively higher pungency than that of TSP.

These findings suggest that DAP has additional advantage over TSP in inducing the pungency of onions. This could be attributed to the presence of 2% S in DAP (CTAHR, 2012) which in one way play part in improving onion pungency development. Many studies have shown a significant effect of S nutrition on onion pungency (Freeman and Mossadeghi, 1970). Randle *et al.* (1995) reported that pungency in onion was derived from the hydrolysis of S-alk (en)yl cysteine sulfoxides via enzymatic reaction of allinase as result of sulphur nutrition from the soil (when SO_4^{2-} is absorbed from the soil and reduced to S^{2-}). This reaction produces volatile S compounds and the byproducts pyruvic acid and ammonia (Randle *et al.*, 1995). These results are in line with Poornima (2007) who reported that sulphur application at 30 Kg S ha^{-1} significantly increased the pyruvic acid content in onion bulb while the lowest pyruvic acid content was recorded in control where no sulphur was applied. Increased uptake of S by crop would increase synthesis of volatile sulphur compounds and hence development of higher pungency in onion.

5.4 Effect of N Fertilizer Sources on Growth, Yield and Quality of Onion

5.4.1 Effect of N fertilizer sources on growth and yield

The results during dry and wet seasons show that application of Urea (at 100 kg N ha^{-1}) or CAN at 50 kg N ha^{-1} enhanced vegetative growth and yield. Samavat *et al.* (2007) reported that the highest yield was obtained with Urea while in other studies the fresh and dry weight were greater with NO_3^- as the N source as compared with NH_4^+ or Urea (Inal *et al.*, 2001). These indicate the significance of N in improving the vegetative growth and accelerating the photosynthates in storage organs

of bulbs resulting in an increased diameter and weight of the bulb (Sharma, 1992). Similarly, Baloch *et al.* (1991) and Morsy *et al.* (2012) reported that higher nitrogen level between 100 to 120 kg N ha⁻¹ achieved significant increase in number and size of leaves and hence yield compared to the lower nitrogen rate of 90 kg N ha⁻¹. In this study poor growth and yield performance obtained from application of CAN^r (at 100 kg N ha⁻¹) could be attributed to the effect of excess Ca⁺² to the soil pH. The optimum pH for growth of onion ranges between 6.0 to 7 while the pH at experimental site was 7.4. Therefore addition of excess Ca⁺² might result to the increase of pH and ultimately poor growth of the onion plants.

5.4.2 Effect of N fertilizer sources on quality

Highest proportion of bulb splitting from application of Urea at any rate could have been attributed to higher percentage composition of N present in Urea that could be easily degraded into simple absorbable form compare to % N in CAN. Similarly, Abdissa *et al.* (2011) reported the highest proportion bulb splittings obtained from application of highest level of N.

Large bulb diameter obtained from Urea (at 100 kg N ha⁻¹) or CAN at 50 kg N ha⁻¹ signifies its high rate of dissociation to immediately release N for onion uptake and utilization. This in turn increases chances of dry matter partitioning, hence increased bulb diameter. In this study the smallest bulb diameter produced from application of Urea at 50 kg N ha⁻¹ may have been attributed to low amount of N present in it. These results agreed with the findings obtained by Fatma *et al.* (2012) who reported that increasing nitrogen application rates significantly enhanced growth of bulb

width. Similarly, Jongatae *et al.* (2003) found that the highest value for bulb diameter was obtained from high rate of N. Results reveal that low level of N from CAN is required in the formation of bulb length compared to N from Urea. These may be attributed to food partitioning processes in bulbs, such that more N is utilized in increasing the width rather than the length of bulbs. These results are in agreement with the findings obtained from Abdissa *et al.* (2011) who reported that Nitrogen fertilization significantly increased bulb diameter without affecting bulb length. Similarly, Soleymani and Shahrajabian (2012) found that bulb length significantly increased at an application rate of 200 kg N ha⁻¹ that did not differ statistically with application of 300 kg N ha⁻¹.

The development of thicker bulb necks due to application of CAN and Urea (at 50 and 100 kg N ha⁻¹, respectively) signifies the role of N in the increase of bulb necks. Similarly, Randall *et al.* (1999) reported that excess N levels may result to large necks. Moreover, Jilani (2004) and Shrawan Singh *et al.* (2004) reported increasing trend of the thick-necked bulbs with increasing N level.

Application of the same rate of CAN and Urea (at 100kg N ha⁻¹) independently produced the highest pungency of bulbs over the control. The results show that high pungency was attributed to the absorption of excess N and S in CAN and N in Urea. Similarly, Randall *et al.* (1999) reported that high nitrogen and sulphur application levels may result in higher pungency.

5.5 Effect of N and P Fertilizer Combinations on Growth, Yield and Quality of Onion

5.5.1 Effect of N and P fertilizer combinations on growth and yield

The results reveal that any possible combination of DAP with CAN or Urea at any rate is superior over combinations involving TSP. These could be attributed to the added advantage of amount of N from both DAP and CAN or Urea compare to P- N interactions from TSP with either of the N source fertilizer. In agreement with the current finding, Aliyu *et al.* (2007) that reported N and P interaction not be significant with bulb yield. Abdissa *et al.* (2011) reported that application of N gave better growth and yield compared to N-P interaction. Similarly, Cizauskas *et al.* (2003) reported that application of 60 kg N ha⁻¹ gave highest vegetative growth and yield.

5.5.2 Effect of N and P fertilizer combinations on quality

The findings obtained from the study suggest that bulb splitting is equally affected by different P and N sources but the extent is more favoured by DAP and Urea in combination. This effect could be attributed to the importance of N provided by DAP and Urea, as pointed out by authors in previous studies.

The increased diameter due to combination of small rates of DAP and Urea is triggered by N present in these fertilizers, which is not the case for TSP which contains P only as the essential macronutrient. A study by Akhtar *et al.* (2002) reported that top dressing with 26 kg N ha⁻¹ of Urea fertilizer applied at 30 days after planting is important for onion bulb production because of its use for vegetative and

bulb growth. These results are in line with findings obtained by Fatma *et al.* (2012); Jongatae *et al.* (2003); Mallangowda *et al.* (1995) and Patel and Vachani (1994).

