OPTIMIZATION OF FERTILIZER APPLICATION RATES FOR ONION, TOMATO AND AMARANTH IN MOROGORO MUNICIPAL, TANZANIA

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ABSTRACT

Most small scale farmers in Morogoro apply inorganic fertilizers to vegetable crops they grow. However no standard fertilizer application recommendations exist. This may lead to under supply or over supply of nutrients, resulting into economic loss and environmental hazard. Experiments were conducted to establish and recommend the best optimum NPK fertilizer application levels for tomato, onion and amaranth crops in Morogoro Municipal agro - ecological conditions. The experiments were carried out at the Crop Museum of the Sokoine University of Agriculture between December 2016 and May 2017. Single carrier fertilizers of different ratios were used. These fertilizers were Urea, Tripple Super Phosphate and Muriet of Potassh were laid out in randomized complete block design (RCBD) replicated three times. The varieties Assilla, Red Bombay, Lishe for tomato,onion and amaranth respectively and fertilizer levels were assigned to the plots. The fertilizer levels for tomato were; 0, 45, 90,180 kg N ha^{-1} ; 0, 70,140 kg P ha^{-1}, ; 0, 75,150 kg K ha^{-1}. onion ; 0, 25, 50,100 kg N ha^{-1}, ; 0, 25, 50 kg P ha^{-1}, ; 0, 25, 50 kg K ha^{-1} and amaranth ; 0, 85,170, 200 kg N ha^{-1}, ; 0, 30, 60 kg P ha^{-1}, ; 0, 30, 60 kg K ha^{-1}. Data were collected on vegetative growth, yield and quality parameters. The data were subjected to analysis of variance using GENSTAT 14th Edition at significance level of 5 %. The results show relative increase with respect to control hence revealed that nitrogen, phosphorus and potassium of 45:140:150 NPK kg ha^{-1}, 50:50:25 NPK kg ha^{-1} and 200:60:30 NPK kg ha^{-1} for tomato, onion and amaranth respectively produced higher growth, yield and quality than control. Those rates are recommended to be applied while considering other agronomic practices. However, field study to confirm the findings of this study for those fertilizers to those vegetable crops in this soil type and others with similar characteristics in Morogoro, could particularly be the viable option before it’s recommended to farmers.

DECLARATION

I, Joas Wiliam Balinkebera do hereby declare to neither the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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DEDICATION

I dedicate this work to the ALMIGHTY GOD for keeping me healthier and strong enough to accomplish this study. I am also thankful to my parents the late Wiliam Lutakumwa Balinkebera and Laulencia Wiliam Balinkebera whose unfailing love and care 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 Adelaida Ernest Machume for her eagerness to take care of the family and encouraging me during my study. To my children Jastin, Christian, Angel, Agrey and Catherin.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AVRDC	Asian Vegetable Research and Development Center
BER	Blossom End Rot
CEC	Cation Exchange Capacity
DMRT	Duncan Multiple Range Test
EC	Emulsifiable concentrate
F1	First filial generation
FAO	Food Agriculture Organization of United Nations
FYM	Farm Yard Manure
Ha	Hectare
MAFC	Ministry of Agriculture Food Security and Cooperative
MALF	Ministry of Agriculture Livestock and Fisheries
MOP	Muriet of Potash
NPK	Nitrogen Phosphorus and Potassium fertilizer
NSCA	National Sample Census of Agriculture
pH	Negative Logarithm of Hydrogen Ion Concentration
RCBD	Randomized Complete Block Design
SEVIA	Seed of Expertise for the Vegetable Industry of Africa
SUA	Sokoine University of Agriculture
TMA	Tanzania Meteorological Agency
TSP	Triple Super Phosphate
TSS	Total Soluble Solid
USA	United State of America
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Vegetables are important in the diet as health promoting foods. Globally, vegetable production has grown intensively especially on a per capita basis, with an increase of 60 % over the last 20 years. Vegetables in Tanzania form a significant part of daily diet (Weinberger and Msuya, 2004), while production of vegetables is a valuable economic activity, providing employment and income (Weinberger and Lumpkin, 2005). Vegetables cover 1.1 % of the world's total agricultural area. Europe and Central Asia contribute 12 % of total global area cultivated with vegetables and 14 % of global products (FAOSTAT, 2010).

In Tanzania, the area under vegetable production amounted to 115 000 ha in 2007, with a total production of 635 000 tons (NSCA, 2012). Population growth and urbanization in the country increase the demand for commercially produced vegetables. Production is mainly done by small scale growers who still practice traditional methods of growing vegetables. Farmers apply inorganic fertilizers, however no standard recommendations exist. This may lead to under supply or oversupply of nutrients resulting into economic loss and environmental hazards (Chen, 2006). In order to avoid under or over fertilization, it is important to understand optimal levels of application.

1.2 Problem Statement and Justification

Vegetable production is one of the important economic activities in Morogoro region. The most cultivated vegetable crops are tomato, cabbage, onion, carrot, spinach and amaranth. Despite the importance of vegetables, their productivity and supply are still low due to several biotic and abiotic factors. Production of tomato, onion and amaranth per annum is estimated to be 21 747, 4 686 and 849 tons ha^{-1} which are equivalent to 51 %, 11 % and 2 % of total quantities of vegetable production in Morogoro (NSCA, 2012). The yields of these vegetables range from 2.2 to 16.5 tons ha^{-1} for tomato (Maerere *et al.,* 2006), 7 to 11 tons ha^{-1} for onion (Mamiro *et al*., 2014) and 1.5 tons ha^{-1} for amaranth (NSCA, 2012).

Research work on plant nutrients and fertilizer application rates in Tanzania has been done on the major cash crops; coffee, tea, cotton and some food crops such as maize and common beans (Mowo *et al.,* 1993). Less research work has been done on vegetable crops. As a result, there is limited information on appropriate fertilizer types and application rates (Namwata *et al*., 2010).

This study was carried out in order to contribute to recommendations of optimum fertilizer application rates for tomato, onion and amaranth crops in Morogoro. The results will guide growers on the appropriate fertilizer levels that would enhance yield, quality and ultimately, their livelihoods while safeguarding the environment.

1.3 Objective

1.3.1 Overall objective

To develop optimal fertilizer application rates for improved vegetable production in Morogoro Municipal.

1.3.2 Specific objectives

i To determine growth and yield response of onion, tomato and amaranth to varying fertilizer levels.

ii To determine the effects of different fertilizer levels on quality of onion, tomato and amaranth.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Vegetable Production in Tanzania

There is a wide diversity of vegetables grown in the different regions in Tanzania. They account for 50 % of non-staple food production in the country. Tanzania consumption are far less than the desired of 0.4 kg per day or 115 kg per capita cosumption recommended by World Health Organization. WHO (2003) reported that Tanzania eat 0.146 kg per day or only 60 kg per capita consumption. Production is characterized by small scale subsistence farms. Approximately 85 % of the arable land is used by small scale holders cultivating between 0.2 ha and 2.0 ha mainly depending on rainfall (Maerere, 2006).

2.2 Limitations of Vegetable Production in Tanzania

Small holder farmers, who use fertilizers, lack information on proper fertilizer use for specific crops under different agro ecological conditions. Poor production organization (inadequate supply and unavailability of seeds, inputs, research and extension services), poor marketing system resulting in quality deterioration and huge post-harvest losses (Kaizzi *et al*., 2016). Inadequate storage, packaging technology and processing facilities which in turn creates gluts and critical shortages of vegetable products during off season. Poor roads, particularly feeder roads and lack of appropriate transportation logistics and poor quality control system (Amani, 2005). Either farmer may not obtain the returns in crop yield or revenue from crop sales necessary to pay for the fertilizers (Fleming, 1980; Mowo *et al*., 2006). In such a situation, co-operation between farmers and soil fertility scientists will help to increase farmer’s knowledge and appreciation of soil fertility issues and other factors limiting production (Namwata *et al*., 2010). In case of nutrient deficiencies, such effort would likely result in better economically justified nutrient application. Production statistics of the researchable vegetable for Tanzania are indicated (Appendix 3) from MALF (2016).

2.3 Botany of Tomato, Onion and Amaranth

Tomato is the edible fruit of *Solanum lycopersicum* L., which belongs to the family Solanaceae. It is a dicot and grows as a series of branching stems, with a terminal bud that does the actual growing. The plants typically grow to one to three meters in height. They have a weak stem that often sprawls over the ground and climb on other plants (Gercek, 2017). The stems are pubescent with their fine hairs turning into roots wherever the plant is in contact with the ground and moisture (Rubatzzky and Yamaguchi, 1996). Tomato can be grown from seeds in nursery or directly sown in the field. It is perennial in its native habitat but grown as an annual crop in temperate climates. Determinate types are annual, semi determinate are biannual while indeterminate are perennial being capable of a life span up to three years in green houses in some cases. An average tomato fruit weighs approximately 100 g. While tomatoes are botanically berry-type fruits, they are considered culinary vegetables (Weinberger and Msuya, 2004).

Onion is a biennial crop grown for bulb production and then for seed production in the second season (Brewster, 2008). The leaves are hollow and emerge in two ranks at 180 degrees to each other. Onion leaves consist of two parts; one is the leaf and the other is the blade. The leaf blade is also a hollow tube that is closed at the tip (Suresh, 2007). The leaf sheathes and young leaf blades are formed in concentric rings called the pseudostem, which is distinguished from the true stem at the base of the onion (Malik, 1994). 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 bulb or the edible part of the onion consists of a vegetative stem axis and a leaf base (Rubatzzky and Yamaguchi, 1996).

Amaranth is a broad leaf plant. Some amaranth species are cultivated as leafy vegetables, pseudo cereals, and ornamental plants (Costea and De Mason, 2001). Depending on species, amaranth leaves vary in shape, size and colour (green, red, purple). This plant can grow up to 3 m. It's stem is sometimes branched and terminates in a branched inflorescence. The inflorescence is usually indeterminate and reaches different lengths with the glomerulus as a basic unit. It contains female, male or both flower sets. Seeds have a lenticular shape (1-2 mm) (Alemayehu *et al*., 2015).

2.4 Nutritional Importance of Vegetable

The benefits of consuming fruits and vegetables of all kinds, including tomato, are impressive. As the proportion of plant foods in the diet increases, the risk of heart disease, diabetes, and cancer goes down (Perveen *et al*., 2015). High vegetable intake is also associated with healthy skin and hair, increased energy and lower weight. Increasing consumption of vegetables significantly decreases the risk of obesity and overall mortality (Perveen *et al*., 2015). Tomato has been referred to as a "functional food "due to its beneficial phytochemicals such as lycopene, folic acid, carotenoid and high potassium contents. Tomato also plays a role in preventing chronic diseases and delivers other health benefits (Weinberger and Msuya, 2004).

Onion has its own distinctive flavor and is used in soups, meat dishes, salads and sandwiches. Its pungency is due to the presence of volatile oil (allyl propyl disulphide) (Malik, 1994). 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. The bulb is useful as diuretic and heart stimulant (Suresh, 2007).

Amaranth species are cultivated and consumed as leaf vegetables in many parts of the world. Cooked amaranth leaves are an excellent source of vitamin A, vitamin C, calcium, manganese and foliate. It's benefits are not limited to people with gluten-related disorders, but are applicable to the general population. Amaranth contains phytochemicals that may be anti-nutrient factors, such as polyphenols, saponins, tannins and oxalates which are reduced in content and effect by cooking (Keller *et al*., 2005).

