

**EFFECTS OF LEAF EXTRACTS, ORGANIC, INORGANIC  
FERTILIZERS ON SOIL pH, GROWTH, SOIL MACRONUTRIENTS,  
BETA-CAROTENE OF *Amaranthus* IN KIAMBU COUNTY, KENYA**

**BY**

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### DECLARATION

I Njeru Charity Nyaguthii hereby declare that the work contained in this thesis is my own and that other scholars' works referred to here have been duly acknowledged. I also declare that this research thesis is original and has not been presented in any other university or institution for consideration.

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## **DEDICATION**

I dedicate this research thesis to my family; my husband Francis Ngigi and children Andrew, Mark and Faith and my sister Regina Njeru for their support, love and encouragement and Kenyatta University for providing the funding for this project.

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## **LIST OF ABBREVIATIONS AND ACRONYMS**

**ALVs** : African leafy vegetables

**ANOVA** : Analysis of variance

**LSD** : Least significant difference

**RCBD** : Randomized complete block design

**SAS** : Statistical analyses variance

**FMY** :Farm Yard Manure

**µg** :Micrograms,units for measuring betacarotene levels

**ppm** :Parts per million units for measuring phosphorus levels

**me/100g**:Milliequivalent per 100 grams units for measuring potassium

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## ABSTRACT

Soil is a significant reservoir for plant nutrients and hence necessary for plant growth. Soil pH is a very important chemical property of the soil, as it dictates the availability of plant nutrients. Low soil pH reduces soil nutrients. Some of the factors leading to acid soils include continuous cultivation of soil due to scarcity of arable land, excessive use of inorganic fertilizers, climate change and deforestation. Reclamation of acidic soils includes addition of lime which is expensive and requires re-application. These do not add all the nutrients required by plants and may also contain soil contaminants which can make the soil unproductive or may result in contaminated products harmful to humans if consumed. Some plant leaves and their extracts reduce soil acidity and add plant nutrients to soils as well as improving soil texture. The objective of this study was to evaluate the effects of leaf extracts from selected trees on soil acidity, their effect on soil macro nutrients, growth and betacarotene levels of amaranthus. Plant leaves that were tested were Turril (*Vitex keniensis*), Mexican sunflower (*Tithonia diversifolia*) and Indian nettle (*Plectranthus barbatus*). Amaranthus (*Amaranthus* spp.) leaves are a good source of vitamin A, vitamin C, and folate and were therefore used as a test crop. The experiment setup was in a randomized complete block design (RCBD) with three replicates, arranged in a two by seven factorial with two species of amaranthus. The soil treatments were the three leaves extracts, lime, farm yard manure, inorganic fertilizer and control. Data on plant height, leaf area, number of leaves, fresh weight and dry weight and levels of beta carotene were collected from the amaranthus grown on the treated soil. AOAC method was used for analysis of beta carotene. All data was subjected to analysis variance (ANOVA) at 5% level of significance using SAS and least significant difference (LSD) for means separation, every week for four weeks. The results showed that leaf extracts, *Plectranthus barbatus* reduced soil acidity (pH 5.9) to (pH 6.7), while inorganic fertilizer increased the acidity (pH 5.9) to (5.3). On the growth parameters, FYM (47.0g) and leaf extract *Vitex keniensis* (45.17g) gave the highest increase while control (26.3g) the least. On the macronutrients analysis in the soil, F.Y.M (0.244%) gave the highest nitrogen levels while control gave the least (0.138%), on phosphorus inorganic fertilizer (32.75ppm) and F.Y.M. (32.42 ppm) gave the highest levels while lime (25.08ppm) the least and on potassium, leaf extract *Plectranthus barbatus* (1.416me/100g) gave highest levels and control (1.311me/100g) the least. Betacarotene levels, F.Y.M (51.1 $\mu$ g) and leaf extract *Plectranthus barbatus* (46.1 $\mu$ g) gave the highest betacarotene levels while control the least (19.22 $\mu$ g). Amaranthus with high levels of betacarotene, have an antioxidant which fights cancer cells. The outcome, of the research will be used in recommendation of economical organic fertilizer leading to decreased dependence on inorganic fertilizer especially for small scale farmers with 0.4 ha and below within Juja Ward in Kiambu County, Kenya.

## **CHAPTER ONE**

### **INTRODUCTION**

#### **1.1 Background Information**

Too much overuse of inorganic fertilizer has led to low soil pH which reduces the availability of essential nutrients to the plants (Mokaya 2016, Singh *et al.*, 2015; Cheng-Wei Liu *et al.*, 2014). This results in low rates of decomposition of organic matter. It also leads to depletion of micronutrients leading to the production of food of low quality nutritionally (Rashid *et al.*, 2016; Brar *et al.*, 2015). Unless the problem is addressed, the soil will eventually become unproductive. The organic matter is a necessity to increase buffering capacity of the soil and also releases nutrients to the plant. The soil pH is increased by liming, which is an expensive exercise and does not add fertility to the soil. There is a need for an alternative method to the application of inorganic fertilizers and liming materials.

The increased human population has not only increased overuse of the land but also has resulted in low yields leading to encroachment of forest cover, which, in turn, leads to reduced rainfall (Liu *et al.*, 2017; Kitula *et al.*, 2015). Therefore, there is need to look for an alternative to inorganic fertilizers that can also increase the forest cover. Studies have shown that certain plants have a litter that can decompose easily to releasing plant nutrient and increasing buffering capacity of soil (Han *et al.*, 2016; Singh *et al.*, 2015; Sharma *et al.*, 2013). *H. annuus* (L) (sunflower) and *T. diversifolia* (H.A. Gray) have leaf extracts with a high rate of humification, mineralisation and buffering capacity (Gittings *et al.*, 2015;

Indrusummunar *et al.*, 2013). Therefore plants whose leaves decompose easily can be used as sources of organic manure.

Organic farm manure produced in the farm itself serves various fertilization purposes. It is useful in the farm due to its organic content. The availability of organic matter in soil is vital as it contains utilizable energy and nutrients and other vital benefits to organisms in the soil (Cohan 2015; Majumdar *et al.*, 2015). Decayed plants are used as organic manure in farms. The quality of this manure depends on the type of plants used to make it in the farms prompting the need to carefully select quality plants that would provide high quality manure. However, decomposition rate of leaves various plants and levels of their macronutrients have been investigated (Cole *et al.*, 2016; EmsEns *et al.*, 2016).

Most local indigenous trees have been replaced with exotic trees. It has been reported that some of these exotic plants produce litter that takes too long to decompose, and decomposition products may be acidic (Yue *et al.*, 2017; Tamura *et al.*, 2016; Austin *et al.*, 2015). It is believed that organic matter plays an important role in buffering capacity of the soil (Cooper, 2017; Lei *et al.*, 2017). Leaves with high buffering capacity have a relatively high level of essential elements (Pühringer, 2016; Toit *et al.*, 2016). Organic farming relies on developing biological diversity in the field to disrupt habitat for organisms and the purposeful maintenance and replenishment of the soil fertility (Fawzy *et al.*, 2016; Vinitha *et al.*, 2015). Organic farmers feed soil biota and build soil organic matter

with cover crops, compost, and biologically based soil amendment (Lal, 2015; D'Hose *et al.*, 2016), resulting in healthy plants that are able to resist diseases and insect predation (Liu *et al.*, 2017; Søren Bak *et al.*, 2016).

The application of mineral fertilizers alone in rehabilitating degraded soils have yielded limited success in farming even when they are available and affordable to farmers (Schröder *et al.*, 2018; Goulding *et al.*, 2016). Organic nitrogen and phosphorus owing to their biogenic origin (Kiyoshi *et al.*, 2017; Kopytko *et al.*, 2017) have the virtue of being released slowly and steadily (Kopytko *et al.*, 2017) to meet the nitrogen demand of crops at all stages of growth. This is opposed to nitrogen in soluble mineral fertilizers is released rather fast and that a part of it may be lost through leaching especially if the rate of release transcends plant uptake. Duong (2013) and Masunga *et al.* (2015) noted that composts made from organic wastes supply plant nutrients in a slow pattern. When applied in farms, they increase soil organic matter and slowly release organic nutrients as well as preventing luxury consumption (Bley *et al.*, 2017). While examining the suitability of corn-cob compost on plants in acid red soil, Mutezo (2013) reported that composts are suitable in mitigating adverse effects that result harvest loss due to acidity. Successful application of organic manures has prompted more research to be conducted in order to come up with the organic nutrient sources to supplement or even be superior the expensive mineral fertilizer formulations used in crop production. There is need to investigate the effect of selected plants leaf

extract with high levels of macronutrients in leaves and high mineralization (He *et al.*, 2015; Maillard *et al.*, 2015).

## **1.2 Problem Statement and Justification**

Continuous cultivation of diminishing farms to feed the growing population has resulted in soil degradation and consequently a rise in use of inorganic fertilizers to increase crop yield. Inorganic fertilizers tend to change soil pH if applied for a long period since they are acidic in nature (Goulding *et al.*, 2016). The lowering of soil pH has negative effect on the growth of the plants and soil organisms and, therefore, reduces expected yields. This is because the acid deposition leads to leaching of essential nutrients such as potassium (Duan *et al.*, 2016; Goulding *et al.*, 2016). Soil with high buffering capacities may not be affected much by application of acidic fertilizers. Buffering capacity is the ability of an ecosystem to maintain a constant pH, despite addition of an acid or a base. Buffering is important in preventing rapid lowering of pH in soils (Zhang *et al.*, 2016; Husson, 2013). Studies have shown that areas with high organic content are not affected by acidic deposition and it is believed that the decayed products of these areas buffer the effects of acid (Goulding *et al.*, 2016). The inorganic fertilizers are expensive and hence out of reach to most rural farmers, majority of whom are women. In addition inorganic fertilizers are not always available, especially subsidized ones which results in late planting and thus poor yields. Studies of plant leaves and leaf extracts have been shown to increase soil pH and crop

biomass possibly due to availability of nutrients (Wiklund, 2017; Carter *et al.*, 2013). Therefore, there was need to optimize productivity using natural environment using individual leaf extracts to optimize plant nutrients and reduce soil acidity especially for the small scale farmers with 0.4 ha and below within Juja ward in Kiambu County in Kenya.

## **Research Objectives**

### **1.3. 1 General Objective**

To investigate the effects of leaf extracts and other treatments on the growth and nutritional value of *Amaranthus* species

### **1.3.2 Specific objectives**

- i. To determine the effect of *Vitex keniensis*, *Tithonia diversifolia* and *Plectranthus barbatus* leaf extracts, lime, farm yard manure and inorganic fertilizer on soil pH.
- ii. To investigate the effects of the leaf extracts of *Vitex keniensis*, *Tithonia diversifolia* *Plectranthus barbatus* leaf extracts, lime, farm yard manure and inorganic fertilizer on the growth parameters of *Tricolor* and *Cruetus* varieties of *Amaranthus*.
- iii. To determine the effect of *Vitex keniensis*, *Tithonia diversifolia* and *Plectranthus barbatus* leaf extracts, lime, farmyard manure and inorganic fertilizer on nitrogen, phosphorus and potassium levels in the soil.

- iv. To determine beta-carotene levels in *Tricolor* and *Cruetus* varieties of *Amaranthusspp* grown in the soils treated with leaf extracts of *Vitex keniensis*, *Tithonia diversifolia* and *Plectranthus barbatus*, lime, farm yard manure and inorganic fertilizer.

#### **1.4 Hypotheses**

- i. There is decrease in acidity in the soils treated with *Vitex keniensis*, *Tithonia diversifolia* and *Plectranthus barbatus* leaf extracts, lime, farmyard manure and inorganic fertilizer.
- ii. There is significant effect on the growth rate and productivity of *Amaranthusspp* due to treatments with *Vitex keniensis*, *Tithonia diversifolia*) and *Plectranthus barbatus* leaf extracts, lime, farm yard manure and inorganic fertilizer.
- iii. There is increase in the levels of macro nutrients in the soils treated with *Vitex keniensis*, *Tithonia diversifolia* and *Plectranthus barbatus* leaf extracts, lime, farm yard manure and inorganic fertilizer.
- iv. There is improvement in the beta-carotene levels of *Amaranthusspp* grown after treatment with leaf extracts of *Vitex keniensis*, *Tithonia diversifolia* and *Plectranthus barbatus*, lime, farm yard manure and inorganic fertilizer.

#### **1.5 Significance of the Study**

This study sought to know if leaf extracts could be substituted for fertilizer to reduce the use of expensive inorganic fertilizer especially for the small scale

farmers with 0.4 ha and below within Juja Ward. A positive result will enable poor farmers to improve amaranthus growth rate without much of inorganic fertilizer, and boosts its nutritional value, generating income. The farmers will be encouraged to grow much of these plants as their leaf extracts reduce the soil acidity and buffering of the soil at the same time curbing the cost of lime which is commercially used to reduce soil acidity. Use of leaf extract will also increase soil macro nutrients enriching the soil fertility. Further, it is hoped that the project outputs will empower women by presenting them with an opportunity to identify *Amaranthuspp* since it was used in this study as a test crop.

### **1.6 Conceptual Framework**

There are many factors that affect the growth of the two varieties of the *Amaranthuspp*, The effects of the treatments on soil pH and soil macro nutrients (objective 1 and 3). The growth parameters are the indicators on the effects of the treatments (objective 2). *Amaranthuspp* with high nutritional levels (objective 4) and also a decrease of soil acidity and increase in soil macro nutrients (Figure 1.1).

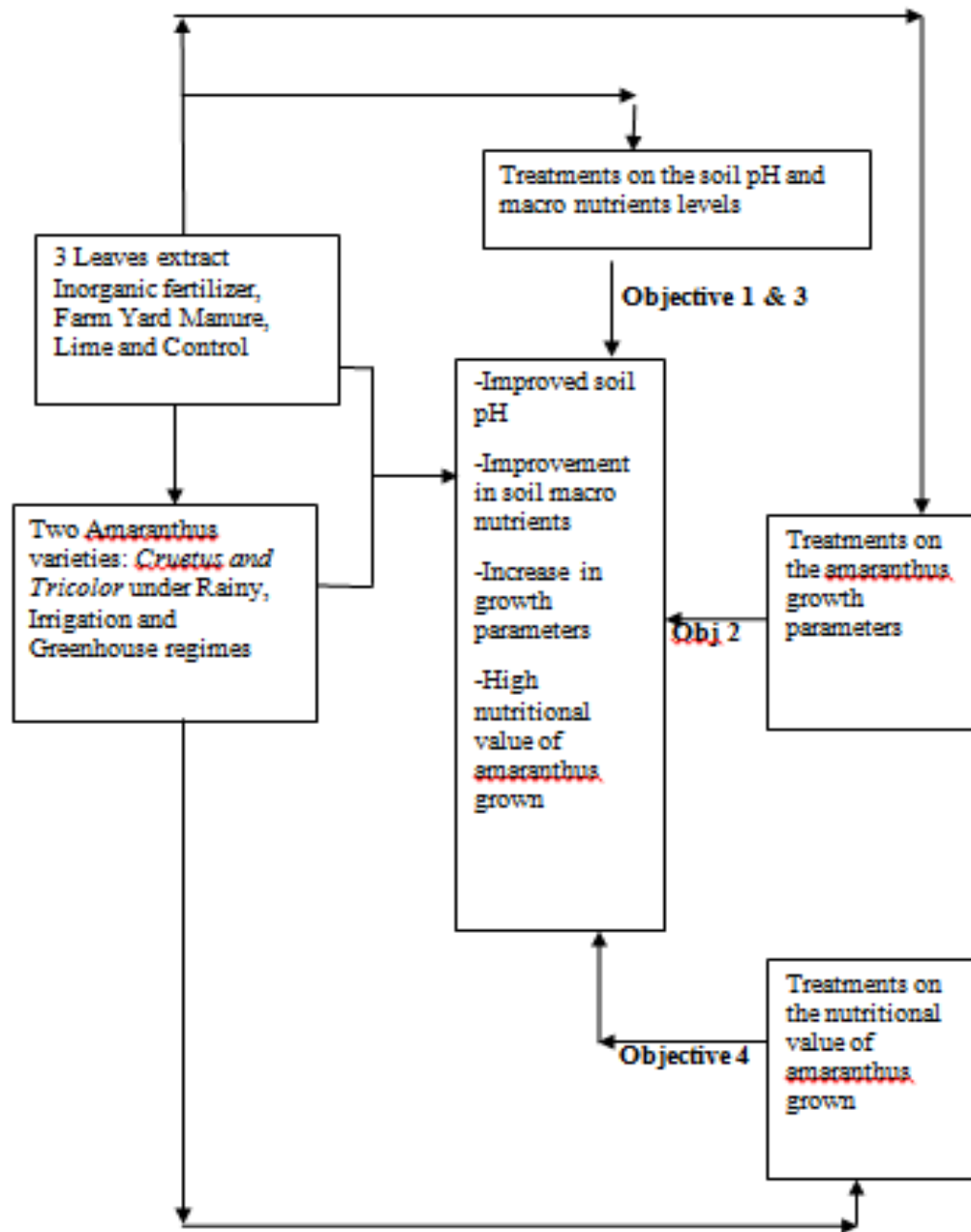


Figure 1.1: Conceptual framework of the factors affecting the growth of *Amaranthus spp.* under green house in Kenyatta University and under rainy and irrigation regimes in Juja experimental sites.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

Food security is the concern of governments throughout the world. This is compounded by population growth resulting in continuous cultivation of arable land leading to exhaustion of soil nutrients thus reducing crops production (Moshy, 2017; Mubiruet *et al.*, 2017). To correct this, most farmers rely on inorganic fertilizers which also lead to soil acidity and eventually reduced productivity due to reduced pH and soil texture (Abebe *et al.*, 2017; Haute, 2017).

In Kenya, the land owned by nuclear family is no longer sufficient for large scale farming due to subdivision, hence an urgent need to increase crop yield to feed the growing population. Increased population has also resulted in deforestation, climate change and pollution, all of which end up affecting the soil. Food insecurity has been associated with compromised crop production due to over use of commercial inorganic fertilizer in small pieces of land which tend to be the ultimate solution in maintaining high yields of food crop (Nyaundi, 2014; Gichure, 2013).

Too much over use of inorganic fertilizer has led to low soil pH which reduces the availability of essential nutrients to the plants (Goulding *et al.*, 2016; Singh *et al.*, 2015; Liu *et al.*, 2014). Kumar *et al.* (2017), Tariq *et al.* (2016) and Ahemad

(2015) have reported that low soil pH causes exchange of nutrients with hydrogen ions thereby destroying the roots. This calls for mechanisms or techniques for increasing soil pH. Kisinyo *et al.* (2015) also reported the effects of increased acidity on soil nutrients while Abebe *et al.* (2017) and Han *et al.* (2016) reported the effects of combining organic and inorganic fertilizers on the growth of maize.