The findings of thicker neck bulbs due to the combination of 50 kg P ha⁻¹ of DAP and 50 kg N ha⁻¹ of CAN or Urea indicate that neck thickness was equally affected by different P and N sources. This corresponds with results obtained by Fatma *et al.* (2012) who reported significant interaction effect of nitrogen plus phosphorus on bulb necks.

High pungency produced from the combination of any rate of DAP with 50 kg N ha⁻¹ CAN or Urea signifies the effect of N in increasing pyruvate concentrations rather than P-N interaction. This could be attributed to synergetic effect of N on the increase of sulphur availability to plants. These results agreed with findings of Tekalign *et al.* (2012) who reported that the pyruvate content of the bulbs increased in response to N fertilization.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study was conducted to establish and recommend the best combination and rate of N and P fertilizer sources for onion under Kilosa agroecological conditions. The onion variety Red Bombay was found to be the best performer in all vegetative growth, yield and bulb quality characters in both dry and wet seasons. It is therefore the best variety compared to Red creole for production under Kilosa agroecological condition.

The wet condition was observed to provide better results on growth and yield in contrast to the dry season. However, the former was also found to produce low quality bulbs of higher proportion of splits and thick necks. Therefore the results suggest moisture condition in optimal amount is very important for the performance of onion, although dry season provided better results with less proportion of split and thin necked bulbs.

The study showed that application of DAP at 40 kg P ha^{-1} as a source of P gave the highest yield compared with other P rates. Therefore this study suggest that these type and rate of fertilizer are the most appropriate in Kilosa District than the other rates of P fertilizers, although application of TSP at 40 kg P ha^{-1} , showed average performance in all parameters studied. The study results showed that application of Urea at 100 kg N ha^{-1} as a source of N provided maximum yield with high proportion

of splits and thick necked bulbs compared to other N rates. However, application of CAN at 50 kg N ha⁻¹, showed nearly or similar results in one or more parameters as well as better quality bulbs.

The study results indicate that application of DAF at 50 kg P ha⁻¹ and 100 kg N ha⁻¹ Urea gave highest yield compared to other N and P fertilizer sources combinations but of poor quality in terms of bulb splits and neck thickness. Application of 50 kg P ha⁻¹ and 100 kg N ha⁻¹ of TSP and CAN, respectively provided average performance in all growth, yield and quality parameters.

6.2 Recommendations

- i. Fertilizer combination of TSP and CAN at 50 kg P ha⁻¹ and 100 kg N ha⁻¹ respectively, recommended for better growth of onion plants and to ensure high yield and good quality of onion bulbs under Kilosa agroecological condition rather than application of individual or other combinations N or P fertilizer sources.
- ii. Further studies on the assessment of these fertilizer types and rates in other different locations in Kilosa district should be conducted in order to confirm the current results.
- iii. Studies on the effect of these fertilizer types and rates on storability of different onion varieties are important in to avoid the post harvest losses of onion bulbs caused by fertilizer application methods.

- iv. The same study is recommended to be carried out with other varieties of onion, in order to observe their response with respect to fertilizer application.

REFERENCES

- Abbey, L. (2004). Electronic nose evaluation of onion headspace volatiles and bulb quality as affected by nitrogen, sulphur and soil type. *Vegetable Crop Production* 145(1): 41 – 50.
- Abbey, L. and Joyce, D. C. (2004). Water deficit stress and soil type effects on spring onion growth. *Journal Vegetable Crop Production* 10(2) : 5 – 18.
- Abbey, L., Joyce, D. C., Aked, J. and Smith, B. (2002). Genotype, sulphur nutrition and soil type effects on growth and dry matter production of spring onion. *Horticulture Science Biotechnology* 77(3): 340 – 345.
- Abdissa, Y., Tekalign, T. and Pant, L. (2011). Growth, bulb yield and quality of onion (*Allium cepa* L.) as influenced by nitrogen and phosphorus fertilization on vertisol I: growth attributes, biomass production and bulb yield. *African Journal of Agricultural Research* 7(45): 5880 – 5985.
- Abdoulaye, T. and Sandes, J. H. (2005). Stages and determinants of fertilizer used in Semi arid African agriculture; The Niger experience. *Journal of Agricultural Economics* 32(2): 167 – 179.
- Abdul, G., Muhammad, S. J., Ghulam, K. and Kashif, W. (2003). Effect of different NPK levels on the growth and yield of three onion (*Allium cepa* L.) varieties. *Asian Journal of Plant Sciences* 2: 342 – 346.

- Addington, B. K. (2010). Consumer acceptability and quality characteristics of sweet onions and novel highbush blueberry cultivars. Dissertation for Award of MSc. Degree at University of Athens, Georgia, 24pp.
- AGL (2002). Crop water management: Onion. FAO [www.fao.org/ag/agl/AGLW/cropwater/onion] site visited on 12/8/2012.
- Ahmad, M. E. M. (2009). Effect of some bio and mineral fertilization levels on the growth, productive and storability of onion. *Annals of Agricultural Science* 54(2): 427 – 436.
- Ajay, K., Singh, J. V., Chetan, S., Kumar, A. and Singh, C. (2000). Influence of phosphorus on growth and yield of onion (*Allium cepa* L.). *India Journal Agriculture Research* 34: 51 – 54.
- Akhtar, E. M., Khurram, B., Zamir, K. M. and Khalid, M. K. (2002). Effect of Potash application on yield of different varieties of onion (*Allium cepa* L.). *Asian Journal of Plant Sciences* 1: 324 – 325.
- Aklilu, L. (1997). Onion research and production in Ethiopia. *Acta Horticulture* 433: 95 – 97.
- Al-Fraihat, A. H. (2009). Effect of different nitrogen and sulphur fertilizer levels on growth, yield and quality of onion (*Allium cepa* L.). *Jordan Journal Agricultural Science* 5(2): 155 – 166.