2.5 Vegetables Nutrients Requirements

Vegetables require adequate levels of essential nutrients for their physiological growth and development (Fageria *et al*., 2010). Nutrients required are categorized as macro and micro nutrients based on their total amount required. Macro nutrients are required in large quantities while micro nutrients are required in relatively small quantities. If one of these nutrients does not satisfy the physiological needs of plants, it's deficiency results in adverse growth and health effects (Chen, 2006: Fageria *et al*., 2010). Hynes and Naidu (1998) reported that the main nutrients applied routinely as fertilizer to agriculture soils are N, P and K. However, worldwide, nitrogen is more heavily used than the others. This is due to the fact that in most of the agricultural systems, nutrient supply is below the minimum requirement of crop to reach maximum yield. The type of nutrient and rate at which it is applied is based on soil testing and the requirement of the crop to be grown (Ndakidemi and Semoka, 2006). A study by Kisetu and Teveli (2013) revealed that application of fertilizer as soil amendment is inevitably pertinent in increasing crop turnout in impoverished soils. On the other hand, overall recommendations given for each fertilizer type are dictated by soil type and its nutrient levels, type of crop and its stage of growth.

Nitrogen promotes vegetative growth, providing sufficient photosynthetic area which in turn helps in flowering and fruit set. Nitrogen compounds constitute 40 to 50 % of the dry matter of protoplasm. Because of this, it is required in large quantities. Adequate supply of nutrient can increase yield, fruit quality, fruit size, keeping quality, colour and taste of vegetables (Mengel *et al*., 2001). It is also advantageous that nitrogen is applied in frequent small increment rather than large quantities at any one time because nitrogen get lost mainly through leaching (Afzal *et al*., 2015).

Phosphorus deficiency leads to stunted growth, abnormal dark green colour of leaves with veins reddish to purple in color. It is used as a starter fertilizer at early growth (Mowo *et al*., 2006). It is essential for the general health and vigor of all plants. Some specific growth factors which have been associated with phosphorus are stimulation of roots development, increased stalk and stem strength, improve flower formation and seed production. Others are more uniform and earlier crop maturity; improve crop quality, increased resistance to plant diseases. Greenwood *et al.* (2001) reported that P deficiencies in vegetable crops growth result into reduced root and leaf growth.

Potassium deficiency cause older leaves to develop brown spots, yellow edges, yellow veins or brown veins (Baitilwake *et al*., 2012). Potassium is fundamental to many metabolic processes through the activation of a large number of enzymes required for chemical reactions. These include synthesis of proteins and sugars required for plant growth. It’s essential role is that of maintaining the water content of plant cells. Potassium helps improve both the uptake of nitrogen from the soil and the conversion of nitrogen in the plant to amino acids and ultimately protein (Afzal *et al*., 2015).

Sulfur is also an important component in plant protein formation. Boron is important in sugar translocation and carbohydrates metabolism, while manganese controls several oxidation reduction systems and photosynthesis. This balanced nutrient regime is important to support rapid and consistent vegetable growth, develop high and quality yield (Baitilwake *et al*., 2012).

2.6 Fertilizer Optimization

Most small-scale farmers apply little or no mineral fertilizers to their crops. They also usually incorporate less organic matter into the soil than the recommended rate. Manure and compost are often available only in limited amounts on small-scale farms. Even if farmers wish to apply some mineral fertilizers to their crops, it is difficult for them to know the right fertilizers to apply and the right rate of application (Kaizzi *et al.,* 2016). This may not be the case in most places. For example a paper by Kimbi *et al*. (2001) and Maerere *et al*. (2001) revealed that in extensive grazing systems plenty of manure is available; what is missing is that “culture” of using animal manure as a source of plant nutrient. The authors recommended that farmers should be sensitized perhaps through demonstration on how to manage and effectively utilize manure for crop production.

Applying wrong fertilizers or using wrong rates can result in failure of farmers to benefit from the purchased fertilizer, leading to low yields and therefore food insecurity (Kaizzi *et al*., 2016). Lou *et al.* (2011) revealed that proper application rates increase crop yields by correcting nutrient deficiencies. The optimum rate of fertilizer application to a crop is a rate that produces maximum economic returns. Fertilizer respose is a function of a number of environmental factors which include availability of soil plant nutrients and available moisture within the rooting depth of a particular crop (Singh and Mohanty, 1998). Fertilizer application rates vary depending on various factors such as economic value of a crop, price of the fertilizer, nutrients available in the soil, ability of crop to absorb nutrients, moisture content of the soil and nutrient removal by crop and soil aeration (Kimbi and Semoka, 2004; Abdoulaye and Sandes, 2005). This study was in agreement with the findings of Everaarts *et al*. (2015) who reported that nitrogen, phosphorus and potassium application in the form of inorganic fertilizers varied considerably in different agro-ecological zones.

2.7 Production of Tomato, Onion and Amaranth

Globally, tomato is the second most important vegetable crops after potato. The present world production is about 100 million tons of fresh fruit produced on 3.7 million ha. Tomato production has been reported for 144 countries (FAOSTAT, 2016) and the major producing countries is China, with cultivated area of 1 255 100 ha and weight of fruits of 50 552 200 tons equivalent to 6.42 % of world total. China is followed by India (18 227 000 tons, 2.46 % of world total), United States (12 574 550 tons, 1.69 % world total) and Egypt (8 533 803 tons with 1.15 % world total) while Tanzania (539 914 tons with 0.3 %) (FAO, 2016).

Onion is grown in at least 140 countries worldwide. The leading country is China which produces 20 507 759 tons followed by India, USA, Egypt and Iran with 13 372 100 tons, 3 320 870 tons, 2 208 080 tons and 1 92 970 tons, respectively (FAO, 2016).

Schippers (2000) reported that there is no adequate information on yield for various African species of amaranth. Good productivity in amaranth however, requires optimum conditions which include judicious use of inputs such as fertilizers.

2.8 Ecological Requirements for Tomato, Onion and Amaranth

Tomato is fairly adaptable and grows well in warm conditions. It's optimum temperatures for growth and development are 25 – 30 ^{0}C during the day and 15 – 17 ^{0}C at night. It is sensitive to low light conditions, requiring a minimum of 6 hours of direct sunlight to flower. However, if the intensity of solar radiation is too high, cracking, sunscald, and uneven coloration at maturity can be seen (Wenjing, 2016). It requires moisture of about 600 mm well distributed throughout the growing season. Excess water, will however, lead to root death in anaerobic soil conditions, as well as delayed, less prolific flowering and fruit set. Too much water after fruit set induces several fruit disorders, most notably cracking (Giri *et al*., 2017). Flowering is also adversely affected under conditions of low moisture stress. Blossom end rot (BER) also becomes a problem due to low water uptake leading to low calcium uptake and distribution (Gercek *et al*., 2017). Tomato can be produced across a wide range of soils as long as drainage and soil structure is good. The plant produces a fibrous root mass, which can exploit the subsoil given the absence of cultivation pans. Most of the root mass though, is normally concentrated in the cultivated zone and 70 % of the total root volume is in the top 15 to 30 cm of top soil. Tomato requires good nutrition. Thus, the best crops are from the more fertile soils (Okiror *et al*., 2017). Optimum soil pH for tomato is between 6.0 and 6.5, but crops are grown in soils with a pH of 5.0 to 7.5. When pH drops below 5.5, magnesium and molybdenum availability drops while above 6.5, zinc, manganese and iron become deficient (Mowo *et al*., 2006).

Onion production is controlled by day length. The critical day length varies from 11 to 16 hours depending on a variety. Proper variety selection is essential, particularly in relation to day length requirements (Rubatzzky and Yamaguch, 1996). The optimum rainfall for onion yield is between 350 and 550 mm. Onion requires substantial water at initial stage, but excessive moisture must be avoided during the growing season (Senkondo *et al*., 2004). The optimal temperature is between 13 and 25 ^{0}C. High temperature favors bulbing and curing. In the tropics only short day or day neutral onion varieties will form bulbs. These thrive in warm climate of 15 – 30 ^{0}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 yield (Lee *et al*., 2013). Onion can be grown on many soil types but medium textured soil is preferred. Optimum pH is in the range of 6.5 to 8 in mineral soil and about 5.8 in peat soils (Njau *et al*., 2017).

Amaranth grows on wide range of soils. Slightly acidic and sandy loams with good drainage are preferred. The roots system is sparse but because the plant is C4, photosynthesis under high temperature and moisture stress is relatively efficient and hence it has good drought tolerance (Keller *et al*., 2005).

2.9 Growth and Development

Tomato growth characteristics range from indeterminate to determinate. Most tomato fruit mature 35 to 60 days after anthesis revailing temperature influences the rate of ripening. The degree – day procedure is used by some growers to schedule planting and harvest periods. Time from planting to harvest range from 70 to 125 days depending on the variety (Scholberg *et al*., 2000).

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 (Suresh, 2007).

2.9.1 Germination

Tomato seeds germination begins when introduced to moist soil and temperature range of 16 – 30 ^{0}C. Once the seed has taken in enough water to activate digestive enzymes, the embryonic plant uses the broken down nutrients inside the seed to power its growth. After about a week at 35 ^{0}C, the growing embryo bursts from the hard seed and pushes up through the soil. Soon, the first pair of true leaves will form (Scholberg *et al*., 2000).

In onion, seed germination occurs within 7 to 10 days. Soil temperature affects this process. For instance, the cooler the soil, the longer it will take for onion seeds to germinate – up to two weeks. Warm soil temperatures, on the other hand, can trigger onion seed germination in a few as four days (Njau *et al*., 2017).

Amaranth seeds germination takes two to three days in warm temperature of 15 ^{0}C – 30 ^{0}C. Temperature, light and moisture all significantly affect seed germination. Germination and seedling percentage increase as incubation temperature increases (Alonge *et al.*, 2007).

2.9.2 Vegetative growth

During the vegetative period, the plant focus is on increasing both root and leaf mass so that it can collect as many building blocks from the environment as possible to fuel photosynthesis. Growth becomes explosive in the presence of warm temperatures and rich soil. This is a good time to stake or cage tomatoes (Bagali *et al*., 2012). Many tomato plants continue to grow even after they have started producing flowers, called indeterminate growth. The term is applied to tomato varieties that grow and produce fruit throughout the growing season in contrast to determinate types which grow in a more bushy shape and is most productive for a single, larger harvest and then either tapers off with minimal new growth of flowers and fruits (Lou *et al*., 2011).

The entire growth of onion is from seed, which at germination produces a single root and single hollow leaf. After the seedling is established, the young onion enters a juvenile phase, where new foliage leaves and new roots continue to be produced. For approximately every two weeks a new leaf grows inside the first leaf before growing out (Senkondo *et al*., 2004; Njau *et al*., 2017). New leaves are produced at the center of the plant and the late formed leaves are larger. 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 one resulting in a change in the shape of the stem as the plant gets older. New roots are continuously producing throughout vegetative growth. Each successive group of roots is produced close to the shot apex or root plate. This results in young roots being produced above the level of older ones (Lee *et al*., 2013).

Amaranth grows tall and can top 150 cm high. Flowers are produced on long straight stems. Vegetative types are generally smooth leafy, with an indeterminate growth habit which produces new succulent axillary growth. The floral buds arise directly in the leaf axils (Alonge *et al*., 2007).

2.10 Time of Fertilizer Application in Vegetables

Time of fertilizer application is an important aspect of fertilizer management practices as it affects use efficiency. Response to fertilizers by crops can be affected by the time of application in relation to stage of crop growth and form of fertilizer (Abdoulaye and Sandes, 2005). Maximum use efficiency of nitrogen fertilizer is obtained during vegetative growth stages of amaranth, bulbing in onion and at flowering stage for tomato. Excessive vegetative growth can reduce early and subsequent bulb and fruit set (Lou *et al*., 2011).

