UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF AGRICULTURE EDUCATION

FACULTY OF AGRICULTURE EDUCATION

MAMPONG- ASHANTI

GROWTH AND YIELD RESPONSE OF TWO ONION (*Allium cepa)* VARIETIES TO INTEGRATED NUTRIENT MANAGEMENT IN THE TRANSITIONAL ZONE OF GHANA

BY

ABDUL-RAZAK DANJE ALI

8152010001

MASTER OF PHILOSOPHY THESIS

MAY, 2019

GROWTH AND YIELD RESPONSE OF TWO ONION (*Allium cepa)* VARIETIES TO INTEGRATED NUTRIENT MANAGEMENT IN THE TRANSITIONAL ZONE OF GHANA

ABDUL-RAZAK DANJE ALI

(BSC APPLIED BIOLOGY)

A THESIS IN THE DEPARTMENT OF

CROPS AND SOIL SCIENCES, FACULTY OF AGRICULTURE EDUCATION

SUBMITTED TO

THE SCHOOL OF RESEARCH AND GRADUATE STUDIES,

UNIVERSITY OF EDUCATION, WINNEBA IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE AWARD OF

MASTER OF PHILOSOPHY (M.PHIL) IN AGRONOMY IN THE

UNIVERSITY OF EDUCATION, WINNEBA

MAY , 2019

DECLARATION

I, Abdul-Razak Danje Ali declare that this dissertation with the exception of quotations and references contained in published works which have all been identified and acknowledged is entirely my own original work and it has not been submitted either in part or whole for another degree elsewhere.

------------------------------------- -------------------------------

ABDUL-RAZAK DANJE ALI **DATE**

(CANDIDATE)

------------------------------------- -------------------------------

MR. E.K ASIEDU **DATE**

(MAIN SUPERVISOR)

------------------------------------- -------------------------------

DR. (MRS) MARGARET E. ESSILFIE **DATE**

(CO-SUPERVISOR)

ACKNOWLEDGEMENTS

I wish to express my profound gratitude to the Almighty God for His guidance and protection throughout the course. I am grateful to Prof. Kofi Agyarko, Head of Crop and Soil Sciences Department. My sincere gratitude also goes to my thesis Supervisors Mr. E. K. Asiedu and Dr. (Mrs) Margaret E. Essilfie who resourcefully and untiringly supervised this work by giving their priceless guidance and constructive criticisms. Their directives, correction and valuable suggestions especially during the write-up were particularly helpful.

I am also indebted to Professor S.Y. Annor Dean, Faculty of Agriculture Education of UEW and Prof. Joseph Manu and senior lecturers in the Department of Crop and Soil Sciences and the following technicians: Mr. Kofi Amponsah, Mr. Otabil, Mr. Richmond and Mr. Anthony Anaba for their suggestions and support in terms of equipment and technical advice. Am also grateful to Mr. Ambrose Kweku Johnson, former headmaster, Kongo SHS and Mr Adiisi James, assistant headmaster of Kongo SHS for their assistance, advice and guidance throughout the program. I cannot forget two wonderful course mates, Mr. Kweku Asante and Mr. Clement for their inspiration and support throughout the course.

Finally, I thank my wife, Charity Abanga and children, Michelle, Mildred and Devine for being there for me through thick and thin and standing by me through difficult times. Thanks for your encouragement and support.

DEDICATION

This work is dedicated to my wife Charity Abanga, my two daughters, Michelle and Mildred and my son, Devine Wedam Danje.

LIST OF ABBREVIATIONS

PM-	Poultry Manure
CD-	Cow dung
NPK-	Nitrogen, Phosphorus, Potassium
TVC-	Total Variable Cost
WAT-	Weeks After Transplanting
BCR-	Benefit Cost Ratio
GB-	Gross Benefit
NB-	Net Benefit

ABSTRACT

Field experiments were conducted in 2016 and 2017 cropping seasons at the University of Education Winneba, Faculty of Agriculture Education, Mampong in the forest-savannah transitional zone of Ghana. The study was to evaluate the growth and yield response of two onion varieties to integrated nutrient management in the transional zone of Ghana. The treatments used were 10 t/ha Cow Dung, 10 t/ha Poultry Manure, 300 Kg/ha NPK, combination of half rate animal manure and half rate NPK 15:15:15 fertilizer (5 t/ha PM +150 kg/ha NPK; 15:15:15 and 5 t/ha CD +150 kg/ha NPK) and control (without amendment), laid out in a split plot design with 3 replications. Variety was laid as main plot while nutrient treatments were assigned to sub-plots. The onion varieties used in the study were Bawku Red and Red Creole.