- Ali, M. Y. and Haque, M. F. (1994). *Production of onion through application of Optimum Fertilizer and Irrigation is a Profitable Technology Booklet*. OFRD, BARI, Faridpur. 6pp.
- Aliyu, U., Magaji, M. D., Singh, A. and Mohammed, S. G. (2007). Growth and yield of onion (*Allium cepa* L.) as influenced by Nitrogen and Phosphorus levels. *International Journal of Agricultural Research* 2: 937 – 944.
- Al-Madini, A. M., Al-Thabt, S. S. and Hamail, A. F. (2000). Effects of different application rates of two compound fertilizers on growth, yield and yield mineral composition of onion (*Allium Cepa* L.). *Egypty Journal Applied Science* 15:10 – 13.
- Al-Moshileh, A. M. (2007). Effects of planting date and irrigation water level on onion (*Allium cepa* L.) production under Central Saudi Arabian conditions. *Journal of Basic and Applied Sciences* 8(1): 1426 – 1428.
- Al-Moshileh, A. M. P. (2001). Effect of nitrogen, phosphorus and potassium fertilizers on onion productivity in central region of Saudi Arabia. *Journal of Agricultural Science* 32: 291 – 305.
- Alt, D., Ladebusch, H. and Melzer, O. (1999). Long term trial with increasing amounts of phosphorus, potassium and magnesium applied to vegetable crops. *Acta Horticulturae* 506: 29 – 36.

- Amin, M. M. U., Rahim, M. A. and Hashem, M. A. (1995). Influences of planting time and nitrogen on the growth and yield of onion. *Bangladesh Journal Scientific and Industries Research* 30: 2 – 3.
- Amin, M. R., Hasan, M. K., Naher, Q., Hossain, M. A. and Noor, R. Z. U. (2007). Response of onion to NPKS fertilizers in low ganges river flood plain soil. *International Journal Sustainable Crop Production* 2(1): 11 – 14.
- Anez, B., Tavira, E. and Figueredo, C. (1996). Onion production in response to fertilizer applications on alkaline soils. *Revista Dela. Facultad de Aronoomica* 13(5): 509 – 520.
- Anwar, M. N., Sarker, J. U., Rahman, M., Islam, M. A. and Begum, M. (2001). Response of onion to nitrogen, phosphorus, potassium, sulphur and zinc. *Journal of Bangladesh Environmental Science* 7: 68 – 72.
- Arshad, A. K., Muhammad, Z., Abdul, B. and Fazal M. (2007). Response of onion (*Allium cepa* L.) growth and yield to different levels of nitrogen and zinc in Swat valley. *Sarhad Journal of Agriculture* 23: 4 – 8.
- Attia, K. K. (2001). Influence of filter mud cake, elemental sulphur applications and micronutrients fertilization on yield and nutrient content of onion. *Assiut Journal of Agriculture Science* 32(5): 105 – 119.

- Bagali, A. N., Patil, H. B., Guled, M. B. and Patil, R. V. (2012). Effect of scheduling of drip irrigation on growth, yield and water use efficiency of onion (*Allium cepa* L.). *Karnataka Journal of Agricultural Science* 25(1): 116 – 119.
- Baloch, M. A., Baloch, A. F., Baloch, G., Ansari, A. H. and Qayyum, S. M. (1991). *Growth and Yield Response of Onion to Different Nitrogen and Potassium Fertilizer Combination Levels Vegetable Crops*. In: Horticulture, Elena, B. and Bantel, R. (Eds.), National Book Foundation, Islamabad, Pakistan. 501pp.
- Berhoyen, M. N. J. (2000). Slow release fertilizers on vegetables: Culture techniques with special emphasis on environment implications of nutrient management. *Proceedings of the 25th International Horticultural Congress*, 1 January 2000, Brussels, Belgium. pp. 125 – 131.
- Bhalekar, M. N., Kale, P. B. and Kulwal, L. V. (1987). Storage behavior of some onion varieties (*Allium cepa* L.) as influenced by nitrogen levels and preharvest spray of maleic hydrazide. *Journal Pkv Research* 11(1):38– 46.
- Bloem, E., Silvia, H. and Ewald, S. (2004). Influence of nitrogen and sulphur fertilization on the allin content of onions and garlic. *Journal Plant Nutrition* 27: 1827 – 1839.

- Bohyan, E. G., Reid, L. T. and Randy, C. H. (2012). Effects of nitrogen, phosphorus and potassium rates and fertilizer sources on yield and leaf nutrient status of short-day onions. *Horticultural Science* 42(3): 653 – 660.
- Boyhan, G. E., Torrance, R. L. and Hill, C. R. (2007). Effects of nitrogen, phosphorus, and potassium rates and fertilizer sources on yield and leaf nutrient status of short-day onions. *Horticultural Science* 42(3): 653 – 660.
- Boyhan, G. E., Torrance, R. L., Curry, D. E., Lewis, P. M., Linton, D. O. and Hill, C. R. (2002). Evaluation of transplant fertility of short-day onions in Southeast Georgia. *Horticultural Science* 37: 651 – 655.
- Bremner, J. M. (1965). Inorganic forms of nitrogen. *Agronomy* 9: 1179 – 1237.
- Brewster, J. L. (1994). *Onions and Other Vegetable Alliums*. CAB International, Wallingford, UK. 236pp.
- 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* L. *Plant Cell Environment* 22: 859 – 866.
- Bybordi, A. (2006). Effects of foliar applications of iron and zinc on the yield and quality of white qom and red rey onion varieties grown in khosrowshahr regions. *Pajouhesh and Sazandegi* 74: 153 – 160.

- Caser, G. A and Amer, A.(2005). Response of three Onion (*Allium cepa* L.) cultivars grown under irrigated and non irrigated cultivation to polyethylene mulching 3- production of dry onion bulbs in spring season. *Mesopotamia Journal of Agriculture* 34(3): 1815 – 1816.
- Cizauskas, A., Viskelis, P., Dris, R. and Oladele, O. I. (2003). Influence of nitrogen rates on onion yield, quality and storability. *Moor Journal Agriculture Research* 4(1): 85 – 89.
- Colwell, J. D. (1994). *Estimating Fertilizer Requirements*. A qualitative approach. CAB International, UK. 262pp.
- Coolong, T., Randle, W., William, W. M. and Wicker, L. (2008). Structural and chemical differences in the cell wall regions in relation to scale firmness of three onion (*Allium cepa* L.) selections at harvest and during storage. *Journal Science Food Agriculture* 88(7): 1277 – 1286.
- CTAHR (2007). Soil nutrient management in Maui country.
[http://www.ctahr.hawaii.edu/mauisoil/c_nutrients02.aspx] site visited on 2/12/2013.
- CTAHR (2012). Fertilizer material. [http://www.ctahr.hawaii.edu/mauisoil/c_material.aspx] site visited on 8/9/2013.