Sustainable agriculture is threatened by widespread acidity in many parts (Duan *et al.*, 2016), however, application of lime has been reported to significantly improve soil fertility Ban *et al.*, 2016). In regards to this, liming is done but it's expensive and requires regular application. Farmers are not commensurate with the plant requirements and/or nutrient levels in the soil (Ademba *et al.*, 2015), as the extent of nutrient depletion is not known on fertilizer and manure application, hence increased acidity in the soils.

## **2.2 Soil Fertility**

Soil fertility has implication in terms of soil degradation, but also on the health of the crops, animals and human beings which depend on it. The manure helps to modify the physical conditions of the soils, by improving water holding capacity, aeration, drainage and friability. Darker colour of organic matter means that the soil warms up faster (Nicol *et al.*, 2015).

Organic fertilizers provide energy needed for increasing microbiological activity (Sun *et al.*, 2017). It also helps to protect crop from temporary gross, excess

mineral salt and toxic substances and from rapid fluctuations in soil reaction by means of their high absorption capacity exerting a ‘buffering’ action. In this way, they can counter the effect of excess liming as far as the availability of micronutrients is concerned.

In addition, nutrients are released more slowly from manures than from the inorganic fertilizers; therefore, the desirable effect of the compost manure can last for more than one season (Polprasert, 2017). Farmers who have domestic animals may take farm yard manure (FYM) which consist of the animal excrete and bedding materials usually straw in varying quantities and varying stages of decomposition (Teenstra *et al.*, 2015). These manures have advantage of supplying essential nutrients either directly or indirectly by eliminating aluminium toxicity or by producing organic acids, thereby increasing nutrients availability (Ditta *et al.*, 2016).

Organic manure is made by composting plants residues, animal dung, ash and green vegetation in Kenya (Mutezo, 2013). Some of the plants reported for making compost are young grass hay, cow pea hay, soya bean hay, maize stalk, leaves and wheat straw (Goopy *et al.*, 2016; Mutezo, 2013). ‘Plant teas’ for top dressing are made with broad leaved young shoots that can easily decompose in water such as those of stinging nettle, comfrey, *Amaranthusspp* and *Tithonia diversifolia* (Njogu, 2013).

### **2.2.1 Nitrogen**

Nitrogen is essential for plant growth and reproduction. It plays a very important role in protein formation and is a constituent of protein and protoplasm of all living cells. It forms part of chlorophyll molecule and makes plants succulent with deep green colour. Nitrogen encourages vegetative growth which is necessary in crops where leaves are harvested such as kales and corianders. Components of amino acids which are the building block of proteins are needed for growth and development of all living tissues. (Muchukuri *et al.*, 2004).

Nitrogen content of most protein varies from 14 - 18 % (Mohanty *et al.*, 2014). It is a very important constituent of chlorophyll which is associated with high photosynthetic activity, vigorous vegetative growth and dark green colour. Lack of nitrogen is the most common cause of nutritional plant stress (Rajasekar *et al.*, 2017). The conventional farmer relies on artificially fixed bagged nitrogen whereas the organic farmer relies on the Rhizobia bacteria in symbiotic association with legumes to make nitrogen available for plant nutrition (Howieson *et al.*, 2016; Santi *et al.*, 2013). Nitrogen is the only nutrient which can be lost at appreciable amount to the atmosphere (Lyons *et al.*, 2014).

The gaseous nitrogen is lost as ammonia, while nitrogen oxide and molecular nitrogen may also be lost in solution form as nitrate ion. For most non leguminous plants, the nitrate ion is the primary source of nitrogen (Biswas *et al.*, 2016;

Lehnert *et al.*, 2015). Over the past century, anthropogenic activities have nearly halved the source available of available nitrogen; invasive nitrophilous species have become more dominant in wetland ecosystems, altering the species composition and diversity (Zhao *et al.*, 2015; Hart *et al.*, 2014). Deficiency symptoms include stunted growth (in young corns) and yellow-green foliage because of reduction of chlorophyll in the leaf, and hence loss of green colour (chlorosis) (Rout *et al.*, 2015; Hellal *et al.*, 2013).

In more mature plants, yellowing of lower leaves following the mid ribs in typical v-shaped fashion is observed but the leaf margin remains green and ‘firing’ that is dying of the lower leaves is also observed (Seebold *et al.*, 2013). Nitrogen reserve is stored in the upper soil horizons of soil as organic matter as organic fractions. During surface mining, the upper soil horizons are removed and stockpiled prior to their disturbance. The storage of topsoil allows rapid conversion of organic nitrogen to soluble nitrate ( $\text{NO}_3^-$ ) that is subject to leaching or conversion to nitrogen gas (denitrification) which volatilizes into the atmosphere. When topsoil is stored, it can spread on a disturbed landscape, thus depleting nitrogen reserves that may be altered by several chemical and biological phenomena (Munshower, 1994). The healthy cycling of nitrogen through the ecosystem may be consequently be inhibited or prevented (Magambo, 2015; Menta, 2012). Nitrogen fertilizer can be applied on lands that need to be reclaimed as well as mine sites where re-vegetation is desired.

Consequently, tilling is not necessary to incorporate the nitrogen into the soil because of the leaching ability of nitrogen. However, tilling may be necessary where nitrogen fertilizer is incorporated with another macronutrient fertilizer. Nevertheless, Nitrogen in soils can be in different forms since it is also incorporated in organic matter and microbes (Brady and Weil, 1999). Nitrogen can also be released in various forms into the soil solution when organic matter decomposes by microbial processes or when the microbes themselves die and decompose (Cheng *et al.*, 2017; Dijkstra *et al.*, 2013).

### **2.2.2 Phosphorus**

Phosphorous is an important element in establishment of crops. It encourages the formation, development and establishment of roots particularly secondary roots (White *et al.*, 2013; Lynch *et al.*, 2012). Phosphorous is a constituent of many specific compounds making up the plant structure. Phosphorous is needed for cell division as it is a part of nucleoproteins which are involved in cell reproduction process. It forms part of a chemical essential to the synthesis and degradation of carbohydrates. Phosphorous is essential for seed germination, root development, flowering, fruit formation and crop maturation. It hastens the ripening of the fruits and strengthens the skeletal structure of the plants, thereby preventing lodging in cereals thus countering the effects of excess nitrogen (Young, 1976).

Phosphorous affects the quality of certain crops, especially forages and vegetable whose palatability improves when sufficient phosphorous is available (Zhu *et al.*, 2017; Polprasert, 2017). It increases plant resistance to diseases. Its most essential function is in energy storage and transfer. It is necessary for all cell division, growth of root and shoots tissue and developing seed and kernel of grain. Deficiency of phosphorus leads to stunted growth, slow emergence and slow growth of most annual crop. It leads to off colour green foliage with purple venation especially on the underside of leaves (Lévai *et al.*, 2013). It also makes petioles have a purple (accumulation of anthocyanin) cast, root development becomes poor, less fruits are produced and plant often look spindly stunted. Wheat and barley take up their phosphate in the early stage of growth (Naceur *et al.*, 2017; Gol *et al.*, 2017). Starvation during this period cannot be rectified by a good supply later (Lust, 2017; Meng *et al.*, 2015). Excess phosphate over the amount required by crops sometimes depresses the yields (Łukowiak *et al.*, 2016; Corbeels *et al.*, 2014).

### **2.2.3 Potassium**

The availability of Potassium is associated with protein activity during the maintenance of a positive ion balance. It enables the satisfaction of negative ion charges on the protein. Potassium is also required during rapid enzyme activation when cell division is taking place to form primary tissues (Glenske *et al.*, 2018; Marín-Buera *et al.*, 2015; Ahmad *et al.*, 2014). Potassium provides osmotic

regulation in plants by making them 'pull' or draw water from the soil into the plant roots. It aids transportation of by regulating the opening of stomata. The translocation of sugar produced by photosynthesis is made possible by potassium as it helps the production of high energy phosphate molecule as well as other functions of energy.

Uptake of nitrogen and protein of synthesis require potassium. Deficiency of potassium symptoms includes development of whitish spot on non leguminous plants leaves as well as marginal yellowing and browning. Shortening of internodes, dwarfing, small size of fruits and seeds. Loss of green colour, marginal discoloration from the base to the tip starting with older leaves leads to their premature death of plant. (*Ryoung et al.*, 2006). Resistance to drought in plants is occasioned by an excess of nitrogen relative to potassium rendering leaves prone to fungal and bacterial diseases (*Sunder et al.*, 2016; *Bostock et al.*, 2014). Micas (biotite and muscovite) and potassium feldspar are the original sources of potassium (*Abdulqader et al.*, 2017; *Machado et al.*, 2015). Due to the weathering of these minerals, the potassium becomes more available and readily exchangeable as soluble potassium absorbable by plants roots.

Most of the times, soil potassium is in primary minerals and non-exchangeable forms. In fertile soils release potassium solution in forms that plants can use directly accelerating their growth. Chemical fertilizers and poultry manure, or

wood ashes are applied in non-fertile soils where the levels of exchangeable and soluble potassium are low (Brady and Weil, 1999). Where the supply of available potassium is depleted over a period of years, the productivity of the soil will likewise decline (Abdulqader *et al.*, 2017; Neba *et al.*, 2016; Dorneles *et al.*, 2014).

### **2.3 Soil Acidity**

Acidic soils also result to low rates of decomposition of organic matter. Low pH also leads to depletion and unavailability of micronutrients leading to production of nutritionally low-quality food. Liming and de-acidification are used to counteract the effects of acidity (Wiklund, 2017; Rengel, 2015). Tyrrell *et al.* (2014) and Venn *et al.* (2012) have investigated factors that influence de-acidification. However, this is effective for a short time in addition to cost implications. Liming has also been implicated in interfering with uptake of other nutrients (Agostinho *et al.*, 2017; Goulding, 2017). Reduced acidity results in more nutrient availability, especially of nutrients prone to leaching and movement during rainfall. Abdulaha-Al Baquy *et al.* (2017) and Kisinyo *et al.* (2014) investigated that acidity has been found to retard plant growth through  $H^+$  and  $Al^{3+}$  ionic effects, mineral ion toxicity or by indirectly interfering with mineral availability.

Thus, there is urgent need for alternative methods to the application of inorganic fertilizers and liming materials. Apart from food insecurity, over population has

resulted to encroachment of the forest cover leading to reduced rainfall. This calls for alternative methods for increasing forest cover and counteracting soil acidity.

#### **2.4 Leaf Extracts as Organic Fertilizer**

Studies have shown that certain plants have litter that can decompose easily releasing plant nutrient and increasing buffering capacity of soil (Fahad, 2017; Zhu *et al.*, 2016 and van der Ham, 2015). The study showed that *Helianthus annuus*, *Tithonia diversifolia* have leaf extracts with high rate of humification, mineralisation and buffering capacity (Oyenyi *et al.*, 2016; Rodriguez *et al.*, 2015). The study by Oyenyi showed that the plants studied released minerals in deionized water in the range of (7.74 to 399.90, (units) for potassium, 2.154 to 31.325 (units) for phosphate and 8.387 to 72.054 for nitrate. The acidic soil pH (initially at 5.32) ranged from 5.26 to 6 (Oyenyi *et al.*, 2016). Others like *Cassia spectabilis* (cassia), *Jacaranda mimosifolia* (jacaranda), *Manihot esculenta* (cassava), *Carica papaya* (pawpaw), *Vitex keniensis* (meru oak) and *Albizia gummifera* (peacock flower) were also good (Nyangaga, 2008; Onyancha, 2011). Previous studies using potted non-leguminous plants showed increase in biomass (Génard *et al.*, 2017; Pérez-Montano *et al.*, 2014).

Studies showed that some leaves extracts, *Tithonia diversifolia*, increased levels in soil for nitrogen from 2000-4000 µg/kg and the recommended range in the soil is 2000-10000 µg/kg and annual uptake is 100µg/kg. In *Vitex keniensis* and

*Tithonia diversifolia* the common range levels in soil for phosphorus is 100-5000 µg/kg and the recommended range enriched soil is 400-2000 µg/kg and annual uptake is 20 µg/kg (Oyeniyi *et al.*, 2016).

The yield and yield components of *telfairia* were significantly increased by the applied organic fertilizer types (Abebe *et al.*, 2017; Mokgolo, 2016). The optimum values were recorded at 60 kg N / ha. The highest yield and yield components of *telfairia* was recorded from neem organic fertilizer closely followed by *Tithonia* compost while control gave the least value. Therefore, neem compost, poultry manure and *tithonia* compost in descending order are adjudged as the best organic fertilizers for farmers because they are cheap and readily available (Haute, 2014).

## **2.5 Nutrition value and Health benefits of *Amaranthusspp***

*Amaranthusspp* is one of the traditional vegetative plants known for having highly nutritious components for animal and human consumption (Kavita *et al.*, 2017; Muriuki, 2015). When amaranth leaves are cooked, they make a good source of vitamin A, vitamin C, and folate; they are also a good complementary source of thiamine, niacin, and riboflavin vitamins and dietary minerals including calcium, iron, potassium, zinc, copper, and manganese. *Amaranthusspp* grains are also a complementary source of vitamins such as thiamine, niacin, riboflavin, and folate. They possess such dietary minerals as calcium, iron, magnesium, phosphorus, zinc, copper, and manganese that are found in common grains such

as wheat germ and oats(Choudhury, 2015; Gil *et al.*, 2012). *Amaranthusspp* oil has been found to be predominantly unsaturated oil; high in linoleic acid necessary for human nutrition (Longato *et al.*, 2016; Venskutonis *et al.*, 2013) noted that oil extracted from *Amaranthus cruentus* contained around 19% palmitic acid, 3.4% stearic acid, 34% oleic acid and 33% linoleic acid. Docosaenoic acid (C22: 1) was present at the level of 9%. The ratio of saturated to unsaturated fatty acids was approximately 1:3 (Longato *et al.*, 2016; Alegbejo, 2013).

Beta-carotene is the main safe dietary source of vitamin A, essential for normal growth and development, immune system function, and vision (Fascetti *et al.*, 2016). Beta-carotene has antioxidant properties that can help neutralize free radicals – reactive oxygen molecules potentially damaging lipids in cell membranes and genetic material, which may lead to the development of cardiovascular disease and cancer (Maciejczyk *et al.*, 2017; Nimse *et al.*, 2015). Beta-carotene and other carotenoids can facilitate communication between neighboring cells by stimulating the synthesis of proteins that form pores in cell membranes, allowing communication through the exchange of small molecules (Assefa, 2017). Some clinical trials have found that beta-carotene supplementation improves several parameters of immune function, such as increasing the number of white blood cells and the activity of natural killer cells (Palaniswam, 2018). Documented research has proven that, oats and amaranth seeds or oil are of beneficial to people suffering from hypertension and

cardiovascular diseases;their regular consumption reduces blood pressure and cholesterol levels, while improving antioxidant status and body immune system as well(Ullah *et al.*, 2016).

*Amaranthusspp* leaves contain 17.4-38.3 % dry matter as crude protein averaging 5% lysine and thus having potential as a protein supplement (Andini *et al.*, 2013; Ball *et al.*, 2013). The major unsaturated fatty acids in *A. tricolor* are linoleic in seeds (49%) and stems (46%) and linolenic in leaves (42%), while the major saturated fatty acid in seeds, stems, and leaves is palmitic acid at 18-25% of total fatty acids (Mohadjeran *et al.*, 2015). Vitamins C and A are present at nutritionally significant levels, averaging 420 ppm of vitamin C and 250 ppm of beta-carotene (Moura *et al.*, 2016; Naidu, 2016).

## **CHAPTER THREE**

### **MATERIALS AND METHODS**

#### **3.1 Study Area**

The experiment was carried out in Juja, Kiambu County (Figure 3.1) in two regimes, under irrigation and during the rainy season. It was also done in the greenhouse in the Research and Demonstration field in Kenyatta University. The University is 20 Km by road from Nairobi the largest city in Kenya. The main campus lies between Nairobi and Thika at an altitude of 1520-1760 m above sea level. The area has minimum temperatures of 12°C and maximum of 24.6°C. The rainfall ranges 1000-1100mm and the distribution pattern is bimodal. The soils are dark reddish brown to dark brown loam. Juja lies at an altitude of 1300-1500 m above sea level and the rainfall ranges between 700-900 mm.



Figure 3.1: Kenyan map with pointer showing Juja and Kenyatta University

### **3.2 Collection of Leaves and Preparation of Leaf Extract**

Mature leaves and those fallen were collected randomly from Kiambu County. Plant leaves tested were Turrill (*Vitex keniensis*), Mexican sunflower (*Tithonia diversifolia*) and Indian nettle (*Plectranthus barbatus*).

A taxonomist was used to identify various plants before collection. The leaves were washed, sun dried and subjected to milling/hand crushing, then weighed, packed and labeled. For leaf extracts, both milled and hand crushed leaves were soaked in distilled water for sixty days and pH and buffering capacity monitored for individual plant leaves. Optimization of the leaf extracts for soil remediation and growth of the crops was done for open fields. Distilled water alone was kept under the same conditions pH and buffering capacity was monitored for a period of sixty days (Miller and Kissel, 2010).



**Plate 3.1: Experimental Study Design (R.C.B.D)**

**(a) Amaranthus at the Beginning of Data Collection**

**(b) Amaranthus at the Third Week of Data Collection**

### **3.3 Study Design and Treatment Application**

The experiment setup(Plate 3.1) both for the rainy regime and under irrigation regime was a  $2 \times 7$  factorial laid out in a randomized complete block design (RCBD), This was also the same design for the greenhouse regime using 42 pots. Two varieties of *Amaranthusspp* were studied; *Tricolor* and *Cruetus*. The treatments were the three leaves extracts, lime, farm yard manure inorganic fertilizer and the control where nothing was applied was bare soil. The

*Amaranthusspp* seeds were bought from the Department of Horticulture, Jomo Kenyatta University of Agriculture and Technology. The seeds were then planted direct to plots already prepared to a fine tilt at a spacing of 30cm x 10cm. Experimental plots were 42 each having 60 plants (Plate 3.1).

*Amaranthusspp* plants were subjected to treatments after two weeks of germination in the plots. The concentration of each of the leaves extract was 2kg of ground leaves diluted with 20 litres of distilled water. To apply treatment on the *Amaranthusspp* on weekly basis, 3.5litres of this solution was diluted with 15 litres of water. This was then applied through drenching in the soil at the rate of 30 ton/ha of each of the leaf extract per plant, two middle rows once per week for six weeks. Farm yard manure was applied once during planting at the rate of 80 ton/ha. Di-ammonium phosphate and Lime were applied once at planting at a rate of 2 ton/ha and 52 ton/ha per respectively. All the seven treatments were replicated thrice. Individual plots measured 2 m by 1.2 m. Individual blocks were spaced 1 m apart and the plots within the blocks were separated by 0.5 m.

