EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON GROWTH, YIELD AND QUALITY OF AMARANTHS IN KIAMBU COUNTY, KENYA

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DECLARATION

Declaration by Student

I declare that this research thesis is my original work and has not been presented for a degree in any other university or for any other award.

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Signed: ………………………   Date: ……………………………

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Supervisors

We confirm that the work reported in this thesis was carried out by the candidate under our supervision and has been submitted with our approval as university supervisors

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DEDICATION

To my husband and mother for the moral, spiritual and financial support they gave to me as I pursued this course. To my children for their prayers and confidence in me, you are a gift from God.

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LIST OF ABBREVIATIONS AND ACRONYMS

AAS: Atomic Absorption Spectrometer

AIDS: Acquired Immuno-Deficiency Syndrome

ANOVA: Analysis of Variance

CCB: Carbon Content of Blank

CCS: Carbon Content of Sample

CEC: Cation Exchange Capacity

DAP: Di-Ammonium Phosphate

DW: Dry Weight

Ha: Hectare

HIV: Human Immuno-Deficiency Virus

LAI: Leaf Area Index

LSD: Least Significant Difference

MC: Moisture Content

NPK: Nitrogen Phosphorous and Potassium

pH: Potential of Hydrogen

ppm: Parts Per Million

RCBD: Randomized Complete Block Design

SAS: Statistical Analyses System

T/ha: Tonnes per Hectare

ABSTRACT

An experiment was carried out for two seasons in Kiambu County to investigate the influence of organic and inorganic fertilizer on growth, anti-nutrients characteristics in amaranth species and the changes in the soil rhizosphere. This is because continuous usage of inorganic fertilizer affects soil structure. Hence, organic manures can serve as alternative to mineral fertilizers. Application of pesticides and inorganic fertilizers had adverse effects on nutrient leaching, pesticide contamination, species extinction, and evolution of pesticide resistance. The experiment was 2×3×3 factorial arrangement in Randomized Complete Block Design (RCBD) with three replicates. The three factors were: two amaranth species (*A. tricolar* and *A. cruentus);* three NPK 17-17-17 rates (0, 250 kg/ha and 500 kg/ha); and three quail manure rates (0, 8.45 t/ha and 16.9 t/ha). The growth parameters assessed were root length, shoot length, leaf area and biomass of roots and shoot. Macro and micronutrients were also assessed in the plant tissue. The experiment was carried out for two seasons. Pre cropping soil analysis was carried out to assess soil pH, macro and micro-nutrients, analysis was also carried out after application of the fertilizers. Secondary metabolites (phenolics and oxalics) were determined in the two amaranth species. Soluble and total oxalates concentration and Phenolic concentrations were determined. Data was subjected to analyses of variance (ANOVA) at 95% confidence level using SAS computer software version 9.0 model TS1M2. The result showed that macronutrients increased except for phosphorous while the micronutrients and pH increased, nitrogen significantly $p \leq 0.05$ increased in the soil from 0.07% to 2.17%, potassium from 0.9% to 1.34%, the pH increased from 5.2 to 6.2, iron increased from 59.3 ppm to 167 ppm when 250 kg/ha of NPK + 8.45 t/ha of organic quail manure were used at 500 kg/ha +16.9 t/ha calcium increased from 1.7 to 3.93 me% in the second season and manganese from 0.16 me% to 2.61 me%. Sole NPK which is inorganic fertilizer slightly increased magnesium from 0.73 me% to 1.49 me% in the first season and to 1.52 me% in the second season, manganese was raised from 0.16 me% to 0.37 me% in the first season and to 0.46 me% in the second season. Oxalates and phenolic compounds significantly $p \leq 0.05$ increased with the highest recorded at the rate 16.9 t/ha of organic and 500 kg of inorganic fertilizer. The root length was highly significant at $p \leq 0.01$ in the first season but was lower at $p \leq 0.05$ in the second season. Root length reduced from 18.23 cm in season one to 12.86 cm in season two in *A. cruentus* when 16.9 t/ha of organic quail manure was applied at 16.9 t/ha+500 kg/ha in season one *A. cruentus* had 0.625 g of root dry weight which increased to 2.468 g but *A. tricolor* increased to 2.328 g from 0.72 g at the same application rate. There was no significant difference between the two varieties in absorption and assimilation of organic and inorganic fertilizer. Enhancement of macro and micronutrients can be linked to presence of cation exchange sites in the organic matter. Acidity also interfered with the microbial activities thus reducing the breakdown of organic matter because as the inorganic fertilizer rate increased the pH reduced. The results showed that a balanced use of organic manure and inorganic fertilizer at the rate of 250 kg/ha of NPK + 8.45 t/ha of quail manure should be applied to enhance macro and micronutrients and pH in the soil as well as the growth of amaranth.

CHAPTER ONE: INTRODUCTION

1.1 Background information

There are major developments that have been made since the agrarian revolution. Chamberlain *et al.* (2001) noted that, since 1945 after the Second World War, application of pesticides and inorganic fertilizers to increase agricultural productivity had effects on the flora and fauna. Chamberlain *et al.* (2001) stated that non-cropping habitats (e.g. island habitat, ditches) have been erased, and fields have become larger. French-Constant *et al*. (2000) argues that agricultural practises and landscape changes have had adverse effects on nutrient leaching, pesticide contamination, species extinction, and evolution of pesticide resistance because of continuous use of pesticides. In an Alabama study measuring the separate and combined effects of irrigation, organic materials, and fertilizer rates, there was an increase in the average yield of 11 vegetable crops by 2,752 pounds per acre by irrigation, organic material by 4,987 pounds, and higher fertilizer rates by 3,127 pounds (Johannessen *et al.*, 2004).

The Kenyan economy depends highly on agriculture which contributes to 25% of the Gross Domestic Product (GDP) and 75% of industrial raw materials (MOA, 2013). The agricultural sector comprises the following subsectors, forestry, fisheries, livestock, food crops, horticulture and industrial crops. Fertilizers supplement plants with vital nutrients for optimal, healthy growth. Fertilizers can be organic or inorganic, inorganic fertilizer can come in single nutrient or multi-nutrient formula containing macro or macro nutrients (Silva *et al.*, 2011). The amount of nitrogen, phosphorous or potassium is indicated by three number on the package like 17-17-17 which is a compound fertilizer that is balanced. Animal manures have been used for plant production effectively for centuries

(Eghball *et al*., 2002). Chicken manure has long been recognized as perhaps the most desirable of these natural fertilizers because of its high nitrogen content of about 0.9% to 1.5% (Eliot, 2005). In addition, manures supply other nutrients and serve as soil amendments by adding organic matter (Dauda *et al.,* 2008). Organic matter persistence in soil varies with temperature, drainage, rainfall and other environmental factors (Eigenberg *et al.*, 2002). Arisha and Bradisi (1999) argued that organic matter in soil improves moisture and nutrient retention and soil physical properties. The utilization of manure is an integral part of sustainable agriculture.

Poultry manure is often produced in areas where it is needed for pastures and crop fertilization. The increased poultry operations make poultry manure available in sufficient quantities and on timely basis to supply most crop nutrition amendment (Eliot, 2005). When properly applied, poultry manure can be a valuable resource for grass, small grains and other crops Tindall (1975). The economics of using poultry manure varies considerably (Tijani-Eniola *et al*., 2000). Poultry litter is made out of raw poultry manure and bedding materials such as saw dust, wood shavings, grass cuttings, banana leaves or rice husks (Ojenini *et al.,* 2009). These combinations provide an excellent source of nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) (Savant and Stangel, 1990). There is some disagreement over the value of animal manures in crop production (Johannessen *et al*., 2004). Organic matter content of the soil offers the best index of the productivity and value of agricultural land (Johannessen *et al.,* 2004).

Amaranth is a popular leafy crop grown and consumed in many parts of the world. It is a highly nutritious food rich in protein, vitamins, carbohydrates and mineral salts (Singhal and Kulkarni, 1988). The leaves, shoots and tender stems are eaten as a potherb in sauces or soups, cooked with other vegetables, with a main dish or by itself. The seed or grain is also edible (Berkelaar and Alemu, 2006). Chopped plants have been used as forage for livestock. It was reported through the ECHO network that goats fed amaranth forage consistently bore twins and, the flowers make nice ornamentals, fresh or dried. Amaranth leaves and stems, or entire plants may be eaten raw or cooked as spinach or greens (Gupta, 2005).

1.2 Statement of the Problem

Macronutrients are the most limiting nutrients in our soils due to continuous cropping (Savant and Stangel, 1990). Increased use of inorganic fertilizers, deteriorate the physical properties of the soil (Ogungbile and Olukosi, 1990). Some of the inorganic fertilisers are volatile and others leach to lower horizons where roots cannot reach them, Aisha *et al*. (2007). The quality and quantity of Amaranth is low, growth and development rate is also low in amaranth, this limitation require quick intervention because high quality and quantitative yield of crops, including amaranth can be obtained by incorporating organic manure (Okalebo, 2002). Amaranth species are extensively cultivated; and due to their early maturity and ability to survive when grown with other arable crops, it is an excellent food security crop and a source of income yet it is not intensively cultivated in Kenya (Okalebo, 2005). As a highly nutritious food source, amaranth is one of the vegetables that have diverse uses and is particularly rich in vitamin A and C, iron, potassium, phosphorous, calcium and lysine (Gupta, 2005). Due to its many nutritive attributes, patients conditions like cancer, arthritis and HIV-AIDS are advised to consume the amaranth vegetable (Abukutsa-Onyango, 2005).

Amaranth production is increasing through intensification by researchers but the production is still low (Savant and Stangel, 1990). Aisha *et al.* (2007) showed that inorganic fertilizers generate several deleterious effects to the environment and human health. They argued that inorganic fertilizers should be replenished every cultivation season because, the synthetic compounds of N, P and K fertilizer is rapidly lost by either evaporation or by leaching in drainage water and leads to dangerous environmental pollution. Continuous usage of organic fertilizer affects soil structure because it causes soil to clump, forming soil aggregate thus improving the soil structure, organic manure decompose to form humus which binds soil particles together thus improving the soil structure and its physical properties (Ogungbile and Olukosi, 1990). Hence, organic manures can serve as alternative to mineral fertilizers as reported by Naeem *et al*. (2006) for improving soil structure (Dauda *et al.*, 2008). With the introduction of quail farming in Kenya and other countries including China, this study seeks to determine the effect of quail manure and NPK fertilizer on quantitative and qualitative aspects on Amaranth species and come up with proper quail manure rate for increasing Amaranth productivity.

1.3 General objective

The overall objective of this study was to enhance growth, yield, and nutritional value of amaranth through integration of organic quail manure.

1.3.1 Specific objectives

The specific objectives of this study were;

i. To determine the influence of organic and inorganic fertilizer on the growth, development and yield of two *Amaranthus species.*

ii. To evaluate the effect of organic and inorganic fertilizer on the vitamins, micronutrients, macronutrients and anti-nutrients of two *Amaranthus species*.

iii. To establish the effect of organic and inorganic fertilizer on the chemical and physical properties of the soil rhizosphere.

1.4 Research hypotheses

i. Organic and inorganic fertilizers affect the leaf growth, development and yield of *Amaranthus s*pecies.

ii. Organic and inorganic fertilizers affect the quality and anti-nutritive quality of two *Amaranthus species.*

iii. Organic and inorganic fertilizers significantly affect the soil rhizosphere chemical and physical properties.

1.5 Justification

Nitrogen (N), phosphorous (P) and potassium (K) are most limiting nutrients in Kenyan soils due to various factors like acidity, continuous cropping and continuous broadcasting of NPK where 60% is lost through volatilisation (Savant and Stangel, 1990). Amaranth production is increasing through intensification by researchers but the production is still low, Increase in use of inorganic fertilizer calls for a quick intervention because sustainable yield of 40 tonnes can be obtained by integrating organic manure (Abukutsa-Onyango, 2005). Quail manure in comparison with other organic manure should be more preferred because it has most essential nutrients in high quantities and thus very little quantities are required to provide the essential nutrients (Waldrip *et al.*, 2011). Its use enhances growth, development, yield and quality of Amaranth (Aisha *et al*., 2007).

It is very light in weight and very rich in nutrients unlike other organic manures, so transportation is very easy (Waldrip *et al.*, 2011). Its use in the long run improves nutrients holding capacity, and this lowers capital investment because much less inorganic fertilizer will be required. It is a fast composting manure because it takes two to three month unlike others that take to 6 months and this reduces volatilization rate (Aisha *et al*., 2007). This study sought to underscore the effects of using organic and inorganic manure on amaranthus species.

1.6 Significance of the study

The study was fundamental in providing scientific facts on effect of quail manure on overall Amaranth production. The research developed appropriate recommendations for the quail manure rates, which is 250 kg/ha per hectare to be applied by the farmers thus increasing amaranth production. The results study can act as a basis for advising farmers on use of the orphaned vegetable that is high yielding, high nutritive and matures within a short time. By carrying out this study, it may end up as a source of knowledge on the effects of organic and inorganic manure on overall crop production. This will also assist Amaranth production farmers on efficient production of Amaranth using organic quail manure.

1.7 Conceptual Frame Work

A conceptual frame work is used to classify the research variables, the variables are Amaranthus spp, NPK as inorganic fertilizer, quail manure as organic fertilizer (Figure 1.1). Amaranth production in the country is still very low and the cause leading to low production is continuous use of inorganic fertilizers which leach very fast due to its high solubility.

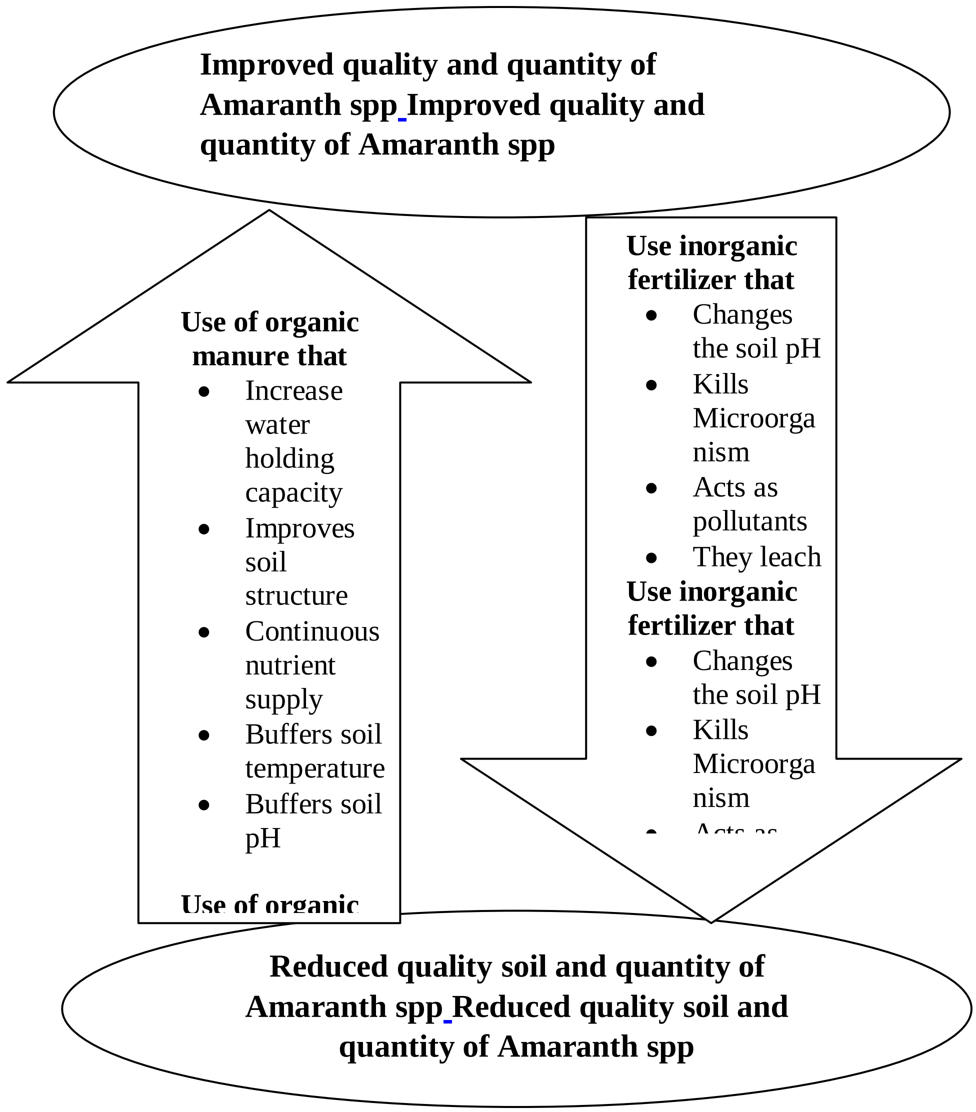

Figure 1.1 Conceptual Frame work

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

In this modern age individuals are becoming more and more aware of the effect that inorganic crop production has adverse effects on the environment, hence they are taking crucial measures to mitigate these environmental effects. Manure is an environmentally safe way to ensure enrichment of the soil with nutrients required for crops production (Eghball *et al.,* 2002). In many agricultural systems, management of the nutrient system is very crucial and there ought to be a balance between the import as well as the export of nutrients within the system (Dauda *et al*., 2008). Manure plays a positive role in the nutrient balance as it ensures minimal loss of nutrients in the system. It is also an important way of nutrient cycling since the large fraction of nutrient from the manure is taken up by crops (Schroder, 2005).

2.2 Origin, Habit and Distribution of Amaranth.

Amaranth is the collective name for the genus Amaranthus. Centeotl (2002) concluded that Amaranthus is one of the oldest food crops in the world having been cultivated from early as 6000 years in Mexico. O'Brien and Prince (2008) however argue that Amaranthus dates back over 8,000 years during the Mayan civilization in South and Central America, Amaranthus was a staple food for Aztecs and was deeply incorporated into Aztecs religious ceremonies. In 1500, Amaranthus plant was prohibited in Spain due to unknown reasons and continues to grow in Spain as a wildflower; used in making "Alegria", a confectionary of honey mixed with chopped Amaranthus (Mlakar *et al*., 2009). Srivastava (2011) indicated that this genus has received considerable attention in many countries due to its high nutritional value and therefore as an important source of food in grain or vegetable form.

National Research Council of Washington in 1984 reported that the Amaranthus species produces edible leaves in two weeks and therefore makes it one of the most productive vegetable crops in the world. Wambugu and Muthamina, (2009) indicated that Amaranthus is one of the most adaptable and cheap vegetables to produce. Its adaptability makes it a very good plant to establish for food security purposes in Africa. Jacob (2005) reported that the crop is drought tolerant and matures in 45-75 days. Amaranths are tall plants measuring 0.5 to 2 m and moderately branched from their main stems (Williams and Brenner, 1995). Amaranth grain type forms large loose panicles at the tips of the stems. Vegetable types form flowers and seeds along the stems. Root morphology, growth, development and distribution in the soil, as well as responses to availability of nutrients and water have been barely investigated in amaranths (Mlakar *et al.* 2009) and observations show that Amaranth root system without competition develops rapidly, reaching nearly its maximum extent (2.4 m depth and 1.8 m spread). The stem of Amaranths normally measures from 0.5 to 3.5 m in height depending on species, genotype and growth conditions, but mainly on plant density (Mlankar *et al*., 2009).

Amaranth leaves develop into various shapes; key being elliptic, rhombic, ovate, lanceolate or rhombate-ovate, with acute, obtuse or acuminate leaf tips, of green, red or silver colour (Centeotl., 2002). Because of anthocyanin (amaranthine) coloration, entirely red plants and plants with reddish or silver spots on the leaves also exist (Williams and Brenner, 1995). Inflorescence can be of various colours: yellow, green, purple, orange, pink, violet, brown and two-colored inflorescence (Williams and Brenner, 1995).

Amaranth is a monoecious plant. The first flower in each glomerulus is staminate (male) while the following are all pistillate (female). The crop is mainly anemophilus, up to 90 % pollination occurs on the same crop, but in some genotypes and circumstances the rate of cross-pollination can increase up to 30% (Muriuki *et al.*, 2014).