- Dabhi, N. M., Patel, M. V. and Patel, V. R. (2004). *Effect of Sources and Levels of Sulphur on Yield and Chemical Composition of Onion in Loamy Sand*. National Seminar on Development in Soil Science, Hyderabad, India. 124pp.
- Dankhar, B. S. and Singh, J. (1991). Effect of nitrogen, potash and zinc on storage loss onion bulbs (*Allium cepa* L.). *Journal of Vegetable Science* 18: 16 – 23.
- De mason, D. A. (1990). *Morphology and Anatomy of Allium*. In: Rabowitch, H. D. and Brewster, J. L. (Eds.), *Onions and Allied Crops* CRC Press, Boca Raton. 52pp.
- De Putter, M., van Koesveld, J. and de Visser, C. L. M. (2007). *Overview of the Vegetable Sector in Tanzania*. African Vegetable Report No. 1. The Netherland. 95pp.
- Doyle, A. S. (1993). *Onion Production in the Tropics*. Chemonics International consulting Division, Northwest, Washington, DC. 115pp.
- ECI-Africa (2004). Competitive analysis of onions in Iringa region. private enterprise support activities. [<http://rudi-tz.org/reports/13.%20Competitive%20Analysispdf>] site visited on 13/8/2012.

- El-Shafie, F. S. and El-Gamaily, E. (2002). Effect of organic manure, sulphur and microelements on growth, bulb yield, storability and chemical composition of onion plants. *Minufiya Journal of Agricultural Research* 27(2): 407 – 424.
- Ethel, N., Singh, V. B., Singh, A. K. and Harmandeep, S. (2011). Fertilizing for sustainable onion production systems. *Better Crops* 95: 45 – 58.
- FAO (1977). *Guidelines for soil profile description* (2nd Eds.). Soil Development and Conservation Services. Land and water division, FAO, Rome. pp 97.
- FAO (2000). *Fertilizers and their Use A Pocket Guide for Extension Officers*. (4th Ed.), International Fertilizer Association, Rome, Italy. 24pp.
- FAO (2003). A global review of area and production of major vegetables crops. [www.fao.org/vegtab/onion/pdf] site visited on 23/3/2012.
- FAO (2010). Faostat data base on onion yield. [<http://faostat.faoorg/site/567/default.aspx#ancor>] site visited on 22/3/2012.
- FAO (2013). Crop water information: Onion water development and management unit. [http://www.fao.org/nr/water/cropinfo_onions.html] site visited on 29/3/2013.

- Fatma, A., Rizk, A. M., Shaheen, E., Abd El-Samad, H. and Omaima, M. S. (2012). Effect of different nitrogen plus phosphorus and sulphur fertilizer levels on growth, yield and quality of onion (*Allium cepa* L.). *Journal of Applied Sciences Research* 8(7): 3353 – 3361.
- Forney, C. F., Jordan, M. A., Campbell-Palmer, L., Fillmore, S., McRae, K. and Best, K. (2010). Sulphur fertilization affects onion quality and flavor chemistry during storage. *Acta Horticulturae* 877: 163 – 168.
- Freeman, G. G. and Mossadeghi, N. (1970). Effect of sulphate nutrition on flavor components of onion (*Allium cepa* L.). *Journal of Science of Food and Agriculture* 21:610-615.
- Gamiely, S., Randle, W. M., Mills, H. A., Smittle, D. A. and Banna, G. I. (1991). Onion plant growth, bulb quality, and water uptake following ammonium and nitrate nutrition. *Horticultural Science* 26: 1061 – 1063.
- Gaviola, S., Lipinski, V. M. and Nijensohn, L. (1998). Response of onion for drying to fertilization. *Ciencia-del-suelo* 16: 119 – 121.
- Gee, G. W. and Bauder, J. W. (1979). Particle size analysis by hydrometer: A simplified method for routine textural analysis and a sensitivity test of measured parameters. *Journal of American Society of Soil Science* 43: 1004 – 1007.

- Ghulam, N., Abdur, R., Sayed, J. A., Farhatullah, F. M. and Ibrar, H. (2010). Influence of different levels of potash on the quantity, quality and storage life of onion bulbs. *Pakistan Journal Botanic* 42(3): 2151 – 2163.
- Greenwood, D. J. Stones, D. A. and Barnes, A. (2001). Root development of vegetable crops. *Plant Soil* 68: 75 – 96.
- Grubben, J. H. and Denton, D. A. (2004). *Plant Resources of Tropical Africa*. PROTA Foundation Back huys, Leiden CTA, Wageningen. 12pp.
- Gupta, S. S. and Gaffar, M. A. (1990). Effect of row spacing and different combinations of NPK fertilizer on the yield of onion. *Bangladesh Horticulture* 8(2): 8 – 12.
- Hadwani, G. J. and Gundalia, J. D. (2005). Effects of NPK levels on yield, nutrient content, uptake and quality of summer grown onion on Typic Haplustepo. *Journal of Indian Society of Soil Science* 53(1): 125 – 128.
- Halder, N. K., Zaman, M. W. U., Chowdhery, M. M. and Wag, B. L. (1998). Effect of nitrogen and phosphorus on the uptake of different nutrient elements by onion bulb. *Journal of Bangladesh Science Research* 33: 404 – 440.
- Halvorson, A. D., Follet, R. F., Bartolo, M. E. and Schweissing, F. C. (2002). Nitrogen fertilizer use efficiency of furrow irrigated onion and corn. *Agronomy Journal* 94: 442 – 449.

- Hamilton, B. K., Pike, L. M. and Yoo, K. S. (1997). Clonal variations of pungency, sugar content and bulb weight of onions due to sulphur nutrition. *Science Horticulture* 71: 131 – 136.
- Hanelt, P. (1990). *Taxonomy Evolution and History*. In: Rabowitch, H. D. and Brewster, J. L. (Eds.), Onions and allied crops. CRC Press, Boca Raton. 26pp.
- Hanna-Alla, M. H., El-Kafoury, A. K., Ibrahim, M. Y. and El- Gammal, M. M. (1991). Effect of nitrogen fertilizer levels on bulb yield and quality of some onion cultivars. *Minufiya Journal Agriculture Research* 16(2): 1637 – 1644.
- Hochmuth, G. and Hanlon, E. (2000). Nutrition and fertilizers for vegetables. Florida cooperative extension service, institute of food and agricultural sciences, University of Florida. [http://edis.ifas.ufl.edu/B ODY_CV009] site visited on 12/2/2012.
- Inal, A., Tarakc, X. and Oglu, C. (2001). Effects of nitrogen forms on growth, nitrate accumulation, membrane permeability, and nitrogen use efficiency of hydroponically grown bunch onion under boron deficiency and toxicity. *Journal Plant Nutrition* 24: 1521–1534.
- INFONET – BIOVISION (2013). Onion. General information and agronomic practices. [www.infonet-biovision.org] site visited on 29/3/2013.