### **3.4 Crop Establishment and Agronomic Practices of the experiment**

Land preparation was done one month before sowing by clearing the weeds followed by ploughing. The field was harrowed to create a suitable tilth. Seeds were planted at a depth of 2 mm in the raised plots. Routine field maintenance practices such as weeding, watering, spraying against pests and fungal diseases

were done when necessary using recommended pesticides and fungicides and respectively.

### **3.5 Data Collection and Analysis**

The data collected per individual plot for the four sampled plants per plot was by uprooting the whole plant. The growth parameters measured were: plant height, number of leaves, leaf area, fresh weight and dry weight. This was done after six weeks from planting, on weekly basis for four weeks. The dried *Amaranthusspp* leaves were ground and later analysed for the betacarotene levels. The data analysis was done at Kenyatta University in the Chemistry Department Laboratories and also at Jomo Kenyatta University of Agriculture and Technology, Food Science Department Laboratories located in Juja, Kiambu County.

#### **3.5.1 Effect of Leaves Extract on Soil pH**

Soil samples for pH was taken from the experimental site and using 1:2 Ratio, Soil to Water. This was from a depth of 0-20 and 20-40cm. The samples was air-dried for two weeks in the drier and ground to pass through a 2mm sieve and analyzed for pH according to (Miller and Kissel, 2010).

#### **3.5.2 Determination of the Effects of Leaf Extracts on the Growth Parameters of *Amaranthusspp***

The growth rate of *Amaranth spp.* was determined by measuring on weekly basis plant shoot, root heights, leaf area, number of leaves, and fresh weight of edible

yield per plant and the dry weight of the two species of the *Amaranthusspp*. Dry weight and yield was determined by weighing the products. Harvested leaves were weighed using digital sensitive balance. The weight was determined by grams.

### **3.5.3 Effect of Leaves Extracts on Soil Macro Nutrients**

The minerals ultra violet/visible (UV/Visible) volumetric and colorimetric methods were used to determine nitrogen and phosphorus. Nitrogen, was tested using wet chemistry standard procedures (Maguire and Heckendorn, 2005) Total (N) was determined by 2M KCl extraction, followed by steam distillation and acid titration (Conklin, 2014). Flame photometry was used for potassium (K) determination. The soil analysis was done before planting and after harvesting to check the leaf extract effect.

### **3.5.4 Determination of the Effects of Leaf Extracts on Betacarotene Levels of *Amaranthusspp***

The yield of grown *Amaranthusspp* was analyzed for beta-carotenes. Determination of Beta-carotene was by carotene equivalent using acetone as solvent, by AOAC method (AOAC, 2006). It involved extraction and pigment separation. The concentration of carotene was read directly from UV visible spectrophotometer at 440nm after proper calibration of the instrument with standard solutions of pure beta-carotene (Sigma chemical Co., St. Louis, and Mo).

### **3.6 Statistical Data Analysis**

All the plant physiological, morphological and biochemical data was subjected to analysis of variance (ANOVA) using the General Linear Model. Proc GLM code of SAS- computer software (SAS 2002; Version 16.0) was used, where significant ( $p > 0.05$ ), mean separation was done using LSD.

## CHAPTER FOUR

### RESULTS AND DISCUSSIONS

#### 4.0 Overview

This chapter is divided into four sections. Section one (4.1 and 4.2) reports on and discusses findings related to the effect of leaf extracts, farm yard manure, inorganic fertilizer, lime and control on soil pH. Section two (4.3) reports and discusses findings on the effects of treatments on the various growth parameters of *Tricolor* and *Cruetus* varieties of *Amaranthus spp.* Results on effects of treatments on soil macro nutrients are in section (4.4) and in section (4.5) has the results and discussions on the effects of treatments on betacarotene levels in *Tricolor* and *Cruetus* varieties of *Amaranthus spp.*

#### 4.1 Effects of Distilled Water pH after Adding Ground Leaves Extracts

Table 4.1 shows the range of the pH of the distilled water after soaking the ground leaf extracts from day 1 to 60 days. Determination of the pH values of the leaf extracts under study was done, which were *Tithonia diversifolia*, *Vitex keniesis* and *Plectranthus barbatus*. The pH of leaf extract in day 1 was not significantly difference from the initial pH ( $p > 0.05$ ). By day 15 there was drop in pH in all the leaf extracts but it increased gradually for all the leaf extracts.

**Table 4.1: The pH of Distilled Water after Soaking Ground Leaves Extracts from Day1 to 60 Days.**

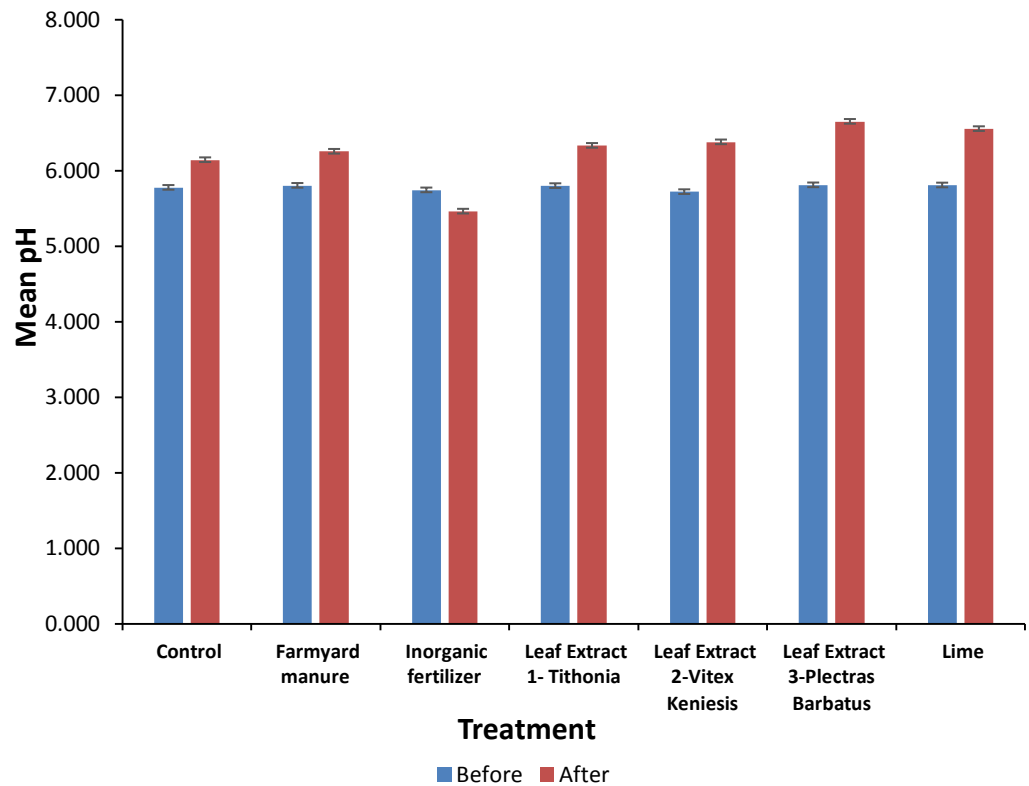
Plant species	Days				
	1	15	30	45	60
<i>T.diversifolia</i>	6.32	6.21	6.30	6.41	6.49
<i>V.kenienses</i>	6.22	6.15	6.25	6.33	6.40
<i>P.barbatus</i>	6.45	6.32	6.41	6.50	6.67

The pH for *P. barbatus* ranged from 6.45 to 6.67 which imply that its leaf extracts would be best for treatment of acidic soil. The pH of leaf extract for the other species also ranged from 6.22 to 6.40 for *Vitex keniensis* and *Tithonia diversifolia* from 6.32 to 6.49 (Table 4.1). The trend for leaf extracts in this study agrees with those of Huang *et al.* (2013) where pH dropped and then increased depending on the type of leaves and the length of soaking time in distilled water. This also compares with (Murungi, 1990; Njagi, 2008) where pH dropped and then increased depending on the type of leaves and the duration the leaves were soaked in distilled water.

#### **4.2: Effects of Treatments on the Soil pH before and after Growing *Amaranthus spp* under Green house conditions**

The results of the effects of the treatments on the soil pH after growing the *Amaranthus spp.* under greenhouse conditions at Kenyatta University experimental site. (Figure 4.1) The soil pH indicated significant ( $P < 0.05$ )

differences among the treatments under the greenhouse conditions and also over time, however there were no significant differences in the two varieties, also on the interaction between treatments (Figure 4.1).

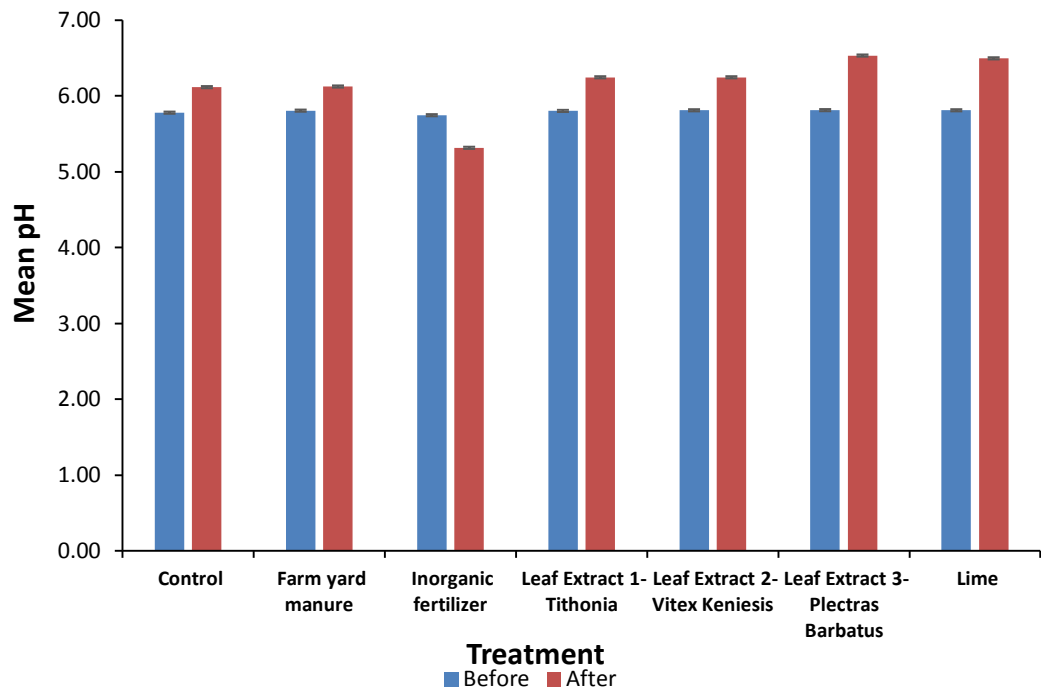


**Figure 4.1: Effects of Treatments on the Soil pH, before and after Growing *Amaranthus spp* Under Greenhouse Conditions at Kenyatta University.**

Under greenhouse conditions, the soil pH increased for all the treatment except for inorganic fertilizer where there was a decrease after growth of *Amaranthus spp*. This ranged from 6.7 to 5.5 with the highest pH was for leaf extract 3, *Plectranthus barbatus* (6.7) and the lowest was for inorganic fertilizer (5.5) (Figure 4.1) This concurs with Han (2016) that inorganic fertilizers increases soil

acidity. This is because under greenhouse the soils are not leached hence a lot of retention both for the leaf extracts and the inorganic fertilizer (Figure 4.1).

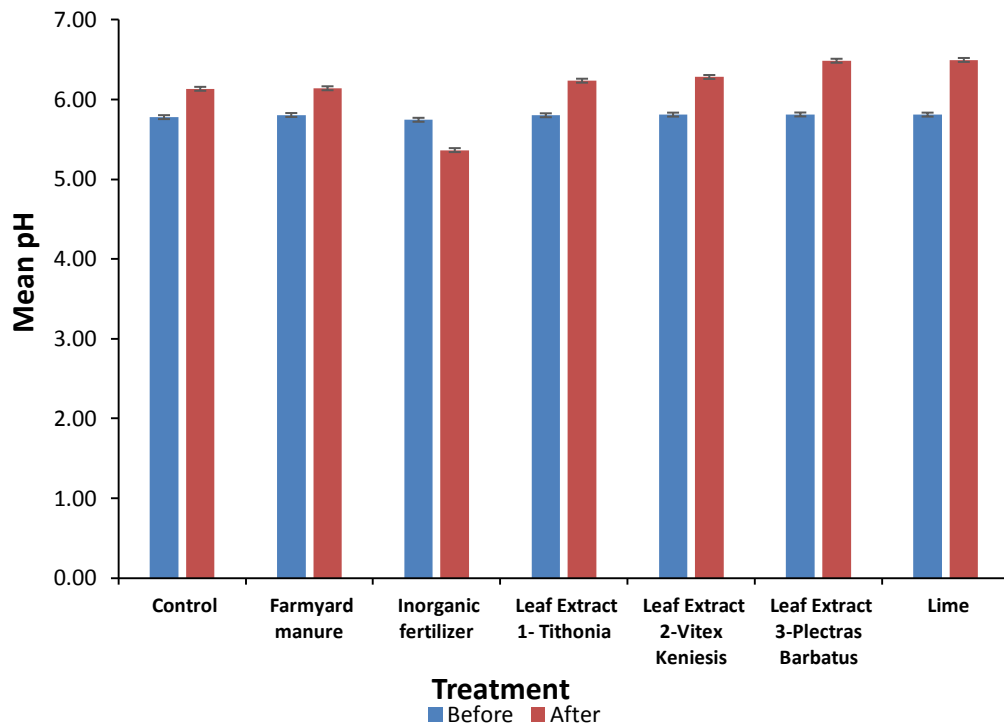
Similar results were got by Mwaura and Woomer, 1999; and Mucheru Monica, 2003, that inorganic fertilizers increases soil acidity. Figure 4.2 shows the results of the effects of the treatments on the soil pH after growing the *Amaranthus spp.* under irrigation conditions at Juja experimental site. The soil pH indicated significant ( $P < 0.05$ ) differences among the treatments.



**Figure 4.2: Effects of Treatments on the Soil pH before and After Growing *Amaranthus spp* Under Irrigation Conditions at Juja**

Under irrigation conditions, the highest pH was leaf extract 3, *Plectranthus barbatus*(6.7) followed by leaf extract 2, *Vitex keniesis* (6.6) and the lowest was inorganic fertilizer (5.3) (Figure 4.2).Lime treatment recorded increased pH. This agrees with *Kisinyo et al. (2009)* and *Shetty et al. (2014)*that liming curbs soil acidity, though reapplication is needed hence costs implication,not sustainable and does not add nutrients.Also (*Wiklund, 2017;Rengel, 2015*).*Tyrrell et al. (2014)* and *Venn et al. (2012)* I reported that liming and de-acidification are used to counteract the effects of acidity influencing de-acidification.However, this is effective for a short time in addition to cost implications.

Liming has also been implicated in interfering with uptake of other nutrients (Agostinho *et al.*, 2017 Goulding, 2017). Reduced acidity results in more nutrient availability, especially of nutrients prone to leaching and movement during rainfall. Abdulaha-Al Baquy *et al.* (2017) and Kisinyo *et al.* (2014) investigated that acidity has been found to retard plant growth through H<sup>+</sup> and Al<sup>3+</sup> ionic effects, mineral ion toxicity or by indirectly interfering with mineral availability. Figure 4.3 shows the results of the effects of the treatments on the soil pH after growing the *Amaranthus spp.* under rainy conditions at Juja experimental site. The soil pH indicated significant (P<0.05) differences among the treatments.



**Figure 4.3 Effects of Treatments on the Soil pH before and after Growing *Amaranthus spp* Under Rainy Conditions**

The soil pH increased for all treatment except inorganic fertilizer treatment. The highest pH was for leaf extract 3, *Plectranthus barbatus* (6.5) and lime (6.5) and the lowest soil pH was for inorganic fertilizer (5.3) under the rainy conditions (Figure 4.3). The soils pH were slightly higher than in this regime than the others as under rainy conditions, there is vertical movement of dissolved cations, which enhances more decomposition and accumulation of soil organic carbon in the area and this agree with what (Olojugba *et al.*, 2015) reported.

This is also in agreement with Van der Ham *et al.* (2015) that certain plants have litter that can decompose easily increasing buffering capacity of the soil.

This implies that leaf extract *Plectranthus barbatus* played a role of reducing soil acidity and at the same time buffering of the soil. Buffering is important in preventing rapid lowering of pH in soils (Zhang *et al.*, 2016; Husson, 2013). Studies have shown that areas with high organic content are not affected by acidic deposition and it is believed that the decayed products of these areas buffer the effects of acid (Goulding *et al.*, 2016).

### **4.3 Effect of Treatments on Growth Parameters after Growing the *Amaranthus spp***

#### **4.3.1 Effects of Treatments on Shoot fresh weight**

Fresh shoot fresh weight was one of the growth parameters indicator and this is paramount as it plays a key role in the yields.

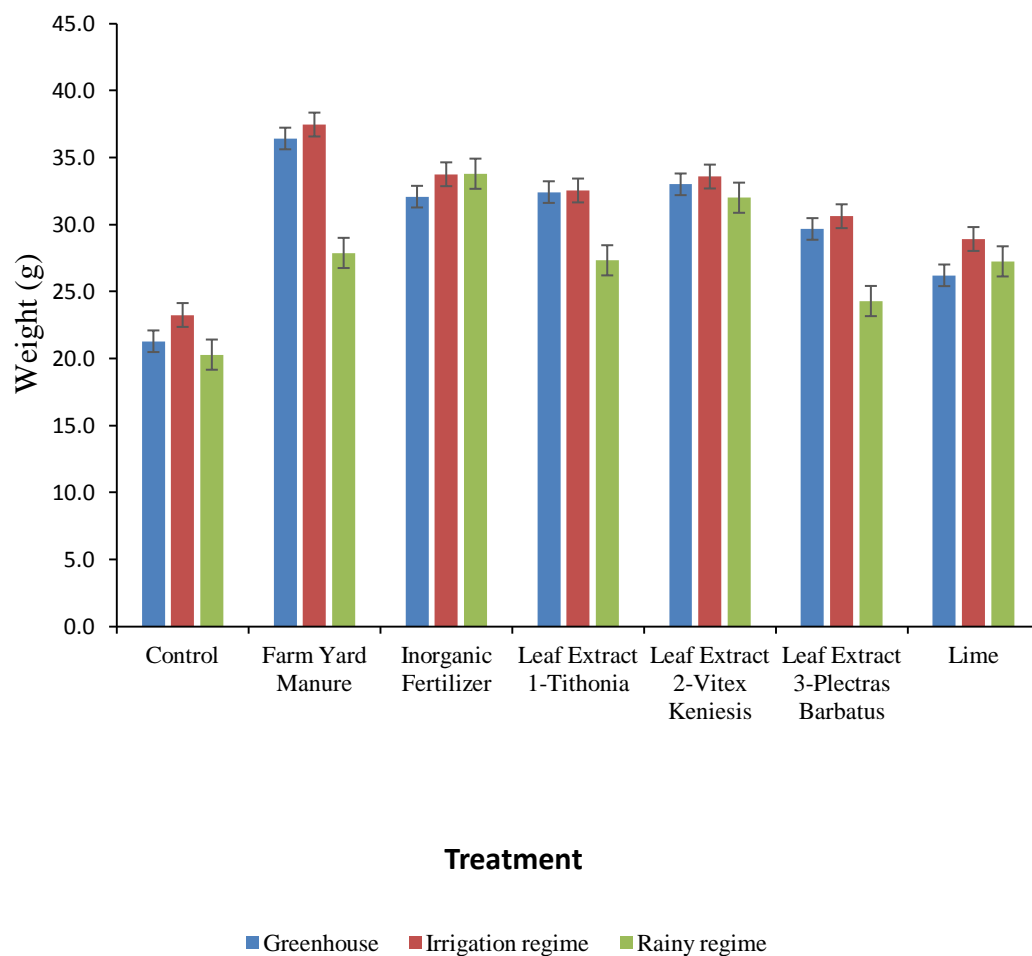
Data analysis of growth parameters under all the three regimes is shown in Plate

4.1



**Plate 4.1 Growth Parameters Data Analysis, Kenyatta University Chemistry Laboratory**

Figure 4.4 shows the comparison of the effects of the treatments on the shoot fresh weight after growing the *Amaranthus spp.* under the three regimes.