2.3 Nutritive significance of Amaranth

Amaranths are some of the traditional vegetative plants known for having highly nutritious components both for animal and human consumption. Tucker (1986) noted that the nutritional value of the Amaranths varies with species. Mnikeni *et al.* (2007) reported that Amaranthus cooked grains contained equivalent of 8.8% to 19.5% protein and is also high in lysine and sulphur-containing amino acids not common in plants. Centeotl (2002) showed that the fibre content in the Amaranth seeds is three times that of wheat and its iron content is five times more than wheat, while Dhellot *et al.* (2006) found out that the oil from the Amaranth seeds (5 to 10%) is predominantly unsaturated and is high in linoleic acid and rich in squalene, its grain consists of 6 to 10% of oil, which is higher than most other cereals (Whelton, 1997). Amaranth oil contains approximately 77% polyunsaturated fatty acids which are mostly within the germ (Whelton, 1997). Amaranth oil has been found to be predominantly unsaturated oil; high in linoleic acid necessary for human nutrition (Gupta, 2005). Yanez *et al*. (1994) noted that oil extracted from *Amaranthus cruentus* contained around 19% palmitic acid, 3.4% stearic acid, 34% oleic acid, 33% linoleic acid while docosaenoic acid (C22: 1) was present at the level of 9%. The ratio of saturated to unsaturated fatty acids was approximately 1:3. The lipid fraction is unique due to such high biologically active compounds, such as: squalene (up to 8%), tocopherols (to 2%), phospholipids (to 10%), and phytosterols (to 2%) (Yanez et *al*., 1994).

2.4 Fertilizer amendment on Amaranth Plant Growth

Manure has numerous benefits; it acts as a great modification to the soil as it provides nutrients that are essential in the growth of crops. In addition, it is able to improve the various aspects of the soil such as soil structure due to the high content of organic matter, Ogungbile and Olukosi (1990). It is an excellent fertilizer that contains phosphorus, nitrogen, potassium as well as other nutrients (Yanez *et al*., 1994). In order for plants to grow, various nutrients have their roles to play in the various parts of a plant (Eghball *et al*., 2002). However, manure obtained from birds may consist of wasted feed, broken eggs, feather and at times sawdust. In addition, it includes dead birds as well as hatchery that go a long way to enriching the manure (Pezzolla *et al*., 2013). There are a number of factors that affect the quality of the manure such as the age of the birds, storage of the manure, litter as well as the type of feed give to the birds (Eghball *et al*., 2002). Storage of the manure is very critical, as it is a major factor that affects the quality of the manure. Open storage of the manure causes ammonia gas as well as nitrates to be lost through volatilization; also, it may cause leaching of potassium, especially during a heavy down pour, Aisha *et al*. (2007). Therefore, it is important to store manure in an enclosed area to ensure retention of all its nutrients, hence, availing nutrients to the plant after application of the manure (Eghball *et al*., 2002).

With the growth and expansion of the agrarian revolution, farmers have continued to use inorganic manure to increase crop yield. Ogungbile and Olukosi (1990) noted that vegetable farmers mostly apply poultry manure in combination with inorganic nitrogen-based fertilizers such as urea and NPK, since farmers hold that organic manure dissolves slowly and might not meet their expected yields. Ainika *et al*. (2012) pointed out that there was a significant difference in the quality and yield of vegetative crops when inorganic manure was applied in farming. Kipkosgei *et al*. (2002) noted that the effect of farmyard manure and nitrogen fertilizer on vegetative growth, leaf yield and quality attributes of *Solanum villosum (*Black nightshade) in Keiyo district Kenya was substantial. They noted that the addition of various rates of organic and inorganic fertilizers that were tested significantly improved vegetative growth and increased leaf yields of black nightshade. In rural areas, farmers spend greater proportion of capital in purchasing inorganic fertilizers, they have also been observed to apply excessive inorganic fertilizers due to the collapse of farmers' extension services in rural areas, this excessive application was notably in vegetative and fruit plants where farmers believe the more they apply the inorganic fertilizer the higher the yields (Stewart *et al*., 2005).

Aisha *et al*. (2007) also indicated that inorganic fertilizers generate several deleterious effects to the environment and human health, they argued that inorganic fertilizers should be replenished in every season because, the synthetic compounds of N, P and K fertilizer is rapidly lost by either evaporation or by leaching in drainage water and leads to dangerous environmental pollution. Hence, organic manures can serve as alternative to mineral fertilizers as reported by Naeem *et al*. (2006) for improving soil structure because organic manure decompose to form humus which binds the soil particles together (Dauda *et al*., 2008).

2.4.1 Composition of Poultry manure

Individuals commonly refer to poultry manure as chicken/guano manure which largely comprises of carbohydrates, lipids and fats. The carbohydrate component is the one responsible for the biodegradable material in the manure that includes sugars, starch as well as cellulose (Ali, 2005). The poultry manure is usually a free flowing material after its removal from the shed and it constitutes of some larger particles (Waldrip *et al.*, 2011). Mariakulandai and Manickam (1975) noted that the chemical composition of poultry manure varied with factors such as source of manure, feed of the birds, age and condition of the birds, storage, handling of manure, and litter used, they observed that poultry waste consists of droppings, wasted feed, broken eggs, feathers, and sometimes sawdust from poultry floor. It also includes the dead birds and hatchery waste, all of which are high in protein and contain substantial amount of calcium and phosphorus due to high level of mineral supplement in their diet, this was noted by Ali (2005) who also concluded that poultry manure contains various nutrients that are dilute solutions similar to that found in the soil in the form of moisture films around soil particles. These nutrients are categorized into macronutrients as well as micronutrients. Macronutrients are the major nutrients found in the soil and the plants require them in large quantities for instance; hydrogen, oxygen, carbon, nitrogen, phosphorus, potassium, magnesium, calcium as well as sulphur. On the other hand micronutrients are known as trace elements the plant only require in small quantities. However, they are very critical for the growth as well as development of crops. Micronutrients consist of the following elements; iron, zinc, manganese, copper, boron, chlorine, molybdenum (Waldrip *et al.*, 2011).

2.4.2 Qualitative Influence of Poultry manure on nutrients and plants

Poultry manure contains nitrogen that is very essential for the growth of leaves, as it enhances vegetative growth which is very crucial, especially in plants where leaves are the source of food, for instance in case of cabbages and kales, Okokoh *et al*. (2011), it is a nutrient essential in the formation of the chlorophyll molecule, giving the leaf its deep green color. As chlorophyll increases, the rate of photosynthesis increases, hence the food is available to plants making it to have a high growth rate that consequently increases the leaf size of the plant (Eghball *et al*., 2002). Potassium is essential for carbohydrates formation that occurs in the leaves of plant through photosynthesis; consequently increasing the leaf size (Pezzolla *et al*., 2013). It is also an important element as it aids in translocation of carbohydrates to the root area ensuring that the diameter of the root increases. Calcium is an element that encourages the increase in the diameter of the root as it is a critical requirement in the cell division process (Waldrip *et al*., 2011). Calcium is a very important nutrient element as it stabilizes the soil pH making nutrient such as nitrogen, potassium and phosphorus available to plants. Calcium is a crucial element in cell division that leads to increase in root length (Pezzolla *et al*., 2013). It is responsible for strengthening cell wall in the plant cells with calcium acetate; it is also required for the formation of the middle lamellae of the leaf as well as for increasing the protein content in the mitochondria to enhance metabolic processes Raja (2001). Therefore, calcium is responsible for the development of the leaf that translates to increase in the leaf size (Pezzolla *et al*., 2013).

Carbon, hydrogen as well as oxygen are the raw materials for photosynthesis where the leaves of plant are able to manufacture carbohydrates in the process of chlorophyll as well as sunlight this consequently leads to growth hence increase in the leaf size of plants (Pezzolla *et al*., 2013). Poultry manure contains phosphorus that is critical for development of roots, as phosphorus increases the length of the root consequently increases. Root elongation is due to enhanced cell division as phosphorus is an important constituent of the nucleoproteins responsible for cell division (Waldrip *et al*., 2011). Phosphorus enhances metabolic process such as respiration, synthesis of carbohydrates, protein as well as fat formation, brings about increase in the root's dry matter (Wardrip *et al*., 2011).

Magnesium is also an essential element required in the formation of the chlorophyll molecule that is critical for the growth of leaves as well as the whole plant since it is responsible for carbohydrate metabolism (Pezzolla *et al*., 2013). Magnesium ensures that carbohydrates are metabolized after which these foods undergo translocation to roots where they are stored increasing the diameter of the root. Magnesium plays a great role in the metabolism of carbohydrates that enhance growth consequently increasing the root length of plants (Pezzolla *et al*., 2013). Poultry manure also contains potassium that is an essential element in the formation of chlorophyll. Potassium in poultry manure is critical as it aids in translocation of carbohydrates from the leaves to the various parts of the plant as required by the plant this consequently leads to increase in the length of the root. Micronutrients such as copper, molybdenum and iron are crucial in enzymatic systems responsible for oxidation as well as reduction chemical reactions in plants. Copper is a nutrient element that is crucial the respiration process in addition, it aids in the utilization of iron. Iron on the other hand is responsible for synthesis of chloroplast that is an essential in the leaves of plants. Molybdenum as well as manganese is critical for specific nitrogen transformation in plants. In addition, molybdenum an element that is required for nitrogen fixation, it required to metabolize amino acids as well as proteins from nitrates (Sjorberget *et al*., 1994). All these micronutrients are critical in ensuring increase of the leaf size (Pinheiro *et al*., 2014).

Poultry manure is crucial to the root of a plant especially in regards to its size. Sulphur is an element essential to the plant that influences the physiological process of plants for instance chlorophyll formation as well as carbohydrate metabolism that are critical for increasing the leaf size of the plant (Pezzolla *et al*., 2013). Sulphur is available to plant in form of sulphate ion that enable uptake of this element by the roots. It plays a major role in the formation of plant proteins as well as plant hormones. It is also responsible for the activation of coenzymes, which are critical in the undertaking of growth and development of a plant that leads to increase in root length (Pezzolla *et al*., 2013). Zinc is a micronutrient that is responsible for the formation of particular growth hormones of the plant, this growth hormone responsible for bringing about increase in the root length as the plant undergoes growth and development (Pinheiro *et al*., 2014). Growth and development brought about by the various physiological processes that sulphur elements influence consequently leads to increase in the girth of the root. Poultry manure also contains micronutrient responsible for the increase in the root diameter, boron is a nutrient involved in water absorption as well as translocation of sugar in plants consequently increasing the root diameter (Pinheiro *et al*., 2014).

Quail and poultry/guano manure have various similarities; one obvious similarity is that these manures come from domesticated birds. Manure from quail or poultry are readily available since these birds are popular with many farmers. Quail as well as poultry manure is relatively cheap in comparison with the wide range of commercial fertilizers found in the market. Manure produce from birds are environmental friendly since they consists of biodegradable materials. In addition, manure from domesticated birds contains various macro-organisms as well micro-organisms that are responsible for stabilization of the soil ecosystem and increasing soil biodiversity (Schroder, 2005). The Quail as well as poultry manure are very similar to the way they affect the soil which in turn affects the availability of nutrients to plants. One of the commonality of these two types of manures is that they are highly rich in nutrients such as nitrogen, phosphorus as well as potassium. Therefore, quail and poultry manure is critical in ensuring nutrient elements are readily available to plants ensuring that they grow in a healthy manner (Pinheiro *et al*., 2014). The nitrogen in these manures is in two forms as uric acid, which represents 70% of the total nitrogen as well as undigested protein that constitute 30% of the total nitrogen (Okokoh *et al*., 2011). In aerobic conditions, the undigested proteins as well as the uric acid undergo chemical processes where they are broken down into ammonia (Waldrip *et al*., 2011).

The degradation of undigested proteins and uric acid to ammonia is very fast by the aid of microorganisms that are fundamental in determining the conversion rate. On application of ammonia to the land, it then undergoes conversion and becomes nitrates that are the form readily available to plants. However, in anaerobic disintegration rate of the uric acid as well as the undigested proteins are slower, hence, most of the nitrogen is in ammonia form. At the time when the manure is in storage, 50-90% of the nitrogen is in the form of ammonia (Eghball *et al*., 2002).

Phosphorus undergoes various processes once it is in the soil as it reacts with iron as well as aluminum to form iron phosphates and aluminum phosphates respectively, in a situation where the soil is acidic (Silva *et al*., 2011). In addition, in alkaline soils phosphorus reacts with calcium to form phosphates of calcium that are insoluble. Phosphorus fixation results occur when phosphorus reacts with calcium, aluminum and iron. This is a problematic issue as a lot of the phosphorus applied into the soil is not available to plants (Mariakulandai *et al*., 1975). Quail manure as well as poultry manure is very important as it regulates the soil pH to ensure that phosphorus is available to plants. Plants absorb phosphorus in the soil in solution form as orthophosphate ions (HPO_4^-) as well as lesser amounts of orthophosphate anions. Phosphorus can only occur in solution form under normal pH conditions (Silva *et al*., 2011).

Phosphorus usually undergoes a wide distribution within the soil making it difficult for plant to obtain the nutrient element within the root zones. It is very crucial that the replenishment using poultry or quail manure ought to be close to the plants as possible to enable the roots to be able to uptake the phosphorus (Waldrip *et al*., 2011). Potassium is an important nutrient that enhances adaptation of plants to stresses, for instance drought conditions as well as colder temperatures. In some instances, potassium enhances water uptake in addition to speeding up a plants biological systems, and plant uptakes potassium in form of potassium ions (K^+). The potassium ions are adsorbed onto organic colloids as well as clay particles as exchangeable potassium. Quail and poultry manure enhances potassium availability to plant since most of the potassium in the soil is in a form that plant cannot be readily utilized (Schroder, 2005).

Quail and poultry manure is critical in combating soil acidity as the manure increases the pH of the soil after application. Quail and poultry manure increases Cation Exchange Capacity (CEC) as well as improves the soil structure hence, enhances water retention capability as well as aeration of the soil. In addition, Cation Exchange Capacity enables exchangeable ions such as magnesium, potassium as well as calcium to be readily available to plants. Furthermore, the cations adsorbed into the exchange sites tend to be more resistant towards leaching or even gravitational movement of soil (Schroder, 2005). However, quail and poultry manure increases the Electrolytic conductivity (EC), and this alteration may lead to salinization of the soil especially, when there is frequent application of organic manure (Schroder, 2005). Increased salinity may cause environmental disruption as it compromises the quality of the water as well as that of the soil. These manures can also bring about pathogens, hence farmer should ensure that handling as well as management of manure to curb pathogenic invasion in the farm (Schroder, 2005). In addition, quail and poultry manure affect soil acidity.

Acidity in soil is a critical problem that affects plants uptake of nutrients. Toxicity from aluminum as well as manganese may cause acidity. Aluminum toxicity causes reduced growth and functionality of roots and it also causes fixing of phosphorus that leads to phosphorus deficiency of plants in addition reduced uptake of essential elements such as magnesium and calcium by plants. On the other hand, manganese toxicity affects growth of crops as it disrupts the process of photosynthesis as well as the normal functioning of plant hormones. Quail manure is more effective in dealing with the issue of acidity than poultry manure (Schroder, 2005). The quantity of carbon in quail manure is higher than of poultry manure where the carbon is responsible for reducing the exchangeable aluminum in soil, consequently producing a liming effect. Therefore, quail manure has a superior liming potential in comparison to poultry manure because adding smaller quantities results to larger increase in the pH of the soil. This means that a farmer will require a larger quantity of poultry manure than quail manure to increase the pH of the soil (Pinheiro *et al.*, 2014).

The three major components are potassium, phosphorus and nitrogen which are higher in quail manure than in the chicken manure; also referred to as poultry manure. This higher nutrient effect is in rice, vegetables as well as other plants. Quail manure also contains a large amount of trace elements. This means that a smaller quantity of quail manure will meet the requirements of crops in comparison with poultry manure (Eghball *et al.*, 2002). Manure use is gaining popularity mainly because it is environmentally safe to use. In addition, it provides nutrients to plants; improves soil structure as well as stabilizing pH. Poultry manure is readily available due to numerous poultry farms. The use of poultry manure is highly beneficial to plants as it is responsible for growth and development of plants. It is responsible for increase in the number of leaves, stem diameter, weight of the plants and pods, leaf size, root length as well as root diameter. The growth is due to the micro and macro-nutrients present in the manure (Kipkosgei *et al.*, 2002).

2.4.3 Quail Manure in relation to other poultry manure

The quail bird has grown in popularity over the years as it grows rapidly, high laying capacity, fertility as well as environmental resistance in comparison to chickens. Quail manure consists of quail droppings, feathers, spilled feed as well as bedding materials. The manure has high organic matter as well as nutrient contents which produce positive effects on the texture of the soil, hence, it is suitable for agricultural soils used for crop growing (Schroder, 2005). Quail manure is beneficial for the growth of plants. Quail manure influences plants positively as it increases the plant height as well as leaf area of plants. Excellent plant height as well as leaf areas are crucial for the process of photosynthesis that eventually affect yield. The manure improves the Cation Exchange Capacity (CEC) as a result avails nutrients in the soil for plant uptake. When plants uptake nutrient there is an increased leaf area as well as the height of plants, In addition, quail manure avails nutrients that are responsible for improving seed quality as well as it increases seed vigour (Pinheiro *et al*., 2014).

CHAPTER THREE: MATERIALS AND METHODS

3.1 The study site

The study was carried at Kenyatta university main campus Department of Agricultural Science and Technology farm. The campus is 20 Km by road from Nairobi the largest city in Kenya along the Nairobi and Thika superhighway (Figure 3.1).

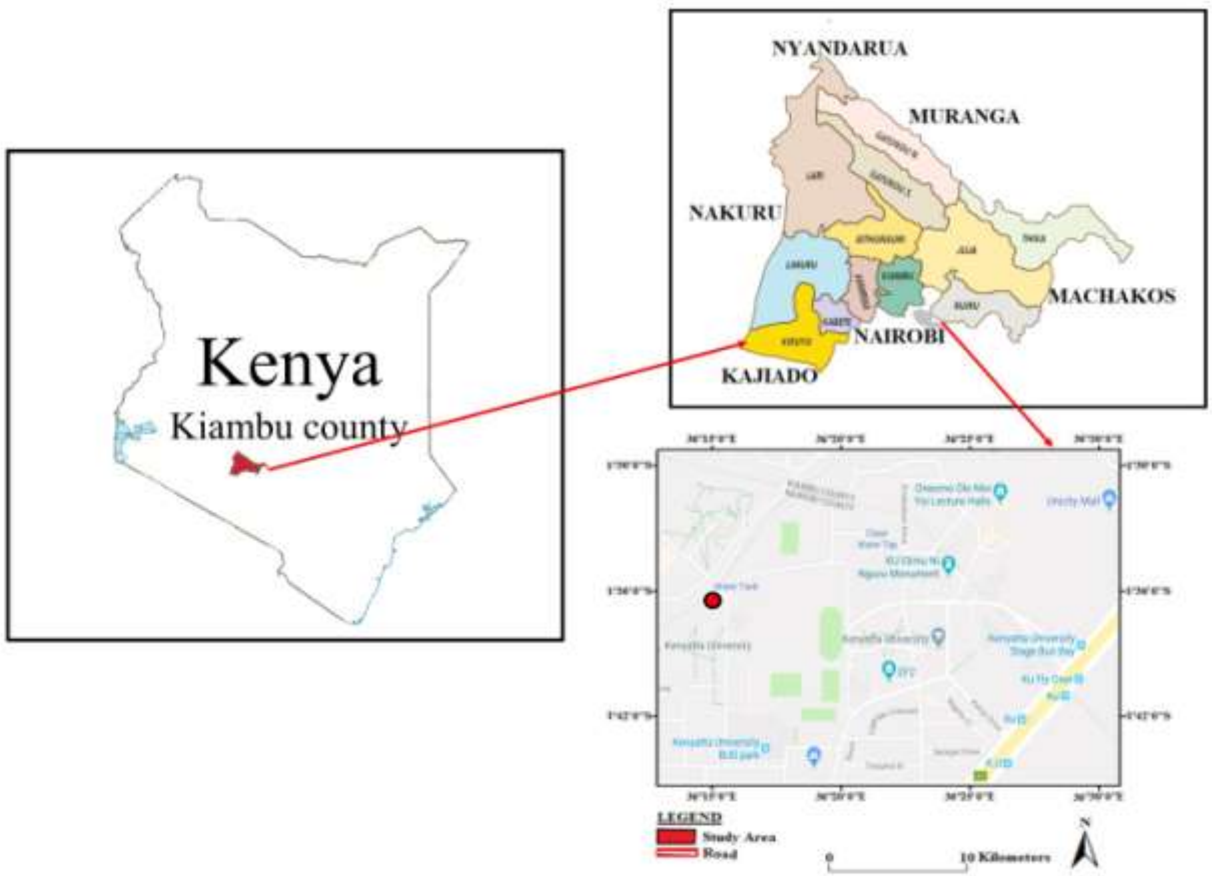

Figure 3.1 Map showing study site

The county has an altitude of 1520-1760 m above sea level. The area had minimum temperatures of 12o C and maximum of 24.6o C. The rainfall range was aggregate 1100 mm with a bimodal distribution during the 2015 year. The long rains were experienced between March to May and the short rains between Octobers to December. The area has dark reddish brown to dark brown loam soil, its total nitrogen was 0.07, total organic carbon 0.74, phosphorous (ppm) 0.74, potassium me% 0.9, calcium was 1.7, magnesium me% 0.7, Manganese me% 0.16, copper (ppm) 15.98, iron (ppm) 59.3, zinc 9.02, Sodium me% 0.16 and pH was 5.2. Kenya has diverse types of soils found in different terrains. The soils are, Andosols which are young volcanic soils that are porous, have high water holding capacity with low pH of 4.5 to 5.0.Nitisols have good soil moisture storage capacity, they are acidic with pH of 5 to 5.5. Acrisols, Alisols, lixisols and luvisols are not porous and have low water holding capacity, Acrisols and Alisols have low pH of 3-4.5, have low levels of nutrients with aluminium and manganese toxicities. Ferrasols are old soils, with low cation exchange capacity, they are deficient in phosphorous and Nitrogen and are rich in Aluminium and iron, and generally they are poorly fertile soils. Planosols and Vertisols are found on flat topography; they have high clay content and are poorly drained.