Application of poultry manure and cow dung and their combination with NPK fertilizer improved soil physical conditions, particularly aeration, total porosity, water holding capacity and gravimetric moisture content than the control. Soil bulk density was high in the control plots while the manure and their combinations reduced the soil bulk density. The sole cow dung and poultry manure as well as their combinations with NPK significantly increased soil organic carbon, N, P, K, Ca, and Mg concentrations over the control. Also, the total exchangeable bases, effective cation exchange capacity and percent base saturations recorded an increase over the control.

Plant height and number of leaves per plant for the 5 t/ha PM + 150 Kg/ha NPK was significantly ($P<0.05$) higher for Bawku Red than the control while the 10 t/ha PM recorded a significantly higher number of leaves and plant height for Red Creole than the control in 2016 cropping season. The 10 t/ha PM recorded a significantly ($P<0.05$) greater number of leaves than the control for both varieties in 2017 cropping season. The 5 t/ha PM + 150 Kg/ha NPK gave the tallest plant in Bawku Red while the 10 t/ha PM gave tallest plant in Red Creole, and these were significantly higher than the control in 2017 cropping season. The percentage crop establishment for the 10 t/ha PM and the 5 t/ha PM+150 Kg/ha NPK was significantly ($P<0.05$) higher than the control for both varieties in 2016 cropping season.

The 5 t/ha PM+150 Kg/ha NPK gave significantly ($P<0.05$) greater bulb diameter than the control, for both varieties in 2016 cropping season. The 5 t/ha PM+150 Kg/ha NPK recorded the highest fresh bulb weight for Bawku Red in both 2016 and 2017 cropping seasons and this was significantly ($P<0.05$) different from the control. However, the 10 t/ha PM recorded significantly ($P<0.05$) higher fresh bulb weight than the control in both cropping seasons for Red Creole variety . In both 2016 and 2017 cropping seasons, marketable bulb yield and total bulb yield were significantly ($P<0.05$) higher than the control for Bawku Red in response to the 5 t/ha PM + 150 Kg/ha NPK, whereas the 10 t/ha PM gave a significantly ($P<0.05$) higher marketable and total bulb yield than the control for Red Creole.

The highest monetary net returns were obtained under the 5 t/ha PM+150 Kg/ha NPK and the 10 t/ha PM from Bawku Red variety and Red Creole variety respectively.

For effective soil fertility management, maximum yield and profitability in onion production, 5t/ha Poultry Manure combined with 150Kg/ha NPK should is recommended for Bawku Red variety while 10t/ha sole Poultry Manure is recommended for Red Creole variety.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Onion (*Allium cepa* L.) belongs to the genus *Allium* of the family *Alliaceae* (Kumar, 2014). It is one of the most important crops cultivated commercially in most parts of the world (Kondal, 2011). It probably originated from Central Asia between Turkmenistan and Afghanistan where some of its relatives still grow in the wild (Kondal, 2011).

Onion is mainly grown for its bulbs, although the green shoots of salad onions are also consumed. Onions add significant nutritional value to the human diet and also possess medicinal properties with unique flavour and the ability to enhance the flavour of other foods (Kapoulas *et al.,* 2017). The matured onion bulb contains important nutrients such as starch, appreciable quantities of sugars, some protein, and vitamins such as vitamin A, B, and C (Colina-Coca *et al.,* 2013). It is also used as preservative and medicine in most parts of the world. Onions are sensitive to day length, as a result several onion types exist depending upon the latitude at which they grow.