2.11 Effect of NPK Fertilizer on Tomato, Onion, Amaranth Growth, Yield and Quality

2.11.1 Amaranth growth, yield and quality

A wide variety of experiments concerning fertilizer sources and treatment levels have been conducted worldwide on amaranth. The study by Alonge *et al*. (2007) reported that the best growth in the amaranthus species resulted from 250 kg NPK ha^{-1}. Adekayode and Ogunkoya (2011) found that organic matter increased by 23.3 % and 0.6 % in the second and third year respectively in plot treated with organic compost, while there was no such increase in amaranth plants from plots treated with 200 kg NPK ha^{-1}. Studies by Tindall *et al*. (1987) showed that application of 168: 112:168 NPK kg ha^{-1} is sufficient for proper growth and development of *Amaranthus spp*. The study by Maerere *et al*. (2001) showed that the most common type of fertilizer being used for amaranth is NPK 15:15:15 although being used for cereals which require high nitrogen levels. A study by Baitilwake *et al*. (2012) on amaranth overall data showed that 250 kg NPK ha^{-1} treatments produce higher shoot growth and grain yield. The organic matter content correlated positively with vitamin C content of amaranth and soil fertility (Skwaryło-Bednarz, 2009).

2.11.2 Tomato growth, yield and quality

According to Almulla *et al*. (2012), incorporation of organic manure increase chlorophyll in leaves, number of fruits and plant height in tomato plants. Adams (2004) reported that the element Nitrogen (N), Phosphorus (P), Magnesium (Mg), Boron (B) and Copper (Cu) are important for fruit setting in tomato plants. A study by Salam *et al*. (2010) reported that at the onset of tomato flowering, top dressing with NPK at 200 kg ha^{-1} is necessary to supply N, P and K needed for flowering. Low production of tomato is caused by salinity, drought, and excessive heat, declining soil fertility, into incidences of pests and diseases; poor crop management and shortage or lack of well – adapted and high yield varieties (Minja *et al*., 2011).

Prativa and Bhattarai (2011) reported that application of farm yard manure (FYM) at 25 t ha^{-1} + 150 % NPK (150:112:82.5 NPK kg ha^{-1}) in tomato was the best for obtaining higher values in respect of growth. Hinman *et al*. (2012) showed that without adequate supply of K and Ca to tomato plants tomato fruit will not accumulate the soluble content (sugar) and will be susceptible to physiological disorders such as blossom end rot.

2.11.3 Onion growth, yield and quality

Kumar *et al*. (1998) reported that application of 150 kg N ha^{-1} to onion crops result in maximum leaf length, number of leaves per plant, high bulb weight and yield. Kumar *et al*. (1998) also found that application of 120 kg N ha^{-1} increases onion yield by 30 % while (Salo *et al*., 2000) reported that onion yield of 40 to 50 t ha^{-1} was obtained from the take up of 117 to 166 kg N ha^{-1}, 18 to 28 kg P ha^{-1} and 117 to 136 kg K ha^{-1}. A study by Ghaffoor *et al*. (2003) with Shah Alam variety of onion at the fertilizer level of 150:100:50 NPK gave the best results with regard to number of leaves per plant (17.57), bulb survival (93.53 %), bulb diameter (7.40 cm), marketable yield, culls percentage (5.24 %) and total yield (13.20 t ha^{-1}).

The study on the growth and yield response of onion genotypes to different levels of fertilizers revealed that different levels of fertilizer influence growth and the yield components of onion (Islam *et al*., 2007). Also the study by Bagali *et al.* (2012) indicated that growth and yield of onion were significantly influenced by irrigation and fertilizer levels.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

The experiment was conducted at the Crop Museum of Sokoine University of Agriculture, Morogoro at $6^0$05'S, $35^0$37'E and 525 m above sea level. Annual rainfall at the site ranges between 800 and 950 mm and annual temperature range between 14 ^{0}C (min) and 34 ^{0}C (max) (Tanzania Meteorological Agency (TMA), SUA station). The area has sand – clay soil.

3.2 Experimental Materials and Field Establishment

3.2.1 Experimental materials

3.2.1.1 Fertilizers

According to Kisetu and Heri (2014) the recommended rate for tomato is 92:75NP kg ha^{-1}. The recommended rate for onion is 100:50 NP kg ha^{-1} (Ashraf, 2014) while that for amaranth is 170 N kg ha^{-1} (Baitilwake *et al*., 2012). These recommended rates were used as baseline information for the levels of fertilizers to be used in this experiment. Single carrier fertilizers were used. These were Urea, Triple super phosphate (TSP) and Muriet of potash (MOP). They were used at different ratios as source of N, P and K. Urea contains 46 % N while TSP contains 46 % P_2O_5, MOP 60 % K_2O. Fertilizer levels for tomato were (i) 0, 45, 90,180 kg N ha^{-1}, (ii) 0, 70,140 kg P ha^{-1} and (iii) 0, 75,150 kg K ha^{-1}. Levels for onion were (i) 0, 25, 50,100 kg N ha^{-1}, (ii) 0, 25, 50 kg P ha^{-1}, (iii) 0, 25, 50 kg K ha^{-1} while for amaranth levels were (i) 0, 85,170 200 kg N ha^{-1} (ii) 0, 30, 60 kg P ha^{-1} and (iii) 0, 30, 60 kg K ha^{-1}. A limitation of 4 N levels and 3 levels for P and K was selected in order to end up with 13 treatments which results to 39 plots after replicated three times for each crop.

Application of nitrogen was done in portions of 50 % at planting and 50 % after four weeks for tomato and onion while the applications of phosphorus and potassium fertilizer were done once at planting. For amaranth nitrogen was added at two weeks after sowing. All recommended cultural practices were applied uniformly according to crop requirements.

3.2.1.2 Varieties

A single variety was used for each crop. These were Assila, Red Bombay and Lishe varieties for tomato, onion and amaranth, respectively. Assila is a high yielding F1 variety. It is vigorous with good vegetative cover and early maturing (75 days). It is resistant to Tomato Yellow Leaf Curl Virus and Root Knot Nematode. It has yield potential of 62.5 tons ha^{-1}. Fruits are oval shaped with very good red colour (Wabebe, 2016).

Red Bombay is a small to medium sized onion, globe to flat shaped, purplish red with yield of between 21 and 40 tons ha^{-1}. It is a fast growing and high yielding variety. In the tropics it matures at 120 days from transplanting. It is very popular among farmers and market. It is also known to have excellent transportability (Njau *et al.,* 2017). Amaranth variety Lishe is a leafy vegetable with high market value. When directly sown in the field it takes 21 to 28 days to harvest (Keeller *et al*., 2005).

3.2.2 Nursery establishment and management

Tomato and onion seeds were raised in nurseries. Tomato seeds were sown in trays of 120 seedling capacity. Thereafter, the seed trays were kept in a growth chamber for three days at 22 – 25^0C and 85 – 95 % of humidity. The seedling trays were then kept under shade for 17 days then was transplanted to the main field at 21 days.

Onion nursery was prepared by ploughing and harrowing using a hand hoe. Seeds were sown by drilling at a spacing of 10 cm between drills and took 45 days to be transplanted to the main field. Watering of seedlings in the two nurseries was done twice daily during the 1^{st} week followed by once per day.

Weeds in onion nursery were removed by hand pulling at an interval of 7 days to avoid competition for nutrients and harboring of pests. Dimethioate 40 EC was applied at the rate of 30 ml per 15 l of water at interval of 15 days to control insect pests such as grasshoppers. Ridomil (Mancozeb and Metalaxy) was applied at the rate of 40 gm per 15 liter of water at an interval of 15 days to control fungal diseases in tomato and onion.

3.2.3 Field soil sampling and nutrient analysis

Soil samples were collected from the Crop Museum and taken to the Department of Soil Science (SUA) laboratory for characterization. The samples were taken by using the random sampling method (Petersen and Calvin, 1986). Thirteen core soil samples were collected from each area using a sampling shovel at 15 to 20 cm depth. The core samples were then mixed thoroughly to form one composite sample. The composite samples were quartered several times so as to obtain a representative sub-sample of one kilogram for laboratory analysis (Petersen and Calvin, 1986). The representative sub-sample was dried, ground and passed through a 2 mm sieve to obtain a fine material for laboratory analysis. The sieved samples were analysed for pH in 1: 2.5 soil to water ratio using the Coleman's pH meter (Thomas, 1996). Organic Carbon was determined by the Wakley and Black procedure (Nelson *et al*., 1992). Organic matter was estimated as organic carbon multiplied by 1.724 (Wakley and Black, 1934). Total nitrogen was determined by the micro Kjeldahl method (Moberg, 2000) while available Phosphorus concentration was determined using the method developed by Olsen *et al*. (1954). Textural analysis was done using the hydrometer method (Gee and Bauder, 1986).

3.2.4 Experimental layout and agronomic practices

The experiment was laid out in a randomized complete block design (RCBD) with three replications and 39 plots for each crop. Plot size for tomato was 2 m x 3 m giving an area of 6 m^2. The total experimental area including 0.5 m between plot and 1 m between replications was 278 m^2. Transplanting was done 21 days from nursery at a spacing of 50 cm x 60 cm which gave 20 plants per plot followed by irrigation at early morning and rate evening daily. Pests were managed as described under 3.2.2.

Plot size for onion was 1.3 m x 1.5 m giving an area of 1.95 m^2. The total experimental area including 0.5 m space between plots and 1 m between replications was 118 m^2. Transplanting was done at 45 days at a spacing of 10 cm x 15 cm giving 72 plants per plot. Earthing up for onion was done immediately after the crop had started forming bulbs. Pests were managed as described under 3.2.2.

Plot size for amaranth was 1.2 m x 2 m giving an area of 2.4 m^2. The total experimental area including 0.5 m between plots and 1 m between replications was 129 m^2. At the center 1 m^2 was marked for data collection. Seeds were sown by drilling at 15 cm apart using 750 grams for all plots (MAFC, 2007). Weeds were removed by hand pulling for broad leaves or by using a hand hoe for grasses such as nut grass (*Cyperus rotudus*) which were not easy to pull by hand.

3.3 Data Collection

3.3.1 Plants selection for data collection

For each experimental plot, plants were demarcated at the centre of each plot by randomly picking and tagging for recording of various data during crop growth. In each plot, five, 10 and 30 plants of tomato, onion and amaranth (1 m^2 from each plot) respectively were selected for data collection. Edge rows in each plot were discarded from sampling to avoid border effects.

3.3.2 Crop growth parameters

Growth parameters including plant height, days to first flowering, days to first fruit set, number of leaves per plant, length of leaves were taken at an interval of two weeks from transplanting to 60 days (the time when the plants completed bulb formation) for onion and from transplanting up to five months at maturity stage for tomato (Tomato variety was semi determinate type) while amaranth parameters were taken at maturity stage (starting at 20 days).

3.3.2.1 Tomato growth parameters

Days to first tomato flowers and fruits set were taken from five tagged plants by visual observation and then recorded. Height of tagged plants was measured using a ruler from the ground level to the tip of the longest leaf by holding the plant vertically. The mean plant height in each treatment was calculated from recorded individual plant height.

3.3.2.2 Onion growth parameters

Number of fully opened leaves for 10 tagged onion plants were counted and recorded. The mean number of leaves plant $^{-1}$ in each treatment was then computed. The length (cm) of longest leaves for 10 tagged plants was measured using a ruler when held vertically. For the longest leaves, measurement was taken from the bulb neck to the tip of the leaf, while the length of plants was measured from the ground level to the tip of longest leaf. The mean length of the leaves and plant height in each treatment were then computed and recorded.

3.3.2.3 Amaranth growth parameters

The size of amaranth leaves was measured from 30 plants. The size was measured by spreading and tracing the leaves on a graph paper. The mean plant size in each treatment was calculated from recorded plant leaf size. The number of days from sowing to harvest was observed and recorded from each plot, whereby the earliest was at 20 days and the latest was at 24 days.