- IPNI (2012). Nutrient source specific. [<http://www.ipni.net/publication/nss.nsf>] site visited on 21/7/2012.
- Isham, J. (2002). The effect of social capital on fertilizer adoption: Evidence from Rural Tanzania. *The Journal of African Economies* 13(16): 1 – 12.
- Ishtiaq, S., Ali, R. and Shah, S. H. (2002). Effect of different levels of sulphur on yield and pungency of onion. *Pakistan Sarhad Journal of Agriculture* 18(2): 183 – 187.
- Islam, M. K., Alam, M. F. and Islam, A. K. M. R. (2007). Growth and yield response of onion (*Allium cepa* L.) genotypes to different levels of fertilizers. *Bangladesh Journal Botanic* 36(1): 33 – 38.
- Jaggi, R. C. and Dixit, S. P. (1999). Onion (*Allium cepa* L.) responses to sulphur in representative vegetable growing soils of Kanger Valley of Himachal Pardesh. *Indian Journal of Agricultural Science* 69: 289 – 291.
- Jaggi, R. C., Suri, V. K. and Dixit, S. P. (2003). Comparative performance of sulphur containing and non containing phosphorus fertilizers on dry chilli (*Capsicum annum* L.) in acid alfisol. *Indian Journal of Agricultural Science* 73(1): 49 – 50.
- Jain, G. L. and Shara, G. (1993). *Fertilizer Management in Maize*. (Edited by Tandon, H. L. S.), New Delhi, India. 97pp.

- Jana, B. K. and Kabir, J. (1992). Effect of sulphur on growth and yield of onion cv. Nasik Red. *Hisar Journal Group of Research* 3(2): 241 – 243.
- Jha, A. K., Pal, N. and Singh, N. (2000). Phosphorus uptake and its utilization by onion varieties at different stages of growth. *Indian Journal of Horticulture* 57: 347 –350.
- Jilani, M. S. (2004). Studies on the management strategies for bulb and seed production of different cultivars of onion (*Allium cepa* L.). Thesis for Award of PhD Degree at Gomal University, Dera, Ismail Khan, 499pp.
- Jilani, M. S. and Ghaffoor, A. (2003). Screening of local varieties of onion for bulb formation. *Internationa Journal of Agricultural Biology* 5(2): 129 – 133.
- Jongatae, L., Injong, H., Changung, I., Jinseong, M. and Yongcho, C. (2003). Effect of N, P₂O₅ and K₂O application rates and top dressing time on growth and yield of onion (*Allium cepa* L.) under spring culture in low land. *Korean Journal of Horticultural Science Technique* 21(4): 260 – 266.
- Kadayifci, A., Tuylu, G. I., Ucar, Y. and Cakmak, B. (2005). Crop water use of onion (*Allium cepa* L.) in Turkey. *Agricultural Water Management* 72. 59 – 68.

- Kahsay, I. Y., Abay, F. and Belew, D. (2013). Intra row spacing effect on shelf life of onion varieties (*Allium cepa* L.) at Aksum, Northern Ethiopia. *Journal of Plant Breeding and Crop Science* 5(6): 127 – 136.
- Kalb, T. (2001). Onion cultivation. [<http://www.avrdc.org/LC/onion/practices.html>] site visited on 12/3/2012.
- Kashi, A. and Frodi, B. R. (1998). Effect of nitrogen on the yield, quality and storability of edible onion cultivars (*Allium cepa* L.) Iran. *Journal of Agricultural Science* 29: 589 – 597.
- Khan, H. M., Ghaffoor, A. and Waseem, K. (2002). Effect of various plant spacing and different levels of nitrogen on the growth and yield of onion (*Allium cepa* L.). *Journal of Biological Science* 2: 545 – 547.
- Kumar, A. and Singh, D. (1995). Effect of sulphur deficiency on plant growth and yield of onion. *Indian Journal of Agricultural Research* 29(3): 127 – 130.
- Kumar, A., Singh, R. and Chhillar, R. (2001). Influence of nitrogen and potassium application on growth, yield and nutrient uptake by onion (*Allium cepa* L.). *Indian Journal of Agronomy* 46(4): 742 – 746.
- Kumar, H. J., Singh, V., Ajay, K., Mahak, S., Kumar, A. and Singh, M. (1998). studies on the influence of nitrogen on growth and yield of onion cv. Patna Red. *Indian Journal of Agricultural Research* 32: 88 – 92.

- Lancaster, J. E. and Randle, W. M. (2002). *Sulphur Compounds in Alliums in Relation to Flavour Quality*. In: Rabinowitch, H., Currah, L. (Eds.), *Allium Crop Science: Recent Advances*. CAB International, Wallingford, Oxon, UK. pp. 329 – 356.
- Landon, J. R. (1991). *Booker tropical soil manual. A handbook of soil survey and agricultural land evaluation in the tropical and subtropical*. Longman, London, UK. 255pp.
- MAFC (2002). *Attributes of Improved Crop Varieties. Technical handbook. Vegetable crops*. Magic Touch, Dar es Salaam, Tanzania. 22pp.
- MAFC (2007). *Improved Agricultural Technologies Recommended in Tanzania*. (1st Ed.), MAFC, Dar es Salaam, Tanzania. 100pp.
- Maier, N. A., Dahlenburg, A. P. and Twigden, T. K. (1990). Effect of nitrogen on the yield and quality of irrigated onions (*Allium cepa* L.) cv. Cream Gold grown on siliceous sands. *Australia Journal of Expenditure Agriculture* 30: 845 – 851.
- Malkouti, M. J., Ziaeyan, A., Khademi, Z., Balali, M. R., Shahabian, M., Basirat, M., Rezaee, H., Davoudi, M. H., Samavat, S., Manouchehri, S. and Kafi, M. (2002). *Effects of Rates and Sources of Potassium of Some Field and Horticultural Crops in Iran*. IPI Golden Jubilee Congress, Iran. 37pp.