It is estimated that over 3,642,000 ha of onions are grown annually across the world. On a worldwide scale, around 80 million metric tons of onions are produced per year. China is by far the top onion producing country in the world, accounting for approximately 28% of the world's onion production, followed by India, USA, Iran, Egypt, Turkey, Russia, Pakistan, Netherlands and Brazil. The worldwide onion exports are estimated at around 7 million Metric tons with the Netherlands being the world's largest onion exporter with a total of around 220 Metric tons (FAO, 2013).

Generally, onions are grown extensively throughout Ghana with commercial production occurring in the Northern, Upper East and Upper West regions (Al Hassan, 2009). However, yields in Ghana are rather low. The comparatively lower onion bulb yields in Ghana could be attributed to inappropriate agronomic practices which include poor soil amendment (Fouda, 2017). The use of appropriate agronomic management practices play a huge role in increasing crop yields. The optimum level of any agronomic practices such as plant population, planting date, harvesting date and amount of fertilizer used for the crop varies with environment.

Maintaining adequate level of soil fertility has been seen as one of the best management practices that influences growth, development and yield of plants (Zahoor, 2016). One of the options to maintain soil fertility as well as higher yield is through application of organic manure along with inorganic fertilizer (Faladun, 2015).

Soil fertility management remains one of the key areas of focus in sustaining crop production, especially in inherent low fertility soils. The initial attempt to improve crop production was with the wide use of inorganic fertilizers on high yielding varieties and indigenous crops. However, cost of inorganic fertilizers and poor distribution system forced farmers to resort either to organic farming or at best the use of organic manures with supplementary application of inorganic fertilizers especially on horticultural crops. Notably among the horticultural crops is onion, widely cultivated as cash crop (Ramsey and Pathak, 2016).

Onion is widely cultivated by farmers in Ghana. However, despite the wide acceptance of cultivation of the crop, its production level is abysmally low. The low production level is attributed to poor fertilization. Integrated nutrient management (INM) has proved to be an alternative by sustaining production and ensuring environmental safety (Ortega, 2015). The primary goal of integrated nutrient management is to combine old and new methods of nutrient management into ecologically sound and economically viable farming systems that utilize available inorganic and organic sources of nutrients in a judicious and efficient way (Thangasamy and Anderson, 2015).

1.2 Problem Statement

Food insecurity is one of the major challenges in Ghana. Onion is a major vegetable crop cultivated in Ghana and serves as a source of nutrient and income for most families. As a result most gardeners cultivate large quantities of onion across the country. However, yield of onion per unit hectare has declined due to constraints of production which include low soil nutrient levels (Jayanthi and Vaideke, 2014). Over cultivation of the same piece of land without a fallow period has depleted the soil of essential macro and micro nutrients needed for the proper growth and yield of onion.

Inorganic fertilizers alone can increase soil fertility levels, but they do lack humus and therefore cannot bind soil particles together (Agbede *et al.,* 2017). Again, due to the rising prices of inorganic fertilizers, farmers cannot afford the application of these fertilizers for soil management (farmer communication). Even though the application of organic fertilizers alone had contributed to improved soil physical properties, it does not adequately improve the mineral nutrient status of the soil (Agbede *et al.,* 2017). Organic fertilizers are broken down into basic nutrients such as nitrogen, phosphorus and potassium which are not available in appropriate proportions. Thus plants may end up absorbing a lot of one nutrient over the others. Again the slow and sustained release of nutrients by organic fertilizer cannot be made to hasten in order to meet the needs of a dying plant. Furthermore, organic fertilizers are not readily available in large quantities for soil amendment (Agbede *et al.,* 2017).

Therefore there is the need to combine the use of organic and inorganic fertilizers to mitigate high cost of chemical fertilizers and unavailability of large quantity of manure, and also to provide the nutrients and soil conditions necessary for proper growth and yield of onion.

1.3 Justification

Nutrition is one of the most important factors which govern onion production. Indiscriminate use of inorganic fertilizers in cultivation of onion has a deleterious effect on soil health. Hence, there is a need for supplementing the chemical fertilizers with organic manures.

The use of these organics results in higher growth, yield and quality of crops. The presence of organic matter improves soil physical properties, such as aggregation, increased soil aeration and lower bulk density, insisting surface crust, increased water retention and supply plant nutrients Li *et al.* (2011).