3.3.3 Yield data

Data for yield was recorded after harvesting. Tomato harvesting was done after every five to seven days. Onion and amaranth yield data were collected at maturity. Amaranth was assessed by uprooting plants, washed to remove soil particle and then weighed to obtain total yield per unit area (1 m^2). The yield was measured based on the weight of fruits, bulbs and amaranth plants in kg per plot and converted to ton ha^{-1}.

3.4 Quality Parameters

Quality of the fruits, bulbs and amaranth (vegetates) for the different treatments was assessed based on fruit diameter, firmness, TSS, pH (for tomato) and splitted bulbs percentage, bulb diameter, bulb length, neck thickness, pungency (for onion) and dry matter contents (for amaranth). These were determined after harvest as follows:

3.4.1 Tomato quality

3.4.1.1 Fruit diameter

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

3.4.1.2 Fruit firmness

This is the accurate way to determine the quality and level of fruit maturity as it is an indirect measure of ripening (pulp firmness) a method by (Underwood and Keller, 1948). Ten fruits picked randomly at maturity stage after showed red color and harvested from each treatment. Measurement was done by using a penetrometer (Wagner fruit test, FT 20 model, Wagner Instruments, Italy) after allowed it to a penetration time of 5 seconds by placing a penetrometer on a firm, flat surface then reading was taken. The average kg/cm^2 was computed and recorded.

3.4.1.3 TSS

This referred to sugar level (fructose) in tomato fruits. Ten fruits picked randomly after harvest from each treatment. Small pieces was sliced from mature red color fruits then squeezed for juice in small beaker. Tomato juice was put on a refractometer (ATAGO, ATAGO Instruments limited, Japan) the average ^{0}Brix % was then computed and recorded.

3.4.1.4 pH

This is the level of acidity of mature fruits. After harvest 10 fruits were picked randomly from each treatment, 25 g of fruits sliced and weighed by using (Electrical balance BX

4200 H, Shimadzu Corporation, Japan) and blended. There after distilled water was added up to 250 mls in beaker and pH probe was soaked in solution for 30 seconds. The average pH was then measured by using pH meter (691 Metrohm, Erisau - Switzerland) and recorded.

3.4.2 Onion quality

3.4.2.1 Bulb splitting

The proportional of splitted onion bulbs was determined by counting the number of split bulbs and expressed as percentage of the total number of bulbs from each plot.

3.4.2.2 Bulb diameter and bulb length

The diameter and length of 10 bulbs randomly picked from each treatment, after harvest were measured using a venier caliper. Diameter of bulbs was measured at the widest portion of each bulb. Bulb length was measured from the base to the neck of the bulb. The average bulb diameter and bulb length were then computed and recorded.

3.4.2.3 Neck thickness

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

3.4.2.4 Pungency

Pungency was determined by using the taste panel method (Al–Lahham *et al*., 2003). Each 10 samples of onion bulbs from each plot were picked randomly after harvesting for odour assessment by two different groups of people. The groups was formed based on gender consisted of five members from each group at an equal ratio of males and females. Sample was divided into portions to each group for assessment and five ranking (1 – 5 scores) was used.

3.4.3 Amaranth quality

3.4.3.1 Dry matter content

Amaranth quality was assessed based on dry matter content. Thirty plants per plot were randomly harvested then washed and oven dried with oven at 65 ^{0}C to constant weight for five days. The mean weight in each treatment was calculated from recorded samples.

3.5 Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using the software GENSTAT 14th Edition (Statistic Service Centre, 2011) at significance of 5 % level. Descriptive statistics (mean, standard deviation and coefficient of variation) were generated. Multiple means comparison was done by using DMRT at 5 % level of significance.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Characteristics of Soil at the Experimental Site

The physical and chemical properties of the soil from the experimental site are presented in Table 1. Particle size analysis indicates that the soil had 42 % clay, 9 % silt and 49 % sand. According to the classification system by FAO (1977), the soil texture was sand clay. Sand clay soil is dominated by sand but contains enough clay and sediment to provide some structure and fertility for vegetable crops. It has been reported that most plants perform well in fine to medium textured soils (Landon, 1991). Based on the textural class the soil at the experimental site is suitable for vegetable production.

Crops grown on sand clay soil need frequent irrigation and fertilization to maintain healthy growth. The best way to improve sand clay soils is to mix organic matter, peat moss and compost into the soil (Mowo *et al*., 2006). The soil pH as determined in 1:2.5 soil: water suspension, was 6.94. Landon (1991) categorized pH value as follows; very high (>8.5); high (7.5 – 8.5); medium (5.5 – 7.0) and low (<5.5). According to this categorization, the pH was rated as medium (Table 1). Results in Table 1 indicate that extractable P levels were low according to the categorization by Landon (1991). Phosphorus availability to plants is strongly influenced by soil pH and its availability is maximized when pH is between 5.5 and 7.5 (Kaaya *et al*., 1994). The low level of Bray -1-P in the experimental soil could probably be due to low level of P in the soil parent material and conversion of P into the form not extractable by the Bray -1-P reagent (Landon, 1991). Phosphorus is deficient in most agricultural soils (Ashifaq *et al*., 2004) due to its continuous uptake by plants without being returned back to the soil through fertilizer sources. Therefore, based on the above critical P level, the experimental soil requires supplemental P from sources such as inorganic fertilizers, manure and rock phosphate for adequate vegetable production.

Organic carbon (OC) in the soil was 1.79 % (Table 1). Landon categorized organic carbon as very high (>20); (10-20) high; (4-10) medium; (2-4) low; (<2) very low. The observed OC value is therefore rated as very low. Soil with low organic carbon levels is also likely to contain low levels of N and other nutrients. Soil organic matter plays a number of roles in the soil. It influences many soil biological, chemical and physical properties that influence nutrient availability (Tisdale *et al*., 1993). It acts as a conditioner by improving soil structure, moisture and iron retention besides being an important source of nutrient elements (Uriyo *et al*., 1979).

Nitrogen is categorized as low, medium or high when the percentage nitrogen values are less than 0.1, 0.2 and > 0.2, respectively. Total N in the study area was 0.18 %, which is low. The observed low value of N is attributed to very low organic matter. According to Ashifaq *et al*. (2004), the quantity of nitrogen is closely related to the amount of soil organic matter which makes approximately 5 % of the soil volume. This calls for adequate application of N from sources such as inorganic and organic fertilizers.

Exchangeable Ca^{2+}, Mg^{2+} and K^{+} values were ranked as high. The value of exchangeable Ca^{2+}, Mg^{2+} and K^{+} could be attributed to the contents in the parent materials from which the soil was formed. Most nutrients like Mg^{2+}, Ca^{2+} and K^{+} dominate soils with medium to high pH (Fageria, 2010).

Table 1: Physical and chemical properties of the experimental soil

Soil properties	Unit	Remarks
pH 1:1 (H_2O)	6.94	Medium
Organic C (%)	1.79	Very low
Total N (%)	0.18	Low
P (%)	1.93	Low
Exchangable cation (cmol (+)/kg soil)		
Ca^{2+} (cmol /kg)	14.8	High
Mg^{2+}	3.52	High
Na	1.51	Medium
K^{+}	0.54	High
Particle size (%)		
Sand	49	
Silt	9	Sand clay
Clay	42	

Since vegetables can grow in a wide variety of soils, sand clay soils could also be used for vegetable production if the deficient nutrients are added to the soil in the form of chemical fertilizers or manure. Improved management techniques are required, for example, addition of organic matter to the soil and inorganic materials that supply a wide range of plant nutrients. Addition of organic matter to the soil will also improve water retention capacity (Gercek *et al*., 2017).

4.2 Effect of Weather during Growing Period

The weather data for the experimental site during the period of the study are presented on (Fig. 1 and 2). The minimum temperature experienced 20.4 ^{0}C while maximum temperature was 33.6 ^{0}C. December to March months experienced hot conditions of 31.3 ^{0}C to 33.6 ^{0}C. December was the hottest (33.6 ^{0}C) (Appendix 1 and 2). Monthly cumulative rainfall was recorded as 14.9 mm (min) and 268.7 mm (max) during December 2016 and April 2017 while in May 2017 rainfall dropped to 174.6 mm where as temperature dropped up to 20.4 ^{0}C.

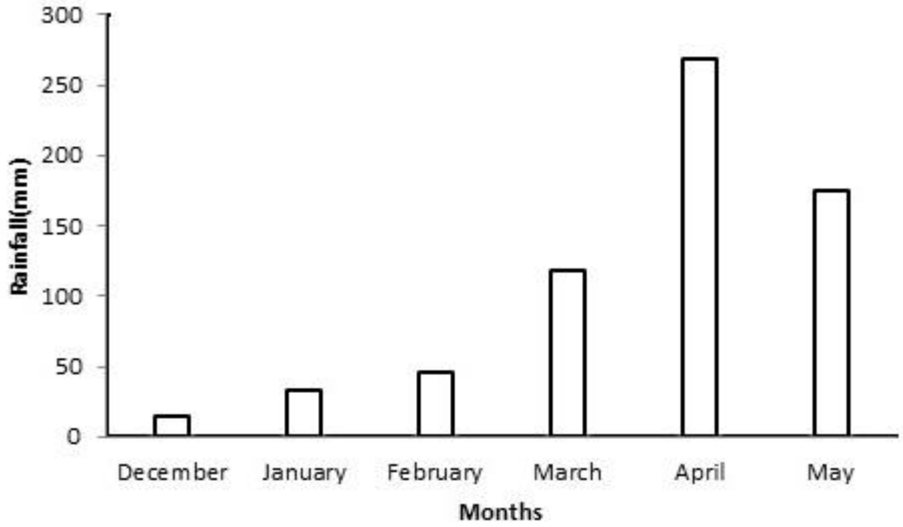

Figure 1: Monthly rainfall (mm) during the experimental period (Source: Tanzania Meteorological Agency (TMA), SUA station)

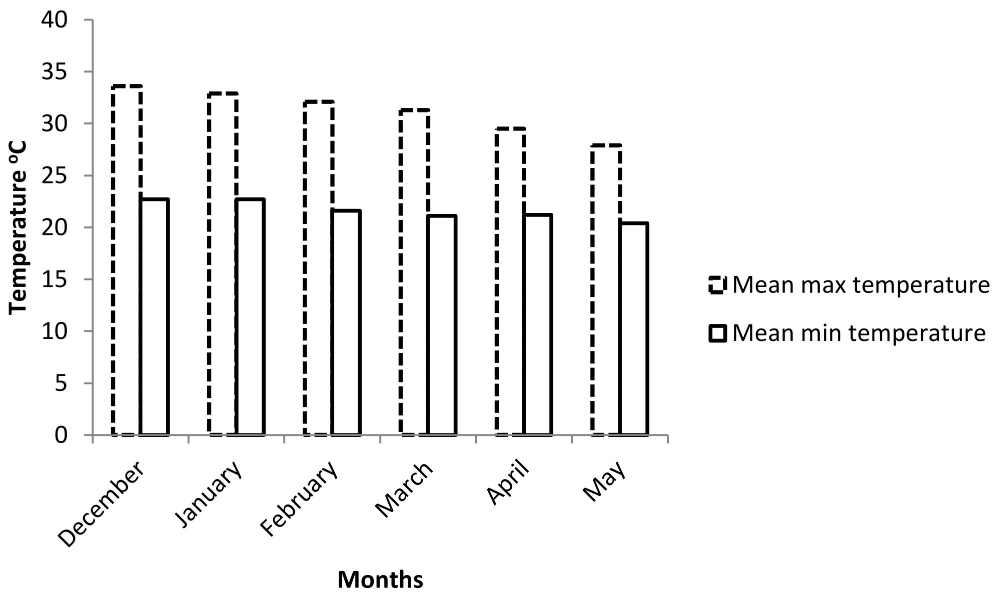

Figure 2: Mean minimum and maximum temperature (°C) during the experiment period (Source: Tanzania Meteorological Agency (TMA), SUA station)

Weekly cumulative rain was 14.9 mm to 268.7 mm received from December 2016 to April 2017. Minimum temperature was 20.5 ^{0}C while maximum was 35.7 ^{0}C in December (Fig. 1 and 2). The weather in December was favourable to seedlings growth during nursery stages. Tomato and onion seedlings require temperature of 18 ^{0}C to 31 ^{0}C and adequate moisture (Rubatzzky and Yamaguch, 1996; Giri *et al*., 2017). The period from January to March was ideal for plant growth in the field due to regular moisture supplied through irrigation (Alemaheyu *et al*., 2015). Al-Lahham *et al*. (2003) reported that most vegetable crops such as tomato and amaranth require regular moisture and ideal temperature for growth and production. The study by (Bagali *et al*., 2012) revealed that onion requires substantial water at initial stage but excessive moisture must be avoided during the growing period. The results indicate that, weather conditions during the experimental period were favorable to tomato, onion and amaranth.