**Figure 4.4 Effects of Treatments on Shoot Fresh Weight (g) under Greenhouse, Irrigation and Rainy Regimes**

Table 4.2 shows the results of multiple comparisons of means on shoot fresh weight under greenhouse, irrigation and rainy conditions.

**Table 4.2: Multiple Comparisons of Means on Shoot Fresh Weight (g) under Greenhouse, Irrigation and Rainy Conditions.**

Treatment	Greenhouse	Irrigation regime	Rainy regime
Control	21.3e	23.3e	20.3d
Farm Yard Manure	36.4a	37.5a	27.9b
Inorganic Fertilizer	32.1b	33.8b	33.8a
Leaf Extract 1-Tithonia	32.4b	32.5bc	27.3bc
Leaf Extract 2-Vitex	33.0b	33.6b	32.0a
Keniesis			
Leaf Extract 3-Plectras	29.7c	30.6cd	24.3c
Barbatus			
Lime	26.2d	28.9d	27.3bc
LSD	2.26	2.48	3.15
CV (%)	13.0	14.0	20.0

Means in the same columns followed by the same letter are not significantly different at 5% probability level.

From Table 4.2, in the multiple comparison of means on shoot fresh weight across regimes, increased and indicated significant ( $p < 0.05$ ) differences among the treatments and regimes. It indicated that the shoot increase in green house conditions were higher than for those of rainy and irrigation conditions. Control and lime treatment had the lowest increase in fresh weight compared with the other treatments.

Under greenhouse conditions FYM had the highest shoot fresh weight(36.4g) that was significantly different ( $p<0.05$ ) from the others. The control had the lowest (21.3g). Under irrigation, FYM had the highest shoot fresh weight (37.5g) that was significantly different ( $p<0.05$ ) from the others. The control had the lowest (23.3g) Those under the rainy conditions, inorganic fertilizer had the highest weight (33.8g) that was significant different ( $p<0.05$ ) from the others. The control had the lowest (20.3g) (Figure 4.4).

The FYM and leaf extract 2, *Vitex keniesis* had the highest shoot weight due to the presence of the primary nutrients (NPK) plus calcium and magnesium found in organic manure, confirmed by FAO (Mokaya, 2016) while control had the lowest as they had to depend mainly on the intrinsic soil fertility.

This could also been as a result of Farm Yard Manure and the leaf extract having higher nutrients and improvement of the soil physico-chemical properties such as increased infiltration rate, water retention, soil aggregate and nutrient stabilizers as reported ( Carsky et al., 2001 and Osaigbovo et al., 2010). Similar findings were observed by Van Averbek et al. 2007 who reported an increased total fresh and oven dry aboveground biomass of *Solanum retroflexum* with increased nitrogen application rates as a result of enhanced nutrient uptake with increasing rates of fertilization till a point of stagnation. Also Farm Yard Manure being rich in macro nutrients hence increase in biomass production.

### 4.3.2 Effects of Treatments on Shoot Height

The comparison of the effects of treatments on shoot height on greenhouse, irrigation and rainy conditions is on Table 4.3

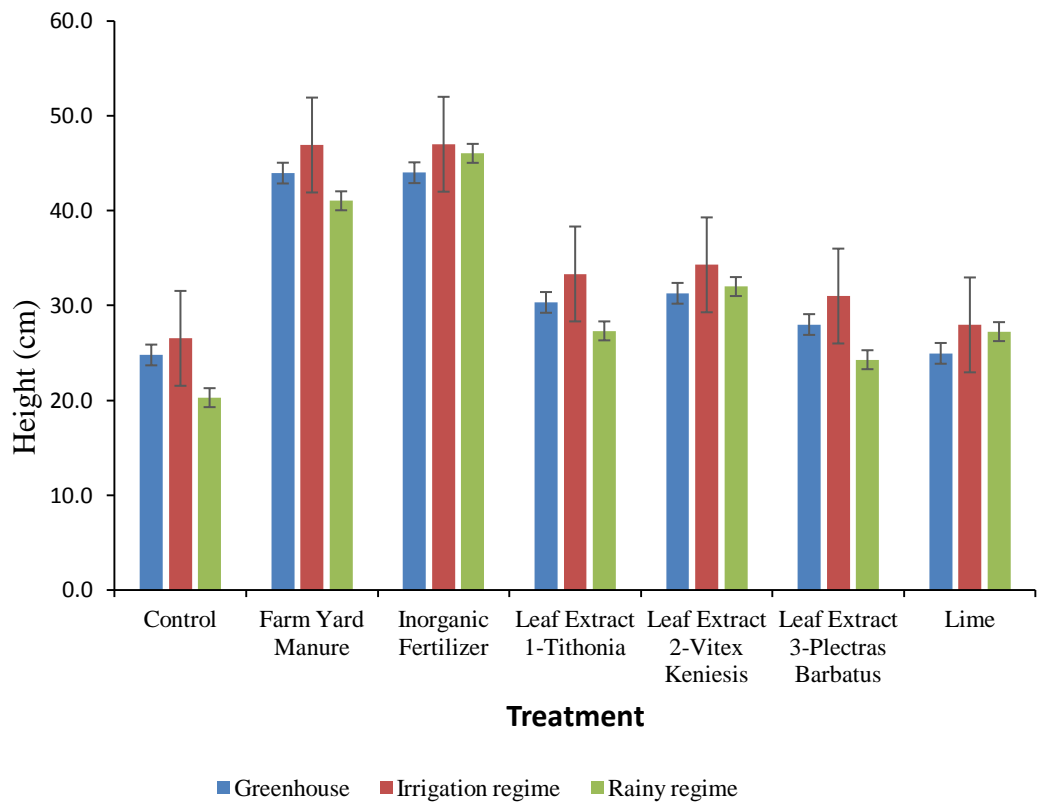
**Table 4.3: Effects of Treatments on Shoot Height (cm) on Greenhouse, Irrigation and Rainy Conditions.**

Treatment	Greenhouse regime	Irrigation regime	Rainy regime
Control	24.8e	26.5e	20.3f
Farm Yard Manure	44.0a	46.9a	41.0b
Inorganic Fertilizer	44.0a	47.0a	46.0a
Leaf Extract 1-Tithonia	30.3bc	33.3bc	27.3d
Leaf Extract 2-Vitex Keniesis	31.3b	34.3b	32.0c
Leaf Extract 3-Plectras Barbatus	28.0cd	31.0cd	24.3e
Lime	25.0de	28.0de	27.3d
LSD	3.056	3.097	2.791

Means in the same columns followed by the same letter are not significantly different at

5% probability level.

Figure 4.5 indicates the effects of treatments on shoot height across the three regimes



**Figure 4.5: Effects of Treatments on Shoot Height (cm) across the Three Regimes**

From Table 4.3 and Figure 4.5, in the multiple comparison of means on shoot height, under greenhouse conditions FYM and inorganic fertilizer had the highest shoot height (44.0cm) that was significantly different ( $p < 0.05$ ) from the others. The control had the lowest height (24.8cm). Under irrigation, inorganic fertilizer had the highest shoot height (47.0) that was significant different ( $p < 0.05$ ) from the others. The control had the lowest height (26.5cm) Those under the rainy conditions, inorganic fertilizer had the highest height (46.0cm) that was significant different ( $p < 0.05$ ) from the others. The control had the lowest height

(20.3cm) The highest height was observed in plants treated with inorganic fertilizer and this was due to quick release of the nutrients in the inorganic fertilizer, however the stems were very fragile compared to the others for the other treatments (Figure 4.5). This agrees with (Jafarpour *et al.*, 2015) that there is increased productivity associated with fertilizer application though has negative effects which include pollution of ground water.

#### 4.3.3 Effects of Treatments on Root length

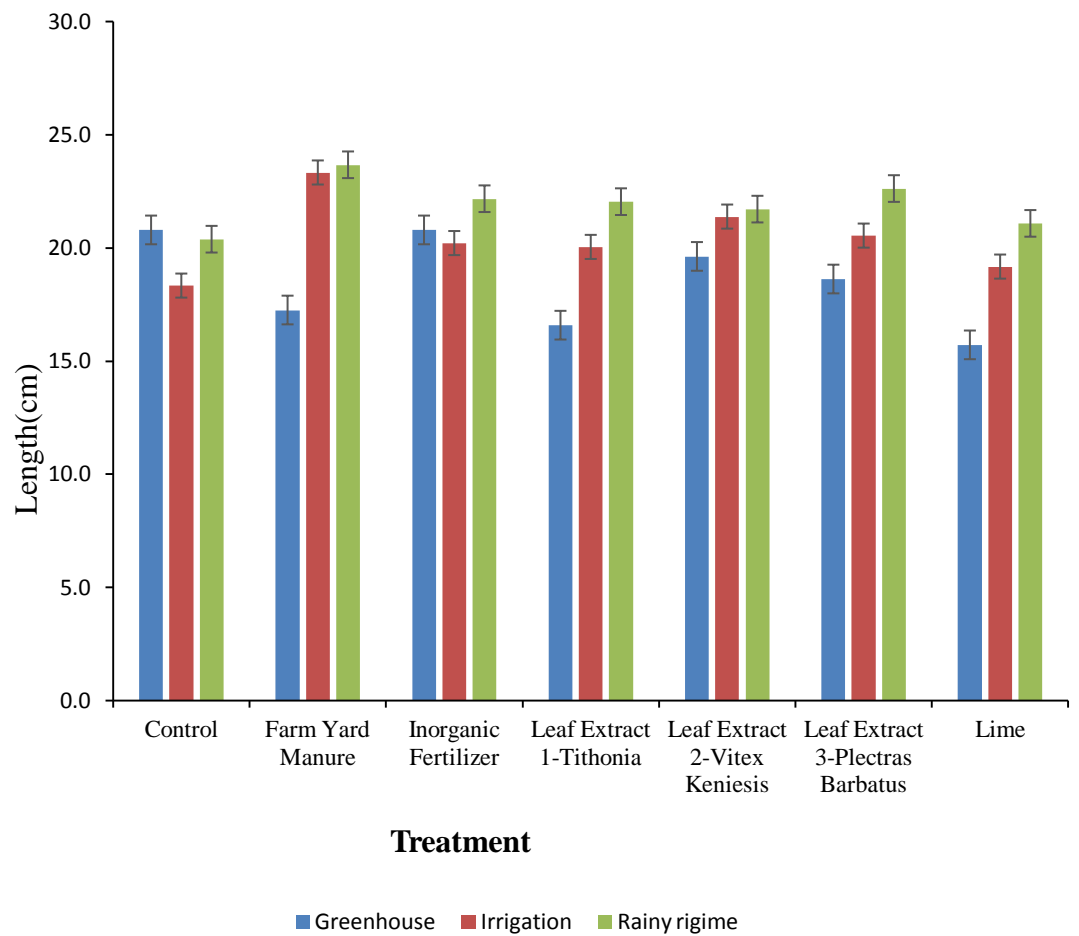
Table 4.4 shows the effects of treatments on root length across regimes and reviewed significant ( $p < 0.05$ ) differences among the treatments and also on regimes over time.

**Table 4.4: Effects of Treatments on Root length (cm) Under Green House, Irrigation and Rainy Regimes.**

Treatment	Greenhouse	Irrigation	Rainy regime
Control	20.8a	18.3d	20.4c
Farm Yard Manure	17.3cd	23.3a	23.7a
Inorganic Fertilizer	20.8a	20.2bc	22.2ab
Leaf Extract 1- <i>Tithonia spp</i>	16.6d	20.0bc	22.0ab
Leaf Extract 2- <i>Vitex keniesis</i>	19.6ab	21.4b	21.7bc
Leaf Extract 3- <i>Plectras barbatus</i>	18.6bc	20.5bc	22.6ab
Lime	15.7d	19.2cd	21.1bc
LSD	1.771	1.486	1.645
CV (%)	16.8	12.8	13.1

Means in the same columns followed by the same letter are not significantly different at 5% probability level

The effects of treatments on root length across regimes is shown in Figure 4.6 and reviewed significant ( $p < 0.05$ ) differences.



**Figure 4.6: Effects of Treatments on Root Length (cm) on the Three Regimes**

From Table 4.4 and Figure 4.6, in the multiple comparison of means on root length, under greenhouse conditions inorganic fertilizer had the longest root length (20.8) that was significantly different ( $p < 0.05$ ) from the others. Lime had the least (15.7).

Under irrigation, FYM had the longest root length (23.3 cm) that was significant different ( $p < 0.05$ ) from the others. The control had the lowest root length (18.3cm) and that was significantly different ( $p < 0.05$ ) from the others. Those under the rainy conditions, inorganic fertilizer had the longest root length (23.7cm) that was significantly different ( $p < 0.05$ ) from the others. The control had the lowest root length (20.4) and that was significantly different ( $p < 0.05$ ) from the others. The longest root length was observed in plants treated with FYM and inorganic fertilizer and this was due to quick release of the nutrients in the latter.

This contradicts Muller (2017) that when the soil pH is lower than 5.5,  $Al^{3+}$  is released to the soil and enters into root tip where it causes inhibition of cell elongation and cell division leading to root stunting accompanied by reduced water and nutrient uptake as lime had the lowest despite the soil pH being high.

#### **4.3.4 Effects of Treatments on The Number of Leaves**

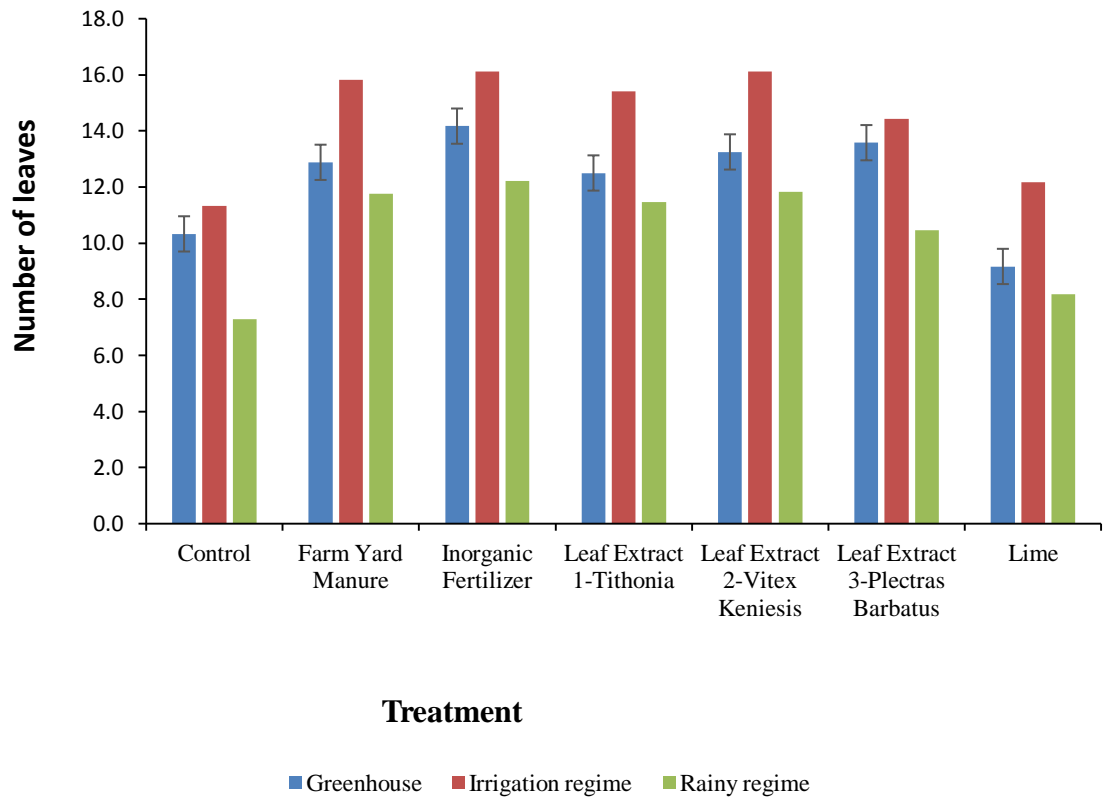
Table 4.5 shows the effects of treatments on the number of leaves across regimes and reviewed significant ( $p < 0.05$ ) differences among the treatments and also on regimes over time.

**Table 4.5 Effects of Treatments on the Number of Leaves on Greenhouse, Irrigation and Rainy Conditions**

Treatment	Greenhouse	Irrigation regime	Rainy regime
Control	10.3b	11.3b	7.3c
Farm Yard Manure	12.9a	15.8a	11.8a
Inorganic Fertilizer	14.2a	16.1a	12.2a
Leaf Extract 1- <i>Tithonia spp</i>	12.5a	15.4a	11.5b
Leaf Extract 2- <i>Vitex keniesis</i>	13.3a	16.1a	11.8b
Leaf Extract 3- <i>Plectras barbatus</i>	13.6a	14.4a	10.5b
Lime	9.2b	12.2b	8.2c
LSD	1.8	1.7	1.6
CV(%)	25.1	21.1	27.1

Means in the same columns followed by the same letter are not significantly different at 5% probability level

Figure 4.7 showed the effects of treatments on the number of leaves across regimes and reviewed significant ( $p < 0.05$ ) differences. This was also an indicator of the amaranth growth parameter.



**Figure 4.7: Effect of Treatment on the Number of Leaves on the Three Regimes**

From Figure 4.7 and Table 4.5, on the number of leaves reviewed significant ( $P < 0.05$ ) differences among the varieties treatments, and regimes over time. In the multiple comparison of means, under greenhouse conditions inorganic fertilizer had the highest number of leaves (14.2) that was significantly different ( $p < 0.05$ ) from the others. Lime had the lowest (9.2) that was significantly different ( $p < 0.05$ ) from the others.