Addition of organic manure to soil enhances microbial activity and increases their ability to conserve soils and consequently increasing their fertility and fertilizers use efficiency as a final goal. Organic manures, apart from improving physical and biological properties of soil, help in improving the use and efficiency of chemical fertilizers (Dunjan *et al.*, 2012).

Cyril (2014) reported that nutrients from mineral fertilizers enhance the establishment of crops, while those from mineralization of organic manure promoted yield when both fertilizers were combined. Use of organic manures in combination with chemical fertilizers in an appropriate proportion improves the soil health for sustainable onion production.

Therefore, integrated nutrient management is a viable strategy for advocating judicious and efficient use of chemical fertilizers with matching addition of organic fertilizers.

1.4 Research Objectives

The main objective of the study is to determine the growth and yield response of two onion varieties (Bawku Red and Red Creole) to Integrated Nutrient Management.

1.4.1 Specific Objectives

Specifically the study sought to:

1. Assess the effect of organic manure (cow dung and poultry manure) and inorganic fertilizers on soil physical and chemical properties.
2. Compare the effectiveness of organic manure (cow dung and poultry manure) and inorganic fertilizer (NPK 15:15:15) on the growth of onion.
3. Determine the effect of cow dung, poultry manure and NPK (15:15:15) as sole soil amendments, and their combinations on the yield of onion.
4. Ascertain cost benefit analysis and recommend to farmers the nutrient practice that would be most profitable for onion production.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and Distribution of Onion

The history of the onion is an interesting story. Most historians agree that onion has been domesticated and cultivated for at least 6000 years, possibly longer (Kim *et al.*, 2000). Onions were likely a prehistoric dietary staple for our hunter – gatherer ancestors. Onions are mentioned on ancient Babylonian tablets in recipe form dating all the way back to 1700-1600 BC. The crop has been used throughout history for a variety of purposes, primarily in cooking (Ghabel *et al.*, 2010). Modern archeologist, botanist and historians are unable to determine exact time and place of their first cultivations (because this vegetable is perishable and its cultivation leaves little to no trace). However, some written records enables us to paint a very interesting picture about its origins.

Onions grew in Chinese gardens as early as 5000 years ago and they are referenced in some of the oldest Vedic writings from India. In Egypt, onions can be traced back to 3500 B.C. Ancient Sumerians widely grew and cooked onions 4000 years ago. The plant has been discovered at the royal palace at Knossos in Crete (Kim *et al.*, 2013).

The Greeks used onions to fortify athletes for Olympic Games. Before competition athletes would consume pounds of onions, drink onion juice and rub onions on their bodies. Additionally, the ancient Greek physician Hippocrates wrote in the fifth and fourth centuries B.C. that a broad variety of onions were eaten regularly in Greece (Kim *et al.*, 2013).

With the arrival of Renaissance and the New trade routes of the Golden Age of Sail, onions were carried to all four corners of the world enabling European colonist and native people from new found continents to grow this incredible vegetable on countless soil types. During the fourth century B.C, Alexander the Great transported onions from Egypt to Greece, from where they spread to other parts of Europe following Alexander's conquests (Ghabel, 2010).

2.2 Taxonomy and Morphological Description of Onion

There is a lot of controversy regarding the taxonomic position of *Allium* and related genera. In early classification onion was placed in the family *Liliaceae* . Some British and American botanists classified onion in the family *Amaryllidaceae.* In a more recent taxonomic treatment of monocotyledons, *Allium* and its close relatives are recognized as the distinct family *Alliaceae*, close to *Amaryllidaceae.* A simple classification of the genus *Allium cepa* is adopted by most Horticulturists (Njue *et al*., 2010).

The onion plant has been bred and selectively grown for at least 7,000 years. It is a biennial plant, but is usually grown as an annual (Tendaj and Mysiak, 2011). Modern varieties typically grow to a height of 15cm to 45 cm. The leaves are yellowish- to bluish green and grow alternately in a flattened, fan-shaped swathe. They are fleshy, hollow, and cylindrical, with one flattened side. They are at their broadest about a quarter of the way up, beyond which they taper towards a blunt tip. The base of each onion leaf is flattened, usually white sheath that grows out of a basal disc. From the underside of the disc, there is an extension of a bundle of fibrous roots a short way into the soil. Food reserves begin to accumulate in the leaf bases and the bulb of the onion swells as the onion matures. The leaves die back and the outer scales of the bulb become dry and brittle, so the crop is then normally harvested. If left in the soil over the dry season, the growing point in the middle of the bulb begins to develop in the rainy season. During this period, new leaves appear and also a long, stout, hollow stem expands. The stem is topped by a bract protecting a developing inflorescence. The inflorescence which takes the form of a globular umbel of white flowers has parts in sixes. The onion seeds are glossy black and triangular in cross section (Petrovic *et al.*, 2019).