- Mallangowda, B., Sulikeri, G. S., Hulamani, N. C., Murthy, B. G. and Mudalgeri, B. B. (1995). Effect of NPK and FYM on growth parameters of onion, garlic and coriander. *Current Research* 24(11): 212 – 213.
- Mangrio, H. K., Baloch, A. F. and Baloch, M. A. (1987). The size and yield of onion bulbs in response to application of phosphorus (P_2O_5) and potassium (K_2O). *Sarhad Journal of Agriculture* 3: 477 – 483.
- Marschner, H. (1995). *Mineral Nutrition of Higher Plants*. (2nd Ed.), Academic Press, London. 196pp.
- Mermoud, A., Tamini, T. D. and Yacouba, H. (2005). Impacts of different irrigation schedules on the water balance components of an onion crop in a semi arid zone. *Agricultural Water Management* 77: 282 – 295.
- Messiaen, C. and Rouamba, A. (2004). *Allium cepa*. L. record from protabase. Grubben, Plant resources of tropical Africa/Ressources végétales de l'Afrique tropicale, Wageningen, Netherlands.
[<http://database.prota.org/search.htm>] site visited on 14/3/2012.
- Metwally, A. K. (2011). Effect of water supply on vegetative growth and yield characteristics in onion (*Allium cepa* L.). *Australian Journal of Basic and Applied Sciences* 5(12): 3016 – 3023.

- Mohsen, K. (2012). Effect of sulphur application rates on some quality traits and yield of Iranian onion varieties. *International Research Journal of Applied and Basic Sciences* 3(6): 1215 – 1217.
- Morsy, M. G., Marey, R. A., Karam, S. S. and Abo-Dahab, A. M. A. (2012). Productivity and storability of onion as influenced by the different levels of NPK fertilization. *Journal of Agricultural Research* 38(1): 171 – 175.
- Moursy, M. E., Khalifa, H. E., Attia, M. M., Sayed, M. A. and Osman, A. M. (2007). Effect of organic and nitrogen fertilizers and plant densities on onion production in sandy soils under drip irrigation system. *Journal of Agricultural Research* 52(1): 103 – 108.
- Mozumder. S. N., Moniruzzaman, M. and Halim, G. M. A. (2007). Effect of N, K and S on the yield and storability of transplanted onion (*Allium cepa* L.) in the Hilly Region. *Journal of Agriculture Rural Development* 5(2): 58 – 63.
- Msuya, D. G., Reuben, S. O. W. M., Mbilinyi, L. B., Maerere, A. P., Msogoya, T., Mulungu, L. S. and Misangu, R. N. (2005). Evaluation of field performance and storage of some tropical short-day onion (*Allium cepa* L.) cultivars. *West Africa Journal of Ecology* 8: 10 – 18.

- Msuya-Bengesi, C., Mwajombe, K., Maerere, A. P., Sibuga, K., Mgembe, E. R., Mwatawala, M. W. and Mamiro, D. (2010). *Baseline Socio – Economic Survey on Onion production*. Integrated Pest Management. Sokoine University of Agriculture, Morogoro, Tanzania 27pp.
- Muendo, K. and Tschirley, D. (2004). *Improving Kenya's Domestic Horticultural Production and Marketing System: Current competitiveness, forces of change, and challenges for the future Horticultural production*. Working Paper No. 8. Tegemeo Institute of Agricultural Policy and Development, Egerton University, Nairobi, Kenya. 27pp.
- Muhammad, A. Gambo, B. A. and Ibrahim, N. D. (2011). Response of Onion (*Allium cepa* L.) to irrigation intervals and plant density in Zuru, Northern Guinea Savanna of Nigeria. *Nigerian Journal of Basic and Applied Science* 19(2): 241 – 247.
- Nagaich, K. N., Tridevi, S. K. and Fajesh, L. (1998). Effect of sulphur and potassium fertilization on onion (*Allium cepa* L.). *South Indian Horticulture* 46(6): 266 – 271.
- Nandi, A. and Nanda, R. R. (1992). A role on the onion yield as influenced by different levels of nitrogen and potash. *Haryana Journal of Horticultural Science* 21(2): 110 – 111.

- Nandi, R. K., Deb, M., Maity, T. K. and Sounda, G. (2002). Response of onion to different levels of irrigation and fertilizer. *Crop Research* 23(2): 317 – 320.
- 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 sulphur fertilization. *Bangladesh Journal of Agricultural Research* 32(3): 413 – 420.
- Negash, A. and Weldekidan, A. (2010). *Onion Yield Response to Fertilizer Rates Under Irrigation Condition*. Edition No. 1. VDM Publishing House, 116pp.
- Nelson, D. W. and Somers, L. E. (1992). *Total Carbon, Total Organic Carbon and Organic Matter*. In: *Methods of Soil Analysis*, Miller, A. L. (Eds.), Agronomy Monograph, Madison. pp. 539 – 580.
- Ole, H., Torben, L., Lars, P. C., Ulla, K., Nazmul, H. and Shakuntala, H. A. (2004). Contents of iron, zinc and β carotene in commonly consumed vegetables in Bangladesh. *Journal of Food Composition and Analysis* 17: 587 – 595.
- Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean, L. A. (1954). *Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate*. US Department of Agriculture, USA. 939pp.

- Pandey, U. B., Panwar, D. S. and Sharma, V. P. (1994). Effects of spacing and levels of nitrogen on growth and seed yield of Kharif Onion. *Seed Research* 20: 147 – 148.
- 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 Development Report* 8: 5 – 9.
- Patei, J. J. and Patel, A. T. (1990). Effect of nitrogen and phosphorus levels on growth and yield of onion Gujrat. *Journal of Agricultural Research* 15: 1 – 5.
- Patel, Z. G. and Vachani, M. U. (1994). Effect of NPK fertilization on the yield and quality of onion. *Horticultural Journal* 7(1): 75 – 77.
- Pillai, K. G. (2005). Rice (*Oryza sativa* L.). World fertilizer use manual. Rice crop Data. [www.fertilizer.org/ifa/publicat/html/pubman/rice.htm.] site visited on 18th June, 2013.
- Pire, R., Ramire, H., Riera, J. and Gomez, T. N. (2001). Removal of NPK and Ca by an onion crop in a silty clay soil in seminar region of Venezuela. *Acta Horticulturae* 555: 103 – 109.
- Poornima, K. S. (2007). Effect of potassium and sulphur on yield and quality of onion and chilli intercrops in a vertisol. Dissertation for Award of MSc Degree at University of Agricultural Sciences, Dharwad, 105pp.