Under irrigation, FYM had the highest number of leaves (15.8) that was significantly different ( $p < 0.05$ ) from the others. The control had the lowest number of leaves (11.3) and that was significantly different ( $p < 0.05$ ) from the others. Those under the rainy conditions, inorganic fertilizer had the highest (12.2) that was significantly different ( $p < 0.05$ ) from the others.

The control had the lowest number of leaves (7.3) and that was significantly different ( $p < 0.05$ ) from the others. The highest number of leaves was observed in plants treated with FYM as rich in nitrogen which boosts the *Amaranthus spp* leaves. Also, inorganic fertilizer had the highest number of leaves and this was due to quick release of the nutrients in the organic fertilizer. This agrees with Mokaya, (2016) that nutrients are released more slowly from manures than inorganic fertilizers. Muchukuri et al., 2004 also reported on nitrogen as it encourages vegetative growth which is necessary in crops where leaves are harvested such as kales and corianders. Building block of proteins which are the components of amino acids are required for growth and development of tissues.

#### **4.3.5 Effects of Treatments on Mean Leaf Area**

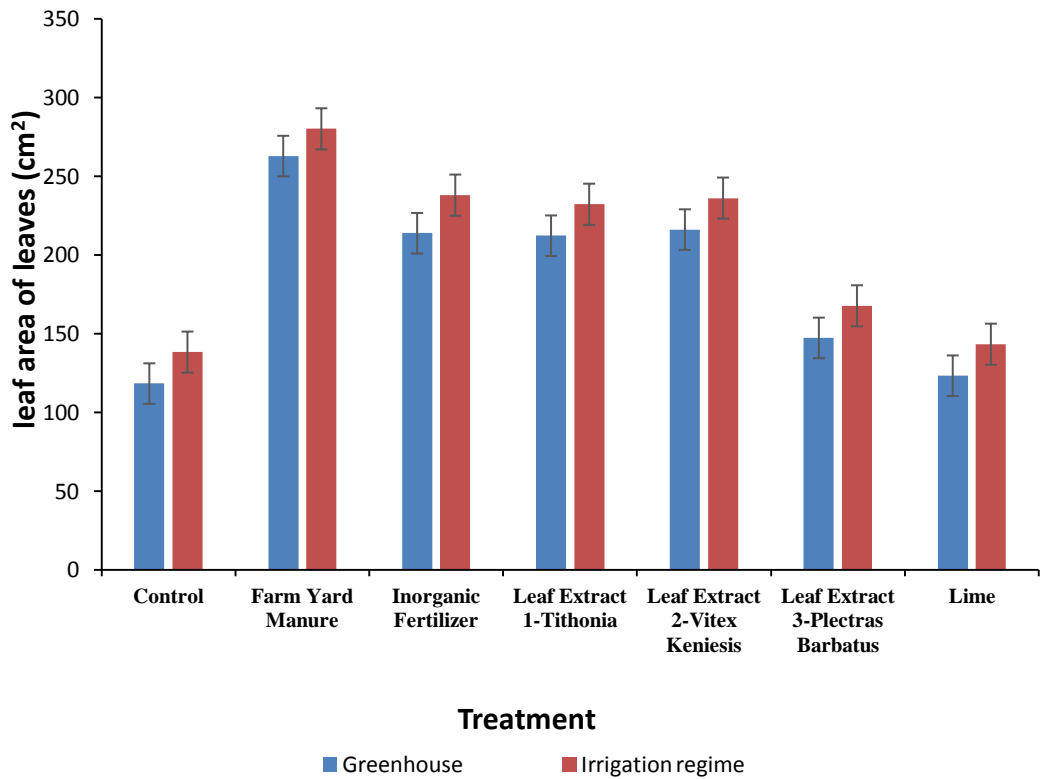
Table 4.6 showed the effects of treatments on leaf area across regimes and reviewed significant ( $p < 0.05$ ) differences among the treatments and also on regimes over time.

**Table 4.6: Effects of Treatments on the Leaf Area (cm<sup>2</sup>) on Green House, Irrigation and Rainy Conditions.**

Treatment	Green house	Irrigation	Rainy
	regime	regime	regime
Control	118.4c	138.4c	98.4c
Farm yard manure	262.9a	280.2a	239.4 a
Inorganic fertilizer	213.9b	238.1b	198.1 b
Leaf extract 1- <i>Tithonia spp</i>	212.3b	232.3b	191.9 b
Leaf extract 2- <i>Vitex keniesis</i>	216.2b	236.2b	196.2 b
Leaf extract 3- <i>Plectras barbatus</i>	147.4c	167.8c	127.8 c
Lime	123.4c	143.4c	104.2 c
LSD	36	36.5	36.56
CV (%)	34.1	31.2	38.8

Means in the same columns followed by the same letter are not significantly different at 5% probability level

Figure 4.8 showed the effects of treatments on leaf area across regimes and reviewed significant ( $p < 0.05$ ) differences.



**Figure 4.8: Effects of Treatments on the Leaf Area (cm<sup>2</sup>) across the Three Regimes.**

From Table 4.6 and Figure 4.8 on the leaf area, there was significant ( $p < 0.05$ ) differences among the treatments and regimes over time. On leaf area (cm sq.) in the multiple comparison of means, under greenhouse conditions FYM had the largest leaf area (262.9) that was significantly different ( $p < 0.05$ ) from the others, while control had the lowest (118.4).

From (Figure 4.8) under irrigation, FYM had the largest leaf area (280.2) that was significantly different ( $p < 0.05$ ) from the others. The control had the lowest leaf area (138.4) followed by lime and that was significantly different ( $p < 0.05$ ) from the others. Those under the rainy conditions, FYM had the largest leaf area (239.4) that was significantly different ( $p < 0.05$ ) from the others. The control had the lowest leaf area (98.4) followed by lime and that was significantly different ( $p < 0.05$ ) from the others. The highest leaf area was observed in plants treated with FYM as its rich in nitrogen which boosted the *Amaranthus spp* leaf area. The result also confirms importance of farmyard manure as it supplies nutrient, gradually releasing of nutrient and impacting the physical effects on soil condition through good aeration, water holding capacity, structure and increased microbial activity (Ainika et al., 2011). Cook (1982) had similar results as found out that Farm Yard Manure sustains cropping system as it supplies nutrients influencing physical effects on the soil condition.

#### **4.3.6 Effects of Treatments on the Dry Weight**

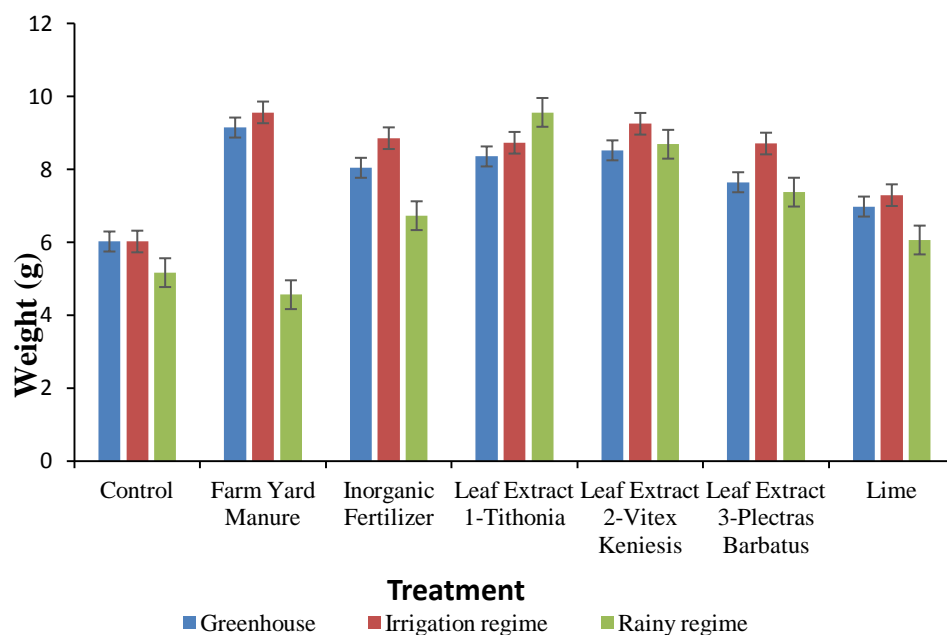
Table 4.7 shows the effects of treatments on dry weight across regimes and reviewed significant ( $p < 0.05$ ) differences among the treatments and also on regimes over time.

**Table 4.7: Effects of Treatments on Dry Weight (g) across the Regimes**

<b>Treatment</b>	<b>Green house</b>	<b>Irrigation regime</b>	<b>Rainy regime</b>
Control	6.021 e	6.021d	5.167d
Farm Yard Manure	9.146 a	9.562a	8.562a
Inorganic Fertilizer	8.042bc	8.854ab	6.729b
Leaf Extract 1- <i>Tithonia spp</i>	8.354 bc	8.729b	9.562a
Leaf Extract 2- <i>Vitex spp</i>	8.521 ab	9.25ab	8.688a
Leaf Extract 3- <i>Plectrathus</i>	7.646 cd	8.708b	7.375b
Lime	6.979 d	7.292c	6.062c
LSD	0.767	0.831	1.104
CV (%)	17.2	17.5	28.2

Means in the same columns followed by the same letter are not significantly different at 5% probability level

Figure 4.9 shows the effects of treatments on the dry weight of leaves across regimes and reviewed significant ( $p < 0.05$ ) differences



**Figure 4.9: Effects of Treatments on Dry Weight (g) of Leaves across Regimes**

From Figure 4.9 and Table 4.7, On the dry weight (g) in the multiple comparison of means, under greenhouse conditions FYM had the highest weight (9.146g) that was significantly different ( $p < 0.05$ ) from the others. The control had the lowest weight (6.021g) followed by lime that was significantly different ( $p < 0.05$ ) from the others. Under irrigation, FYM had the highest dry weight (9.562g) that was significantly different ( $p < 0.05$ ) from the others. The control had the lowest dry weight (6.021g) and that was significantly different ( $p < 0.05$ ) from the others. Lime had the second lowest which was also significantly different from others.

Those under the rainy conditions, leaf extract 1, *Tithonia diversifolia* had the highest dry weight (9.562g) that was significantly different ( $p < 0.05$ ) from the

others. The FYM had the lowest dry weight (4.562g) and that was significantly different ( $p < 0.05$ ) from the others (Figure 4.9). This follows what was observed in the fresh weight as it's only the water content in the plant that was dried but the weight remained intact. This agrees with the role organic fertilizer in promoting higher plant growth, healthier crops and better yield (Liu et al., 2014).

On dry weight, under greenhouse Farm Yard Manure and leaf extract *Vitex keniesis* were the highest weight while control had the lowest weight. On irrigation, Farm Yard Manure and *Vitex keniesis* had the highest weight while control had the lowest weight and under rainy conditions, leaf extract *Tithonia diversifolia* and *Vitex keniesis* had the highest weight while control had the lowest weight followed by lime. Table 4.8 shows the comparison of effects of treatments on growth parameters across regimes and reviewed significant ( $p < 0.05$ ) differences

**Table 4.8: Comparison of the Effects of Treatments on the Growth Parameters**

<b>Treatment</b>	<b>Shoot Fresh weight</b>	<b>Root length</b>	<b>Shoot height</b>	<b>No. of leaves</b>	<b>Leaf area</b>	<b>Dry weight</b>
Control	26.33 f	25.0 a	24.67 e	9.3 e	127.2 d	7.1 c
Farm Yard	47 a	19.5 d	47.5 b	15.5 ab	325.8 a	12.1 a
Inorganic Fert.	34 d	24.5 ab	54.67 a	16.3 a	310.ab	9.1 b
Le 1-Tithonia	42.5 b	20.8 cd	31.67 d	15 b	295.0 b	11.8 a
Le 2-Vitex	45.17 a	23.2 ab	37.17 c	15.8 ab	296.2 b	11.8 a
Le 3-Plectr.	39.33 c	22.7 bc	29.33 d	12.8 c	169.7 c	9.9 b
Lime	31.33 e	19.3 d	32.33 d	11.3 d	142.8 d	8.0 c
LSD	1.997	2.067	3.247	0.997	15.95	1.054
CV(%)	4.4	7.9	7.4	6.1	5.6	8.9

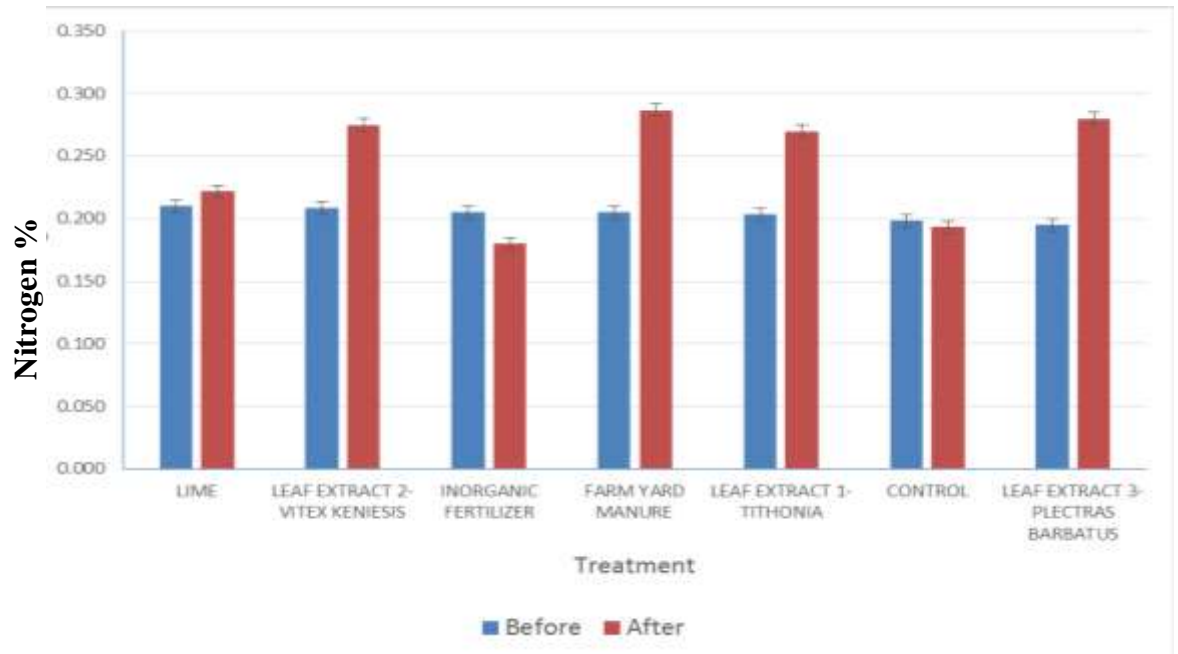
Means in the same columns followed by the same letter are not significantly different at 5% probability level

From Table 4.8, the growth parameters indicated significant ( $P < 0.05$ ) differences among the treatments. On shoot fresh weight, Farm Yard Manure and leaf extract *Vitex keniesis* had the highest dry weight while control had the lowest. On root length, control had the highest while lime had the lowest. Inorganic and Farm Yard had the highest on shoot height and control the lowest. On the number of leaves, *Vitex keniesis* had the highest while control the lowest. Leaf area, Farm Yard and inorganic fertilizer had the highest leaf area while control had the lowest and on dry weight Farm Yard Manure, *Tithonia diversifolia* and *Vitex keniesis* had the heaviest dry weight while control had lowest.

#### **4.4 Effects of treatments on soil macro nutrients**

##### **4.4.1 Effects of Treatments in the Nitrogen in Soil after Growing *Amaranthusspp* under rainy conditions.**

The results of the effects of treatments on nitrogen levels under rainy conditions at experimental site in Juja are in Figure 4.10



**Figure 4.10: Effect of Treatments on Nitrogen Levels, (%) in the Soil Before and After, During the Rainy Regime at experimental site in Juja**

From (Figure 4.10), the nitrogen levels in the soil increased after treatment for all except inorganic treatment which decreased during rain regimant. Farm Yard Manure (0.287%) had the highest nitrogen levels followed by leaf extracts and inorganic fertilizer (0.18%) the lowest nitrogen level followed by control and lime treatment. Nitrogen levels results under irrigation conditions are in Figure 4.11

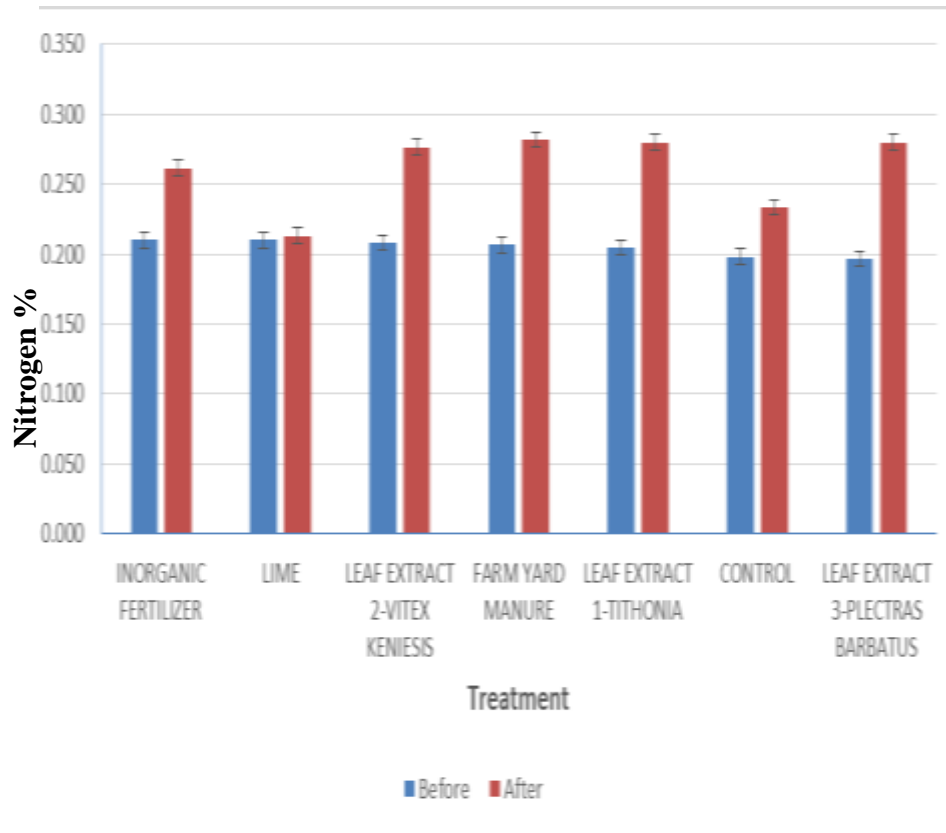
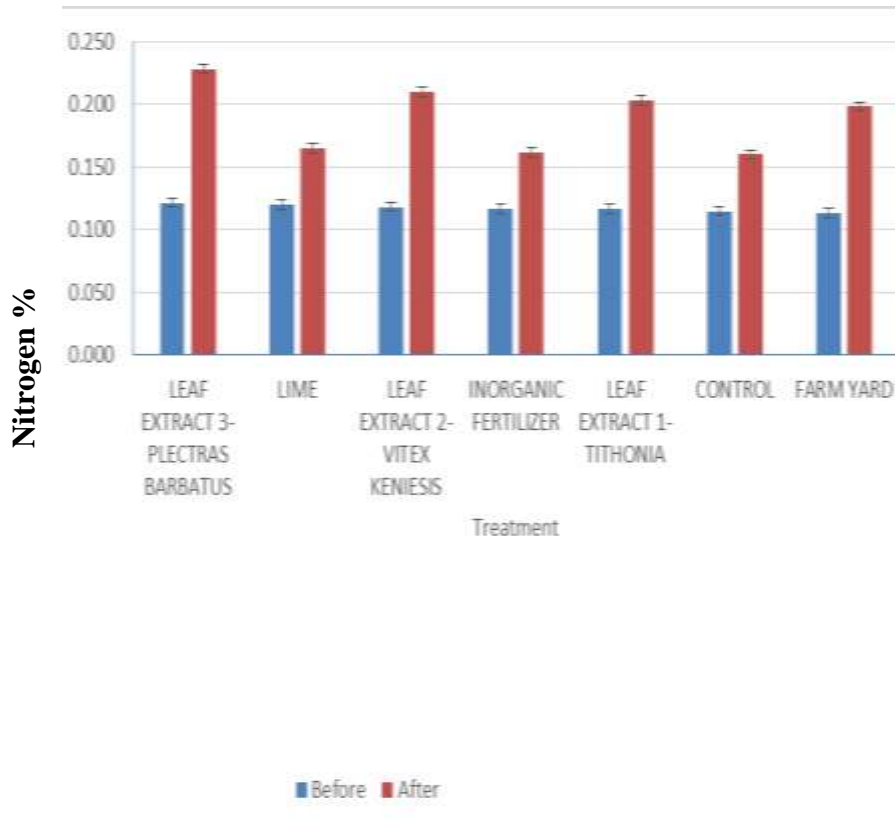


Figure 4.11: Effect of Treatments on Soil Nitrogen Levels (%) in the Soil before and after, during the Irrigation Regime at experimental site in Juja

The levels ranged from 0.213% to 0.281% with Farm Yard Manure the highest nitrogen levels and lime the lowest respectively ( Figure 4.11). In all the treatment under irrigation regime, there was increase in nitrogen levels except under lime where there was no change in nitrogen levels.