3.2 The experimental design

The experiment was carried out in a 2×3×3 factorial arrangement in a randomized complete block design (RCBD) with three replications (Table 3.1).

Table 3.1 Treatment combination between NPK and quail manure rates

Levels of NPK	500 kg/ha	0 , 500	8.45, 500	16.9 , 500
	250 kg/ha	0, 250	8.45, 250	16.9 , 250
	0 kg/ha	0, 0	8.45 , 0	16.9, 0
		0 t/ha	8.45 t/ha	16.9 t/ha
	Levels of Quail Manure			

The fertilizers were two, organic quail manure and organic NPK (17-17-17) each was applied at three levels. The organic manure levels were 0, 8.45 t/ha, and 16.9 t/ha whereas the inorganic manure rates were 0, 250 kg/ha and 500 kg/ha. Each level of organic manure was combined with each level of inorganic mineral fertilizer. There were three factors under study quail manure, NPK fertilizer and two amaranth varieties *A. cruentus* and *A. tricolor* (Table 3.2).

Table 3.2 Variety, quail manure rates, NPK fertilizer rates and symbols for treatment combinations

Treatment N^0	Variety	Quail manure	NPK rate	Symbol
1	V1	0	500	V1Q0N2
2	V1	8.45	500	V1Q1N2
3	V1	16.9	500	V1Q2N2
4	V1	0	250	V1Q0N1
5	V1	8.45	250	V1Q1N1
6	V1	16.9	250	V1Q2N1
7	V1	0	0	V1Q0N0
8	V1	8.45	0	VIQ1N0
9	V1	16.9	0	V1Q2N0
10	V2	0	500	V2Q0N2
11	V2	8.45	500	V2Q1N2
12	V2	16.9	500	V2Q2N2
13	V2	0	250	V2Q0N1
14	V2	8.45	250	V2Q1N1
15	V2	16.9	250	V2Q2N1
16	V2	0	0	V2Q0N0
17	V2	8.45	0	V2Q1N0
18	V2	16.9	0	V2Q2N0

KEY: V1 =Variety *A. cruentus*, V2= Variety *A. tricolor*, Q0 =0 t/ha, Q1=8.45 t/ha, Q2 =16.9 t/ha, N0 =0 kg/ha, N1 = 250 kg/ha, N2 =500 kg/ha

3.3 Experimental layout

Experimental area had dimensions of 16 m by 27.5 m (440 m^2) while each block measured 4 m by 27.5 m (110 m^2) individual plots measured 4 mx1 m (4 m^2) individual blocks were spaced 1m apart while the plots within the blocks were separated by 0.5 m. There were three blocks (Table 3.3).

Table 3.3 Field layout

Plot No.	**Block 1**	**Block 2**	**Block 3**
1	V1Q1N2	V2Q2N2	V1Q0N2
2	V2Q0N1	V1Q0N0	V1Q2N0
3	V1Q2N0	V2Q0N2	V2Q1N2
4	V2Q2N1	V1Q1N1	V1Q2N2
5	V1Q1N0	V2Q1N1	V2Q2N0
6	V2Q0N2	V1Q1N2	V2Q0N2
7	V1Q0N0	V1Q1N0	V1Q2N1
8	V2Q0N1	V2Q2N0	V2Q1N0
9	V2Q2N2	V1Q2N2	V1Q0N0
10	V1Q2N2	V2Q1N0	V2Q2N1
11	V2Q1N2	V1Q0N1	V2Q1N1
12	V1Q2N1	V2Q1N2	V1Q0N1
13	V1Q1N1	V1Q2N0	V2Q0N0
14	V2Q1N1	V2Q0N0	V1Q1N1
15	V1Q0N2	V1Q0N2	V2Q2N2
16	V2Q2N0	V2Q2N1	V1Q1N0
17	V1Q0N1	V1Q2N1	V2Q0N1
18	V2Q1N0	V2Q0N1	V1Q1N2

Each of the plots contained 100 plants. Well decomposed quail manure was applied in dry weight at three rates, 0, 8.45 t/ha and 16.9 t/ha, the recommended rate by Akintoye and Olaniyan (2002) and Raja (2001), was 16.9 t/ha. NPK was applied based at the recommended rate of 500 kg/ha of NPK (Abukutsa-Onyango, 2005) at three levels 0, 250 kg/ha and 500 kg/ha.

3.4 Management of the experiment /agronomic practices

The land was cleared one month before sowing. The land was then mechanically ploughed and leveled to create a suitable tilth. The plot units were slightly raised about 25-30 cm high to ensure that inter plot spacing was maintained. The two varieties were sown in a seed nursery well prepared due to their small size and seeds were mixed with soil at a ratio of about one to ten (1.10) to ensure even distribution of seed. Sowing of the seeds was done in November and transplanting was carried out in December 2014 during the long rains. Sowing was carried out in drills measuring 30 cm apart. The seedlings were transplanted to the individual experimental units by use of a garden trowel at an inter row spacing of 30cm and intra spacing of 10 cm apart a giving a plant population of 100 plants per sub-plots. Routine field maintenance practices e.g. weeding was carried out by uprooting the weeds and diseases were controlled by rouging, field hygiene and maintenance of the correct plant population was done, watering was also carried out early in the morning or late in the evening, through overhead irrigation.

3.5 Data Collection

Data collected was soil samples, quail manure, growth parameters and yield.

3.5.1 Soil, quail manure chemical analysis

Quail manure samples were collected and analysed to determine their physical and chemical properties (Table 3.4).

Table 3.4 Chemical composition of quail manure used

Total N %	Total Organic Carbon %	Phosphorus ppm	Potassium me%	pH	Calcium me%	Magnesium me %	Manganese me%	Copper ppm	Iron ppm	Zinc ppm	Sodium me%
4.5	5.3	9.748	1.3	6.4	3.2	0.29	0.089	20	460	900	0.08

Soil samples were collected and analysed to determine their physical and chemical properties (Table 3.5).

Table 3.5 Chemical properties of soil at the experimental site before the experiment

Total N %	Total Organic Carbon %	Phosphorus ppm	Potassium me%	pH	Calcium me%	Magnesium me %	Manganese me%	Copper ppm	Iron ppm	Zinc ppm	Sodium me%
0.07	0.74	6	0.9	5.2	1.7	0.73	0.16	15.98	59.3	9.02	0.16

3.5.2 Soil sampling procedure before application of treatment

The vegetation was cleared. By use of zigzag method the spots were identified where soil was to be collected. Ten random sampling spots were identified. Using soil auger, soil samples at a depth of 20 cm was taken. Unusual areas were avoided like around the paths and under fences. All the composite samples from the identified spots were mixed and dried. The sub samples were weighed to 100 grams for laboratory analyses and put in a clean container (Van reewijk, 1993). After harvesting in the second season, soil samples were collected from a depth of 20 cm from each sub-plot in different spots from each block in order to evaluate the changes of the soil nutrient content that might have taken place within the two seasons. These soil samples were also analyzed for chemical and physical properties.

3.5.3 Solid quail manure sampling procedure

Solid manure was collected from fifteen points in a zigzag manner from the house, samples around watering troughs and feeders were also collected, they were thoroughly mixed in a clean bucket and were spread on a clean concrete surface and mixed further, a sub-sample from the mixed composite sample was taken for analyses as the representative sample in dry and clean container as described by Waldrip *et al.*, (2011).

3.5.4 Sampling procedure of plants

Simple random procedure was used, where a plant in the plot had an equal chance of being selected. Growth parameters such as leaf area, number of nodes and auxiliary buds were taken from the plots with quail treatment, NPK and from the unfertilized plots which served as the negative control. Twenty two plants were randomly picked from the rows at the centre of the plots; plants from the edges were avoided due to reduced competition. This was carried out from the first week of germination to 6^{th} week during maturity. The number of the leaves, auxiliary buds and nodes was taken from the middle parts of the plants and the average taken. Number of leaves, mean leaf area per plant, plant height, and stalk diameter were taken. The plant height was measured from root tip to shoot tip for *A.tricolar and* to head tip for *A. cruentus* using a tape measure. Stalk diameter was measured using a Vernier calliper rule. Leaf Area Index (LAI) for the two varieties was computed using mean leaf area per plant divided by ground area per plant (Pearcy *et al.*, 1989). Harvested leaves from *A.tricolar* and *A. cruentus* were weighed using digital sensitive balance and calculated and converted to the number of leaves per square meter and converted in tonnes per hectare.

3.5.5 Leaf Mineral Composition Analyses

At maturity sampled leaves were cut using a pair of scissors. The leaves were dried at 80°C for about 48 hours until constant weight was gained and samples were taken for analysis. Total nitrogen was determined following the Kjeldahl method (Okalebo, 2002.) Tissue phosphorus was determined by the calorimetric method after being extracted using the wet oxidation method. Available Magnesium, Iron, and Potassium were determined by use of Atomic Absorption spectrophotometer (Shimadzo corp. Kyto Japan).

3.5.6 Leaf growth rate

Determination of leaf area Index (LA1) was carried out on sampled plants. The length of the first, middle and last leaf was measured and their averages used for calculation of leaf area Index. The relationship LA1=LxWxNx0.72/A where L= Length of leaves, W =

Width of leaves N= Number of leaves per plant A= Area covered per plant and 0.72= constant for the determination of leaf area index (Watson *et al.*, 2006).

3.6 Soil mineral composition analysis

3.6.1 Soil organic carbon

Organic carbon was determined by Walkey and Black method (Nelson and Somers, 1982). One gram of dried soil was ground to pass 0.5 mm, was weighed out and introduced in an Erlemeyer flask of 250 ml then 2 ml of water was added, and also 10 ml of 5 aqueous potassium dichromate $K_2CR_2O_7$ was added in order to completely wet the soil. A standard was prepared using a pipette, 2 ml of each working standard was transferred into dry labeled digestion tubes .The digestion tubes contained 0, 5, 10, 15, 20 and 25 mg carbon 0.5 ml of concentrated sulphuric acid was added in the mixture and digested at 150 degrees Celsius for 30 minutes and cooled. After, 100ml of water was added and mixed. Solution was brought to 100ml by adding water and was allowed to cool overnight, Concentration of standard and sample was read at 600 nm of the spectrometer. The content of the total organic Carbon in the air dry soil was calculated and expressed in percentage by using the formula below

$$\text{Total soil organic carbon (\%)} = \frac{\text{CCS (mgC)} - \text{CCB (mgC)} \times 100}{\text{DW (g)}}$$

Where

CCS=carbon content of the sample

CCB=carbon content of the blank

DW=dry weight of the soil sample

3.6.2 Soil mineral composition analysis

K, Ca, Mg and Na were determined using atomic absorption spectrophotometer (Okalebo *et al.* 2002) where five grams of air dried soil of less than 2mm was weighed into a clean plastic flask with a stopper and 100 ml of 1M (NH_4OAc) ammonium acetate solution (pH 7) was added, an internal standard and a repeat sample within each batch of test soils was also added. The content was shaken for 30 minutes and filtered through no 42 Whatman filter papers. The concentration was then calculated using the following formula MgKg-1 K, Ca, Na, and Mg in soil = ((a-b)×v×f×1000)÷(1000×w) where a = concentration of K, Ca, Na, and Mg in the sample extract;

B = concentration of the element in the blank extract; v = volume of the extract solution; w = weight of the soil sample; f = dilution factor. To determine soil phosphorous 2.5 g of air dried soil of 2 mm was weighed into 250 ml plastic bottle and 50ml of extracting solution (a reagent grades Anti-nutrient is any compound that reduces the ability to absorb or use essential nutrients like vitamins ammonium fluoride (NH_4F) was mixed with distilled water, 250 ml of previously standardized (1M Hcl) was added .After which the solution was shaken for a period of five minutes. Extracts were filtered through Whatmans paper No.42. Phosphorous was the measured by colorimetry using a blank prepared in the Bray P-1 extracting solution. The calculation was made using the following formula,

PmgKg-1 = (a-b) × v × f × 1000÷1000 × w

where a = Concentration of Pmg1-1 in extract solution, b = Concentration of Pmg1-1 in blank sample,

c = extract volume,

w = weight of air dried sample and

f = additional dilution factor,

To determine soil nitrogen 1g of dried soil of 0.5mm was weighed and introduced into a Kjeldahl digestion tube and then one gram of selenium powder to act as catalyst was added. After, 10 ml of concentrated H_2SO_4 was added. The mixture was digested at 300oc for two hours until a green colour appeared. The solution was cooled and traversed into a volumetric flask of 100ml and filled to 100 marks with distilled water. The blank was also prepared, after which 10ml of aliquot of the digest was taken and put into a distillation tube which also received 10 mls of distilled water. To the mixture, a 10 ml of NaoH 50% was added and distillation commenced. The distillate was distilled and collected in an Erlenmeyer flask of 250 ml containing 5 ml of boric acid 2% (H_3BO_3) approximately 100ml of distillate was collected. The solution obtained was titrated with 0.005M H_2SO_4 until a pink colour appeared, titration continued to the point where the whole solution turned pink. The volume of 0.005M H_2SO_4 used was noted and the percentage of N calculated using the following formula,

$\% N = (T\text{-}BL) \times 0.2 \times FC \times FD \times 100 \times 1000$, Where

BL =blank

FD =corrective factor

FD =dilution factor (=10)

3.7 Soil pH

Soil pH was measured in 1:2.5 (soil: water) ratio where a total of 10 g of dried soil of each soil sample was weighed and 25ml of distilled water was added, and mixture was stirred for 15minutes and allowed to settle for 40 seconds before using a calibrated pH meter to read the pH. The pH meter was immersed in the solution and pH was recorded for each sample (Okalebo *et al.*, 2002).

3.8 Analyses of Anti-nutrients

Anti-nutrient is any compound that reduces the ability to absorb or use essential nutrients like vitamins and minerals the most common anti-nutrients in vegetables are phyto-oestrogens, lignin, phenolic compounds, and phytic acid in Amaranth, oxalates and nitrates are common.

3.8.1 Analyses of oxalates

Soluble and total oxalates concentration was determined by titrimetric method of Oke (1966).

3.9 Data analyses

Data was subjected to analyses of variance (ANOVA) at 95% confidence level using SAS computer software version 9.0 models TS1M2 and where there were significant differences further mean separation was obtained by least significant difference (LSD) at 5%.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Effect of quail manure and NPK on the growth, development and yield of the two Amaranth

The results revealed that varieties were significantly different ($p \leq 0.05$) during the long rain season for leaf area, number of leaves and shoot length while non-significant differences ($p \leq 0.05$) were observed on the root length, shoot dry weight, total oxalates and total phenolic compounds Appendix 1.1. NPK rates showed significant differences ($p \leq 0.05$) during the long rain season for leaf area, number of leaves, shoot length, root length, and shoot dry weight, total oxalates and total phenolic compounds. Quail manure rates showed significant differences ($p \leq 0.05$) during the long rain season for the leaf area, number of leaves, shoot length, root length, shoot dry weight and root dry weight while other variables were not significantly different ($p \leq 0.05$). Significant interactions ($p \leq 0.05$) were observed between the Variety and NPK rates levels on the root length in the first season but non-significant differences ($p \leq 0.05$) were observed on the number of leaves, root dry weight, shoot dry weight, shoot length, leaf area, total oxalates and total phenolic compounds.

Significant interactions ($p \leq 0.05$) were observed between variety and quail manure rates on the number of leaves and shoot dry weight during the first season however non-significant differences ($p \leq 0.05$) were observed on the leaf area, shoot length, root length, root dry weight, total oxalates and total phenolic compounds. Significant interactions ($p \leq 0.05$) were observed between NPK and quail manure rates on the root length during the long rain season while non-significant differences ($p \leq 0.05$) were observed on the leaf area, number of leaves, shoot length, root dry weight, total oxalates and total phenolic compounds. Significant interactions ($p \leq 0.05$) were observed between Variety, NPK and quail manure rates which is a second order interaction on the shoot dry weight during the first season while in the second season, non-significant differences ($p \leq 0.05$) were observed on the leaf area, number of leaves, root length, shoot length, root dry weight, total oxalates and total phenolic. Result revealed that varieties were significantly ($p \leq 0.05$) different for leaf area, number of leaves, shoot length, root length and shoot dry weight, root dry weight, but non-significant differences ($p \leq 0.05$) were observed on the oxalate and phenolic compounds. The observation revealed NPK rate were significantly ($p \leq 0.05$) different for leaf area, number of leaves, shoot length, root length, shoot dry weight, root dry weight, oxalate and phenolic.

Results revealed that quail rate were significantly ($p \leq 0.05$) different for number of leaves, shoot length, root length however leaf area, shoot dry weight, root dry weight, while non-significant differences ($p \leq 0.05$) were observed on the oxalate and phenolic compounds. Results revealed that interaction between variety and NPK were significantly ($p \leq 0.05$) different for root length however, leaf area, number of leaves, shoot length, shoot dry weight, root dry weight, oxalate and phenolic were not significantly ($p \leq 0.05$) different. Results revealed that interaction between variety and quail manure rate were not significantly ($p \leq 0.05$) different for number of leaves but leaf area, shoot length, root length, shoot dry weight, root dry weight, oxalate and phenolic were not significantly ($p \leq 0.05$) different. The results reviewed that interaction between NPK rate and quail manure while non-significant differences ($p \leq 0.05$) were observed on leaf area, number of leaves, shoot length, root length, shoot dry weight, root dry weight, oxalate and phenolic compounds. Results revealed that interaction between varieties, NPK rate and quail manure rate were significantly ($p \leq 0.05$) different for shoot dry weight however leaf area, number of leaves, shoot length, root length, root dry weight, while non-significant differences ($p \leq 0.05$) were observed on the oxalate and phenolic compounds.

4.2 Effect of organic and inorganic fertilizers on plant Leaf area

Significant differences ($p \leq 0.05$) between the treatments were observed on leaf area (Fig.4.1).