4.3 Effect of NPK Fertilizer Sources on Crop Growth and Yield

4.3.1 Tomato

4.3.1.1 Plant height and number of days to first flowering

Results regarding plant height (Table 2) indicated that the height of tomato plants was significantly different ($p \leq 0.05$) influenced by treatments. Application of 45:140:75 NPK kg ha^{-1} produced the tallest plants with a mean height (58.21 cm) and 45:70:75 NPK kg ha^{-1} gave similar height (51.13 cm) which was different at application rate of 180:70:75 NPK kg ha^{-1} which produced short plants (50.25 cm). Shortest plants (46.09 cm) were observed from control 0: 0: 0 NPK kg ha^{-1} respectively.

This means that NPK at a rate of 45:70:75 NPK kg ha^{-1} is the optimum rate to trigger an increase in plant height per area having the nutrient status observed (Table 1). This is testified by the fact that further increase in NPK above that did not have a direct proportional effect on the plant height. The soil at experimental site has high level of potassium. High levels of Potassium can supress the availability of other nutrients. Conversely, high application of N, calcium or magnesium can lower the availability of potassium to plant (Tisdale and Nelson, 1993; Mowo *et al.,* 2006). Malvi (2011) reported that optimum level of nitrogen ensure optimum uptake of potassium as well as phosphorus, magnesium, iron, zinc from the soil. Everaarts *et al*. (2015) reported that, for staked tomato best growth performance was at nitrogen application rate which ranged from 41 to 154 kg ha^{-1}, while phosphorus and potassium application were from 0 to 48 and from 0 to 22 kg ha^{-1}, respectively.

The effect of different levels of NPK on number of days to first flowering was significantly different ($p \leq 0.05$) between NPK fertilizer sources (Table 2). The application of NPK at 45:140:75 NPK kg ha^{-1} showed early flower set at 26.67 days compared to NPK fertilizer of 180:70:150 NPK kg ha^{-1} which led to first flowers at 34.67 days. Treatments with 90:70:75 NPK kg ha^{-1} showed first flowers at 28.67 days and treatments with 180:70:75 NPK kg ha^{-1} enabled flowering at 33 days. The results indicate that further increase in NPK above 45:140:75 NPK kg ha^{-1} did not have a direct proportional effect on earliness of flowering. Either more increase of N fertilizer caused late flowering. Mengel *et al*. (2001) suggested that adequate N fertilizer promotes more vegetative growth.

Table 2: Effect of NPK fertilizer rates on tomato growth and yield

NPK rates	Plh(cm)	Dyf	Dfs	Y(t/ha)
0kgN, 0kgP, 0kgK	46.09ab	29abc	39ab	43.7a
45kgN, 70kg P, 75kg K	51.53abc	29abc	39.33ab	48.3ab
45kgN, 70kg P, 150kg K	48.98a	29.33abc	38ab	51.1ab
45kg N, 140 kg P, 75kg K	58.21c	26.67a	36a	60.3bc
45kgN, 140kg P, 150kg K	57.12bc	31.67abc	40bc	62.9bc
90kg N, 70kg P, 75kg K	50.92abc	28.67ab	39.33abc	50.8ab
90kg N, 70kg P, 150kg K	49.35a	31.67abc	39.67abc	59.3bc
90kg N, 140kg P, 75kg K	52.69b	32.33bc	40.33bc	51.5ab
90kg N, 140kg P, 150kgK	50.61bc	31abc	41.33bc	57.5ab
180 kg N, 70kg P, 75kg K	50.25ab	33bc	43c	59.5bc
180kg N, 70kg P, 150kgK	53.62abc	34.67c	40.67bc	57.7ab
180kg N, 140kg P, 75kgK	54.08abc	31abc	39.33abc	51.2ab
180kgN, 140kgP, 150kgK	54.58abc	30abc	40.33bc	55.3ab
Grand mean	52.45	30.62	39.72	54.5
P value	0.12	0.16	0.046	0.49
CV (%)	4.8	3.3	0.8	8.8
SE ±	2.51	1	0.32	4.79

Key: Dyf=Days of flower set, Dfs=Days of fruit set, Plh=Plant height, Y=Yield and abc ≥ ab

4.3.1.2 Number of days to fruits set

Days of fruit set was not differed significantly at $P \leq 0.05$ (Table 2). Treatment with 45:140:75 NPK kg ha^{-1} showed first fruits set at 36 days where as application of 180:70:75 NPK kg ha^{-1} showed fruits set at 43 days. Treatments with 180:140:150 NPK kg ha^{-1} set fruits at 40.33 days whereas treatment with 90:140:150 NPK kg ha^{-1} had fruits at 41.33 days while the control (0:0:0 NPK kg ha^{-1}) set fruits at 39 days (Table 2).

Number of days of tomato fruits set was more influenced by application of mulching; during 18 to 21 days mulching was applied to the tomato fields. At fruit set temperature was 32.13 ^{0}C and 31.32 ^{0}C for February and March, after mulching application stress was reduced. Giri *et al*. (2017) reported that mulching control the change in temperature and reduce moisture evaporation from the soil. Ideal temperature influence fruits set in tomato crop (Isah *et al.*, 2014). Weijing (2016) found that with ideal temperature range, fruits set have a possibility to be large. Similar findings were obtained by Ozores and Avoy (2010) who found that reducing stress results in reducing flower drops which result in maintaining uniform fruits set. Some type of stress may be nutritional, environment, or combination of the two. Also at that stage were at optimal use of N, P and K nutrients which significantly affect plants fruit set. Adam (2004) observed that small requirement of the element N, P, Mg, B and Cu are important for fruit setting in tomato plants.

4.3.1.3 Tomato yield

Tomato yield was significantly different ($p \leq 0.05$) between fertilizer treatments (Table 2). Application of 45:140:150 NPK kg ha^{-1} produced the highest yield (62.9 tons ha^{-1}) compare to that of 45:70:75 NPK kg ha^{-1} produced low yield of 48.3 tons ha^{-1}. The control (0:0:0 NPK kg ha^{-1}) gave the lowest yield of 43.7 tons ha^{-1}. Treatment with 90:70:75 NPK kg ha^{-1} produced 50.8 tons ha^{-1} while treatment with 180:140:150 NPK kg ha^{-1} gave 55.3 tons ha^{-1} (Table 2).

This points to the fact that NPK at a rate of 45:140:150 NPK kg ha^{-1} was the optimum rate to trigger an increase in production per unit area of experimental soil followed by 45:140:75 NPK kg ha^{-1}. Further increase in NPK above that did not have a direct proportional effect on the yield of tomato (Fig. 3). The results of analysed soil used for experimental presented (Table 1) gave low N, P and high K . Application of 45 N kg ha^{-1} and 150 P kg ha^{-1} contributed to high yield hence N and P have a significant effect on crop yield (Fg. 3). However the study by Tisdale and Nelson (1993) revealed that high application of nitrogen, calcium or magnesium can lower availability of potassium to plant and result to low yield. Mowo *et al.* (2006) observed that some specific growth factors which have been associated with phosphorus are stimulation of roots development, increased stalk , stem strength, improve flowers formation, increase production of plants. Lou *et al*. (2011) observed that optimum rate of fertilizer application to a crop is a rate that produces maximum returns. Prativa and Bhattarai (2011) reported that application of NPK at the rate of 150:112:82.5 NPK kg ha^{-1} in tomato was the best for obtaining higher yield. Kisetu and Heri (2014) reported that NPK (23:10:5) fertilizer at 40 kg ha^{-1} are sufficient for tomato plants. This research is in agreement with the finding of Adam *et al*. (1978) who observed that application of optimum N, P and K fertilizer to soil produces high tomato fruit yield. Isah *et al*. (2014) found that application of NPK fertilizer between 250 to 280 kg ha^{-1} was efficient for total fruit yield. Either high yield was contributed by mulching application in tomato plants. Giri *et al*. (2017) revealed that mulching improve plant environment, nutrients applied, hastens maturity and result in higher yields.

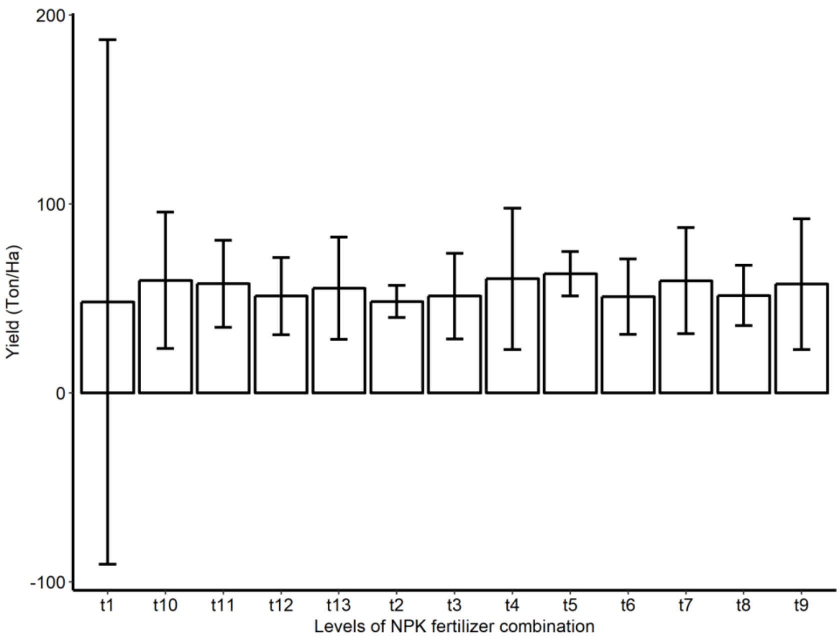

Figure 3: Bar graphs of tomato yield response due to fertilizer levels

Error bars = 95 % confidendence interval, denotes t1 – t13 = N:P:K levels (kg ha^{-1}) t1 = 0:0:0, t2 = 45:70:75, t3 = 45:70:150, t4 = 45:140:75, t5 = 45:140:150, t6 = 90:70:75, t7 = 90:70:140, t8 = 90:140:75, t9 = 90:140:150, t10 = 180:70:75, t11 = 180:70:150, t12 = 180:140:75, t13 = 180:140:150

4.3.2 Onion

4.3.2.1Plant height and length of leaves

The height of plant and length of leaves were significantly different ($p \leq 0.05$) among the treatments (Table 3). Treatment with 25:50:50 NPK kg ha^{-1} produced the tallest plants with a mean height of 37.24 cm while short plant (30.63 cm) was recorded from application of 50:25:50 NPK kg ha^{-1}. The control treatment produced the shortest plants with a height of 27.57 cm. The application of 25:50:25 NPK kg ha^{-1} produced the longest leaves of 32.72 cm which was almost similar to 32.18 cm from 25:25:25 NPK kg ha^{-1}. The shortest leaves (24.73 cm) were produced from control (Table 3).