Figure 4.12 shows the effects of treatments on nitrogen levels under greenhouse conditions.



**Figure 4.12: Effect of Treatments, before and after, On Soil Nitrogen Levels (%) under Greenhouse Conditions at Kenyatta University**

From Figure 4.12, the levels of nitrogen increased after the growth of *Amaranthus spp.* and ranged from 0.160% to 0.228% with control the lowest nitrogen levels and leaf extract *Plectranthus barbatus* the highest respectively. This was low compared to the irrigation regime as in the greenhouse there could have been excessive water flux resulting to nitrogen leaching (Turkeltaub *etal.*, 2015; Cameira *et al.*, 2017).

Table 4.9 shows the effects of treatments on nitrogen levels in the soil after the growth of amaranth. This is a comparison across regimes.

**Table 4.9: Effect of Treatments on Soil Nitrogen Levels(%) across Regimes**

Treatment	Irrigation	Rainy	Greenhouse
Control	0.216b	0.20c	0.138d
Farm yard manure	0.244a	0.25a	0.156c
Inorganic fertilizer	0.236a	0.19c	0.139d
Leaf extract 1- <i>Tithonia sp</i>	0.243a	0.24a	0.160bc
Leaf extract 2- <i>Vitex keniesis</i>	0.243a	0.24a	0.164b
Leaf extract 3- <i>Plectras barbatus</i>	0.238a	0.24a	0.175a
Lime	0.212b	0.22b	0.143d
LSD	0.011	0.010	0.007
CV (%)	5.8	5.4	5.9

Means in the same columns followed by the same letter are not significantly different at 5% probability level

In Figure 4.12 and in Table 4.9, the multiple comparison of means, on nitrogen levels, under greenhouse conditions Leaf extract 3, *Plectranthus barbatus* had the highest levels (0.175%) that was significantly different ( $p < 0.05$ ) from the others. The control had the lowest (0.138%) that was significantly different ( $p < 0.05$ ) from the others. Under irrigation, FYM had the highest nitrogen levels (2.44%) that was significantly different ( $p < 0.05$ ) from the others. Lime had the lowest (0.21%) and that was significantly different ( $p < 0.05$ ) from the others.

Those under the rainy conditions, FYM had the highest nitrogen levels (0.25%) that was significantly different ( $p < 0.05$ ) from the others. The inorganic fertilizer had the lowest (0.19%) and that was significantly different ( $p < 0.05$ ) from the others. This can be explained as during the rainy season, there is an increase in activity of nitrogen fixing microbes (Wolińska *et al.*, 2017; Fatubarin *et al.*, 2014).

Organic fertilizers when combined with inorganic materials can be used to replenish the soil and improve plant fertilization. Organic fertilizers also add nutrients in soil making it possible for plants to easily absorb them. They also activate soil micro-organisms activity and increase microbes, which help the decomposition processes of organic matter. Apart from the role of organic manure as a store house for plant nutrients it acts as a major contributor to cation exchange capacity and as a buffering agent against undesirable pH fluctuations (Amhakhian *et al.*, 2016; Pradhan, 2016).

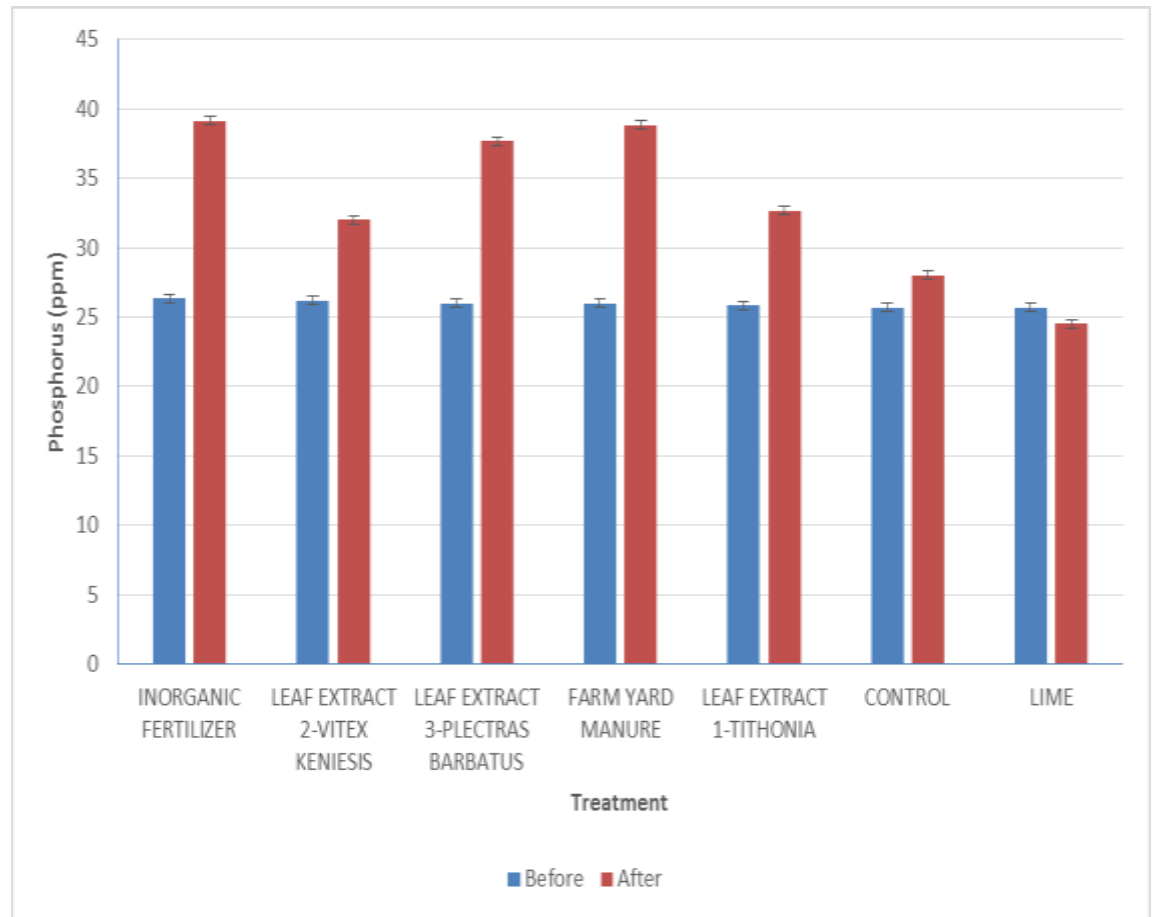
Soil organic C depletion can be related to an imbalance between the amount of organic matter inputs compared to the amount of organic C outflows, mainly regulated by temperature and water availability. When a limited fraction of root exudates such as death roots and a certain fraction of leaf litter are integrated into the soil they form a high organic C biochemical quality in terms of low lignin

content coupled with abundant labile C fraction and low C/N ratio. This kind of plant tissues quickly decomposes and almost disappears within few months, when added into the soil providing a marginal contribution for the maintenance of soil organic C stock (Lehman *et al.*, 2015; Scotti *et al.*, 2015). The supply of plant-derived organic C coupled with high biochemical quality can be stimulated with the microbial mineralization of more stable and recalcitrant soil organic C fractions through priming effect (Fabian *et al.*, 2017; Wang *et al.*, 2016).

Organic matter plays a critical role in soil ecosystem because it provides substrates for decomposing microbes (that in turn supply mineral nutrients to plants), improves soil structure and water holding capacity (Rashid *et al.*, 2016; Gougouliaset *al.*, 2013), increases natural resistance against soil-borne pathogens (Latz *et al.*, 2016; Chellemi *et al.*, 2015; Penton *et al.*, 2014), and reduces heavy metal toxicity (Zhai *et al.*, 2015; Aishankar *et al.*, 2014).

#### **4.4.2 Effects of Treatments in the Phosphorus in Soil after Growing *Amaranthus spp.***

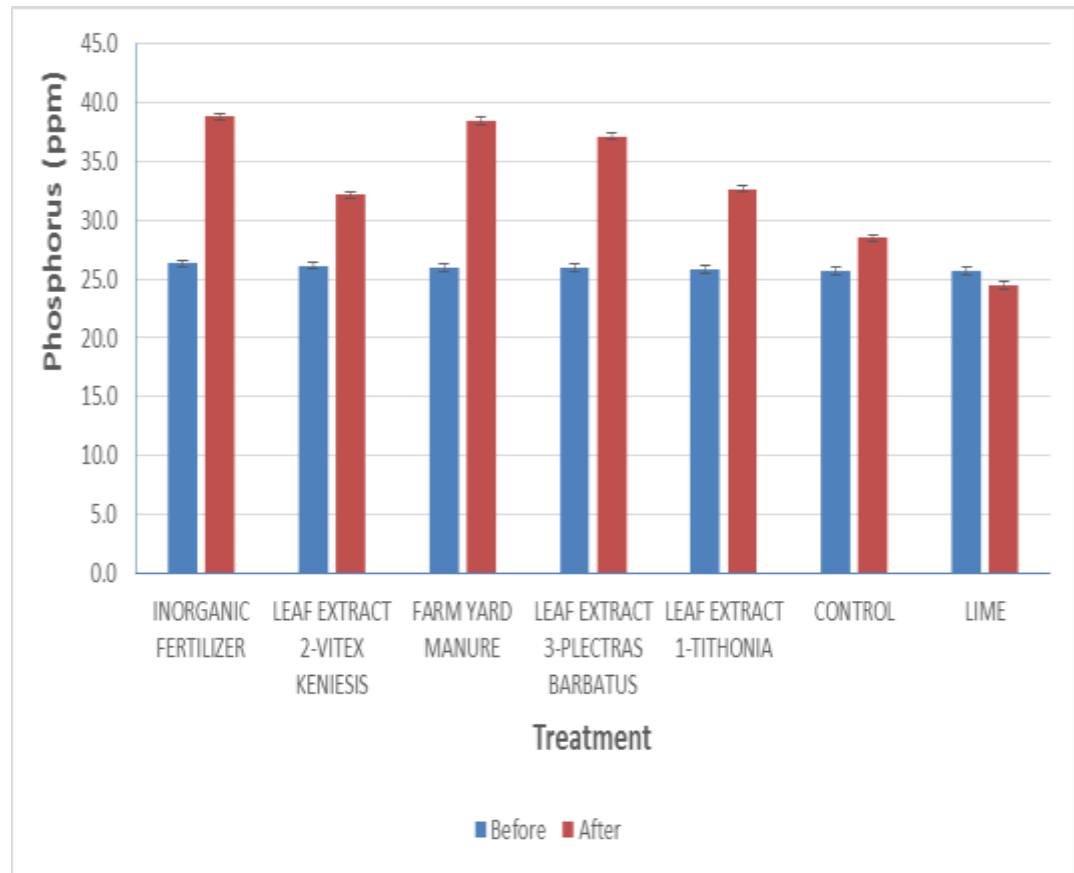
Figure 4.13 shows the effects of treatments on phosphorus levels under rainy conditions in Juja site. The phosphorus levels were analysed before planting the *Amaranthus spp.* and also after the growth of the *Amaranth spp.* after data collection.



**Figure 4.13: Effect of Treatments on Soil Phosphorus Levels (ppm), before and after Amaranth growth, during the Rainy Regime**

From Figure 4.13, the levels of phosphorus in the soil increased for all the treatment except for lime treatment which decreased slightly during rainy regime. The levels ranged from 28.0 ppm to 39 ppm with control the lowest and inorganic fertilizer having the highest phosphorus levels (Figure 4.13).

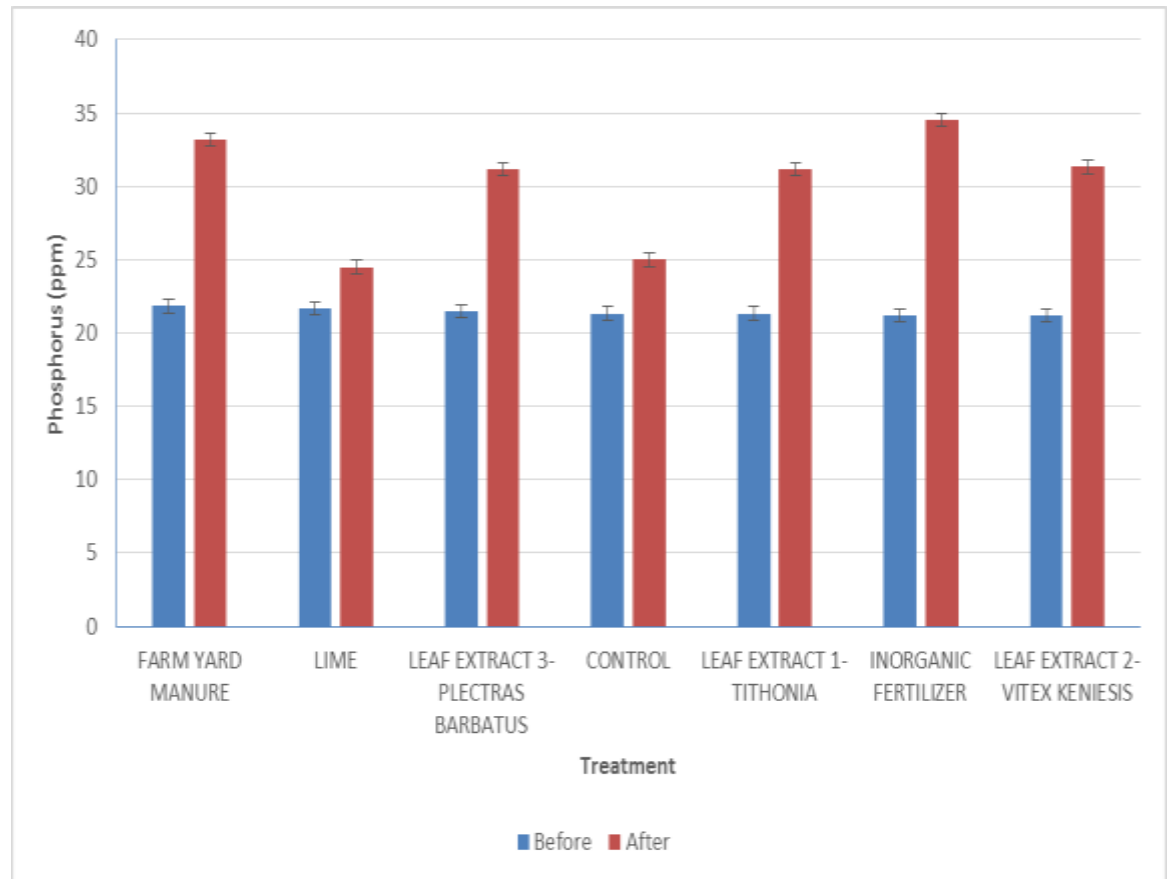
The results of the effects of treatments on phosphorus levels under rainy conditions are shown in Figure 4.14



**Figure 4.14: Effect of Treatments on Soil Phosphorus Levels (ppm), In the Soil before and After, Growing the *Amaranthusspp* during the Irrigation Regime**

The phosphorus during irrigation regime followed the same pattern as rainy regime with the levels ranging from 24.5ppm to 38.8ppm with inorganic fertilizer the highest and lime the lowest (Figure 4.14).

Phosphorus levels under greenhouse conditions are shown in Figure 4.15



**Figure 4.15: Effect of Treatments on Soil Phosphorus Levels (ppm), before and after, during the Greenhouse Regime**

From Figure 4.15 the levels of phosphorus in the soil after growth of amaranthus increased in all the treatment in green house regime. The levels ranged from 24.5ppm to 34.5ppm with inorganic fertilizer having the highest phosphorus levels and lime the lowest(Figure 4.15)., Table 4.10 shows the effects of treatments on phosphorus levels across regimes and reviewed significant ( $p < 0.05$ ) differences.

**Table 4.10: Effect of Treatments on Soil Phosphorus (ppm) Levels across the Three Regimes**

Treatment	Irrigation	Rainy	Greenhouse
Control	27.08d	26.83d	23.17c
Farm yard manure	32.25a	32.42ab	27.5a
Inorganic fertilizer	32.58a	32.75a	27.83a
Leaf extract 1- <i>Tithonia sp</i>	29.25c	29.25c	26.25b
Leaf extract 2- <i>Vitex keniesis</i>	29.17c	29.08c	26.25b
Leaf extract 3- <i>Plectras barbatus</i>	31.58b	31.83b	26.33b
Lime	25.08e	25.08e	23.08c
LSD	0.6242	0.6146	0.903
CV (%)	2.6	2.5	4.3

Means in the same columns followed by the same letter are not significantly different at 5% probability level.