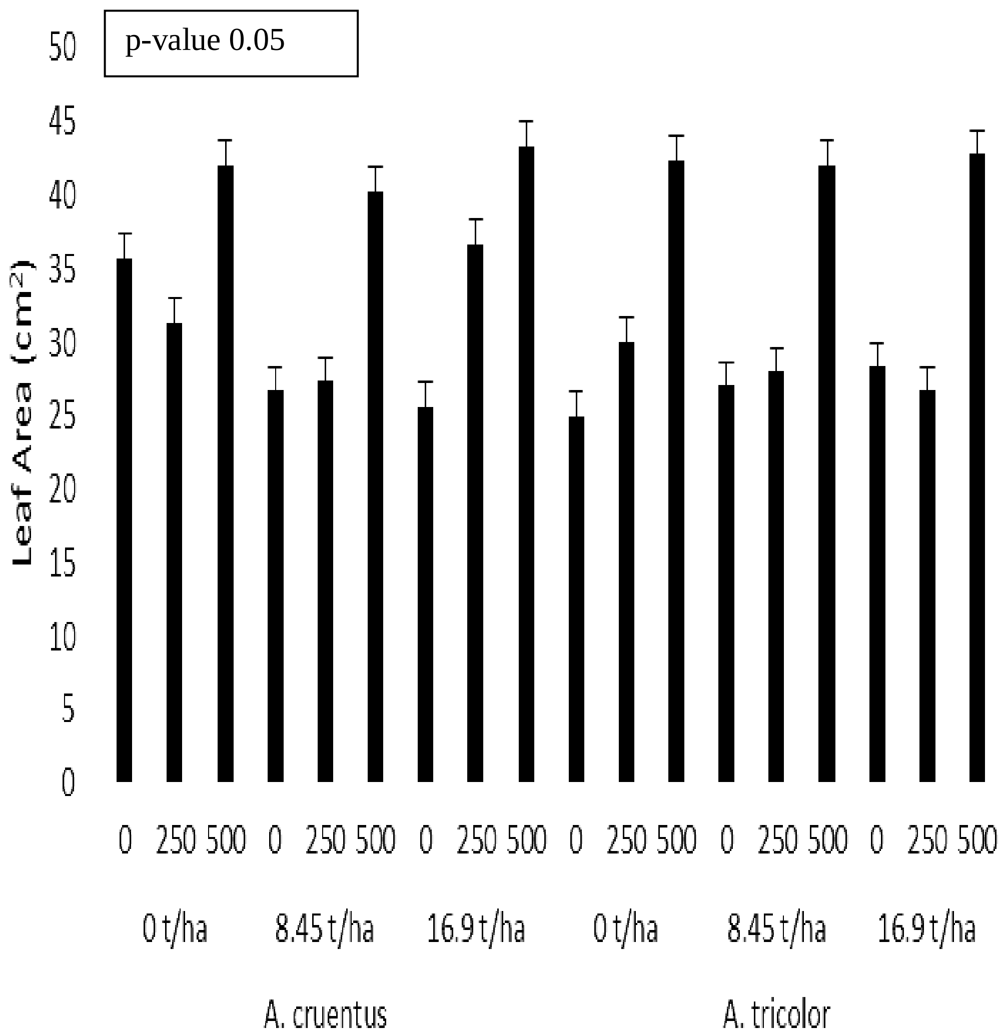

Figure 4.1 The interaction effect of NPK rates and quail manure rates on leaf area in season one in the two amaranth varieties

The highest leaf area was observed on the *A. cruentus* variety at an application of 16.9 t/ha of quail manure plus the highest NPK rate (500 kg/ha). The leaf area was 43.33 cm^2 during the first season and 42.78 cm^2 during the second season (Fig 4.1). The lowest leaf area was recorded in both varieties where no fertilizer was applied for both seasons. There were significant differences ($p \leq 0.05$) between NPK and quail manure fertilization at different rates (Fig. 4.2) in the main effects. The leaf area increased as the supply rate of NPK and quail manures increased in the interaction but at 16.9 t/ha +500 kg/ha the leaf area increased probably due to high amount of micro elements in the quail manure hence high growth rate (Fig. 4.2).

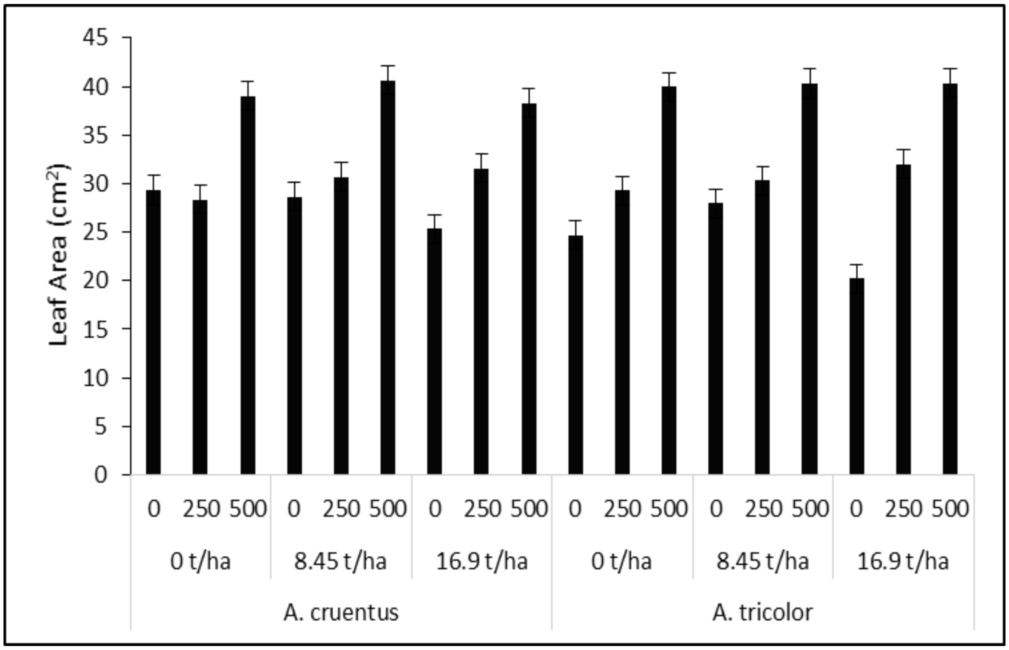

Figure 4.2 The interaction effect of NPK rates and quail manure rates on leaf area in season two in the two amaranth varieties

The previous work of Richert and Salomon (2012) reported a similar result as increased leaf area of lettuce and cabbage crops when chicken manure was used as organic fertilizer. The highest leaf area was obtained 45 cm^2 when sole NPK was applied (Fig 4.1 and Table 4.2) at 500 kg/ha in season two, in season one NPK still had the highest leaf area 41.2cm^2 at the same rate. Therefore, increase in quail manure and NPK increased the leaf area. Changes in the number of leaves are bound to affect the overall performance of A*maranthus* as the leaves serve as photosynthetic organ of the plant. Ammonium/urea based fertilizers tend to create lush or soft growth resulting in larger leaves and darker green plants (Anon, 2006).

4.3 Effect of inorganic and organic fertilizers on number of leaves

Application of organic and NPK had significant effects ($p \leq 0.05$) on the number of leaves on the two amaranth varieties for both seasons. The highest number of leaves was exhibited on the 500 kg/ha + (16.9 t/ha) with a mean of 19.67 leaves per plant observed on the A.tricolor, but A. cruentus variety had 20.67 at the same rate in the short rain season (Fig 4.3 II), while significantly ($p \leq 0.05$) the lowest number observed on the controls with a minimum of 5.33 in A. tricolor in season one. The number of leaves in the first season in A. cruentus were significantly higher than in A. tricolor, the highest number was in the plant that were fertilized in the NPK fertilizer at 500 kg/ha+8.45 t/ha of quail manure, A. tricolor had 16.33 and *A. cruentus* had 14.67 in the short rain season in the main effects (Fig 4.3).

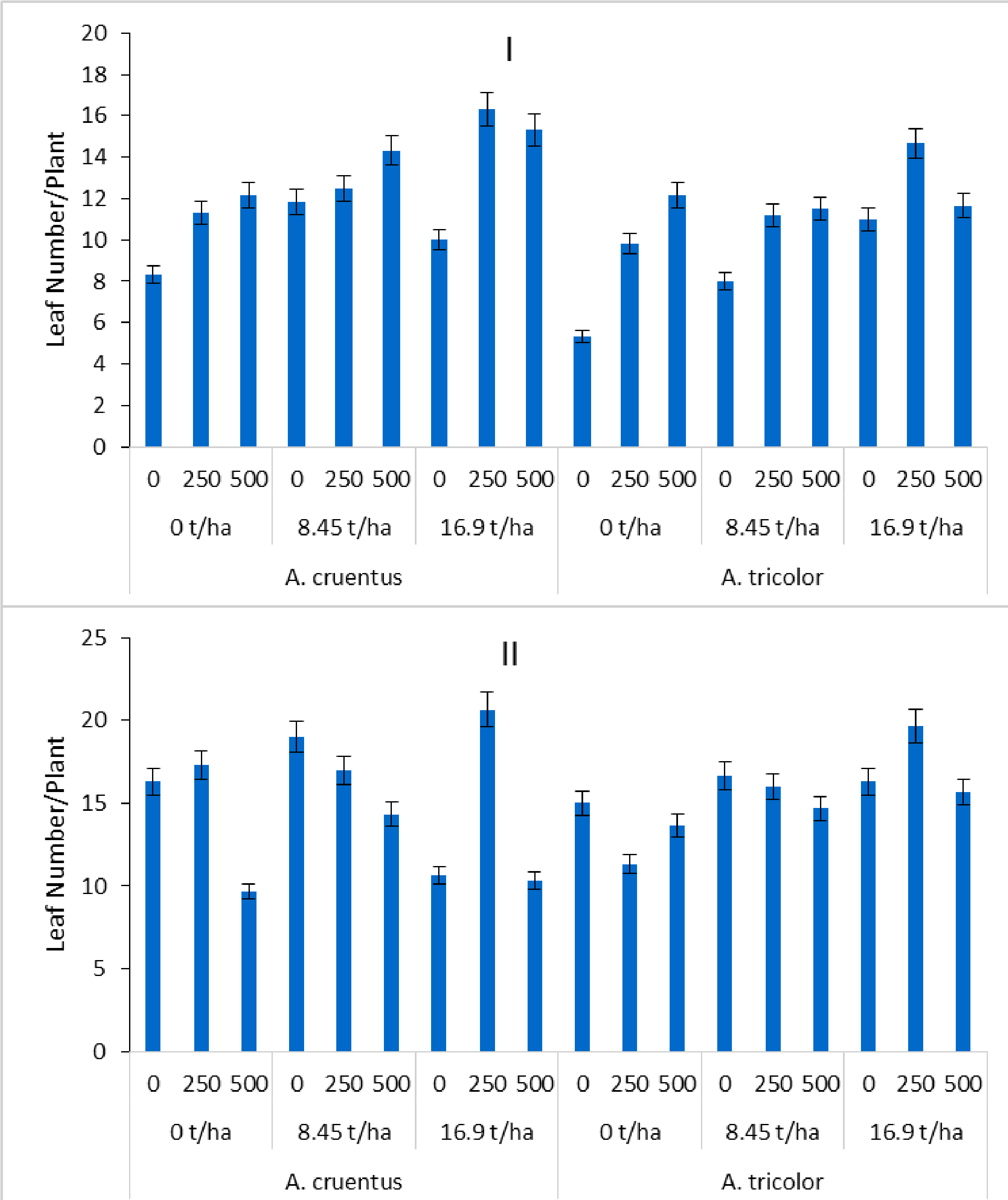

Figure 4.3 Effect of inorganic and organic fertilizers on number of leaves

The number of the leaves reduced in the plants that were treated with NPK to 15.67 at 250 kg/ha and at 500 kg/ha the number of leaves further reduced to 14.06 (Fig. 4.3), contrary to the plants that were fertilized with quail manure. In the first season in the main effects A. tricolor had fewer number of leaves in the soil that was treated with NPK fertilizer, the highest being 14.2 at 500 kg/ha but in the short rain season the same variety had 17.5 leaves at the same NPK treatment. The plants in the control showed the lowest number of leaves. The increase in number of leaves had been claimed to be directly influenced by N supply in fertilizer applied (Ehigiator, 1990). Gungula (1999) reported that nutrient availability especially nitrogen (N) determined plant vegetative development, Changes in the number of leaves are bound to affect the overall performance of the plant as the leaves serve as the organ of photosynthesis for the manufacture of assimilates. Nitrogen is an essential component of chlorophyll, protoplasm, protein and nucleic acid and its absence at appropriate levels could cause yellowing of leaves and stunting of plant growth (Bergman, 1992). The increase in height and number of leaves as NPK rates increased reconfirmed the role of nitrogen in promoting vigorous vegetative growth in leafy vegetables (Tisdale and Nelson, 1990). The increased in number of leaves under organic and NPK and compost application, reconfirmed the role of fertilizer in promoting vegetative growth in leafy vegetables (Tijani-Eniola et al., 2000). This responsiveness number of leaves in amaranth to nitrogen fertilization is also comparable to the findings of other researchers (Myers, 1996; Jefferson Institute, 1999; Bruce and Philipe, 2008). As the major constitutive element of amino acids and proteins, nitrogen is an essential element in the biological functioning of all forms of life where in higher plants, nitrogen plays an integral role in photosynthesis, carbohydrate use, and metabolic processes through various plant secondary compounds. This accounts for the positive correlation between amaranth nutritive content and nitrogen fertilizer application (Brady and Weil, 1999).

4.3.1 Shoot length

Application of quail manure and NPK significantly ($p \leq 0.05$) influenced the shoot length of the amaranth varieties (Table 4.1).

Table 4.1The influence of interactions between variety and quail manure rates on leaf area, number of leaves, shoot length, root length and root dry weight during the long rains season

Variety	Quail Rate	Leaf Area (cm^2)	Leaf Number	Shoot Length (cm)	Root Length (cm)	Root Dry Weight (g)
A. cruentus	0 t/ha	20c	9.86c	20.9c	16.58a	1.20c
	8.45 t/ha	27.4a	11.56b	24.7b	16.82a	1.56a
	16.9 t/ha	29.04a	13.7a	31.1a	18.23a	1.037
A. tricolor	0 t/ha	23b	9.56c	26.8b	11.39b	1.28c
	8.45 t/ha	28.8a	13.28a	31.9a	12.86b	1.39b
	16.9 t/ha	29a	14.56a	24.7b	11.81b	1.23c
	LSD	2.36	1.12	2.81	3.12	0.08
V×Q		*	*	*	**	**

Means in a same column followed by different letter (s) are significantly different at

$P \leq 0.05$ NS = Not significant. * Significant at $\alpha=0.05$** Significant at $\alpha=0.01$

As the rate of NPK increased so did the shoot length, the longest shoots were realized at the rate of 8.45 t/ha of quail manure plus 500 kg/ha rate of NPK in season two (Table 4.2).

Table 4.2 The interaction influence of variety and quail manure rates on leaf area, number of leaves, shoot length, root length and root dry weight during the short rain season

Variety	Quail Rate	Leaf Area (cm^2)	Leaf Numb Er	Shoot Length (cm)	Root Length (cm)	Root Dry Weight (g)
A. cruentus	0 t/ha	22c	7.86c	20.8d	14.73a	1.27c
	8.45 t/ha	28b	16.96a	26.9c	11.04b	1.85a
	16.9 t/ha	29.9ab	17.7a	34.7a	12.86b	1.86a
A. tricolor	0 t/ha	22c	10.56b	32ab	11.94b	1.24c
	8.45 t/ha	30a	17.28a	31.9b	11.20b	1.55b
	16.9 t/ha	32a	17.56a	32.7ab	12.89b	1.9a
	LSD	2.16	1.09	2.49	2.89	0.07
V×Q		**	**	*	*	*

Means in a same column followed by different letter (s) are significantly different at $P<0.05$ NS = Not significant. * Significant at $\alpha=0.05$** Significant at $\alpha=0.01$

The shortest shoots were observed on the controls where they recorded less than 10 cm for each. The highest level of sole NPK (500 kg/ha) exhibited the tallest plants (33.5 cm) in *A. tricolar* and the shortest plants were under the control with 15 cm in season 1 (Table 4.3).

Table 4.3 The interaction influence of variety and NPK rates on leaf area, number of leaves, shoot length, root length and root dry weight during the long rain season

Variety	NPK Rate	Leaf Area (cm^2)	Leaf Number	Shoot Length (cm)	Root Length (cm)	Root Dry Weight (g)
A. cruentus	0 kg/ha	24d	8.00c	15.0c	16.58a	1.28c
	250 kg/ha	34.6c	12.64b	28.2b	12.82b	1.84a
	500 kg/ha	41.3a	12.86b	33.5a	13.23b	0.83d
A. tricolor	0 kg/ha	21d	8.67c	10.0d	17.39a	1.25c
	250 kg/ha	37b	17.67a	25.9b	12.96b	1.55b
	500 kg/ha	45a	17.06a	27.5b	13.81b	1.91a
	LSD	6.89	3.58	2.91	3.11	0.06
V×N		**	*	**	*	*

Means in a same column followed by different letter (s) are significantly different at $P<0.05$ NS = Not significant. * Significant at $\alpha=0.05$** Significant at $\alpha=0.01$

There was a significant difference ($P \leq 0.05$) in A. tricolor and *A. cruentus* shoot length values obtained from the treatment of NPK and quail manures during growing period. The *A. cruentus* shoot length obtained in season one at control had shorter shoot length having a length of 9.5 cm as it rely on the native soil fertility which was deficient in nutrients compared to season two shoot length of 30.5 cm (Table 4.4).

Table 4.4 The interaction influence of variety and NPK rates on leaf area, number of leaves, shoot length, root length and root dry weight during the second season

Variety	NPK Rate	Leaf Area (cm^2)	Leaf Number	Shoot Length (cm)	Root Length (cm)	Root Dry Weight (g)
A. cruentus	0 kg/ha	22c	9.00b	15.0d	18.73a	1.28b
	250 kg/ha	28b	12.64ab	27.2b	16.04a	1.60a
	500 kg/ha	35ab	15.86a	30.5a	17.86a	0.50c
A. tricolor	0 kg/ha	23c	9.67b	19.0c	18.94a	1.23b
	250 kg/ha	32b	15.67a	26.9b	11.22b	1.22b
	500 kg/ha	40a	14.06a	28.5ab	16.89a	0.57c
	LSD	7.11	3.18	2.34	2.81	0.43
V×N		**	*	*	*	*

Means in a same column followed by different letter (s) are significantly different at P<0.05 NS = Not significant. * Significant at α=0.05** Significant at α=0.01

Similar results were observed by Elbehri *et al*. (1993), who reported increased Amaranths' plant height at higher nitrogen application rate. The highest level in the same species had 31.1 cm and the control had 20.9 cm. (Table 4.2), but the control had the lowest height of 19 cm in *A. tricolor* and 15 cm in *A. cruentus.* The sole NPK application in A. tricolor in season two had 30.5cm and the control had the least shoot height 15cm.

Both varieties *A. tricolor* and *A. cruentus* were significantly influenced ($p \leq 0.05$) by the application of NPK and quail manures. The positive performance of NPK plus quail manure on the growth response of *A. tricolor* and *A. cruentus* may be due to the balanced nutrients they contained (Okokoh and Bisong, 2011). The mean shoot length was directly related to the quantity of NPK and quail manure supplied to the *A. cruentus.* Makinde *et al.* (2010) earlier obtained similar increase in shoot length in *A. cruentus,* though with increased organo -mineral fertilizer applications in soil.

4.3.2 Root length

There were significant differences (p≤0.05) in *A. tricolor* and *A. cruentus* on the root length as influenced by the treatments. The root length was significantly enhanced due to increased supply rate of NPK and quail manures. In season one the value of root length was relatively higher than in the long rain season as in season two the majority of the nutrients were available in the soil from the previous NPK and quail manure application. Similar results were reported by Wright *et al*. (2012), who observed that maximum root growth and rooting depth of barley crop were higher in treatments, which received organic and inorganic fertilizer relative to where manure was not applied. The root length in long rain season (Table 4.3 and 4.4), was high in comparison with short rain season two, *A. tricolor* had the longest root at 16.9 t/ha, 250 kg/ha of 21 cm in *A. cruentus* and *A. tricolor* had 18.23 cm treatment at the same treatment, the lowest length was at the control, *A. tricolor* had 14cm and *A. cruentus* having 10 cm in season one, in short rain season the root length reduced to 14 cm in season two and in *A. tricolor* the root length further reduced to 10 cm. These results differ with those of shoot length growth which indicated that application of quail manure resulted in highest levels of soil available N and P compared to the other hence the higher growth rate (Table 4.1and 4.2). The results therefore suggest that the observed response was largely due to decreased availability of macro and micro elements in season one since quail manure nutrients are dissipated slowly unlike in the inorganic fertilizer. Significant differences ($p \leq 0.05$) were observed between the treatments for both seasons. The longest roots were recorded in the highest rate of NPK (500 kg/ha) under the quail manure with 18cm in control, the 500 kg/ha NPK rate and the 8.45 t/ha rate of quail manure, and the 250 kg/ha NPK rate and the highest quail manure rate (16.9 t/ha). The root length in season two was significantly ($P \leq 0.05$) enhanced due to increase the supply rate of NPK and quail manures. In the long rain one the value of root length at was relative higher than in the short rain season; this is because in the short rain season the majority of the nutrients were available in the soil from the previous NPK and quail manure application. Similar results were reported by Wright *et al*. (2012), who observed that maximum root growth and rooting depth of barley crop was higher in treatments which received organic and inorganic fertilizer in relative to where manure was not applied. Root length in A.cruentus was higher than in A. tricolor (Table 4.5).