2.3. Varieties

There are several onion varieties accross the world. Red Pinoy is a good variety for all areas. It is deep red and attractive bulbs with a high market demand. It matures early; matures in 90 day with yields of 25 t/ha. It has a long shelf life of up to 6 months at room temperature.

Red Creole is good for medium - low altitude areas. It has a deep red colour and matures in 150 day. It is an ideal onion for the fresh market. It has yields of 20 t/ha with good storage quality and long shelf life of up to 6 months at room temperature. Bombay Red is good for all areas. It has deep purple red colour and matures in 150 days with yields of 20 t/ha. It is a very popular red onion with farmers and the market. Also, it is a very pungent onion with excellent shelf life and transportability (Suwarso and Anggraeni, 2017). Texas Grano is a high yielding variety and well adapted for the tropics. It is white in colour with golden exterior and matures in 120 days. It is very popular white onion with farmers and the market with yields of 21 t/ha. It has excellent shelf life and transportability (Kahsay, 2013). Bawku Red onion is commonly found in the markets in Ghana and is from the upper regions of Ghana. It is called Bawku because it widely cultivated and traded in the town of Bawku in the Upper East Region of Ghana. It is easily distinguished from other onions grown in Ghana. It is compact in appearance with deep green leaves and very firm bulbs when mature. The bulbs vary in size, shape and colour. The largest bulb may have a diameter of about 8 cm, and the colours range from white to all shades of pink and purple to red. It is very pungent and is preferred to the foreign cultivars (Addai, 2014).

2.4. Production Estimate

An estimated 3,642,000 ha, of onions are grown around the world, annually. About 170 countries cultivate onions for domestic use and about 80% of the global production is traded internationally (FAO, 2012).

Top Ten Onions (dry) producers-2012 (metric tons) include China (20,507,759), India (13,372,100), United States (3,320,870), Egypt (2,208,080), Iran (1,922,970), Turkey (1,900,000), Pakistan (1,701,100) Brazil (1,556,000), Russia (1,536,300) and Republic of Korea (1,411,650). The world total is estimated as l 74,250,809 metric tons (FAO, 2012).

2.5 Nutritional Value and Uses

Onions are full of antioxidants and contain a number of sulfur-containing compounds. This definitely makes this vegetable appealing. Onions are found in many different sizes and can be eaten raw or cooked. A medium sized onion is composed of 89% water, 1.7 % fiber and 9% of carbohydrates. Onions contain 9.3 g of carbohydrates, 1.1 g of protein, 0.01 g of omega 6, 1.7 g of fiber and 4.2 grams of sugar. Onions also contain multiple vitamins and minerals. They are a good source of vitamin B6, vitamin B9, vitamin C, folate, and potassium. There are multiple phytonutrients that are found in onions. These are Anthocyanins, quercetin. Sulfur-compounds, and thiosulfinates (Sharma and Arpita, 2014). All these components have multiple benefits, which solidify the belief that onion is a super food.

Onions are used to enhance the flavour of meals. Besides they are rich in manganese that offers protection against cold and flu. Allium and allyl disulphide, two phytochemicals in onions, are converted into allicin post ingestion. Allicin, as per certain studies, has properties to fight cancer and diabetes. It can also reduce the stiffness of blood vessels and lower blood pressure levels (Sharma and Arpita, 2014).

Onions also contain quercetin, another antioxidant that fights inflammation. More interestingly, cooking onions in soup doesn’t diminish their quercetin value but simply transfers the antioxidant from the vegetable to the soup broth. And not just the vegetable, even the essential oil from onions has benefits. The oil has antiseptic and antibacterial properties. Onions, when combined with garlic, could have greater benefits. The two, together, are known to be effective antidepressants, painkillers, anticoagulants, and anti-inflammatory (Sharma and Arpita, 2014).