From Table 4.7, the multiple comparison of means, on phosphorus levels in the soil, under greenhouse conditions inorganic fertilizer had the highest levels (27.83 ppm) that was significantly different ( $p < 0.05$ ) from the others. Lime had the lowest phosphorus level (23.08 ppm) that was significantly different ( $p < 0.05$ ) from the others (Table 4.10). Under irrigation, inorganic fertilize treatment soil had the highest levels (32.58 ppm) that was significantly different ( $p < 0.05$ ) from the others. Lime soil had the lowest phosphorus level (25.08 ppm) and that was significantly different ( $p < 0.05$ ) from the others.

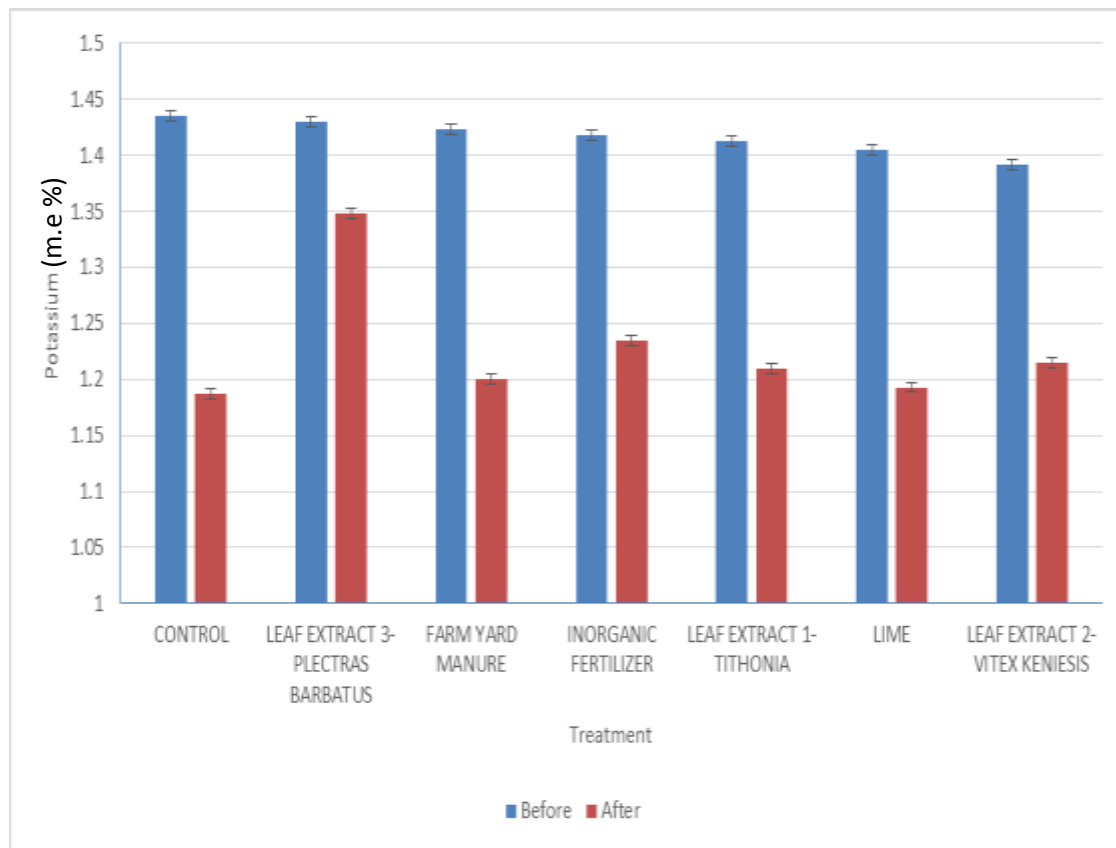
During irrigation there could have been little or no leaching of available phosphorus and exchange acidity, hence the concentration of available

phosphorus. Those under the rainy conditions, inorganic fertilizer had the highest levels (32.75 ppm) that was significant different ( $p < 0.05$ ) from the others. Lime had the lowest phosphorus level (25.08 ppm) and that was significantly different ( $p < 0.05$ ) from the others. The inorganic fertilizer was Diammonium phosphate which is rich in phosphates explaining why it had the highest levels.

#### **4.4.3 Effects of Treatments in the Potassium in Soil after Growing**

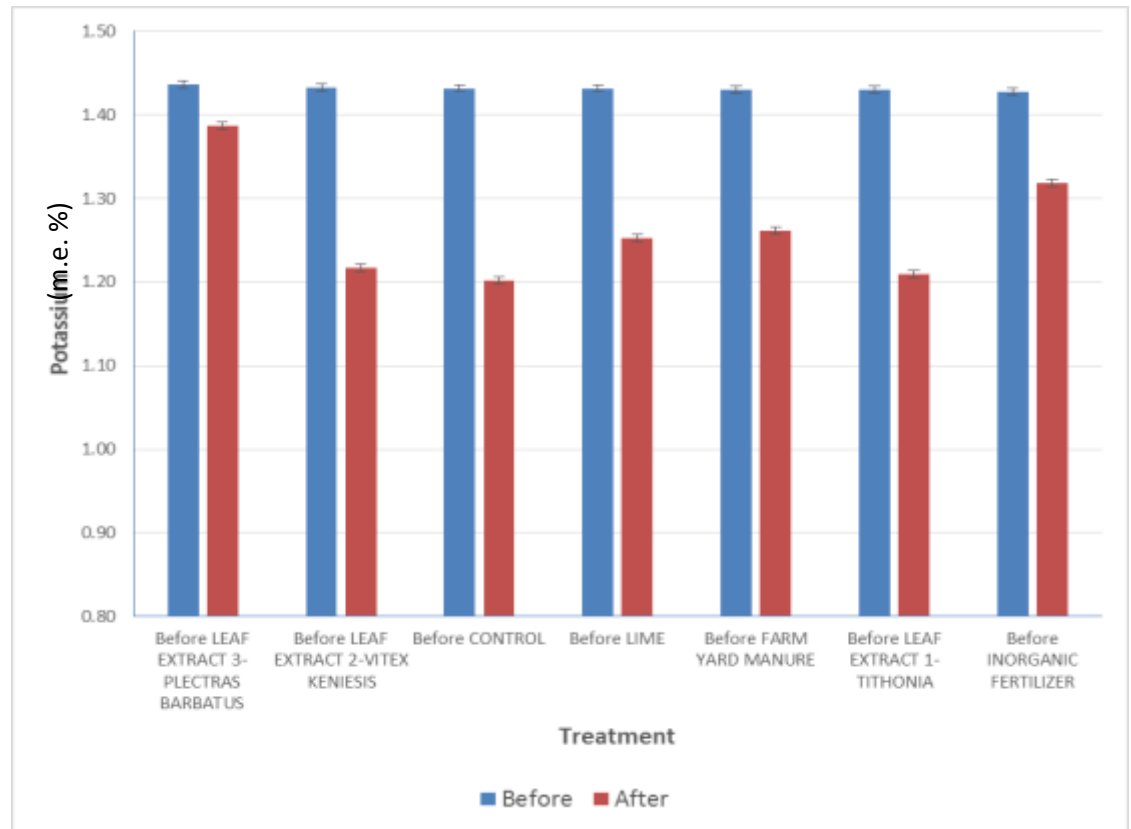
##### ***Amaranthusspp***

The results of the effects of treatments on potassium levels under rainy conditions are shown in Figure 4.16



**Figure 4.16: Effect of Treatments, before and after, on Potassium Levels (m.e %) during the Rainy Regime**

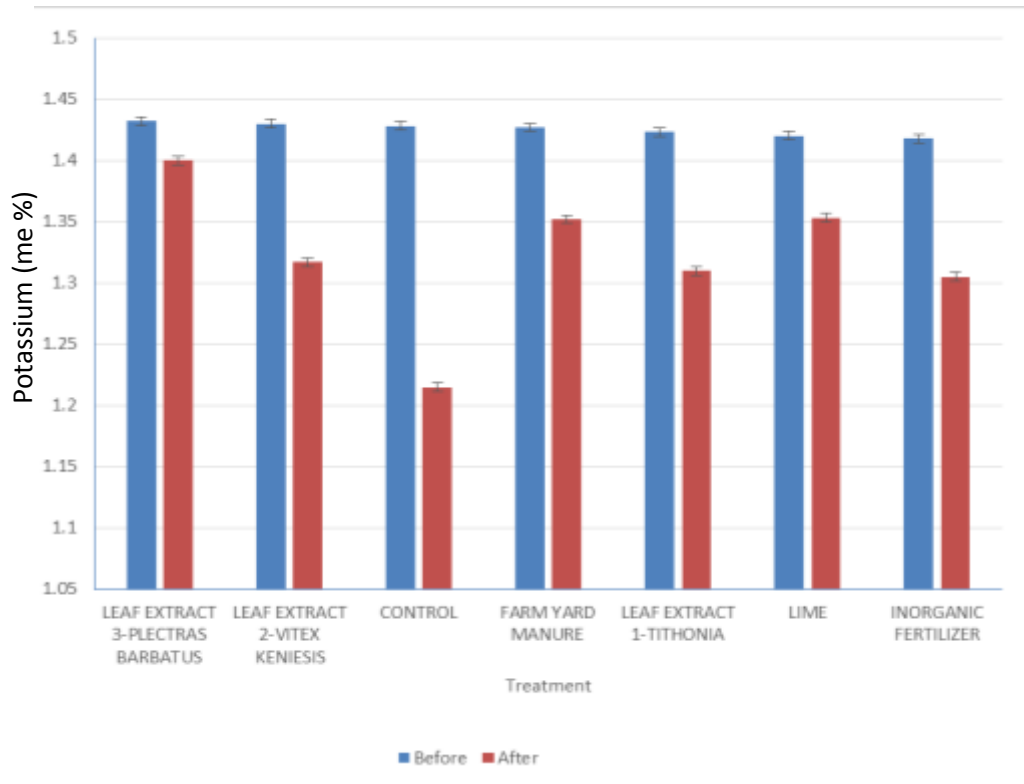
The levels ranged from 1.18m.e% to 1.34m.e% with leaf extract 3, *Plectranthus barbatus* and control the lowest (Figure 4.16). Potassium levels under irrigation conditions in Juja experimental site are shown in Figure 4.17



**Figure 4.17: Effect of Treatments, before and after, on Soil Potassium Levels (m.e %) under Irrigation Regime in Juja experimental site**

From Figure 4.17 the potassium levels decreased after the growth of *Amaranthus spp.* but the decrease was lower in the soil treated with the leaf extract and inorganic fertilizer. The levels ranged from 1.38 m.e% to 1.20 m.e% leaf extract 3, *Plectranthus barbatus* the highest potassium levels and control the lowest (Figure 4.17).

The results of the effects of treatments on potassium levels under green house are in Figure 4.18



**Figure 4.18: Effect of Treatments, before and after, on Soil Potassium Levels (m.e %) under Green House Regime in Juja experimental site.**

From Figure 4.18, the levels of soil potassium decreased after *Amaranthus spp.* growth with the control having the highest decrease. The levels ranged from 1.40.e%to 1.21m.e%with soil treated with *Plectranthus barbatus* having the highest. potassium levels and control the lowest for the green house regime.

Table 4.1 shows the comparison of the effect of treatments on soil potassium (m.e%) Levels across the three Regimes

**Table 4.11: Effect of Treatments on Soil Potassium (m.e%) Levels across the Three Regimes**

Treatment	Irrigation	Rainy	Greenhouse
Control	1.317d	1.311c	1.322e
Farm yard manure	1.346c	1.312c	1.389b
Inorganic fertilizer	1.373b	1.327b	1.362d
Leaf extract 1- <i>Tithonia sp</i>	1.32d	1.312c	1.367cd
Leaf extract 2- <i>Vitex keniesis</i>	1.325d	1.303cd	1.373c
Leaf extract 3- <i>Plectras barbatus</i>	1.412a	1.389a	1.416a
Lime	1.342c	1.299d	1.387b
LSD	0.009	0.009	0.007
CV (%)	0.8	0.8	0.6

Means in the same columns followed by the same letter are not significantly different at 5% probability level.

In the multiple comparison of means, on soil potassium levels, after amaranthus growth in greenhouse conditions, leaf extract 3, *Plectranthus barbatus* had the highest potassium levels (1.416 m.e%) that was significantly different ( $p < 0.05$ ) from the others. Control had the lowest (1.322m.e%) that was significant different ( $p < 0.05$ ) from the others (Table 4.11).

Under irrigation, the soil treated with leaf extract 3, *Plectranthus barbatus* had the highest potassium level (1.412m.e%) that was significant different ( $p < 0.05$ ) from

the others. Control had the lowest potassium level (1.31m.e%) and that was significantly different ( $p < 0.05$ ) from the others.

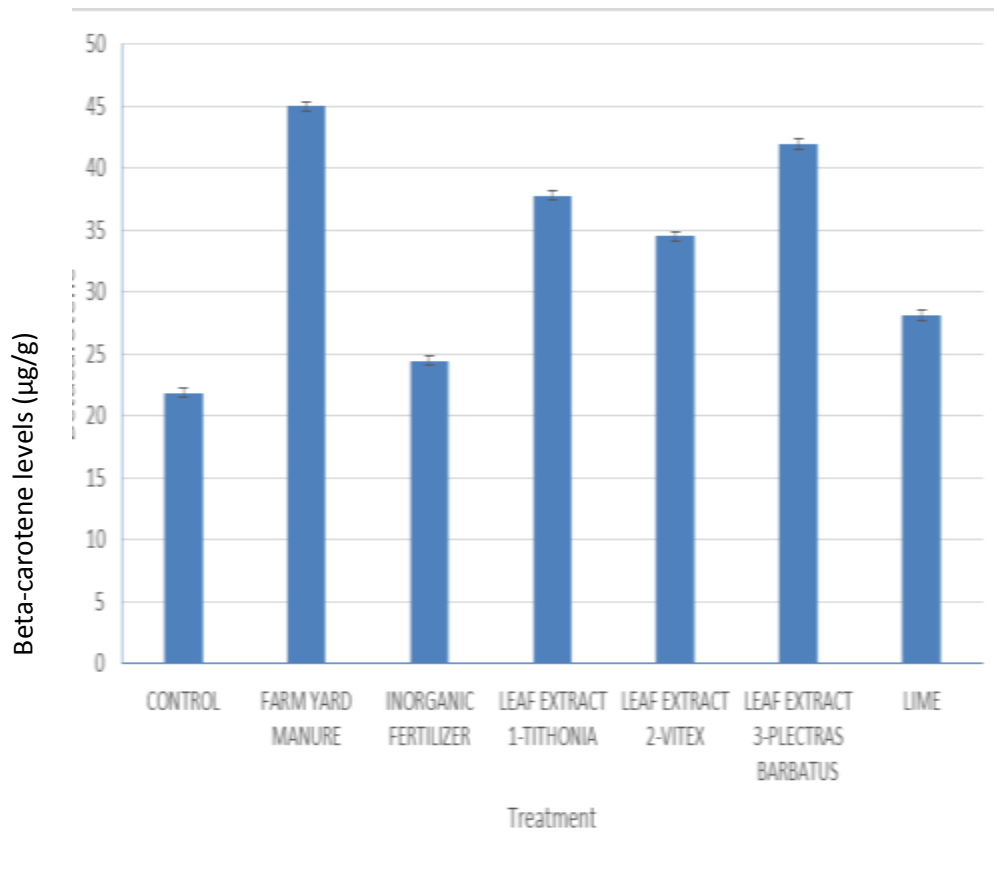
Those soil under the rainy conditions, leaf extract 3, *Plectranthus barbatus* had the highest (1.389m.e%) that was significant different ( $p < 0.05$ ) from the others. Soil treated with Lime had the lowest potassium level (1.299m.e%) and that was significantly different ( $p < 0.05$ ) from the others.

This could be explained as during the rainy season potassium salts dissolve easily and the ions in the solution diffuse through the soils from the areas of high potassium concentrations to the areas of low potassium concentrations. Low concentrations of potassium is on the rhizosphere due to the uptake of potassium ions from the solution to the roots, the wetter the soil the more mobile the potassium ions will be as during the rainy regime there is sufficient water hence the element is being utilized by the regenerating plants therefore reducing the amount in the soil (Table 4.11) The Farm Yard Manure followed under irrigation regime and this concurs with Kihanda (1996) and Hunter *et al.* (1997) who reported an increase in potassium due to farmyard manure and green manure application. (Gachengo, 1996; Hunter *et al.*, 1997; Jama *et al.*, 2000) who explained an increase in potassium could have been as a result of high and readily potassium which is decomposable.

#### **4.4.4: Effects of soil treatments on beta-carotene levels in the amaranthus**

Beta carotene content is determined by its precursor which is vitamin A. This is influenced by the kind of fertilizer applied, whether organic or inorganic and also the stage of growth.

Figure 4.19 shows the effect of soil treatments on Beta-carotene ( $\mu\text{g}$ ) levels in *Amaranthus* during the rainy regime in Juja experimental site. This was to check on the effects of the treatments on the nutritional value of the amaranthus.