Table 4.5 The influence of interactions between variety and quail manure rates on leaf area, number of leaves, shoot length, root length and root dry weight during the long rains season

Variety	Quail Rate	Leaf Area (cm^2)	Leaf Number	Shoot Length (cm)	Root Length (cm)	Root Dry Weight (g)
A. cruentus	0 t/ha	20c	9.86c	20.9c	16.58a	1.20c
	8.45 t/ha	27.4a	11.56b	24.7b	16.82a	1.56a
	16.9 t/ha	29.04a	13.7a	31.1a	18.23a	1.037
A. tricolor	0 t/ha	23b	9.56c	26.8b	11.39b	1.28c
	8.45 t/ha	28.8a	13.28a	31.9a	12.86b	1.39b
	16.9 t/ha	29a	14.56a	24.7b	11.81b	1.23c
	LSD	2.36	1.12	2.81	3.12	0.08
V×Q		*	*	*	**	**

Means in a same column followed by different letter (s) are significantly different at P<0.05 NS = Not significant. * Significant at α=0.05** Significant at α=0.01

4.3.3 Root dry weight

The lowest root dry weight was observed on the controls and at all the given rates of quail manure especially during the long rain season due to deficiency of nutrients in the soil. In this case, there was a significant difference ($p \leq 0.05$) in A. tricolor and A. cruentus root dry weight obtained from the treatment (Table 4.5). The lowest root dry weight was observed on the controls in short rain season due to deficiency of nutrients in the soil, in both A. tricolor and A. cruentus (Table 4.6).

Table 4.6 The interaction influence of variety and quail manure rates on leaf area, number of leaves, shoot length, root length and root dry weight during the short rain season

Variety	Quail Rate	Leaf Area (cm^2)	Leaf Numb Er	Shoot Length (cm)	Root Length (cm)	Root Dry Weight (g)
A. cruentus	0 t/ha	22c	7.86c	20.8d	14.73a	1.27c
	8.45 t/ha	28b	16.96a	26.9c	11.04b	1.85a
	16.9 t/ha	29.9ab	17.7a	34.7a	12.86b	1.86a
A. tricolor	0 t/ha	22c	10.56b	32ab	11.94b	1.24c
	8.45 t/ha	30a	17.28a	31.9b	11.20b	1.55b
	16.9 t/ha	32a	17.56a	32.7ab	12.89b	1.9a
	LSD	2.16	1.09	2.49	2.89	0.07
V×Q		**	**	*	*	*

Means in a same column followed by different letter (s) are significantly different at $P \leq 0.05$ NS = Not significant. * Significant at $\alpha=0.05$** Significant at $\alpha=0.01$

4.4 Effect of organic andNPK on the micronutrients, macronutrients and anti-nutrients of two *Amaranth* species

Application rates significantly ($p \leq 0.05$) influenced the content of some chemical properties of the two varieties under the two main factors. Quail manure besides improving the efficiency of chemical fertilizers, it also improve physical, chemical and biological conditions of the soil. A study by Akanini and Ojenini (2007), observed that poultry manure increased uptake of macro and micro nutrient due to increased organic matter. The macro and micro elements increased above the control treatment, calcium recorded 2.05%, 3.08% and 2.23% for *A. cruentus* and *A. tricolor* respectively at the control, and the amount of calcium progressively increased to 2.57% and 3.08 % for *A. cruentus and A. tricolor* respectively at 16.9 t/ha and 500 kg/ha in season one (Table 4.7).

Table 4.7 The interaction effect of variety, NPK rates and quail manure rates on plant tissue macro and micronutrients properties during the long rain season

Variety	NPK Rate	Quail Manure	N %	P %	Ca %	K %	Fe (mg/kg)
A. cruentus	0 t/ha	0 kg/ha	1.87c	0.37b	2.05c	0.6c	50.73c
		250 kg/ha	1.87c	0.36b	2.09c	0.88ab	63.40b
		500 kg/ha	2.58a	0.40a	2.59a	0.89ab	66.06ab
	8.45 t/ha	0 kg/ha	2.00b	0.37b	2.07b	0.87ab	65.51ab
		250 kg/ha	2.13a	0.36b	2.23ab	0.87ab	65.77ab
		500 kg/ha	2.16a	0.39a	2.38ab	1.03a	64.10ab
	16.9 t/ha	0 kg/ha	2.03b	0.38b	2.35ab	0.84ab	64.86ab
		250 kg/ha	2.2a	0.47a	2.80a	1.85a	69.58a
		500 kg/ha	2.03b	0.30b	3.08a	0.96ab	62.00b
A. tricolor	0 t/ha	0 kg/ha	1.82c	0.25c	2.23b	0.67c	53.50c
		250 kg/ha	1.97b	0.34b	2.61a	0.87ab	64.07ab
		500 kg/ha	2.21a	0.41a	2.16b	0.79ab	61.60b
	8.45 t/ha	0 kg/ha	1.85b	0.34b	2.09b	0.90ab	64.13ab
		250 kg/ha	2.17a	0.36b	2.23b	0.92ab	66.83a
		500 kg/ha	2.14a	0.39a	2.05b	0.88ab	67.57a
	16.9 t/ha	0 kg/ha	2.11a	0.36b	2.67a	0.87ab	66.07ab
		250 kg/ha	2.93a	0.39a	2.48ab	0.92ab	65.30ab
		500 kg/ha	2.24a	0.41a	2.57ab	1.01a	65.97ab
	LSD		0.155	0.054	0.774	0.186	4.212
	V×Q×N						

Means in a same column followed by different letter (s) are significantly different at $P \leq 0.05$NS = Not significant. * Significant at α=0.05** Significant at α=0.01

Integration of poultry with NPK fertilizer increased nutrients in the soil, growth parameters and also the residual basis (Chamberato *et al*., 2011). The study of Ayeni *et al*. (2008) showed that poultry manure. Increased uptake of N, P, K, CA, Mg, Zn, Fe and Cu, in maize. This is consistent with the current study that poultry manure enhanced nutrient status in amaranth, Okanini *et al.* (2007) observed that poultry manure increased tissue Nitrogen Potassium and Phosphorous in tomatoes, they also observed that it also increased intake of Nitrogen, Phosphorous, potassium, Calcium and Magnesium in the tomato plant. Quail manure have cation exchange sites (Okanini *et al*. 2007), so micronutrient organic matter is known to form chelate with micro-nutrients, increasing availability of micronutrients like Fe, Cu, Zn and Mn and are mostly available when there is reduced soil pH, micro nutrients cations are soluble and available under acidic conditions(Brady *et al*., 1999). The highest value of pH was due to effect of chicken manure which contained calcium carbonate (Camerato and Mitchell, 2011).

A combined integration of organic and inorganic ensured availability of essential nutrients, trend in the data shows that to maximize nutrient status in the soil and in the plant tissue NPK fertilizer should be combined with poultry manure. The higher macro and micro elements in short rain season, could be due to higher nutrients dissipated from the organic fertilizer over the two seasons, also due to improvement of soil physio-chemical properties like increased water infiltration rate, and retention soil aggregate and nutrients stabilizers (Brady *et al.*, 1999). Organic fertilizer application rate significantly influenced the phosphorus, sulphur, calcium, magnesium and manganese content of the two amaranth spp.

4.4.1 Nitrogen

The highest quail manure rate and the 250 kg/ha NPK rate showed significantly ($p<0.05$) the highest nitrogen content in the amaranth plant tissues with 2.93% on the *A. tricolor* variety during the first season and 2.98% during the short rain season (Table 4.8).

Table 4.8 The interaction effect of variety, NPK rates and quail manure rates on plant tissue macro and micronutrients properties during the second season

Variety	Nitrogen Rate	Quail Manure	N %	P %	Ca %	K %	Fe (mg/kg)
A. cruentus	0 t/ha	0 kg/ha	1.21c	0.33c	0.13c	0.77c	120.9g
		250 kg/ha	1.89b	0.34c	0.16ab	0.87b	118.6g
		500 kg/ha	2.13a	0.39b	0.15ab	0.89b	159.8e
	8.45 t/ha	0 kg/ha	1.93b	0.36b	0.14ab	0.89b	164.3d
		250 kg/ha	2.20a	0.34c	0.15ab	0.80b	138.2f
		500 kg/ha	2.21a	0.38b	0.15ab	1.04a	162.7d
	16.9 t/ha	0 kg/ha	1.96b	0.36b	0.15ab	0.87ab	168.9c
		250 kg/ha	2.73a	0.46a	0.15ab	0.90ab	69.58i
		500 kg/ha	2.33a	0.30c	0.25a	0.98a	191.2a
A. tricolor	0 t/ha	0 kg/ha	1.79c	0.35b	0.16ab	0.72c	181.1b
		250 kg/ha	1.98bc	0.36b	0.14ab	0.87ab	91.6h
		500 kg/ha	2.20b	0.40a	0.15ab	0.87ab	129.0g
	8.45 t/ha	0 kg/ha	1.85b	0.34b	0.15ab	0.79c	120.9g
		250 kg/ha	2.23a	0.36b	0.17ab	0.90ab	118.4g
		500 kg/ha	2.13a	0.36b	0.17ab	0.92ab	170.0c
	16.9 t/ha	0 kg/ha	2.07ab	0.37b	0.17ab	0.88b	169.2c
		250 kg/ha	2.98a	0.37b	0.16ab	0.91ab	149.9e
		500 kg/ha	2.34a	0.40a	0.16ab	0.99a	166.3d
	LSD		0.385	0.058	0.034	0.223	7.85
	V×Q×N		**	*	NS	*	**

Means in a same column followed by different letter (s) are not significantly different at $P \leq 0.05$ NS = Not significant. * Significant at α=0.05** Significant at α=0.01

For both seasons, the lowest nitrogen content in the plant tissues were observed in the controls with as low as 1.21% on the *A. cruentus* variety and 1.82% on the *A. tricolor* variety (Table 4.8). As shown in Appendix 3, the nitrogen content of amaranth increased with quail manure applications in season two while the NPK fertilizer only marginally increased the nitrogen content. In the long rain season, the nitrogen content increased with increase in NPK rate, this is because NPK fertiliser dissipates nutrients very fast unlike the organic that dissipate nutrients slowly over a long period of time (Brady *et al.*, 1999). *A. cruentus* that received 8.45 t/ha of quail manure compost contained significantly more nitrogen than in the control and 16.9 t/ha organic treatments including *A. cruentus* that did not receive any organic fertilizer. In a study conducted by Warman and Havard (1997) where chicken manure (170 kg N ha'^{1}) was applied over a period of 3 years, the nitrogen content of spinach significantly increased compared to Spinach grown in inorganic fertilized soil. The NPK increased the nitrogen content in the long rain season, above the control, the highest being 2.199%, the amount was increased at a decreasing rate in the short rain season, the lowest being 2.009% of *A. tricolor*.

4.4.2 Phosphorous

It is the second important nutrient required by plants its important component of nucleic acid, lipid and proteins which control plants life processes (Brady *et al.*, 1999). The amount of phosphorus in the plant tissue was significantly influenced by organic and NPK treatments. The highest phosphorus content stood at 0.466% in *A. cruentus* in season two while treated with 16.9 t/ha. The phosphorus content of amaranth was significantly influenced by the organic fertilizer rate. The highest application rates (16.9 t/ha) of poultry manure significantly increased the phosphorus content (0.449% and 0.466%, respectively) in season two of *A. cruentus* and *A.tricolor*, respectively. According to Lairon *et al.* (1986) the phosphorus content of potatoes and carrots treated with organic fertilizer for two seasons was higher than those treated with NPK. In season two, the short rain season phosphorus content of amaranth was significant increased by the organic fertilizer, *A. cruentus* had 0.466% and *A. tricolor* had 0.449% at 16.9 t/ha at 8.45 t/ha whereas *A. tricolor* had 0.364% but *A. cruentus* had 0.364 due to application of NPK at 500 kg/ha.

4.4.3 Calcium

A maximum of 3.08% calcium was shown under the highest rate of quail manure and NPK on the *A. cruentus* variety with the lowest being observed on the control of *A. cruentus* variety (Table 4.8). Both organic fertilizer and application rates significantly ($p \leq 0.05$) influenced the calcium content of the two *Amaranth spp*. As the organic fertilizer rate increased the calcium content of the two species increased compared to the amaranth that did not receive any organic treatment. *A. cruentus* had 2.591% at 16.9 t/ha and *A. tricolor* had 2.474% in season one, in season two *A. tricolor* had a higher calcium content of 2.279% in comparison with *A. Cruentus* which had 2.266% at the same treatment (Table 4.7). Calcium significantly decreased irrespective of the application rate when the amount of NPK was increased from 250 kg/ha to 500 kg /ha in the two seasons (Table 4.8). Although the unfertilized soil still had the lowest amount of calcium, 0.231% in *A. cruentus* and 0.228% *A. tricolor*. The amount of calcium was further decreased in the second season in the soils that were treated with organic quail manure, Lampkin (2000) found high calcium levels in organic grown products than inorganic grown ones. Increase in acidity decrease calcium uptake, the absorbed calcium combine with oxalate forming calcium oxalate making the calcium unavailable to the plant (Camberato and Mitchel, 2011).

4.4.4 Magnesium

Quail manure significantly ($p \leq 0.05$) influenced the magnesium content of amaranth. *A. cruentus* that received organic fertilizer at 8.45 t/ha had significantly lower magnesium than all the other organic fertilizer treatments including the control in the two seasons (Table 4.8). In this study, the inorganic treated amaranth contained higher magnesium levels than amaranth that did receive organic fertilizer and also than the control. Alfoldi *et al.* (1996) reported that the magnesium content of potatoes that received fresh and composted farmyard manure plus slurry for three years was lower than inorganic fertilized potatoes.

4.4.5 Manganese

Organic fertilizer rate at 8.45 t/ha significantly ($P \leq 0.05$) decreased the magnesium content of *A. cruentus* compared to that did not receive any organic fertilizer in season one (Table 4.7 and 4.8). In the present study, amaranth that received NPK contained more manganese than those that received organic fertilizer in season one. But in the second season the amaranth that received organic fertilizer recorded the highest manganese at 8.45 t/ha in the second season *A. cruentus* had 0.361 and *A. tricolor* recorded 0.372. The amount of manganese in inorganic treated soil decreased with increase in the NPK. Warman and Havard (1997) obtained higher manganese levels in carrots treated with compost (170 kg N ha^{-1}) over a period of 3 years compared to inorganic fertilized carrots.

4.4.6 Iron

Iron content of *A. cruentus* was significantly ($P \leq 0.05$) lower in the two seasons (Table 4.7 and 4.8) that received both quail and NPK fertilizers in comparison with *A. tricolor* that was fertilized with the two different types of fertilizer in the two seasons, but where the soil was unfertilized in the two seasons the iron content was much lower. *A. cruentus* had the highest iron of 68.52% while treated with 250 kg/ha of NPK whereas the highest in *A. tricolor* was 173% while treated at the same rate of NPK. It was observed that the iron content in the amaranth that received organic fertilizer increased with increase in addition of the manure but at a very low margin, the conventionally grown amaranth had higher iron content in season one the *A. tricolor* variety of *amaranth* grown at 250 kg/ha NPK had 172% in the long rain season (Table 4.7) followed by 173.7% fertilized with 500 kg/ha in the short rain season which is contrary to Smith (1993) who reported a higher iron content in organic grown vegetables in comparison with inorganic NPK grown vegetables.

4.4.7 Sodium, Potassium, Copper and Zinc

In season one the amount of sodium was not significantly affected ($p \leq 0.05$) due to the treatment of quail or NPK fertilizers. The highest amounts of sodium was at the unfertilized soil with 0.063 followed by quail manure at 8.45 t/ha and the least of the sodium was 0.004 in A. tricolor at 16.9 t/ha in season two (Table 4.9).

Table 4.9 The interaction effect of variety, NPK and quail manure rates on sodium, copper and zinc plant tissues during the first season

Variety	Treatments	Sodium	Copper	Zinc
A. tricolor	0 t/ha+0 kg/ha	0.063b	5.253a	27.57a
	0 t/ha+250 kg/ha	0.63a	4.75a	29.5a
	0 t/ha+500 kg/ha	0.7a	5.063a	30.1a
	8.45 t/ha+0 kg/ha	0.056b	4.22a	25.4b
	8.45 t/ha+250 kg/ha	0.7a	4.7a	26.2b
	8.45 t/ha+500 kg/ha	0.61a	4.653a	28.27b
	16.9 t/ha+0 kg/ha	0.004bc	4.5a	25.2b
	16.9 t/ha+250 kg/ha	0.3b	3.9b	26.1b
	16.9 t/ha+500 kg/ha	0.35b	3.3b	27.5a
A. cruentus	0 t/ha+0 kg/ha	0.06b	4.67a	28.97ab
	0 t/ha+250 kg/ha	0.66a	5.903a	30.3a
	0 t/ha+500 kg/ha	0.76a	5.473a	33.9a
	8.45 t/ha+0 kg/ha	0.7a	4.6a	26.3b
	8.45t/ha+250 kg/ha	0.65a	4.75a	25b
	8.45 t/ha+500 kg/ha	0.04b	5.83a	26.4b
	16.9 t/ha+0 kg/ha	0.015bc	4.45a	24b
	16.9 t/ha+250 kg/ha	0.35b	3.59b	26b
	16.9 t/ha+500 kg/ha	0.32b	3.4b	28.5a
	LSD	0.51	1.06	4.56
N× V×Q		*	NS	*

Means in a same column followed by different letter (s) are significantly different at $P \leq 0.05$ NS = Not significant. * Significant at $\alpha=0.05$** Significant at $\alpha=0.01$

The highest amount of copper and zinc in season one were recorded at 250 kg/ha of inorganic manure, in *A. cruentus* variety. In season two the highest amount of copper was recorded at 500kg/ha and the highest amount of zinc which was 33.9 was recorded at 500 kg/ha (Table 4.10).

Table 4.10 The interaction effect of variety, NPK and quail manure rates on sodium, copper and zinc plant tissues during the second season

Variety	Treatments	Sodium	Copper	Zinc
A. tricolor	0 t/ha+0 kg/ha	0.06a	4.253ab	27.57 a
	0 t/ha+250 kg/ha	0.07a	4.765ab	29.5 a
	0 t/ha+500 kg/ha	0.07a	5.063a	29.1 a
	8.45 t/ha+0 kg/ha	0.01a	4.12a	31.4 a
	8.45 t/ha+250 kg/ha	0.17a	4.5ab	26.2b
	8.45 t/ha+500 kg/ha	0.161a	4.73ab	32.27a
	16.9 t/ha+0 kg/ha	0.004b	4.57ab	24.9b
	16.9 t/ha+250 kg/ha	0.13a	3.86abc	26.2b
	16.9 t/ha+500 kg/ha	0.3a	3.2acb	27.39a
A. cruentus	0 t/ha+0 kg/ha	0.05a	4.77ab	28.97a
	0 t/ha+250 kg/ha	0.06a	5.913a	30.3ab
	0 t/ha+500 kg/ha	0.06a	5.973a	33.9ab
	8.45 t/ha+0 kg/ha	0.01a	5.23a	30.4ab
	8.45 t/ha+250 kg/ha	0.17a	4.5ab	25.1b
	8.45 t/ha+500 kg/ha	0.04a	5.85a	26.45b
	16.9 t/ha+0 kg/ha	0.003b	4.45ab	23.9b
	16.9 t/ha+250 kg/ha	0.21a	3.5abc	26.3b
	16.9 t/ha+500 kg/ha	0.01a	4.6ab	34.5a
	LSD	0.45	0.99	6.37
V×Q×N		NS	*	*

Means in a same column followed by different letter (s) are significantly different at $P \leq 0.05$ NS = Not significant. * Significant at $\alpha=0.05$** Significant at $\alpha=0.01$

The initial properties of the plant were significantly ($p \leq 0.05$) influenced during the second season and it was clear that organic fertilizer rate influenced most of the chemical properties. Inorganic manure rates 250 and 500 kg/ha significantly increased the, copper and zinc content of the tissue especially in the second season (Table 4.10). Inorganic manure significantly increased copper and zinc content of the plant tissue more than the quail; this is because micro nutrients are more absorbed in acidic conditions than in neutral or alkaline conditions. The chemical properties of amaranth were mainly influenced by inorganic fertilizer application rates. The copper and zinc content of the two amaranth species that receive the two highest application rates (250 and 500 kg/ha) were significantly higher than those that did not received any inorganic fertilizer sodium content was significantly lower at the two rates application rates compared to the control.