This means that NPK at a rate of 25:50:50 NPK kg ha^{-1}, 25:50:25 NPK kg ha^{-1} and available moisture could have triggered an increase in plant height and leaves length. Further increase in NPK above that did not have a direct proportional effect on the plant height and leaves length of onion. Abdoulaye and Sandes (2005) reported that fertilizer response is a function of a number of environmental factors which include availability of plant nutrients and available moisture within the rooting depth of a particular crop. They also observed that significant vegetative growth was caused by shorter interval with high level of irrigation.

Table 3: Effect of NPK fertilizer rates on onion growth and yield

NPK rates	Plh(cm)	Ll(cm)	Nlp	Y(t/ha)
0kg N, 0kg P, 0kg K	27.57a	24.73a	4.22a	4.85a
25kg N, 25kg P, 25kgK	35.4ab	32.18ab	5.22bc	17.3b
25kg N, 25kg P, 50kgK	31.92ab	27.58ab	4.78abc	19.73b
25kg N, 50kg P, 25kgK	37.12b	32.72b	5abc	17.68b
25kg N, 50kg P, 50kgK	37.24b	31.9b	5.11abc	17.57b
50kg N, 25kgP, 25kgK	32.07ab	29.38ab	5.22bc	18.25b
50kg N, 25kgP, 50kgK	30.63ab	27.57ab	5.11abc	22.44ab
50kg N, 50kgP, 25kgK	32.54a	29.98ab	5.11abc	24.3bc
50kg N, 50kgP, 50kgK	34.54ab	30.7ab	4.33ab	22.12ab
100kgN, 25kgP, 25kgK	35.85b	30.97ab	5abc	21.23ab
100kgN, 25kgP, 50kgK	30.72ab	27.86ab	4.78abc	19.8ab
100kgN, 50kgP, 25kgK	35.96b	32.36b	5.67c	24.8bc
100kgN, 50kgP, 50kgK	34.93ab	32.15b	6.56d	24.82bc
Grand mean	33.57	30	5.09	19.61
P value	0.224	0.201	0.002	0.003
Cv (%)	3.1	0.3	0.3	13.9
SE±	1.026	0.015	0.148	2.719

Key: Plh = Plant height, Nlp = Number of leaves per plant, Ll = leaves length, Y= Yield and abc ≥ ab

4.3.2.2 Number of leaves

The number of leaves of onion plants was not significantly different ($p \leq 0.05$). Application of 100:50:50 NPK kg ha^{-1} produced 6.56 leaves. The smallest number of leaves (4.33) was produced from application of 50:50:50 NPK kg ha^{-1}. Application of 50:50:25 NPK kg ha^{-1} produces 5 leaves which were at par with 5 leaves from application of 100:25:25 NPK kg ha^{-1} (Table 3).

This means that further increase in NPK above that has direct proportional effect on the number of onion leaves. A study by Ghaffoor *et al*. (2003) with Shah Alam variety of onion at the fertilizer level of 150:100:50 NPK kg ha^{-1} gave the best results with regard to number of leaves per plant (17.57).

4.3.2.3 Yield

Yield was not significantly different ($p \leq 0.05$) among the treatments. Results indicate that an application of 100:50:50 NPK kg ha^{-1} produced the highest yield (24.82 tons ha^{-1}) which was at par with application of 100:50:25 NPK kg ha^{-1} which gave 24.8 tons ha^{-1} . Application of 50:50:25 NPK kg ha^{-1} gave 24.3 tons ha^{-1}, application of 50:25:25 NPK kg ha -1 gave 18.25 tons ha $^{-1}$ and control gave 4.85 tons ha^{-1}.

This means that NPK at a rate of 50:50:25 NPK kg ha^{-1} was optimum rate to trigger an increase in production per unit area futher increase in NPK above that did not have a direct proportional effect on the yield of onion (Fig. 4). The results of analysed soil used for experiment were presented (Table 1) which gave low N, P and high K of soil nutrients. Addition of N and P produced significantly high yield. Addition of nitrogen as well as phosphorus plays an important role in crop production but varios levels had highly significant effect on yield per plot (Singh and Mohanty, 1998). Kumar *et al.* (2013) obseved that NPK levels cause interraction which results to un antagonism between those element due to different metabolic functions. More over, because potassium intergrate different biochemical functions in the physiological process to maintain the osmotic potential and ionic balance. Ghaffoor (2003) revealed that crop response to N fertilizer varies with rate, timing and method of N application.

The research by Bagali *et al*. (2012) suggested that irrigation and other cultural management play an important role in yield of onion crop. Lou *et al*. (2011) observed that optimum rate of fertilizer application to a crop is a rate that produces maximum economic returns. Islam *et al*. (2007) reported that genotype, different levels of fertilizers influenced yield of onion. Pandey and Ekpo (1991) observed that maximum bulb yield (460.2 tons ha^{-1}) and average bulb weight (197.8 gm) were obtained with 120 NPK kg ha^{-1}. Singh and

Mohanty (1998) observed that onion productivity could be enhanced considerably by application of 100:30.8:83 NPK kg ha^{-1}.

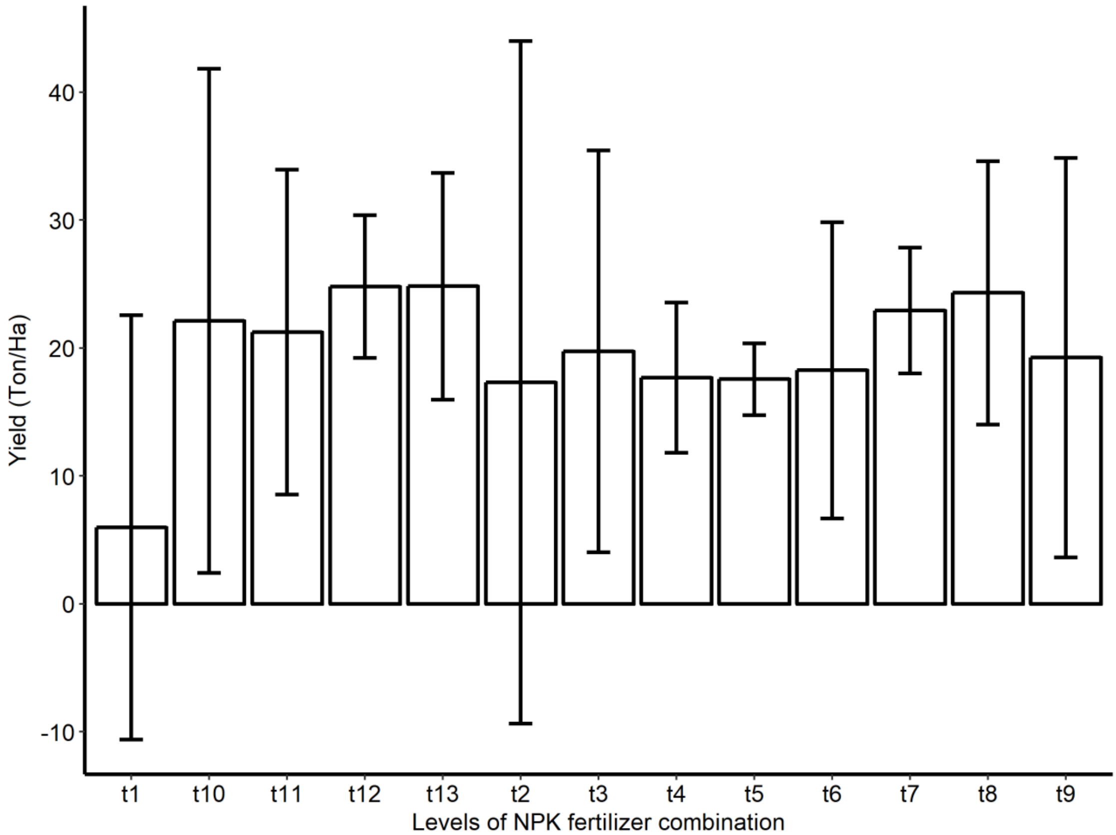

Figure 4: Bar graphs of onion yield response due to fertilizer levels

Error bars = 95 % confidendence interval, denotes t1 – t13 = N:P:K levels (kg ha^{-1}) t1 = 0:0:0, t2 = 25:25:25, t3 = 25:25:50, t4 = 25:50:25, t5 = 25:50:50, t6 = 50:25:25, t7 = 50:25:50, t8 = 50:50:25, t9 = 50:50:50, t10 = 100:25:25, t11 = 100:25:50, t12 = 100:50:25, t13 = 100:50:50

4.3.3 Amaranth

4.3.3.1 Plant height

The height of amaranth plant was significantly different ($p \leq 0.05$) among treatments (Table 4). Treatment with 200:60:30 NPK kg ha^{-1} produced the tall plants (26.7 cm) and plants with 26.23 cm produced from application of 200:60:60 NPK kg ha^{-1}. The shortest plants (21.65 cm) were recorded from application of 85:30:60 NPK kg ha^{-1} (Table 4).

The results indicate that increase in plant height at high N and P levels from NPK fertilizer might be an increase in N and P availability to amaranth plants since those nutrients was low before fertilizer application at experimental soil (Table 1). Nitrogen as well as phosphorus fertilizer plays an important role in plant height. Alonge *et al.* (2007) suggested that adequate N fertilizer promotes more vegetative growth which results to good amaranth performance. The study by Baitilwake *et al*. (2012) observed that high N level increase the plant height of amaranth. Hynes and Naidu (1998) reported that the main nutrient applied routinely as fertilizer to agricultural soils are N, P and K but worldwide, nitrogen is more heavily used than the others. This is due to the fact that in most of the agriculture systems, nutrient supply is below the minimum requirement of crop to reach maximum growth.

Table 4: Effect of NPK fertilizer rates on amaranth growth and yield

NPK rates	**Plh(cm)**	**Dm**	**Sl(cm)**	**Y(t/ha)**
0kg N0kg P, 0kg K	21.12a	24a	7.48a	7.2a
85kg N, 30kg P, 30kg K	26.06ab	20.67a	13.3bcd	12.8ab
85Kkg N, 30kg P, 60kg K	21.65ab	22.33a	8.6ab	14.4ab
85kg N, 60 kg P, 30kg K	26.2ab	21a	10.06abc	17.7ab
85kg N, 60kg P, 60kg K	22.75ab	20.67a	10.83abc	12.97ab
170kg N, 30kg P, 30kg K	25.08ab	21a	12.41abc	22.9b
170kg N, 30kg P, 60kg K	25.83ab	22a	13.51bcd	21ab
170kg N, 60kg P, 30kg K	24.7ab	20.67a	18.75d	22.3b
170kg N, 60kg P, 60kg K	25.76ab	21.33a	11.27abc	14.4ab
200kg N, 30kg P, 30kg K	22.48ab	22a	15.23cd	22.03b
200kg N, 30kg P, 60kg K	23.9ab	21.33a	11.68abc	24.03b
200kg N, 60kg P, 30kg K	26.7b	20.67a	13.81bcd	25.4b
200kg N, 60kg P, 60kg K	26.23ab	20.67a	15.63cd	25.1b
Grand mean	24.5	21.41	12.51	18.6
P value	0.21	0.007	0.009	0.13
Cv (%)	2.3	0.5	20.7	12.9
SE ±	0.57	0.12	2.59	2.41

Key: Sl=Size of leaves, Dm= Days to Maturity, Ph=Plant height, Y=Yield and abc ≥ ab

4.3.3.2 Days from sowing to harvest

During the growing period there was no significant difference ($p \leq 0.05$) among the number of days from planting to harvesting. Treatment with 200:60:60 NPK kg ha^{-1} resulted in earliest maturity at 20.67 days while treatment with 170:30:60 NPK kg ha^{-1} resulted into the latest maturity at 22 days which was similar with 22 days produced from the application of 200:30:30 NPK kg ha^{-1} and 24 days from control (Table 4).