- Quareshi, A. and Lawande, K. E. (2004). Influence of sulphur on yield, quality and storability of onion (*Allium cepa* L.). *National Seminar on Development in Soil Science. 69th Annual Convention*, Hyderabad, 27 – 30 October, 2004. 91pp.
- Rabinowitch, H. D. and Brewster, J. L. (1990). *Agronomy, Biotic Interactions, Pathology, and Crop Protection*. CRC Press, Inc., Boca Raton. Florida. 130pp.
- Rahim, M. A., Bashir, M. A., Begun, A. and Hakim, M. A. (1992). Onion storage in Bangladesh. *Onion Newsletter for the Tropics* 4: 55 – 56.
- Rajas, R. N., Ghulaxe, S. N. and Tayde, S. R. (1993). Effect of varying levels of sulphur and spacing combined with frequencies of irrigation on yield of onion grown in Vidarbha. *Journal of Soils and Crops* 3(1): 37 – 40.
- Randall, H., Hector, V. and Robin, S. (1999). *Bulb Onion Production in Hawaii*. College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa. 12pp.
- Randle, W. M. and Bussard, M. L. (1993). Pungency and sugars of short day onion as affected by sulphur nutrition. *Journal of American Society Horticultural Science* 118(6): 766 – 770.

- Randle, W. M., Hay, R. L., Bussard, M. L., Sutton, K. H., Lancaster, J. E. and Shaw, M. L. (1995). Quantifying onion flavor compounds responding to sulphur fertility—sulphur increases levels of alk(en)yl cysteine sulfoxides and biosynthetic intermediates. *Journal of American Society for Horticultural Science* 120(6):1075-1081.
- Reddy, K. C. and Reddy, K. M. (2005). Differential levels of vermicompost and nitrogen on growth and yield in onion (*Allium cepa* L.) and radish (*Raphanus sativus* L.) cropping system. *Journal Research* 33(1): 11 – 17.
- Rizk, F. A. (1997). Productivity of onion plant (*Allium cepa*, L.) as affected by method of planting and NPK application. *Egyptian Journal of Horticulture* 24(2): 219 – 238.
- Rodríguez, S. N., Belmar, N. C. and Valenzuela, P. A. (1999). Effect of nitrogen, phosphorus and potassium rates, sources and forms upon onion (*Allium cepa* L.) bulb yield and quality. Efecto de dosis, fuentes y formas de aplicación de nitrógeno, fósforo y potasio en la producción y calidad de bulbos de cebolla. *Agricultura Técnica* 59: 122 – 132.
- Rubatzky, V. E. and Yamaguchi, M. (1997). *World Vegetables Principles Production and Nutritive Values: (2nd Ed.)*, Chapman and Hall, New York. 75pp.

- Sachdev, M. S., Sachdev, P., Mittal, R. B. and Luthra, V. K. (1991). Fertilizer nitrogen recovery by onion (*Allium cepa* L.) as influenced by N and S application in a sulphur deficient soil. *Journal of Nuclear Agriculture and Biology* 20(4): 248 – 254.
- Sadaria, S. G., Malavia, D. D., Khanpara, V. D., Dudhatra, M. G., Vyas, M. N. and Mathukia, R. K. (1997). Irrigation and fertilizer management in onion (*Allium cepa* L.) and its residual effect on groundnut (*Arachis hypogaea* L.). *Indian Journal of Agronomy* 42(4): 709 – 712.
- Salo, T., Suojala, T. and Kallela, M. (2002). The effect of fertigation on yield and nutrient uptake of cabbage, carrot and onion. *Acta Horticulturae* 571: 235 – 241.
- Sam, R. J. (2007). Effect of biofertilizer on seed yielding capacity of onion (*Allium cepa* L.). *Plant Archives* 7(1): 255 – 256.
- Samavat, S., Baybourdi, A., Rostamforodi, F., Khiri, K. and Kahbazi, M. (2007). *Study the Effects of Different Source and Amounts of Nitrogen Fertilizer on Characteristics of two Onion Cultivars*. Soil and Water Research Institute, Tehran, Iran. 34pp.
- Sankaran, K., Bharathi, C. and Sujatha, S. (2005). Effect of sulphur fertilization on yield and nutrient uptake by onion in red soil (Uodic Haplustalf). *Journal of Maharashtra Agriculture University* 30(2): 135 – 136.

- Satyendra, K., Imtiyaz, M., Ashwani, K. and Ranbir, S. (2007). Response of onion to different levels of irrigation water. *Agricultural Water Management* 89(2): 161 – 166.
- Shaikh, M. A., Ansari, A. H., Qayyum, S. M. and Qayyum, M. B. (1987). Technical report on effect of nitrogen doses on the growth and crop yield of onion. *Pakistan Journal of Agriculture* 9: 35 - 37.
- Shamima, N. and Hossain, A. K. M. (2004). Nutrient uptake and yield of onion as influenced by chemical fertilizer and organic manure. *Indian Journal of Agriculture Research* 38(3): 164 – 170.
- Sharma, R. P. (1992). Effect of planting material, nitrogen and potash on bulb yield of rainy season onion (*Allium cepa* L.). *Indian Journal of Agronomy* 37: 868 – 869.
- Sharma, M. P., Singh, A. and Gupta, J. P. (2002). Sulphur status and response of onion *Allium cepa* L. to applied sulphur in soils of Jammu districts. *Indian Journal of Agricultural Science* 72(1): 26 – 28.
- Sharma, R. P., Datt, N. and Sharma, P. K. (2003) Combined application of nitrogen, phosphorus, potassium and farmyard manure in onion (*Allium cepa* L.) under high hills, dry temperate conditions of north-western Himalayas. *Indian Journal of Agricultural Science* 73: 225 – 227.