Organic fertilizer application rate 3 significantly ($p \leq 0.05$) increased the content of zinc in *A. cruentus* in comparison to the same application in *A. tricolor* in the two seasons, while the phosphorous content of amaranth that received organic fertilizer at 8.45 t/ha was significantly lower than those that did not receive any organic fertilizer.

4.4.8 Oxalates as a result of application of organic and inorganic fertilizer

The plants fertilized with NPK had significantly ($p \leq 0.05$) higher levels of oxalates in relation to the plants treated with the organic fertilizer in the two seasons (Table 4.11).

Table 4.11 The interaction influence of variety and quail manure rates on the total oxalate compound content in amaranth during the first season and second season

Variety	Quail Rate	Oxalate mg/100Fw (season 1)	Oxalate mg/100Fw (season 2)
A. cruentus	0 t/ha	6.28c	6.2c
	8.45 t/ha	6.9b	6.78b
	16.9 t/ha	7.85a	7.23a
A. tricolor	0 t/ha	6.69b	6.3c
	8.45 t/ha	7.16a	7.2a
	16.9 t/ha	6.11c	7a
	LSD	0.48	0.39
V×Q		*	*

Means in a same column followed by different letter (s) are significantly different at $P \leq 0.05$

NS = Not significant. * Significant at $\alpha=0.05$** Significant at $\alpha=0.01$

The highest oxalate amount was found in A. tricolor treated with NPK at 500 kg/ha it recorded 10.47 mg/100Fw in season one and the same variety had the highest amount with 11.34 mg/100Fw at the same application in season two the amount of oxalates was high The highest oxalate amount was found in A. tricolor treated with NPK at 500 kg/ha it recorded 10.47 mg/100Fw in season one and the same variety had the highest amount with 11.34 mg/100Fw at the same application in season two the amount of oxalates was highly reduced in the two seasons where there was integration (Fig 4.4).

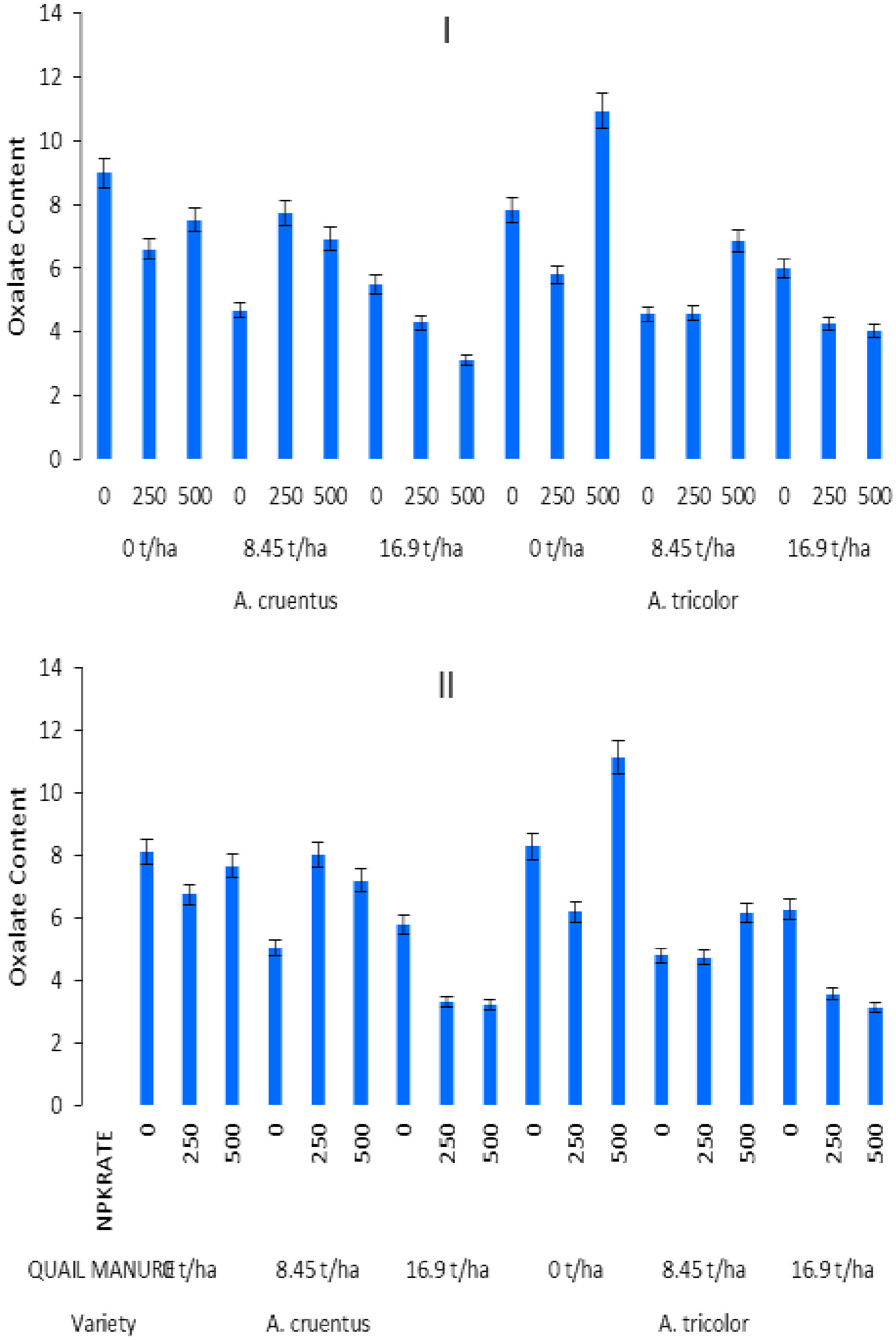

Figure 4.4 The interaction effect between the variety, NPK and quail manure rates on the oxalate content during the first (I) and second (II) seasons

Anti-nutrients in amaranth like oxalic acid, nitrates and Saponins, oxalic acid reduce availability of calcium in human beings. Oxalate in leaf were significantly affected by the different levels of the fertilizers in the two seasons, in season one mean values of data showed that NPK applied at 500 kg/ha in season one had the highest amount of oxalate of 10.93mg/100Fw. The lowest oxalate was shown at the control, followed by quail manure that was applied at 16.9 t/ha + 500 kg/ha of NPK that recorded 3.13 mg/100Fw for A. cruentus and A. tricolor had 4.04 mg/100Fw in season one, in season two A. cruentus had 3.25 mg/100Fw whereas A. tricolor had 3.15mg/100Fw in season two (Table 4.11).

Table 4.12 The interaction influence of variety and quail manure rates on the total oxalate compound content in amaranth during the first season and second season

Variety	Quail Rate	Oxalate mg/100Fw (season 1)	Oxalate mg/100Fw (season 2)
A. cruentus	0 t/ha	6.28c	6.2c
	8.45 t/ha	6.9b	6.78b
	16.9 t/ha	7.85a	7.23a
A. tricolor	0 t/ha	6.69b	6.3c
	8.45 t/ha	7.16a	7.2a
	16.9 t/ha	6.11c	7a
	LSD	0.48	0.39
V×Q		*	*

Means in a same column followed by different letter (s) are significantly different at P≤0.05

NS = Not significant. * Significant at α=0.05** Significant at α=0.01

Amaranth besides providing nutrients also accumulates high levels of anti-nutritional factors e.g oxalate (Gupta *et al.*, 2005). Oxalates play an important role in plants like calcium regulation ,plant protection and detoxification of certain metals (Nakata, 2005), like Lead oxide and also accumulate oxalate in vivo to cope with aluminium and lead toxicity (Yangel *et al*., 2000). Calcium oxalate crystals acts as an effective defense against chewing insects (Korth *et al*., 2006). Despite their protection roles in plants

(Nakata, 2005), noted that high levels can be toxic to human by forming kidney stones (Gupta, 2005).

4.4.9 Phenolic compounds

Total phenolic contents in the leaves were significantly affected ($p \leq 0.05$) by the different levels of the fertilizers. The highest mean values showed maximum leaf total phenolic compound on plants with 8.45 t/ha+500 kg/ha in season one and at 8.45 t/ha +500 kg/ha in season two. A. *cruentus* in season one at 8.45 t/ha + 500 kg/ha had 40.33 GAE/kgDM in season one whereas, A. tricolar at the same application had 40.67gGAEkg/DM. In season two A. *cruentus* had the highest TPC at 42.33gGAE/kg DM (Figure 4.5).

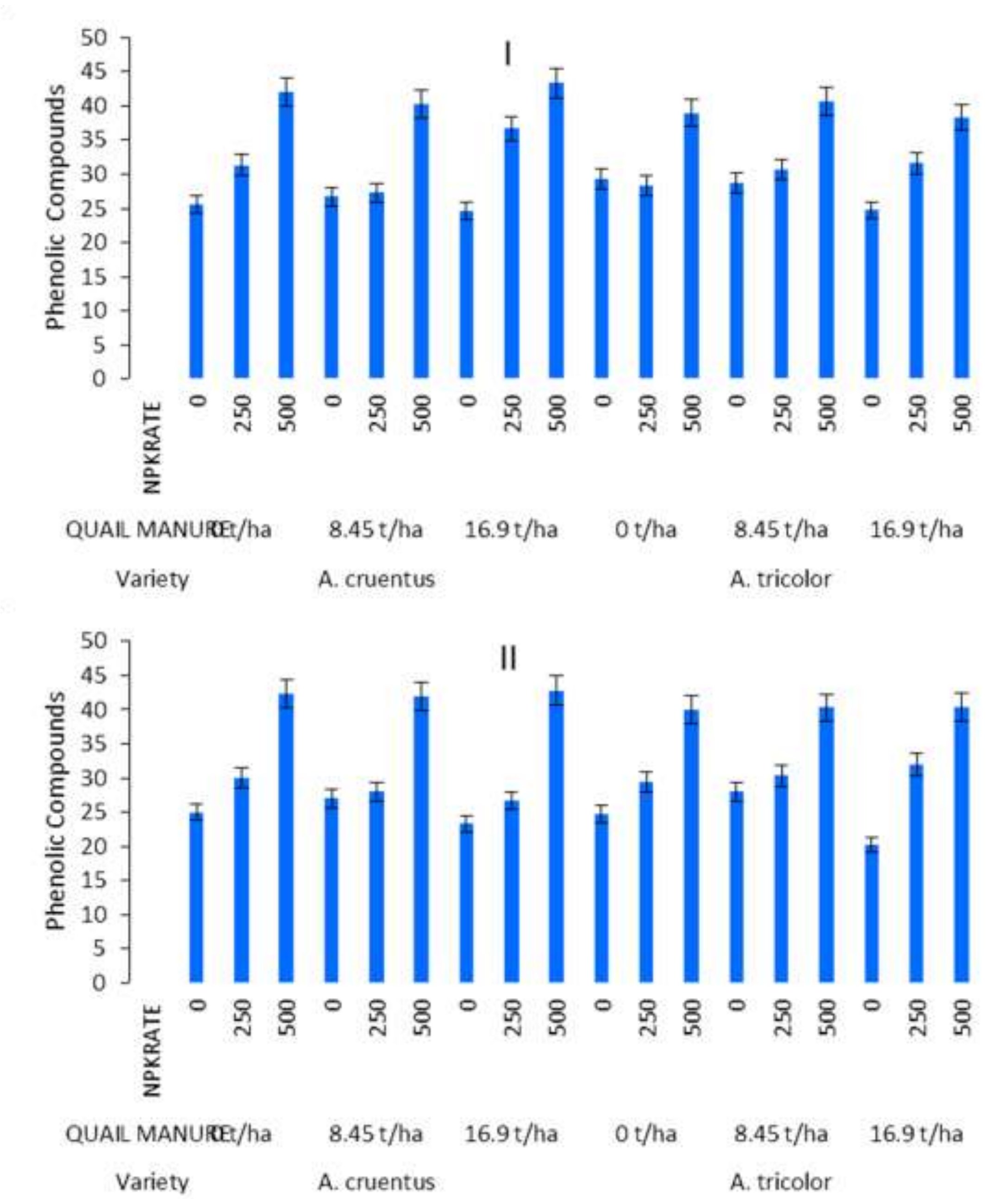

Figure 4.5 The interaction effect between the variety, NPK and quail manure rates on the total phenolic compound content during the first (I) and second (II) seasons

In season two A. cruentus had the highest TPC at 42.33gGAE/kg DM .The minimum phenolic in season one was at 0 t/ha of the organic and 0kg/ha of NPK, of 25.67gGAE/kg/DM for A. cruentus and 24.67gGAE/kg DM for A. tricolor, in season two the highest amount was recorded *A. cruentus* variety which had 43.33 gGAE/kg/DM in season one and in season two it had 42.78gGAE/kg/D (Table 4.13).

Table 4.13 The interaction influence of variety and NPK fertilizer rates on the total phenolic compound content in amaranth during the first and second season

Variety	NPK Rate	Phenolic Compounds (season 1)	Phenolic Compounds (season 2)
A. cruentus	0 kg/ha	26.9a	25.4c
	250 kg/ha	23.4b	38b
	500 kg/ha	22.5c	44.3a
A. tricolor	0 kg/ha	26.2a	26.5c
	250 kg/ha	24b	39.1b
	500 kg/ha	20.21d	44.4a
	LSD	0.96	3.52
V×N		*	**

Means in a same column followed by different letter (s) are not significantly different at $P \leq 0.05$NS = Not significant. * Significant at $\alpha=0.05$** Significant at $\alpha=0.01$

In season two *A. cruentus* had the highest TPC at 42.33gGAE/kg DM .The minimum phenolic in season one was at 0 t/ha of the organic and 0 kg/ha of NPK, of 25.67 gGAE/kg/DM for *A. cruentus* and 24.67 gGAE/kg DM for *A. tricolor*, in season two the highest amount was recorded *A. cruentus* variety which had 43.33 gGAE/kg/DM in season one and in season two it had 42.78 gGAE/kg/D. Phenolic are examples of secondary metabolites. Different plants produce different types of secondary metabolites. They are usually secreted when the plant is in stress full condition, due to disease and pest attack, they are not involved in plant growth. Phenolic in amaranth is also useful in human body, Ferry *et al*. (2000) showed that phenolic have got anticancer activities and inhibit cancer cell growth. Ryan et *al*. (1999) noted that different plants have different reservoir for phenolic in different parts like in the roots, shoot and leaves. Faller *et al*.

(2009) total phenolic were higher in convectional onions than organic onions, NPK reduce antioxidant levels but organic fertilizers increase its levels contrary to this study, (Duma *et al*. 2013) all shown that phenolic had anticancer activities that are able to inhibit cancer cell growth.

4.5 Effect of Organic quail manure and NPK on the soil chemical and physical properties of the rhizosphere

The results showed that the organic quail manure and inorganic NPK influenced the soil chemical properties of the soil in the two seasons; the application rate also influenced the chemical properties in the soil in the two seasons. Organic fertilizer significantly influenced phosphorous, calcium magnesium, iron and zinc content of the soil more in the second season. The chemical properties of the soil were significantly ($p \leq 0.05$) influenced during the second season and it was clear that inorganic fertilizer rate influenced most of the chemical properties. Organic fertilizer rates 8.45 t/ha and 16.9 t/ha showed an increase in the nitrogen content from 0.18% at 8.45 t/ha rate in season one to 0.23% at 16.9 t/ha, in season two. 0.38% at 8.45 t/ha and 0.24% at 16.9 t/ha, potassium amount also increased from 1.42 me% when 250 kg/ha of NPK was added to 1.62 me%, at 500 kg/ha (Akanbi and Togun, 2002) reported significant reduction in plant growth parameters when soil is deficient in nutrient especially nitrogen as they are often required for chlorophyll and protoplasm formation. The potassium level also increased from 1.11 me% in season one to 1.41% in season two, phosphorous content when NPK was applied at 250 kg/ha decreased from 13.67 ppm in season one to 12.67 ppm in the second season. NPK at 500 kg/ha slightly increased manganese from 0.26 me% in the first season to 0.46 me% in the second season. Organic fertilizer significantly influenced, phosphorous, potassium, calcium magnesium, iron and zinc content of the soil available nitrogen was significantly affected at $p \leq 0.05$, *A. cruentus* rhizosphere recorded the following amount of nitrogen in season one 0.05%, 0.092% 0.14%, 0.092%, 0.15%, 0.17%, 0.11%, 0.18%, 0.15% whereas *A. tricolor* rhizosphere nitrogen amount was 0.05% ,0.11%, 0.13%, 0.1%, 0.14%, 0.15%, 0.2%, 0.15%, 0.16% in season one at the application of the following rates respectively 0 kg/ha+0 t/ha, 0 kg/ha +8.45 t/ha 0 kg/ha+16.9 t/ha, 250 kg/hac+0 t/ha, 250 kg/ha+8.45 t/ha, 250 kg/ha+16.9 t/ha, 500 kg/ha+0 t/ha, 500 kg/ha+8.45 t/ha,+16.9 t/ha. As opposed to use of NPK fertilizers alone combined use of organic and inorganic manure ensures more availability of soil micro and macro elements ensuring a balanced nutrition. All the treatments increased N above the control treatments, soil organic matter form chelate with micronutrients forming cation exchange sites The Nitrogen amount in the soil in the second season reduced in comparison with season one in the two varieties rhizosphere. 60% of Nitrogen is lost through volatilization or is leached becoming ground water pollutant. Sole application of NPK fertilizer recorded low levels of macro and micro nutrients in the rhizosphere of the two varieties, in season one, at 250 kg/ha (Table 4.14).

Table 4.14 The interaction effects of the variety, NPK fertilizer and quail manure rates on the soil chemical properties during the first season

Variety	Nitrogen Rate	Quail Manure	Ca %	Cu ppm	Fe ppm	Mg %	Mn %	K ppm	P %
A. cruentus	0 kg/ha	0 t/ha	1.8d	16.15c	60b	0.74d	0.18f	6e	0.73c
		8.45 t/ha	1.99d	23.14b	64.2a	0.97d	0.21d	10b	0.94c
		16.9 t/ha	2.3c	24.12b	66.59a	1.23c	0.29c	10b	1.04b
	250 kg/ha	0 t/ha	1.97d	22.31b	62.3a	0.88d	0.21d	8c	0.85c
		8.45 t/ha	2.41c	26.1a	69.2a	1.35c	0.25c	10b	0.96c
		16.9 t/ha	3.1b	29.31a	69.4a	1.89b	0.28c	12a	1.14b
	500 kg/ha	0 t/ha	2.12c	24.13b	66.5a	1.02c	0.23d	9c	0.86c
		8.45 t/ha	2.6b	25.31b	68.5a	1.51b	0.31a	11b	1.05b
		16.9 t/ha	3.8a	30.16a	72.5a	2.14a	0.41a	13a	1.19b
A. tricolor	0 kg/ha	0 t/ha	1.81d	16.3c	60.2b	0.74d	0.17f	5e	0.78d
		8.45 t/ha	2.24c	21.23b	61.23ab	1.08c	0.24d	9c	1.01b
		16.9 t/ha	2.61b	21.35b	65.58a	1.75b	0.27c	11b	0.98c
	250 kg/ha	0 t/ha	2.1c	23.15b	63.11a	0.99a	0.2d	10b	0.85c
		8.45 t/ha	2.6b	24.36b	68.41a	1.85b	0.27c	12a	1.08b
		16.9 t/ha	2.97b	26.35a	69.56a	2.42a	0.29c	14a	1.14b
	500 kg/ha	0 t/ha	2.31c	22.54b	63.12a	1.13c	0.21d	10b	0.97c
		8.45 t/ha	2.76b	26.45a	69.31a	2.31a	0.33b	13a	1.06b
		16.9 t/ha	3.98a	29.43a	72.5a	2.51a	0.34b	14a	1.25a
	LSD		2.03	10.6	2.25	1.8	0.05	2	0.5
	V×Q×N		*	*	*	*	**	*	*

Means in a same column followed by different letter (s) are significantly different at $p \leq 0.05$ NS = Not significant. * Significant at α=0.05** Significant at α=0.01

Phosphorous recorded 6.45 ppm,10 ppm,11.57 ppm when applied at 0t/ha, 8.45 t/ha,16.9 t/ha, respectively in season one in comparison in season two that recorded 7.45 ppm,11 ppm,11.57 ppm when applied at 0 t/ha, 8.45 t/ha, 16.9 t/ha, respectively, phosphorous was recorded at 0.8 me%, 1.2 me% and 1.56 me% in comparison with the second season that was highly increased to1.4 me% and 1.66 me% at when quail manure was applied at 8.45 t/ha, 16.9 t/ha, respectively, nitrogen amount also increased from 0.02%, 0.13%, 0.17% when applied at 0 t/ha, 8.45 t/ha, 16.9 t/ha, respectively in season one to 0.03%, 0.33%, 0.44% when organic fertilizer was applied at 0 t/ha, 8.45 t/ha, 16.9 t/ha, respectively in season two. Calcium in the soil also increased highly from 2.93 me% in the first season to 3.93 me% in the second season when the organic rate was at 16.9 t/ha, poultry manure has high calcium carbonate which aid in raising soil pH. The highest quail manure rate,16.9 t/ha +250 kg/ha NPK rate showed significantly ($p \leq 0.05$) the highest nitrogen content in the amaranth plant tissues with 2.93% on the *A. tricolor* variety during the first season and 2.98% during the second season. For both seasons, the lowest nitrogen content in the plant tissues were observed in the controls with as low as 1.21% on the *A. cruentus* variety and 1.82% on the A. tricolor variety. The Nitrogen and phosphorus content of soil that received the two highest application rates (8.45 t/ha and 16.9 t/ha) were significantly ($p \leq 0.05$) higher than those that did not received any organic fertilizer, Calcium and Potassium content were significantly higher in all three application rates compared to the control. Organic fertilizer application rate of 16.9 t/ha significantly ($p \leq 0.05$) increased the copper content if compared to the other application rates. The highest amount of Calcium 3.43% was recorded in the organic fertilized soils at the rate of 8.45 t/ha followed by the quail manure at the rate of 16.9 t/ha the unfertilized soil had the least amount in the organic fertilized soils the highest amount of Calcium was recorded at 500 kg/ha, quail manure has high calcium content.