2.6 Climatic and Soil Requirements

Onion grows in wide ranges of climatic conditions, but thrives best at mild climate without excessive rainfall or extremes of heat and cold. Temperature is the most important factor that influences plant growth and bulb development. The minimum and maximum temperatures for germination are 25°C and 35°C respectively, with an optimum temperature of 24°C. Chope and Terry (2010) reported that high temperature favours bulbing and curing. It is a thermo and photosensitive crop. Hence, the production of bulbs is controlled by photoperiod, though temperature has marked influence. The length of photoperiod requirement for onion varies from 11-16 hours (Okporie, 2009). Khokhar (2008) reports that optimum temperatures requirement for bulb formation ranges from 21°C to 28°C. Rainfall and humidity are important factors during the seedling stage, bulbing and harvesting. Cool wet conditions at the seedling stage results in more diseases, while cloudy conditions at bulbing increase the risk of bolting (Lee *et al*., 2008). According to Põldma *et al.* (2012) dry hot weather is beneficial for drying of bulbs at the harvest stage. Soils need to be well structured and fertile to maximize growth and produce high yields. Seedbed condition is critical, particularly if crops are being grown from seed.

Onions have sparse root systems with short lengths and few root hairs. Thus, it is important to maintain nutrient and soil moisture availability within the shallow rooting area (Ali, 2016).

Research findings suggest that water uptake is restricted to the top 25 cm of soil. While onions can survive long periods of drought stress, water availability is critical for growth and high yields of quality crops. Under drought stress, onions are more likely to split or form double and multiple bulbs (Ali, 2016).

Onions have a high water requirement, usually around 75 mm of water per week however, late season irrigation can delay maturity and lead to skin cracking (Kumar *et al.*, 2006). When grown on particularly light soils, inter-row guard crops of barley or wheat, or the use of straw helps minimize erosion. Clods and stones will hinder growth; herbicide efficiency and mechanical harvesting on heavy or stony soils are usually avoided. Soil pH is normally in the range of 6-7, but on organic soils, onions can be grown down to pH of 4. Onions are very sensitive to salinity and so saline soils and salty irrigation water should be avoided. Nitrate and sulfate forms of fertilizer are preferable; chlorides undesirable (Doe, 2018).

Onion can be grown successfully on any fertile well drained, non-crusting soil (Gambo *et al.*, 2008). Vickers *et al.* (2015) reported that the optimum pH range for onion production is 6.0 to 6.8. Onions should be grown on friable soils, which contain high amounts of organic matter, have good water-infiltration rates and good moisture-holding capacity. Sandy loams and muck soils are often used for onion production. Onions are grown on soil textures ranging from sandy to clay loams. Sandy soils usually are well drained, so they dry quickly following rainfall or irrigation. This characteristic is an advantage for onions because there is less risk of bulb disease problems when fields are dry at harvest time. The disadvantages of sandy soil is that they require more frequent irrigation, and this can result in nitrate leaching more than in other soils (Peng *et al*., 2014).

Poorly drained soils often are high in soluble salts, and onion is relatively sensitive to high soluble salt levels (Joshi and Sawant, 2012). Poorly drained soils are slow to dry following rainfall or irrigation, and therefore have a greater probability of being wet at harvest time. Poorly drained soils are not recommended for onion production due to frequent problems with bulb diseases at harvest time leading to more problems in marketing (Joshi and Sawant, 2012).

2.7 Crop Propagation

2.7.1 Planting Materials

Onions can be planted from seed or from setts (small partly grown onion bulbs). Onion Setts are one of the planting materials used in onion cultivation. Setts are more expensive but they tend to be more reliable in their results and also require less work - no thinning and reduced onion fly risk. Onion setts can usually be bought very cheap in garden centres, and in large quantities too (Peluffo *et al*., 2016). Onion seeds are also widely used in onion cultivation. They are a little slower to grow, but only take about three months. Certified onion seeds should always be used. About 95-100% of certified seeds will grow and therefore less seeds will be needed (Peluffo *et al*., 2016).