These results indicate that NPK fertilizer significantly contributed to amaranth maturity at the same period of time. The research by Alemayehu *et al*. (2015) revealed that amaranth grows well in fertilized soils and responds well to high sunlight and warm temperatures. In addition Rubatzzky and Yamaguch (1996) reported that amaranth grows on a wide range soils; slightly acid, sandy loams and good drainage.

4.3.3.3 Size of leaves

Results in Table 4 show that there were no significant differences ($p \leq 0.05$) in size of leaves. Treatment with 170:60:30 NPK kg ha^{-1} gave a mean leaves size of 18.75 cm^2 whereas treatment with 85:30:60 NPK kg ha^{-1} had a mean size of 8.6 cm^2 which is statistically similar to 7.48 cm^2 produced from the control. Application of 170:60:60 NPK kg ha^{-1} produced leaves size of 11.27 cm^2 and application of 200:30:60 NPK kg ha^{-1} produced leaves size of 11.68 cm^2 which were statistically similar.

This indicates that NPK at a rate of 170:60:30 NPK kg ha^{-1} might be optimum for increase in leaf size. This was consistent with the fact that further increase above that rate did not have effect on size of leaves per plant (Table 4). Studies by Tindall *et al*. (1987) showed that, application of 168:112:168 NPK kg ha^{-1} was sufficient for proper growth and development of *Amaranthus spp.* Alonge *et al.* (2007) reported that *Amaranthus species* generally showed comparable values in root, leaves and shoot growth under 250 NPK kg ha^{-1}.

4.3.3.4 Yield

The amaranth yield was significantly different ($p \leq 0.05$) between the treatments (Table 4). Treatment with 200:60:30 NPK kg ha^{-1} produced the highest yield (25.4 tons ha^{-1}) compared with 12.8 tons ha^{-1} produced from application of 85:30:30 NPK kg ha^{-1} (Fig 5) Application of 200:30:60 NPK kg ha^{-1} produced 24.03 tons ha^{-1} whereas the lowest yield of 7.2 tons ha^{-1} was reported from the control.

These results indicate that increase in yield at high N and P levels from NPK fertilizer might be due to an increase in N and P availability to amaranth plants that had positive impacts on amaranth which resulted in increase in yield (Fig. 5). During the experiment time, environment was favourable for growth. Temperature was between 22.7 ^{0}C to 32.9 ^{0}C, sufficient moisture and NPK supply. Increasing N fertilizer application improve plant physiological characters, dry matter, nitrogen accumulation and yield but their effects will be decreased with increase N fertilizer levels (Mengel *et al.,* 2001). Malvi (2011) revealed that artificially performance of plant depend on relationship between temperature, day length, sufficient moisture, macro and micro nutrients. This give respond in increase of leaf size, stem size and result with high yield. The study by Baitilwake *et al.* (2012) revealed that high N levels increased the yield of amaranth. This is in agreement with the study of Schippers (2000) which revealed that good productivity in amaranth requires optimum conditions which include judicious use of nitrogen fertilizers. Application of right fertilizer in adequate amounts and at appropriate time during crop growth will significantly increase amaranth yield and consequently economic return to farmers.

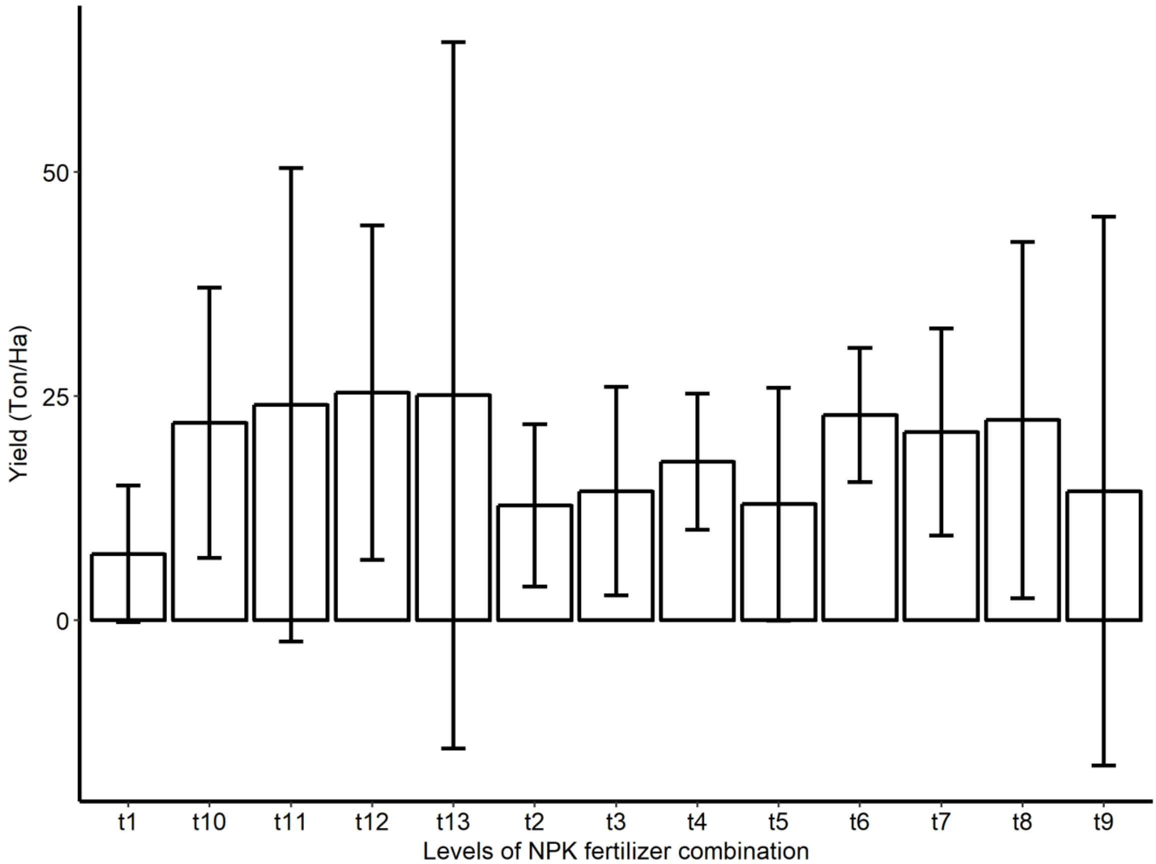

Figure 5: Bar graphs of amaranth yield response due to fertilizer levels

Error bars = 95 % confidendence interval, denotes t1 – t13 = N:P:K levels (kg ha^{-1}) t1= 0:0:0, t2 = 85:30:30, t3 = 85:30:60, t4 = 85:60:30, t5 = 85:60:60, t6 = 170:30:30, t7 = 170:30:60, t8 = 170:60:30, t9 = 170:60:60, t10 = 200:30:30, t11 = 200:30:60, t12 = 200:60:30, t13 = 200:60:60

4.4 Effect of NPK Fertilizers on Crop Quality

4.4.1 Tomato

4.4.1.1 Fruit diameter

Fruit diameter was significantly different ($p \leq 0.05$) among the treatments (Table 5). The application of 180:140:75 NPK kg ha^{-1} produced the biggest fruits of 5.06 cm compared to application of 90:70:150 NPK kg ha^{-1} which produced smaller fruits of 4.5cm. The results indicate that increasing NPK nutrients gives the widest fruits diameter. Adam *et al*. (1978) found that application of optimum levels of N, P and K fertilizer to the soil produced high diameter tomato fruits and improved fruit quality. Prativa and Bhattarai (2011) reported that application of NPK (150:112:82.5 NPK kg ha^{-1}) was the best for obtaining higher values in respect of their diameter. The results are in line with Ilupeju *et al*. (2015) who reported that 100 % NPK application (300 NPK kg ha^{-1} 20:10:10) gave widest fruit diameter of 15.9 cm.

4.4.1.2 Fruit Firmness

Fruit firmness was significantly different ($p \leq 0.05$) among the treatments (Table 5). Application of 180:140:150 NPK kg ha^{-1} produced firmer fruits 3.37 kg/cm^2 compared to 2.76 kg/cm^2 obtained from application of 45:140:75 NPK kg ha^{-1}.

The results are consistent with those indicated in Table 1 which pointed out high Ca (14.8 Cmol/kg) and high potassium. The enzyme response for synthesis of other nutrient in plant is activated by potassium, hence plays a major role in transportation of water and nutrients in the xylem but their effect will be decreased with increasing N fertilizer levels (Mengel *et al.*, 2001).

A study by Malvi (2011) revealed that when potassium supply is reduced translocation of nitrates, phosphorus, calcium, magnesium and amino acids is depressed. High levels of calcium in tomato cell wall improves fruit firmness, fruit diameter and shelf life. The study by Markovick *et al*. (2008) revealed that slow ripening and long shelf life of tomato fruits are traits controlled by several ripening inhibitor genes, Ca^{2+} and balanced K fertilizer in the soil. Similarly, Zdravkovic *et al*. (2008) revealed that quality criteria in tomato include firmness and shelf life of fruits.

Table 5: Effect of NPK fertilizer rates on tomato quality

NPK rates	Fd(cm)	Fm(cm)	p H	TSS (Brix %)
0kgN, 0kgP, 0kgK	4.46a	3.22a	4.33a	4.54ab
45kgN, 70kg P, 75kg K	4.71abc	3.17a	4.31a	4.39ab
45kgN, 70kg P, 150kg K	4.65ab	3.1a	4.85b	4.37ab
45kg N, 140 kg p, 75kg K	4.78abc	2.76a	4.40ab	4.52ab
45kgN, 140kg P, 150kg K	4.8abc	3.1a	4.57ab	4.32ab
90kg N, 70kg P, 75kg K	4.62ab	2.94a	4.54ab	4.45ab
90kg N, 70kg P, 150kg K	4.54ab	3.14a	4.57ab	4.67b
90kg N, 140kg P, 75kg K	4.71abc	3.12a	4.55ab	4.48ab
90kg N, 140kg P, 150kgK	4.85abc	3.21a	4.57ab	4.68b
180 kg N, 70kg P, 75kg K	4.88bc	3.04a	4.59ab	3.82a
180kg N, 70kg P, 150kgK	4.58ab	3.2a	4.6ab	4.17ab
180kg N, 140kg P, 75kgK	5.1c	3.27a	4.65ab	4.16ab
180kgN, 140kgP, 150kgK	4.85abc	3.37a	4.54ab	4.2ab
Grand mean	4.73	3.12	4.54	4.37
P value	0.11	0.99	0.49	0.44
CV (%)	2.7	7.3	3.1	11.1
SE ±	0.1295	0.23	0.14	0.48

Key: Fd=Fruit diameter, Fm=Firmness, pH= pH of fruits juice, TSS=Total soluble solid,

4.4.1.3 pH of the fruit juice and TSS

The level of pH among treatments (Table 5) were significantly different ($p \leq 0.05$). Recorded highest level of pH was 4.85 at application of 45:70:150 kg ha^{-1} compared to lowest (4.4) at application of 45:140:75 kg ha^{-1}. Results in Table 5 also indicate that, the level of Total soluble Solid among treatments was significantly different ($P<0.05$). Recorded highest level of Brix % was 4.68 % for treatment with 90:140:150 NPK kg ha^{-1} compared to 3.82 % which was obtained at application of 180:70:75 NPK kg ha^{-1}. Applications of 45:140:75 NPK kg ha^{-1} gave TSS at 4.52 %.