The chemical properties of the soil were significantly ($p \leq 0.05$) influenced during the second season and it was clear that organic fertilizer rate influenced most of the chemical properties. Organic fertilizer rates 8.45 t/ha and 16.9 t/ha significantly increased the phosphorus, potassium, zinc calcium and copper content of the soil and at rate 16.9 t/ha also significantly increased the manganese and magnesium, NPK slightly increased magnesium and manganese. Both the quail manure and application rate influenced the chemical properties of soil. The chemical properties of soil were mainly influenced by organic fertilizer application rates. The nitrogen and phosphorus content of soil that received the two highest application rates (8.45 t/ha and 16.9 t/ha) were significantly ($p \leq 0.05$) higher than those that did not received any organic fertilizer, calcium and potassium content were significantly higher in all three application rates compared to the control. Organic fertilizer application rate of 16.9 t/ha significantly ($p \leq 0.05$) increased the copper content if compared to the other application rates. The highest amount of calcium 3.43% was recorded in the organic fertilized soils at the rate of 8.45 t/ha followed by the quail manure at the rate of 16.9 t/ha. The unfertilized soil had the least amount.

In season one 500 kg/ha +8.45 t/ha had the highest Cu of 30.16 ppm, Fe of 72.5 ppm and Mn of 0.45 me% in *A. cruentus* variety rhizosphere. Application of 500 kg/ha +16.9 t/ha recorded the highest Ca of 3.98% and K of 14 ppm in *A. tricolor* rhizosphere in season one. Poultry manure residual increases soil organic matter, Cu, Fe, Mg, Mn, K, P, N, Ca and Zn. In very acid soils there is abundance of Fe, Mn, Zn and Cu. NPK application over a long period lowers soil pH. The effects of fertilizers at the second cropping showed that inorganic fertilizers showed better results than in control but organic fertilizers showed much better results than inorganic fertilizers. All the micro and macro elements increased above the control treatment in *A. tricolor* rhizosphere the highest Ca, Mg, K, Na and Nitrogen of 3.97%, 73.5 ppm, 2.61%, 15%, 0.46% and 0.17% was recorded at 500 kg/ha +16.9 t/ha, respectively. In *A. cruentus* rhizosphere, application of 500 kg/ha +16.9 t/ha recorded the highest Cu of 29.99 ppm, Mn of 0.61% and Zn of 13.64 ppm in season one, at 250 kg/ha, Ca was 1.97%, Cu was 22.3 ppm, Fe was 62.3 ppm, Mg was 0.88%, Mn was 0.21% K was 8 ppm, Phosphorous was 0.85%, Nitrogen was 0.09% and Zn was 9.9% but the levels increased once organic manure was integrated at 8.45 t/ha, so at 250 kg/ha + 8.45 t/ha, Ca was 2.41% from 1.97%, Cu increased to 26.1 ppm, Fe recorded 69.2 from 62.3 ppm, Mg increased to 0.25%. K recorded 10 ppm, Phosphorous increased from 0.85% to 0.96%, Nitrogen increased to 0.15% from 0.09% and eventually Zn from 9.9 ppm to 12.4 ppm (Table 4.15).

Table 4.15 The interaction effects of the variety, NPK fertilizer and quail manure rates on the soil chemical properties

Variety	Nitrogen Rate	Quail Manure	Ca %	Cu ppm	Fe ppm	Mg %	Mn %	K ppm	P %	Na %	N %	Organic C %	Zn ppm
A. cruentus	0 kg/ha	0 t/ha	1.7d	16.15c	60.2b	0.74d	0.17f	6.2e	0.733c	0.17f	0.04e	0.81c	9.1c
		8.45 t/ha	1.89d	24.14b	64.82a	0.97d	0.22d	10.4b	0.94c	0.22c	0.09d	0.99b	10.01b
		16.9 t/ha	2.27c	25.12b	65.59a	1.23c	0.31c	11b	1.14b	0.26c	0.13b	1.21a	9.98c
	250 kg/ha	0 t/ha	1.87d	23.31b	61.3a	0.88d	0.31d	9c	0.95c	0.25d	0.09d	0.95b	9.8c
		8.45 t/ha	2.43c	27.1a	69.72a	1.35c	0.35c	9.1c	0.86c	0.28c	0.13b	1.12a	11.4b
		16.9 t/ha	3.2b	28.31a	68.4a	1.89b	0.38c	11.9a	1.04b	0.37b	0.15a	1.19a	10.65b
	500 kg/ha	0 t/ha	2.21c	23.13b	66.5a	1.03c	0.33d	10c	0.89c	0.32d	0.1c	1.01b	10.02b
		8.45 t/ha	2.59b	25.31b	67.5a	1.61b	0.47a	12b	1.45a	0.31b	0.14b	1.25a	13.2a
		16.9 t/ha	3.78a	29.99a	72.5a	2.13a	0.61a	14a	1.29b	0.46b	0.16a	1.5a	13.64a
A. tricolor	0 kg/ha	0 t/ha	1.91d	16.4c	60.2b	0.75d	0.18f	4.6e	0.79d	0.17f	0.06e	0.95c	9.15c
		8.45 t/ha	2.34c	21.73b	62.23ab	1.09c	0.245d	10c	1.02b	0.24d	0.12c	1.22b	10.16b
		16.9 t/ha	2.71b	21.45b	65.68a	1.76b	0.29c	12b	0.97c	0.27c	0.14b	1.45a	10.35b
	250 kg/ha	0 t/ha	2.3c	23.23b	64.11a	0.98d	0.22d	11b	0.87c	0.25c	0.15c	1.11b	9.66c
		8.45 t/ha	2.69b	23.36b	68.71a	1.75b	0.29c	13a	1.09b	0.32c	0.1455a	1.26b	10.47b
		16.9 t/ha	2.98b	26.45a	69.66a	2.432a	0.28c	13a	1.15b	0.38b	0.14a	1.38a	10.35b
	500 kg/ha	0 t/ha	2.321c	22.56b	63.52a	1.23c	0.22d	11b	0.98c	0.23d	0.11b	1.11b	9.67c
		8.45 t/ha	2.66b	26.55a	69.41a	2.41a	0.34b	14a	1.07b	0.421a	0.16a	1.33a	11b
		16.9 t/ha	3.97a	29.53a	73.5a	2.61a	0.35b	15a	1.35b	0.46a	0.17a	1b	11.41b
	LSD		2.4	1.6	9.2	1.8	0.31	6.1	0.6	0.3	0.07	0.8	4.03
	V×Q×N		*	*	*	**	**	*	*	*	**	**	*

The influence of quail manure rates on the soil chemical properties season one, NPK significantly influenced the calcium and iron content. While organic fertilizer application rate significantly influenced the phosphorus, sulphur, calcium, magnesium and manganese (Table 4.16).

Table 4.16 The influence of quail manure rates on the soil chemical properties season 1

Quail Rate	Calcium	Copper	Iron	Magnesium	Manganese	Phosphorus	Potassium	Sodium	Total N
0 t/ha	2.12c	20.28b	62.97b	1.07c	0.242a	6.45b	0.80b	0.24a	0.02b
8.45 t/ha	2.52b	26.26a	67a	1.58b	0.25b	10a	1.2a	0.33a	0.13a
16.9 kg/ha	2.93a	26.34a	67.74a	1.67a	0.32a	11.57a	1.56a	0.24a	0.17a
LSD	0.31	6.4	2.36	0.06	0.17	2.69	0.16	0.28	0.04
V×Q	**	*	*	*	*	*	*	NS	*

Means in a same column followed by different letter (s) are significantly different at $p \leq 0.05$

NS = Not significant. * Significant at α=0.05** Significant at α=0.01

4.5.1 Calcium

Both quail manure and NPK application rates significantly ($p \leq 0.05$) influenced the calcium content in the soil. The highest rate of the organic fertilizer recorded the greatest increase in the calcium content in the soil under both varieties. As the organic fertilizer rate increased the calcium content significantly increased, irrespective of the application rate when compared to soil that did not receive any organic fertilizer. Soils treated within quail manure contained significantly higher calcium than soils treated with NPK. Contrary to the above results, Lampkin (2000) found high calcium levels in inorganic grown products than organic grown ones.

Table 4.17 The influence of quail manure rates on the soil chemical properties season 2

Quail Rate	Calcium	Copper	Iron	Magnesium	Manganese	Phosphorus	Potassium	Sodium	Total N
0 kg/ha	2.02c	19.28c	62.97c	0.97c	0.142c	7.45b	0.67b	0.24b	0.03c
8.45 t/ha	2.82b	25.26b	68a	1.58b	0.25b	11a	1.4a	0.27a	0.33b
16.9 kg/ha	3.93a	27.34a	69.74a	1.67a	0.32a	11.57a	1.66a	0.26a	0.44a
LSD	0.61	1.14	7.23	0.02	0.21	2.89	0.21	0.17	0.04
V×Q	*	*	**	*	*	*	*	*	**

Means in a same column followed by different letter (s) are significantly different at $p \leq 0.05$NS = Not significant. * Significant at α=0.05 Significant at α=0.01**

4.5.2 Magnesium

Quail manure rate significantly influenced the magnesium content of soil. The soils under the both varieties at the highest rates of organic and NPK recorded the highest increase of magnesium in the soil. Soils that received organic fertilizer at 8.45 t/ha had significantly ($p \leq 0.05$) lower magnesium than all the other quail manure levels including the control. In this study, the inorganic treated soils contained higher magnesium levels than soils that not receive any fertilizer but a higher range than the organic treated soils. However, Alfoldi *et al.* (1996) reported that the magnesium content of potatoes soil rhizosphere that received fresh and composted farmyard manure plus slurry for three years was lower than inorganic fertilized soils. Organic fertilizer rate, 8.45 t/ha significantly decreased the magnesium content in *A. cruentus* compared to soils that did not received any fertilizer. In the present study soil that received NPK tended to contained more manganese than those that received organic fertilizer. Contrary to Warman and Havard (1997) obtained higher manganese levels in carrots treated with compost (170 kg N ha^{-1}) over a period of 3 years compared to inorganic fertilized carrots.

Table 4.18 The influence of NPK fertilizer rates on the soil chemical properties season 1

NPK Rate	Calcium	Copper	Iron	Magnesium	Manganese	Phosphorus	Potassium	Sodium	Total N
0 kg/ha	2.02c	20.18b	62.97b	0.82c	0.21c	7c	0.74c	0.21c	0.03c
250 kg/ha	2.42b	26.26a	68a	1.51b	0.37a	13.67 a	1.42a	0.23b	0.18b
500 kg/ha	2.23c	26.34a	69.74a	1.49b	0.26b	12.48b	1.11b	0.25a	0.23a
LSD	0.29	2.47	2.94	0.05	0.13	3.12	0.11	0.19	0.05
V×N	*	*	*	*	*	**	**	*	**

Means in a same column followed by different letter (s) are significantly different at $p \leq 0.05$ NS = Not significant. * Significant at α=0.05 Significant at α=0.01**

4.5.3 Iron

The quail manure and NPK treated plots showed no significant differences in two seasons, in the two amaranth varieties (Table 4.17). Iron content of soils that received quail manure was significantly ($p\leq0.05$) higher than the one that received NPK. Although not significant ($p\leq0.05$), the iron content also increased with an increase in organic fertilizer rates. Smith Worthington (1998) reported higher iron content in organic grown vegetables while in the present study this was also observed especially in season two.

Table 4.19 The influence of NPK fertilizer rates on the soil chemical properties season 2

NPK Rate	Calcium	Copper	Iron	Magnesium	Manganese	Phosphorus	Potassium	Sodium	Total N
0 kg/ha	2.12b	20.28c	61.97b	0.82c	0.11c	7c	0.67c	0.23c	0.023e
250 kg/ha	2.42a	24.26a	69.7a	1.51b	0.37a	12.67 a	1.62a	0.35b	0.28c
500 kg/ha	2.13b	21.34c	69.74a	1.49b	0.46b	12.48b	1.41b	0.27a	0.23d
LSD	0.76	0.99	3.16	0.03	0.27	2.46	0.18	0.15	0.05
V×N	*	*	**	*	*	*	*	**	**

Means in a same column followed by different letter (s) are significantly different at $p \leq 0.05$ NS = Not significant. * Significant at $\alpha=0.05$** Significant at $\alpha=0.01$

4.5.4 Phosphorous

The phosphorus content of soil was only significantly ($p \leq 0.05$) influenced by the organic fertilizer rate (Table 4.17). The highest rates of organic and NPK showed the highest phosphorus content while the controls had the lowest under both varieties though the NPK showed higher amount of phosphorous compared to the organic poultry manure. According to Lairon et al. (1986) the phosphorus content of potatoes and carrots treated with organic fertilizer for two seasons was higher than those treated with NPK.

4.5.5 Total carbon

The controls on both varieties showed the lowest amount of total organic carbon in the soil as shown on Table 4.17 and 4.18. The carbon content of soils that received 16.9 t/ha quail manure was significantly ($p \leq 0.05$) higher than all the other treatments except where no quail manure was applied. The total carbon content of soils was not significantly influenced by NPK. Strauss et al. (2003) also reported on the difference between different applications of organic fertilizers. They reported higher carbon in vegetables treated with co-compost (sludge and municipal organic waste).

4.5.6 Soil pH.

The increase in the quail manure rates led to an increase in the soil pH for both seasons with a peak at 6.3 units while the lowest observed in the controls. In the main treatments the organic treatment showed the highest pH value of 6.3 where sole 16.9 t/ha of quail manure was applied followed by where sole 8.45t/ha of quail manure was applied (Figure 4.6).

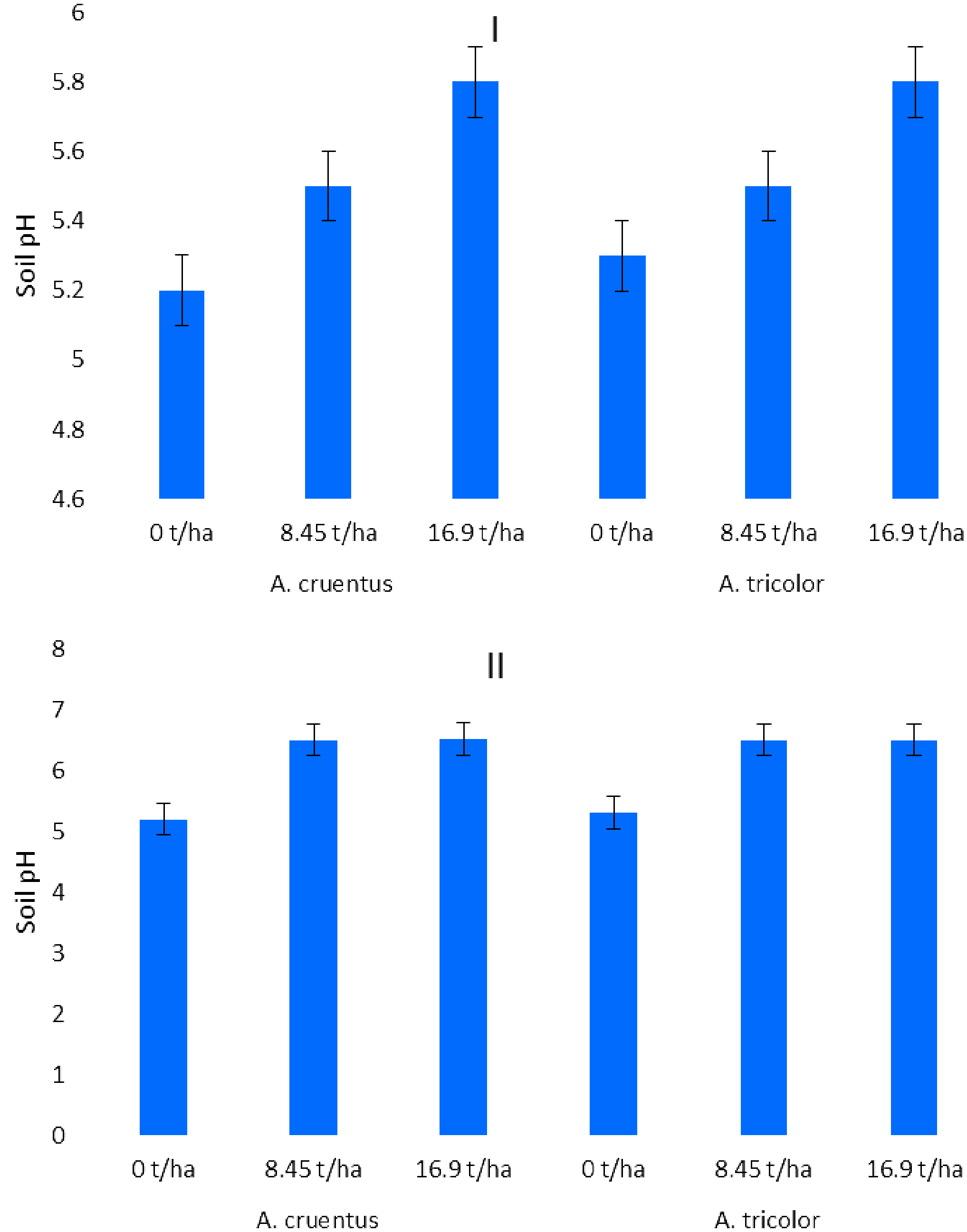

Figure 4.6 The influence of the interaction between variety and quail manure rates on the soil pH content during the first season (I) and second season (II)

Quail manure have cation exchange sites (Okanini et al., 2007), organic matter is known to form chelate with micronutrients, increasing availability of micronutrients like Fe, Cu, Zn and Mn are due to reduced soil pH, micro nutrients cations are soluble and available under acidic conditions (Brady et al., 1999). The maximum increase was 5.3, in the treatment having the highest dose of sole NPK at 500 kg /ha (Figure 4.7).