- Shravan, S., Yadav, P. K. and Balbir, S. (2004). Effect of nitrogen and potassium on growth and yield of onion (*Allium cepa* L.) cv. Pusa Red. *Haryana Journal Horticultural Science* 33(4): 308 – 309.
- Singh, A., Singh, S. P. and Singh, B. O. (2002). Effect of VAM and inorganic fertilizers on growth and yield of onion (*Allium cepa* L.). *Vegetable Science* 29: 40 – 42.
- Singh, H. and Singh, S. (1997). Response of onion to nitrogen and sulphur. *Annals of Vegetable Science* 17(4): 441 – 444.
- Singh, J. and Chaure, N. K. (1999). Effect of age of seedlings and nitrogen levels on growth and yield of onion (*Allium cepa* L.). *Horticultural Forestry* 6: 73 – 77.
- Singh, J. and Dhankar, B. S. (1995). Effect of pre-harvest chemical treatment on the storage loss of onion. *Horticultural Forestry* 4: 119 – 126 .
- Singh, J. V., Kumar, A. and Singh, C. (1998). Studies on the storage of onion (*Allium cepa* L.) as affected by different levels of phosphorus. *Indian Journal of Agricultural Research* 32: 51 – 56.
- Singh, R. B. and Singh, S. B. (2000). Significance of nitrogen, phosphorus and potassium on onion (*Allium cepa* L.) raised from onion sets (bulblets). *Vegetable Science* 27: 88 – 89.

- Singh, R. B. and Singh, S. B. (1999). Effect of nitrogen, phosphorus and potassium on growth and yield of rainy season onion (*Allium cepa* L.) raised from seedling. *Vegetable Science* 26: 93 – 94.
- Singh, S. P. and Mohanty, C. R. (1998). A note on the effect of nitrogen and potassium on the growth and yield of onion. *Orissa Journal Horticulture* 26: 70 – 71.
- Soleymani, A. and Shahrajabian, M. H. (2012). Effects of different levels of nitrogen on yield and nitrate content of four spring onion genotypes. *International Journal of Agriculture and Crop Sciences* 4(4): 179 – 182.
- Sorensen, J. N. and Grevsen, K. (2001). Sprouting in bulb onions (*Allium cepa* L.) as influenced by nitrogen and water stress. *Journal of Horticultural Science Biotechnology* 76: 501 – 506.
- Steer, B. T. (1980). The bulbing response to day length and temperature of some Australian cultivars of onion (*Allium cepa* L.). *Australia Journal of Agricultural Research* 31: 511-518.
- Stone, D. A. (2000). The effects of starter fertilizers on the growth and nitrogen use efficiency of onion and lettuce. *Soil Use and Management* 16: 42 – 48.
- Sumantrakar, H. and Tiwari, R. S. (1993). Effect of sulphur on growth and yield of onion (*Allium cepa* L.) cv. Pura red. *Vegetable Science* 20(2): 118– 120.

- Suresh, C. B. (2007). Studies on effect of organics on seed yield and quality in onion (*Allium cepa* L.). Dissertation for Award of MSc Degree at University of Agricultural Sciences, Dharwad, 79pp.
- Tekalign, T., Abdissa, Y. and Pant, L. M. (2012). Growth, bulb yield and quality of onion (*Allium cepa* L.) as influenced by nitrogen and phosphorus fertilization on vertisol. II: Bulb quality and storability. *African Journal of Agricultural Research* 7(45): 5880 – 5985.
- Thippeswamy, H. J. (1993). Leaf sampling guide and nutrient norms in yield and quality in relation to applied sulphur to onion. Dissertation for Award of MSc University of Agricultural Sciences, Bangalore, 320pp.
- Tisdale, S. L. and Nelson, W. L. (1985). *Soil Fertility and Fertilizers*. (3rd Ed.), Macmillan Publishers Co. Inc., New York. 249pp.
- Tisdale, S. L., Nelson, W. L., Beaton, J. D. and Harlin, J. L. (1993). *Soil Fertility and Fertilizers*. Prentice Hall Upper saddle River, New Jersey. 634pp.
- Vachhani, M. U. and Patel, Z. O. (1993). Effect of nitrogen, phosphorus and potash on bulb yield and quality of onion (*Allium cepa* L.). *Indian Journal of Agronomy* 3: 333 – 334.
- VECO-Tanzania (2010). Onion in Tanzania. Annual report 2008 – 2012
[<http://www.vecos-ngo.org/vecos-eastafrika/programme/onion-tanzania>]
site visited on 10/2/2012.

- Wiederfield, R. (1994). Nitrogen rate and timing effects on onion growth and nutrient uptake in a subtropical climate. *Subtropical Plant Science* 46:32 – 37.
- Woldetsadik, K., Gertsson, U. and Ascard, J. (2003). Response of shallots to mulching and nitrogen fertilization. *Horticultural Science* 38(2): 217 – 221.
- Yadav, R. L., Sen, N. L. and Yadav, B. L. (2003). Response of onion to nitrogen and potassium fertilization under semi arid conditions. *Indian Journal of Horticulture* 60(2): 176 – 178.
- Yash, P. K. (1996). Soil pH: First soil analysis methods validated by the AOAC *International Journal of Forestry Research* 1: 61 – 64.

APPENDIX

Appendix 1: Assessment of the level of onion pungency

NAME:

Sex: 1. M [] 2. F [] Age:

Date:

Signature:

Sample Name	Scale	Level Of Pungency	Comment
1	1	High	
	2	Mild	
	3	Low	
2	1	High	
	2	Mild	
	3	Low	
3	1	High	
	2	Mild	
	3	Low	
4	1	High	
	2	Mild	
	3	Low	
5	1	High	
	2	Mild	
	3	Low	
6	1	High	
	2	Mild	
	3	Low	
7	1	High	
	2	Mild	
	3	Low	
8	1	High	
	2	Mild	
	3	Low	
9	1	High	
	2	Mild	
	3	Low	
10	1	High	
	2	Mild	
	3	Low	
11	1	High	
	2	Mild	
	3	Low	
12	1	High	
	2	Mild	
	3	Low	
13	1	High	
	2	Mild	
	3	Low	

Sample Name	Scale	Level Of Pungency	Comment
14	1 2 3	High Mild Low	
15	1 2 3	High Mild Low	
16	1 2 3	High Mild Low	
17	1 2 3	High Mild Low	
18	1 2 3	High Mild Low	
19	1 2 3	High Mild Low	
20	1 2 3	High Mild Low	
2i	1 2 3	High Mild Low	
22	1 2 3	High Mild Low	
23	1 2 3	High Mild Low	
24	1 2 3	High Mild Low	
25	1 2 3	High Mild Low	