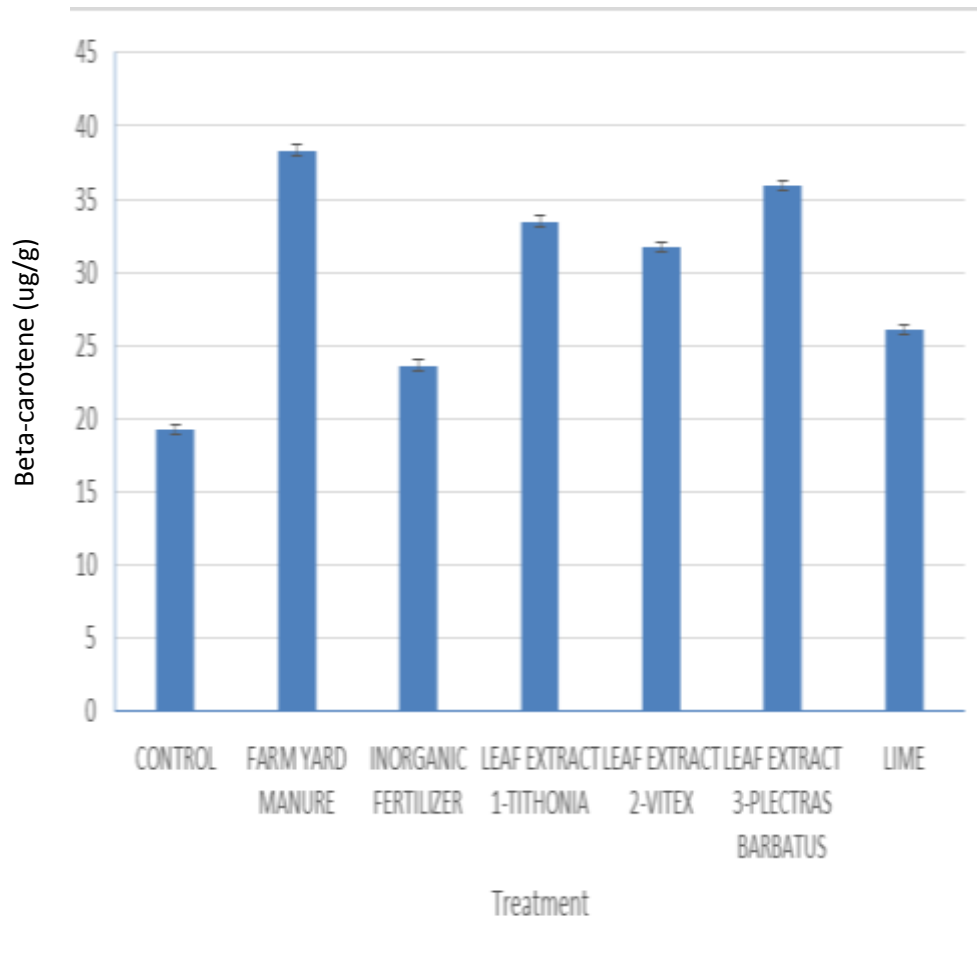


**Figure 4.19: Effect of Soil Treatments on Beta-carotene Levels(µg/g) in Amaranthus During the Rainy Regime.**

The levels of betacarotene in amaranthus ranged from 21.89 µg to 45.02 µg the amaranthus grown in the soil treated with Farm yard manure had the highest beta-carotene levels followed amaranthus grown in soil treated with leaf extracts and control had the lowest, followed by those grown in soil treated with inorganic fertilizer and lime (Figure 4.19).

Figure 4.20 shows the effect of soil treatments on Beta-carotene (µg) levels in *Amaranthus spp.* under irrigation regime in Juja experimental site. This was also

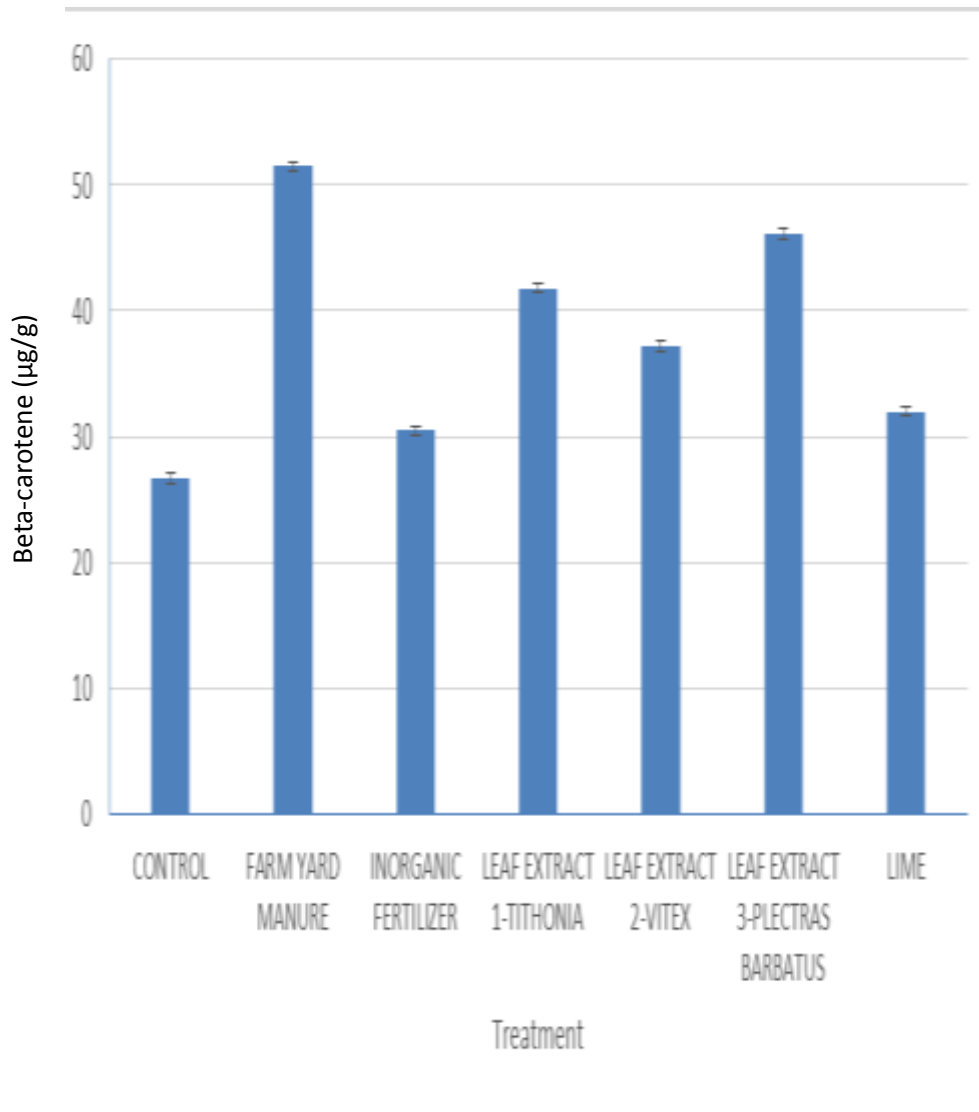
aimed at checking the effects of the treatments on the nutritional value of amaranthus varying the regimes.



**Figure 4.20: Effect of Treatments on Beta-carotene Levels(µg/g) in Amaranthus Leaves Grown in Soil, under Irrigation Regime in Juja experimental site**

From Figure 4.20, the levels of beta-carotene in Amaranthus ranged from 19.22 µg control being lowest to 38.35 µg and Farm yard manure the highest levels.

Figure 4.21 shows the effect of soil treatments on Beta-carotene ( $\mu\text{g}$ ) levels under green house conditions.



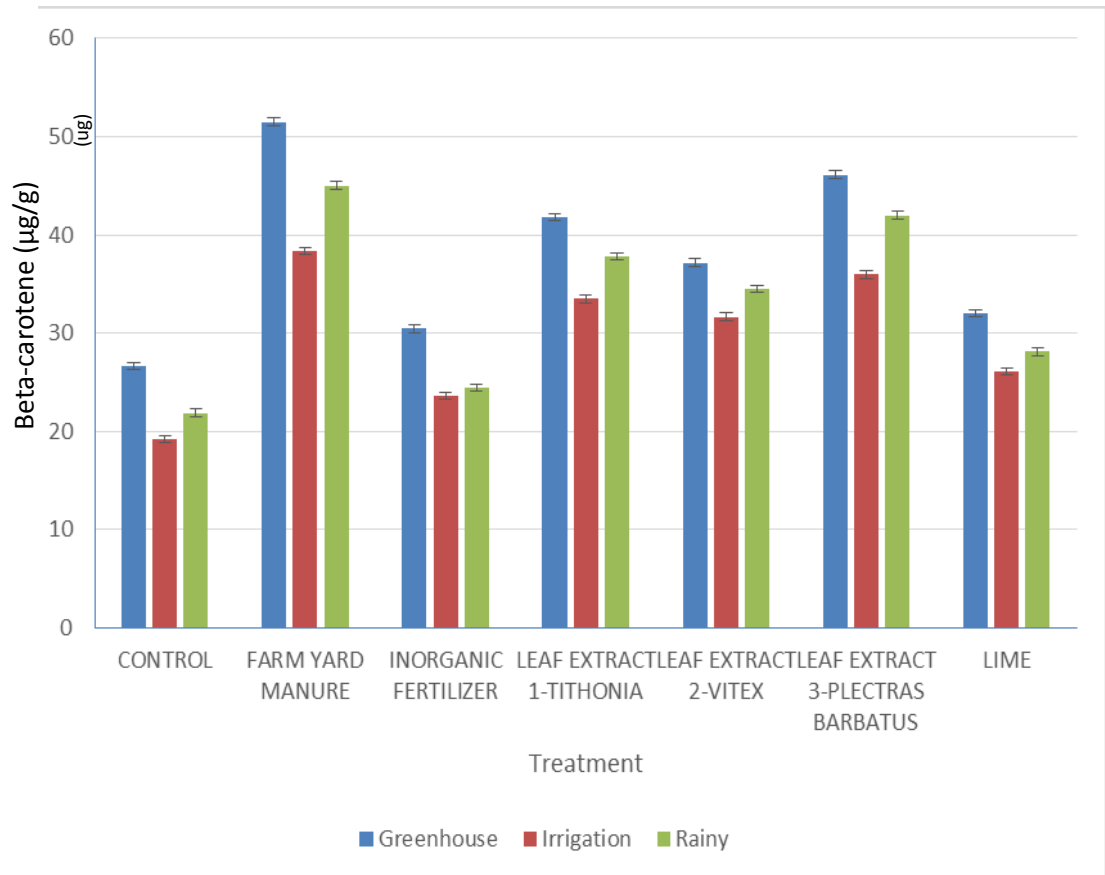
**Figure 4.21: Effect of Treatments on Beta-carotene Levels( $\mu\text{g/g}$ ) in Amaranthus under Greenhouse Regime**

From Figure 4.21, betacarotene levels in amaranthus in treated soils under green house regime ranged from 51.5  $\mu\text{g}$  being the highest to 26.67  $\mu\text{g}$  the lowest hence Farm yard manure and control respectively. They were followed by those treated with inorganic fertilizer and lime.



**Plate 4.2: Beta-carotene Levels Data Analysis at Jomo Kenyatta University of Agriculture Food Science Laboratory**

Figure 4.22 shows the effect of soil treatments on Beta-carotene ( $\mu\text{g}$ ) levels in Amaranthus across regimes. This was aimed at comparison of the betacarotene levels under the three regimes as the amount of water supplied have an effect on the nutritional value.



**Figure 4.22: Effect of Treatments on Beta-carotene Levels (µg/g) in Amaranth Leaves across Regimes**

From Figures 4.22 and Plate 4.2, on beta-carotene levels across the regimes, under greenhouse conditions FYM had the highest levels (51.51 µg) followed by those treated with leaf extract and was significantly different ( $p < 0.05$ ) from the others. Control had the lowest (26.67 µg) followed by those grown under inorganic fertilizer and lime.

Under irrigation, FYM had the highest betacarotene levels (38.36 µg) followed by those grown under leaf extract that was significantly different ( $p < 0.05$ ) from the

others. Control had the lowest (19.22  $\mu\text{g}$ ) and that was significantly different ( $p < 0.05$ ) from the others. The levels of betacarotene grown in soils treated with leaf extract were significantly different from those grown in soils treated with inorganic fertilizers, lime or control.

Those under the rainy conditions, FYM had the highest betacarotene levels (45.02  $\mu\text{g}$ ) that was significant different ( $p < 0.05$ ) from the others. Control had the lowest (21.89  $\mu\text{g}$ ) and that was significant different ( $p < 0.05$ ) from the others. The levels of betacarotene in leaves grown under soils treated with leaf extracts were significantly higher than those grown in soils treated with inorganic fertilizers, lime and control. There were significant differences ( $P < 0.05$ ) in all treatments under all the regimes. However, there were no significant differences in the varieties and also on the interaction between the varieties and the treatment.

In all the regimes, green house had the highest levels of betacarotene for all treatment and this could have been as a result of minimal leaching in the greenhouse as the amaranthus were grown in the pots and there was no water run off unlike in the open field where rainy and irrigation regimes were carried out. On the levels, this was in agreement with Macrae *et al.* (1993), who reported that grain amaranth leaves the levels to be 33.3 mg 100 g<sup>-1</sup> DW which is comparable to *Amaranth tricolor* whose levels ranges between (35.3-53.1) mg 100 g<sup>-1</sup> DW (Yadav and Sengal, 1995).

It was noted that the levels of betacarotene increased with age of the amaranth as were the highest towards the fourth week of data collection compared to the other weeks. This is in harmony with (Rodriguez-Amaya and Kimura, 2004; Cheruiyot, 2011) who found out that maturation in vegetable amaranth is attributed to enhanced carotene genesis hence higher levels of  $\beta$ -carotene at advanced ages of growth.

On leaf extract *Plectranthus barbatus* in all regimes, had the highest levels in betacarotene is comparable to what (Ditta *et al.*, 2016) reported that organic manures have advantage of supplying essential nutrients either directly or indirectly by eliminating aluminium toxicity or by producing organic acids, thereby increasing nutrients availability.

## CHAPTER 5

### 5.0 CONCLUSIONS AND RECOMMENDATIONS

From the studies of the effect of leaf extract, inorganic fertilizer, lime farmyard manure and control on soil pH, nutrients and betacarotene levels grown amaranth leaves under various regimes the following conclusions can be made.

#### 5.1 Conclusions

The soil pH indicated significant differences ( $P < 0.05$ ) among the treatments with leaf extracts farm yard manure and lime increasing the pHs of the soil. Extract *Plectranthus barbatus* increasing the soil pH (from 5.9 to 6.7) in all the regimes. Contrary the inorganic fertilizer decreased the soil pH (5.9 - 5.3)

There was increase on the growth parameters; shoot weight, number of leaves, leaf area of the two varieties treated with *Vitex keniesis*, *Tithonia diversifolia* and Farm Yard Manure.

On the macronutrients in the soil, on nitrogen levels, Farm Yard Manure and *Tithonia diversifolia* recorded the highest while control the lowest.

On phosphorus levels, inorganic fertilizer and Farm Yard Manure recorded the highest while lime the lowest.

Potassium levels, leaf extract *Plectranthus barbatus* recorded the highest and control the lowest.

Beta carotene content is determined by its precursor which is vitamin A. leaf extract *Plectranthus barbatus* and Farm Yard Manure recorded the highest levels while control the lowest in the two varieties, in all the regimes. *Amaranthus* spp with high levels of beta-carotene, have an antioxidant which fights cancer cells. In all the regimes leaf extracts gave better results than lime treatment.

### **5.2 Recommendations from this Study**

- Farmers to be encouraged to plant more of these plants, *Vitex keniesis*, *Tithonia* and *Plectranthus barbatus* so that they can be used as a source of increasing soil macro nutrients, as are not easily depleted as the levels were still high even after the growth of *Amaranthus* spp. Also they assist in buffering of the soil acidity.
- Farmers to reduce use of inorganic fertilizer and increase use of Farm Yard Manure and leaf extracts as a way of increase crops nutrients and especially beta-carotene levels.

### **5.3 Recommendations for Further Research**

- More research is needed to evaluate the effect of the leaf extracts over a longer period of time on the soil pH.
- Check the levels of nutrients such as phosphorus, potassium, iron, zinc, protein among others in the crops grown using the leaves extracts.
- Effects on leaf extracts when they are all combined should be studied.

- Growing other different vegetables especially those with beta-carotene to check their levels as it's an oxidant as cancer diseases are on the rise and can also assist alongside other vegetables.

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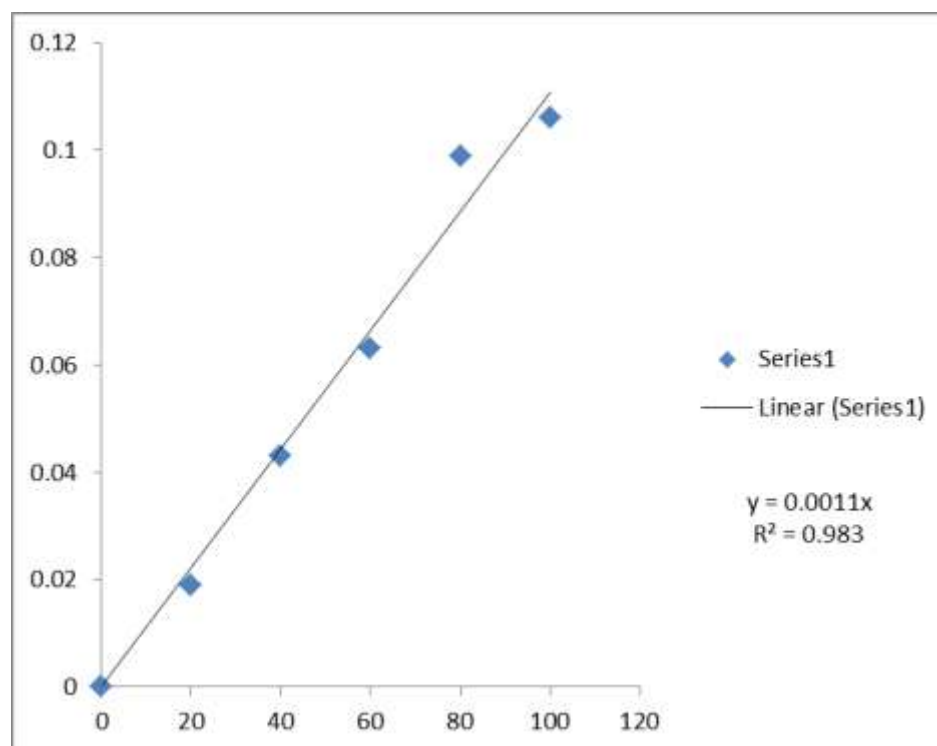
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**APPENDIX 1: CLASSIFICATION OF AVAILABLE NUTRIENTS**

MEHLICH METHOD				
NUTRIENT	DEFICIENCY LEVEL	ADEQUATE LEVEL	EXCESSIVE LEVEL	REMARKS
Potassium (me%)	<0.24	0.24-1.5	>1.5	
Phosphorus(ppm)	<30	30-80	>80	
Total Nitrogen(%)	<0.2	0.2-0.5	>0.5	
Total Organic Carbon(%)	<1.33	2.66-5.32	>5.32	

## APPENDIX II: BETA CAROTENE STANDARD CURVE



**APPENDIX III: CLASSIFICATION OF PH RANGES 1:2 SOIL: WATER**

<b>Class</b>	<b>pH Range</b>
Extremely Acid	3.5-4.4
Very Strongly Acid	4.5-5.0
Strongly Acid	5.1-5.5
Moderately Acid	5.6-6.0
Slightly Acid	6.1-6.5
Neutral	6.6-7.3
Slightly Alkaline	7.4-7.8
Moderately Alkaline	7.9-8.4
Strongly Alkaline	8.5-9.0
Very Strongly Alkaline	>9.0

**APPENDIXIV :IMAGES OF THE TWO Amaranthus spp.VARIETIES  
USED AS TEST CROP**



*Variety Tricolor*



*Variety Cruetus*

**APPENDIX V: IMAGES OF LEAF EXTRACTS USED IN THE STUDY**



Image of *Tithonia diversifolia*



Image of *Plectranthus barbatus*



Image of *Vitex keniesis*