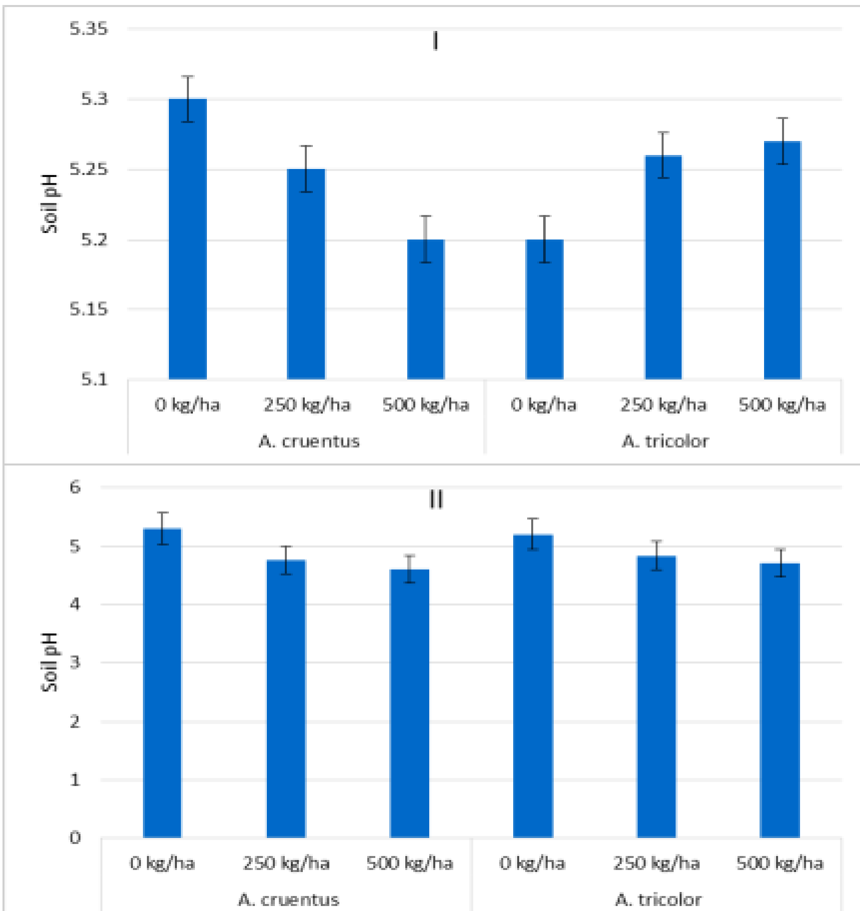

Figure 4.7 The influence of the interaction between variety and NPK fertilizer rates on the soil pH content during the first season (I) and second season (II)

The highest value of pH was due to effect of chicken manure which contains calcium carbonate (Camberato and Mitchell, 2011).

4.6 Correlation

In order to evaluate the correlation between characteristics following the application of different levels of NPK and quail manure also to assess the connection of these characteristics with the yield of *A. tricolor* and *A. cruentus* all correlation coefficients between characteristics were investigated (Appendix 2.1 and 2.2). There were significant positive correlations between all characteristics investigated. Also, significant positive correlations were obtained among yield with all characteristics. Therefore yield increased with increasing characteristics such as shoot length, no. of leaf, leaf area, and root length, shoot dry weight among other characteristics. According to the correlation coefficients, the yield of *Amaranthus* subsp. *cruentus* caused by an increase in no. of leaf gave a higher correlation than other characteristics investigated. In contrast, the relationship between shoot dry weight and root dry weight was lower compared with other interactions.

Table 4.20 The correlation between selected traits of amaranth during the first season

LEAVEAREA1	1	-							
NOOFLEAVES1	2	0.633*	-						
NOOFNODES1	3	0.577*	0.6579	-					
Oxalate1	4	0.1954	0.1998	0.3022	-				
pH1	5	-0.3553	-0.2994	-0.4349	-0.3124	-			
ROOTDRYWEIGH5	6	0.551*	0.4148	0.3202	0.4377	-0.4933	-		
ROOTLENGTH2	7	0.655*	0.5812	0.6268	0.3625	-0.2779	0.4965	-	
SHOOTDRYWEIGHT1	8	0.5547	0.5269	0.641*	0.2183	-0.349	0.277	0.5446	-
SHOOTFRESHWEIGHT1	9	0.808*	0.612	0.6283	0.2885	-0.4697	0.5734	0.6608	0.736*
SHOOTLENGTH1	10	0.749*	0.6974	0.640*	0.3285	-0.528*	0.5891	0.682*	0.6685
phenolic1	11	0.3435	0.2385	0.4139	0.582*	-0.4895	0.4461	0.4468	0.4336
		1	2	3	4	5	6	7	8

NS = Not significant. * Significant at α=0.05** Significant at α=0.01

Table 4.21 The correlation between selected amaranth traits during the second growing season

LEAVEAREA1	1	-							
NONODES1	2	0.0245	-						
OXALATE1	3	0.1043	-0.1145	-					
pH1	4	-0.0082	-0.0958	0.0018	-				
PHENOLIC1	5	0.1945	-0.0788	0.588*	-0.0036	-			
ROOTDRYWEIGHT1	6	-0.0792	0.0375	0.312*	0.062	0.3595	-		
ROOTLENGTH1	7	-0.1103	0.1376	0.1746	-0.0867	0.1761	0.3816	-	
SHOOTDRY_WEIGHT_1	8	-0.0343	0.0063	0.332*	0.0881	0.459*	0.825*	0.3693	-
SHOOTLENGTH1	9	-0.0676	0.0534	0.1537	-0.1252	0.261	0.4357	0.824*	0.
		1	2	3	4	5	6	7	

NS = Not significant. * Significant at α=0.05** Significant at α=0.01

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion of the study

Organic manure and inorganic fertilizer had influence on the growth, development and yield of two amaranth's species, *A.tricolor* and *A. cruentus* crop treated with quail manure (organic manure) recorded higher fresh shoot weight compared to the crop under NPK. The study concluded that the quail manure developed the crops root system significantly compared to NPK.

Leaf number increased with increased application NPK fertilizer. This showed that N promoted the vegetative growth of amaranth. Leaf number also increased with increased levels of compost manure. The increased in number of leaves under organic and NPK and compost application, reconfirmed the role of fertilizer in promoting vegetative growth in leafy vegetables. Changes in the number of leaves are bound to affect the overall performance of the plant as the leaves serve as the organ of photosynthesis for the manufacture of assimilates. The number of leaves increased as organic and inorganic and compost increased up to maximum level.

Organic and inorganic fertilizer had an effect on increasing the plants tissue N, Ca, Zn, Cu, Mg, Mn relative to no-fertilizer (control) and NPK fertilizer, Organic and inorganic fertilizer had an effect on increasing anti-nutrients in the two amaranth species the highest oxalate amount was found in A. tricolor treated with NPK at 500kg/ha it recorded 10.47 mg/100Fw in season one.

The lowest phenolic compound concentration was exhibited at the highest quail manure rate (16.9 t/ha) with a low of 20.21 gGAE/kg in the *A. tricolor* variety. Quail manure at 8.45t/ha is recommended, but it may be advisable to grow amaranth with 500 kg/ha if the grower is targeting phenolic. There were significant differences in the micro and macronutrients absorbed by plants in the different treatments of the study due to effects of organic and inorganic fertilizers; nutrient uptake was significantly affected by the fertilizer types at different rate.

5.2 Recommendations

A.cruentus produced higher number of leaves and hence the breeding of the two can be done to transfer the high yielding genes to *A. tricolor.*

There is need to extract a range of specific phenolics, since they are partitioning in different organs in the plants and check whether there is excretion of these phenolics in different amaranth species.

More research is needed considering the following aspect: To try other improved amaranth varieties or genotypes. Inclusion of other inorganic plant macronutrients beside NPK and micronutrients in the research of amaranth.

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APPENDICES

APPENDIX 1. Anova tables

APPENDIX 1.1 Leaf Area Season One

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	15801	7901	0.93	
REPLICATION.*Units* stratum					
VARIETY	1	34101	34101	4.01	0.053
NPKRATE	2	692112	346056	40.66	<.001
QUALMANURE	2	335148	167574	19.69	<.001
VARIETY.NPKRATE	2	31079	15540	1.83	0.177
VARIETY.QUALMANURE	2	37811	18905	2.22	0.124
NPKRATE.QUALMANURE	4	27777	6944	0.82	0.524
VARIETY.NPKRATE.QUALMANURE					
	4	31334	7833	0.92	0.463
Residual	34	289359	8511		
Total	53	1494522			

APPENDIX 1.2 Leaf Area Season Two

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	204378	102189	2.66	
REPLICATION.*Units* stratum					
VARIETY	1	421173	421173	10.97	0.002
NPKRATE	2	671850	335925	8.75	<.001
QUALMANURE	2	229390	114695	2.99	0.064
VARIETY.NPKRATE	2	168481	84240	2.19	0.127
VARIETY.QUALMANURE	2	13293	6647	0.17	0.842
NPKRATE.QUALMANURE	4	188895	47224	1.23	0.317
VARIETY.NPKRATE.QUALMANURE					
	4	98333	24583	0.64	0.637
Residual	34	1305366	38393		
Total	53	3301160			

APPENDIX 1.3 Number of Leaves Season One

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	7.259	3.63	2.34	
REPLICATION.*Units* stratum					
VARIETY	1	11.574	11.574	7.46	0.01
NPKRATE	2	39.704	19.852	12.8	<.001
QUALMANURE	2	22.259	11.13	7.17	0.003
VARIETY.NPKRATE	2	7.259	3.63	2.34	0.112
VARIETY.QUALMANURE	2	1.815	0.907	0.58	0.563
NPKRATE.QUALMANURE	4	8.963	2.241	1.44	0.241
VARIETY.NPKRATE.QUALMANURE					
	4	11.185	2.796	1.8	0.151
Residual	34	52.741	1.551		
Total	53	162.759			

APPENDIX 1.4 Number of Leaves Season Two

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	4.0864	2.0432	2.11	
REPLICATION.*Units* stratum					
VARIETY	1	9.2366	9.2366	9.55	0.004
NPKRATE	2	63	31.5	32.58	<.001
QUALMANURE	2	61.1481	30.5741	31.62	<.001
VARIETY.NPKRATE	2	0.9424	0.4712	0.49	0.619
VARIETY.QUALMANURE	2	18.3498	9.1749	9.49	<.001
NPKRATE.QUALMANURE	4	9.9259	2.4815	2.57	0.056
VARIETY.NPKRATE.QUALMANURE					
	4	3.1934	0.7984	0.83	0.518
Residual	34	32.8765	0.967		
Total	53	202.7593			

APPENDIX 1.5 Shoot Length Season One

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	9.794	4.897	1.11	
REPLICATION.*Units* stratum					
VARIETY	1	35.77	35.77	8.14	0.007
NPKRATE	2	334.585	167.292	38.05	<.001
QUALMANURE	2	173.496	86.748	19.73	<.001
VARIETY.NPKRATE	2	2.492	1.246	0.28	0.755
VARIETY.QUALMANURE	2	7.986	3.993	0.91	0.413
NPKRATE.QUALMANURE	4	29.769	7.442	1.69	0.174
VARIETY.NPKRATE.QUALMANURE					
	4	11.766	2.941	0.67	0.618
Residual	34	149.5	4.397		
Total	53	755.156			

APPENDIX 1.6 Shoot Length Season Two

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	18.28	9.14	0.24	
REPLICATION.*Units* stratum					
VARIETY	1	301.99	301.99	7.77	0.009
NPKRATE	2	794.58	397.29	10.22	<.001
QUALMANURE	2	582.44	291.22	7.49	0.002
VARIETY.NPKRATE	2	70.96	35.48	0.91	0.411
VARIETY.QUALMANURE	2	24.5	12.25	0.32	0.732
NPKRATE.QUALMANURE	4	184.92	46.23	1.19	0.333
VARIETY.NPKRATE.QUALMANURE					
	4	177.51	44.38	1.14	0.354
Residual	34	1321.44	38.87		
Total	53	3476.62			

APPENDIX 1.7 Root Length Season One

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	5.561	2.78	1.11	
REPLICATION.*Units* stratum					
VARIETY	1	2.187	2.187	0.87	0.358
NPKRATE	2	139.765	69.882	27.8	<.001
QUALMANURE	2	65.716	32.858	13.07	<.001
VARIETY.NPKRATE	2	12.919	6.46	2.57	0.091
VARIETY.QUALMANURE	2	13.416	6.708	2.67	0.084
NPKRATE.QUALMANURE	4	60.351	15.088	6	<.001
VARIETY.NPKRATE.QUALMANURE					
	4	14.705	3.676	1.46	0.235
Residual	34	85.469	2.514		
Total	53	400.089			

APPENDIX 1.8 Root Length Season Two

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	19.511	9.756	2.04	
REPLICATION.*Units* stratum					
VARIETY	1	59.956	59.956	12.52	0.001
NPKRATE	2	134.646	67.323	14.06	<.001
QUALMANURE	2	39.155	19.577	4.09	0.026
VARIETY.NPKRATE	2	227.077	113.538	23.71	<.001
VARIETY.QUALMANURE	2	24.835	12.418	2.59	0.09
NPKRATE.QUALMANURE	4	40.363	10.091	2.11	0.101
VARIETY.NPKRATE.QUALMANURE					
	4	37.222	9.305	1.94	0.126
Residual	34	162.845	4.79		
Total	53	745.61			

APPENDIX 1.9 Shoot Dry Weight Season One

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	0.1804	0.0902	1.56	
REPLICATION.*Units* stratum					
VARIETY	1	0.0155	0.0155	0.27	0.608
NPKRATE	2	1.52372	0.76186	13.14	<.001
QUALMANURE	2	0.75889	0.37945	6.54	0.004
VARIETY.NPKRATE	2	0.15278	0.07639	1.32	0.281
VARIETY.QUALMANURE	2	0.71081	0.35541	6.13	0.005
NPKRATE.QUALMANURE	4	0.07912	0.01978	0.34	0.848
VARIETY.NPKRATE.QUALMANURE					
	4	0.63704	0.15926	2.75	0.044
Residual	34	1.97188	0.058		
Total	53	6.03015			

APPENDIX 1.10 Shoot Dry Weight Season Two

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	16.894	8.447	3.45	
REPLICATION.*Units* stratum					
VARIETY	1	25.384	25.384	10.35	0.003
NPKRATE	2	100.677	50.338	20.53	<.001
QUALMANURE	2	1.962	0.981	0.4	0.673
VARIETY.NPKRATE	2	9.838	4.919	2.01	0.15
VARIETY.QUALMANURE	2	0.847	0.423	0.17	0.842
NPKRATE.QUALMANURE	4	18.846	4.711	1.92	0.129
VARIETY.NPKRATE.QUALMANURE					
	4	28.656	7.164	2.92	0.035
Residual	34	83.359	2.452		
Total	53	286.462			

APPENDIX 1.11 Root Dry Weight Season One

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	1.5395	0.7697	2.35	
REPLICATION.*Units* stratum					
VARIETY	1	0.8513	0.8513	2.6	0.116
NPKRATE	2	5.8311	2.9156	8.9	<.001
QUALMANURE	2	4.8662	2.4331	7.43	0.002
VARIETY.NPKRATE	2	1.8684	0.9342	2.85	0.072
VARIETY.QUALMANURE	2	1.0182	0.5091	1.55	0.226
NPKRATE.QUALMANURE	4	1.374	0.3435	1.05	0.397
VARIETY.NPKRATE.QUALMANURE					
	4	0.6066	0.1517	0.46	0.762
Residual	34	11.1409	0.3277		
Total	53	29.0962			

APPENDIX 1.12 Root Dry Weight Season Two

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	0.8651	0.4326	3.59	
REPLICATION.*Units* stratum					
VARIETY	1	0.0158	0.0158	0.13	0.719
NPKRATE	2	2.7988	1.3994	11.6	<.001
QUALMANURE	2	0.1663	0.0831	0.69	0.509
VARIETY.NPKRATE	2	0.0216	0.0108	0.09	0.914
VARIETY.QUALMANURE	2	0.2719	0.136	1.13	0.336
NPKRATE.QUALMANURE	4	0.5953	0.1488	1.23	0.315
VARIETY.NPKRATE.QUALMANURE					
	4	0.7742	0.1935	1.6	0.196
Residual	34	4.1018	0.1206		
Total	53	9.6109			

APPENDIX 1.13 Total Oxalate Season One

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	1.056	0.528	0.1	
REPLICATION.*Units* stratum					
VARIETY	1	1.067	1.067	0.21	0.653
NPKRATE	2	270.482	135.241	26.11	<.001
QUALMANURE	2	18.842	9.421	1.82	0.178
VARIETY.NPKRATE	2	27.974	13.987	2.7	0.082
VARIETY.QUALMANURE	2	16.133	8.067	1.56	0.225
NPKRATE.QUALMANURE	4	7.192	1.798	0.35	0.844
VARIETY.NPKRATE.QUALMANURE					
	4	8.972	2.243	0.43	0.784
Residual	34	176.093	5.179		
Total	53	527.81			

APPENDIX 1.14 Total Oxalate Season Two

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	1.094	0.547	0.1	
REPLICATION.*Units* stratum					
VARIETY	1	1.976	1.976	0.36	0.554
NPKRATE	2	288.367	144.184	26.1	<.001
QUALMANURE	2	21.047	10.524	1.9	0.164
VARIETY.NPKRATE	2	34.501	17.251	3.12	0.057
VARIETY.QUALMANURE	2	19.705	9.853	1.78	0.183
NPKRATE.QUALMANURE	4	11.261	2.815	0.51	0.729
VARIETY.NPKRATE.QUALMANURE					
	4	10.601	2.65	0.48	0.75
Residual	34	187.83	5.524		
Total	53	576.384			

APPENDIX 1.15 Total Phenolic Compound Season One

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	46.78	23.39	0.82	
REPLICATION.*Units* stratum					
VARIETY	1	0.67	0.67	0.02	0.879
NPKRATE	2	1808.11	904.06	31.85	<.001
QUALMANURE	2	16	8	0.28	0.756
VARIETY.NPKRATE	2	12.33	6.17	0.22	0.806
VARIETY.QUALMANURE	2	49.78	24.89	0.88	0.425
NPKRATE.QUALMANURE	4	68.56	17.14	0.6	0.663
VARIETY.NPKRATE.QUALMANURE					
	4	42.56	10.64	0.37	0.825
Residual	34	965.22	28.39		
Total	53	3010			

APPENDIX 1.16 Total Phenolic Compound Season Two

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	96.44	48.22	2.29	
REPLICATION.*Units* stratum					
VARIETY	1	16.67	16.67	0.79	0.38
NPKRATE	2	1858.11	929.06	44.1	<.001
QUALMANURE	2	22.11	11.06	0.52	0.596
VARIETY.NPKRATE	2	2.11	1.06	0.05	0.951
VARIETY.QUALMANURE	2	42.11	21.06	1	0.379
NPKRATE.QUALMANURE	4	109.78	27.44	1.3	0.289
VARIETY.NPKRATE.QUALMANURE					
	4	37.78	9.44	0.45	0.773
Residual	34	716.22	21.07		
Total	53	2901.33			

APPENDIX 2. Combined analysis for growth and yield components across seasons

	Leaf Area (cm2)	Nitrogen (%)	Total Oxalate	Soil pH	Root Dryweight (g)	Root Length (cm)	Shoot Dryweight (g)	Total Phenolic
Season.VARIETY	NS	NS	NS	NS	NS	NS	*	NS
P Value	0.935	0.717	0.97	0.375	0.876	0.241	0.004	0.842
Season.NPKRATE	NS	NS	NS	*	*	NS	*	NS
P Value	0.073	0.993	0.999	0.003	<.001	0.247	<.001	0.936
Season.QUALMANURE	NS	NS	NS	NS	NS	*	NS	NS
P Value	0.124	0.976	0.996	0.31	0.692	0.021	0.932	0.99
Season.VARIETY.NPKRATE	NS	NS	NS	NS	NS	NS	NS	NS
P Value	0.544	0.986	0.999	0.143	0.936	0.858	0.258	0.995
Season.VARIETY.QUALMANURE	*	NS	NS	NS	NS	NS	NS	NS
P Value	<.001	0.993	0.998	0.32	0.315	0.854	0.991	0.852
Season.NPKRATE.QUALMANURE	NS	NS	NS	NS	NS	NS	NS	NS
P Value	0.514	0.999	0.879	0.546	0.308	0.643	0.118	0.997
Season.VARIETY.NPKRATE.QUALMANURE	*	NS	NS	NS	NS	NS	NS	NS
P Value	0.012	0.998	0.917	0.519	0.168	0.088	0.098	0.965

NS = Not significant. * Significant at α=0.05** Significant at α=0.01