The results indicate that NPK fertilizer, good cultural practices contributing to the best quality in pH and TSS. However,different NPK levels result to significant different. Alonge *et al.* (2007) observed that different N doses as well as P significantly affect K uptake to plant which result to significant different of quality. Kumar *et al*. (2013) reported that application of FYM at 25 t ha^{-1} and 150 % NPK (150:112:82.8 kg ha^{-1}) in tomato was the best for obtaining high value in respect of pH. The authors further reported that the best pH and TSS levels depend on the purpose of the user. This research is in agreement with the findings of Adam *et al*. (1978) who found that application of optimum N, P and K fertilizer produced high tomato fruits with improved fruit quality. Prativa and Bhattarai (2011) reported that application of NPK 150:112:82.5 NPK kg ha^{-1} in tomato was the best for obtaining higher values in respect of quality. Similar results were also reported by Hinman *et al*. (2012) who found that without adequate supply of K and Ca for plant uptake and utilization, tomato will not accumulate soluble solids and will be susceptible to physical disorders such as blossom end rot.

4.4.2 Onion

4.4.2.1 Bulb splitting and neck thickness

Results in Table 6 indicates that proportion of bulb splits formed and neck thickness were variable significantly different ($p \leq 0.05$) among the treatments. Application of 100:25:50 NPK kg ha^{-1} produced the highest proportion of 33.9 % splitted bulbs compare to that from application of 50:50:50 NPK kg ha^{-1} which produced the lowest proportion of 6.4 %. Plants fertilized with 100:50:50 NPK kg ha^{-1} produced the thickest bulb necks of 1.07 cm compared to thinnest bulb necks of 0.88 cm which was from the application of 25:25:25 NPK kg ha^{-1}.

The results indicate that increase of N was increased splitted bulbs and adequate water level resulted in thicker neck. The research by Ashraf (2014) indicated that the formation of splitted bulbs was significantly enhanced by the increase of N. The study by Bagali *et al*. (2012) showed that adequate levels of water resulted in significant thicker necks.

Table 6: Effect of NPK fertilizer rates on onion quality

NPK rates	Sb	Bd(cm)	Bl(cm)	Nt(cm)	Pu
0kg N, 0kg P, 0kg K	19.6ab	4.67a	4.27a	0.99ab	2.00a
25kg N, 25kg P, 25kgK	14.1ab	5.19b	4.59abc	0.88a	3.00abc
25kg N, 25kg P, 50kgK	16.4ab	5.39bcd	4.59abc	0.90b	3.00abc
25kg N, 50kg P, 25kgK	11.68ab	5.65bcd	4.55abc	0.95ab	2.68abc
25kg N, 50kg P, 50kgK	11.4ab	5.46bcd	4.84c	1.05ab	3.00abc
50kg N, 25kgP, 25kgK	15.4ab	5.35bcd	4.75bc	0.96ab	2.33bc
50kg N, 25kgP, 50kgK	10.51ab	5.29bcd	4.32ab	0.94ab	3.33bc
50kg N, 50kgP, 25kgK	11.8ab	5.68bcd	4.63abc	0.95ab	3.33bc
50kg N, 50kgP, 50kgK	6.40a	5.62bcd	4.66abc	0.97ab	3.33bc
100kgN, 25kgP, 25kgK	16.80ab	5.80cd	4.72abc	0.89ab	3.33bc
100kgN, 25kgP, 50kgK	33.9b	5.49bcd	4.59abc	1.01a	3.00abc
100kgN, 50kgP, 25kgK	22.76ab	5.86de	4.83c	0.91ab	3.00abc
100kgN, 50kgP, 50kgK	17.10ab	6.30e	5.28d	1.07b	3.67c
Grand mean	16.0	5.52	4.67	0.96	3
P value	0.67	< .001	0.005	0.33	0.12
Cv (%)	49.5	2.5	0.6	7.2	2.6
SE±	7.92	0.14	0.03	0.069	0.077

Key: Sb= Splitted bulbs, Bd= Bulb diameter, Bl = Bulb length, Nt = Neck thickness,

Pu = Pungency

4.4.2.2 Bulb diameter and bulb length

Bulb diameter and bulb length were not significantly different ($p \leq 0.05$) between the treatments (Table 6). Application of 100:50:50 NPK kg ha^{-1} produced the average bulb diameter of 6.3 cm while application of 50:25:25 NPK kg ha^{-1} produced 5.35 cm bulb diameter. Control treatment produced bulbs of 4.67 cm in diameter. Application of 100:50:50 NPK kg ha^{-1} produced longest bulbs of 5.28 cm while the shortest bulbs (4.32 cm) were recorded from plants treated with 50:25:50 NPK kg ha^{-1}.

The observed responses were probably due to adequate supply of N P and K during the growing period which can be linked with adequate supply of photosynthetic raw material for metabolic processes. Bagali *et al*. (2012) suggested that irrigation and other cultural management practices play an important role in quality and yield of onion crop. A study by Ghaffoor *et al*. (2003) with Shah Alam onion variety provided the best bulb diameter (7.40 cm) at the fertilizer level of 150:100:50 NPK kg ha^{-1}. Also the study by Kumar *et al*. (1998) reported that N at 150 kg ha^{-1} gave the best results with regard to bulb diameter and bulb length.

4.4.2.3 Pungency

Result in Table 6 show that the level of pungency among treatments was significantly different ($P \leq 0.05$). Recorded level of pungency showed that plants treated with 25:25:25 NPK kg ha^{-1} gave similar pungency of (3) with plants treated with 25:25:50 NPK kg ha^{-1} gave (3) but differ with plants treated with 50:25:50 NPK kg ha^{-1}, 50:50:50 NPK kg ha^{-1} gave (3.33) and plants treated with 50:25:25 NPK kg ha^{-1} gave pungency of (2.33).

The observed responses were probably due to a combination of similar level of nutrients such as N and P or P and K that was resulted to significant different level of pungency since one each another can enterrupt the uptake of another nutrient. Nutrient K stands out as a cation having the strongest influence on quality altributes. However many environmental factors often limit adequate up take of K from the soil with K requirement during development to optimize quality (Islam *et al.*, 2007). Salo *et al.* (2000) suggested that two or more element working together to create an overall improved physiological state in plant while excess of the one can reduce or improve the uptake of another. Added that, thus interactions depend on soil type, physiological properties, genetic, ambient temperature, moisture availability and proportion of participating nutrients.

The study by Ashraf (2014) indicated that most pungent onions were produced during wet season and high growing temperatures. However, Islam *et al*. (2007) observed that adequate soil moisture can contribute to lower dry matter content, diluting concentrations of flavour precursors and resulting in milder onions. The study by Poornima (2007) reported that sulphur application at 30 kg ha^{-1} significantly increased onion pungency.

4.4.3 Amaranth

4.4.3.1 Dry matter contents

The amaranth dry matter content was significantly different ($p \leq 0.05$) among the treatments (Table 7). Treatment with 200:60:60 N PK kg ha^{-1} produced the highest dry matter yield of 14.18 g compared to application of 85:30:60 NPK kg ha^{-1} which produced the lowest (9.21g). Application of 200:30:30 kg ha^{-1} gave 11.25 g of dry matter weight whereas application of 170:60:60 NPK kg ha^{-1} gave 17.81 g compared to 7.2 g which was produced from control.

The finding suggests that the observed responses were largely due to applications of NPK. Alonge *et al.* (2007) revealed that different N fertilizer levels result to different increase dry matter content since amaranth require adequate N supply to promote vegetative growth. Rubatzzky and Yamaguchi (1996); Adekayode and Ogunkoya (2011). observed that phosphorus nutrients contribute to earlier crop maturity and thus improvement in crop quality. Afzal *et al*. (2015) reported that potassium helps to improve both the uptake of nitrogen from the soil and amino acid synthesis.

Table 7: Effect of NPK fertilizer rates on amaranth quality

NPK rates	**Dm(gm)**
0kg N0kg P, 0kg K	6.45a
85kg N, 30kg P, 30kg K	14.05bc
85Kkg N, 30kg P, 60kg K	9.21ab
85kg N, 60 kg P, 30kgK	16.22bc
85kg N, 60kg P, 60kg K	12.72abc
170kg N, 30kg P, 30kg K	14.99bc
170kg N, 30kg P, 60kg K	13.36bc
170kg N, 60kg P, 30kg K	13.87bc
170kg N, 60kg P, 60kg K	17.81c
200kg N, 30kg P, 30kg K	11.25abc
200kg N, 30kg P, 60kg K	14.4bc
200kg N, 60kg P, 30kg k	13.99bc
200kg N, 60kg P, 60kg K	14.18bc
Grand mean	13.27
P value	0.086
Cv(%)	4.9
SE ±	0.64

Key: Dm=Dry matter

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Soils at the study site are dominated by sand clay, characterized by low organic matter as well as a low fertility status with respect to N and P. The results indicated that the soil pH was 6.94 which is medium. This implies that there were nitrogen, phosphorus deficiencies and therefore, requires frequent N and P supplementation either from inorganic or organic fertilizers.

The study indicated that application of Nitrogen, Phosphorus, and Potassium affected the growth and development of the three test crops. Application from 0 NPK kg ha^{-1} to 45:140:150 NPK kg ha^{-1}, 50:50:25 NPK kg ha^{-1} and 200:60:30 NPK kg ha^{-1} for tomato, onion and amaranth gave varying responses ranging from minimum to the optimum for the analysed variables.

It can be concluded that NPK levels of 45:140:150 NPK kg ha^{-1}, 50:50:25 NPK kg ha^{-1} and 200:60:30 NPK kg ha^{-1} can be recommended as agronomic optimum levels for tomato, onion and amaranth respectively in the experimental soil and others with similar characteristics.

5.2 Recommendations

i. Evaluation of soil fertility status to other potential vegetable growing areas should be done to know the situation of their nutrient contents.

ii. Since the trial was conducted for one season on one soil type using three vegetable crops, it is recommended that this study be carried out for at least two more seasons in different locations within Morogoro region.

iii. Since this study utilized only inorganic fertilizers, it is recommended that future studies should also focus on the use of organic sources such as animal manure, green manure and compost.

iv. The extent of application of fertilizers (inorganic and organic) is still very low for small-scale farmers in Tanzania. More efforts should be directed to sensitizing these farmers on fertilizer use and management.

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APPENDICES

Appendix 1: Rainfall distribution during the experimental period

Month	Week 1	Week 2	Week 3	Week 4	Total
December	0.0	8.4	6.5	14.9	29.8
January	0.0	15.5	16.4	0.7	32.6
February	0.0	0.0	20.8	22.8	43.6
March	7.8	32.1	61.55	16.5	117.9
April	38.0	44.9	76.8	109.0	268.7
May	71.5	76.5	19.0	7.6	174.6

Appendix 2: Mean monthly temperature during the experimental period

Temperature	Dec	Jan	Feb	Mar	Apr	May
Mean max temperature	33.6	32.9	32.1	31.3	29.5	27.9
Mean min temperature	22.7	22.7	21.6	21.1	21.2	20.4
Mean temperature	28.15	27.25	26.2	25.35	24.15	48.3

Appendix 3: Researchable vegetables production trends 2008/9 - 20112/13 (KGS)

Year	Tomato	Cabbage	Onion	Amaranths	Chinese cabbagge	Okra	Carrot	Green peas	Swiss chard	Egg plant	Sweet pepper	Green beans
2008/09	664 773	369 009	150 718	29 769	8 172	995	4 679	4513	767	5 576	6 937	6 984
2009/10	739 251	389 544	150 600	32 132	9 129	1102	5 109	4 990	795	6 086	7 473	7 775
2010/11	813 729	412 080	150 484	34 495	10 085	1210	5538	5 467	824	6 595	8 010	8 526
2011/12	888 207	434 616	150 367	36 858	11 042	1318	5 967	5 944	852	7 105	8 547	9297
2012/13	962 684	457 151	150 249	39 220	11 999	1425	6 397	6 421	880	7 615	9 083	10 068

Source: MALF (2016)