2.7.2 Planting Distance and Pattern

Planting may be by direct seedling which gives excellent results where the season is sufficiently long to provide early pre-bulbing growth. Seedlings are usually ready 5 to 6 weeks after seeding, when majority of the seedlings necks are pencil – size (65 -80 mm) in diameter, 10-

15 cm tall. Plant spacing of 20 cm between rows and 15 cm within rows can be employed (Essilfie *et al.,* 2017).

2.7.3 Time of Planting

Onions are produced twice a year in the Transitional Zone. The first season is from March to June (major rainy season) while the second season runs from September to December (minor season). For major rainy season cultivation, the recommended planting time for onion is mid-March to mid -June to enable the crop to obtain a cool weather and adequate moisture during the initial growth period (Darabi, 2016). For dry season production, the recommended time of planting is mid-September to mid -October to enable the crop to obtain a warm and dry conditions for maturation, harvesting and curing of the bulbs to produce high quality bulbs and good yield (Darabi, 2016).

2.8 Weed Control

Onions do not compete well with weeds because they are slow growing thus can suffer from successive flushes of weeds. The crop has narrow upright leaves which do not shade out weeds that emerge in the rows. Since onion crops are not competitive against weeds, many species (grass or broad leaf, annual or perennial) may grow, resulting in significant yield losses. Hence controlling weed development during the onion crop cycle is very essential to obtain high and quality yields (Dhananivetha *et al.,* 2017).

The composition of the various weed population is highly variable and depends on several factors like soil type, crop rotation, sowing and growing period. Chemical weed control involves the use of herbicides. It is highly preferred because it's mode of action is fast and easy, there is no mechanical damage to the crop and is cost effective (Strike and Vande, 2017).

Clampdown 480sl 200ml/20l, predator 340ec 25ml/20 and commander 240ec 50ml/20l are some herbicides that are recommended for use in controlling weeds in an onion garden.

Mechanical weed control method involves the use of tools and equipment such as hoes, rakes, fork among others, in controlling weed. Mechanical method of weeding is however, difficult to use due to the following reasons; Onions are shallow rooted, and thus can be easily bruised, the crop is planted at high densities leaving no room for mechanical weed Control in the rows (Snigh *et al*., 2016). Hand weeding is also used, although it is time consuming.

Cultural methods to control weeds include the use of clean seeds free from weed seeds, planting early maturing onion varieties, using irrigation water that is free from weed seeds and mulching (Mohammadi, 2013).

2.9 Diseases and Pests

2.9.1 Black Mold

Black mold is similar to *Penicillium.* Black mold is a major onion disease which occurs during storage, processing and transport. Symptoms of black mold disease include a powdery, black mass of pores below the dried skin which is invisible on the outside. The spores can occur on each of the scales. Infected scales will first appear watery, after which white, fluffy mycelium appears on which black spores quickly develop. The bulbs will start to shrivel in advanced stages of the disease. Black mold is often followed by a secondary infection which causes the bulbs to rot.

Black mold can be prevented by preventing damage to leaves and also by avoiding damage to the bulbs during harvesting, storage and transport (Ozer and Nuray, 2011).

2.9.2 Neck Rot

Neck rot is a major constraint for onion cultivation throughout the world. The disease arises during storage and transport and can cause considerable losses. Bulbs generally develop soft neck due to the disease. Sometimes a white to grey coloured fungal growth can be seen. In a more advanced stage of the disease, the bulb will shrivel and become covered with a grey fungal growth. The disease can be prevented by removing waste heaps or covering them well (Hu, 2019). Again, avoiding damage or injury to the leaves will prevent points of entry to neck rot. Harvesting at the correct time, when the weather is dry and at least 50% of the foliage has died is essential in preventing neck rot.

2.9.3 *Pantoea ananatis*

This is bacterial disease that can cause a form of bulb rot and also symptoms on the leaves of onion plant (Carr *et al.,* 2013). The bacteria mainly occur in warm regions and can cause serious reduction in yield. The initial symptoms show on the young inner leaves. Watery lesions that quickly spread over the leaf and white stripes and patches that appear are symptoms of the disease (Carr *et al.,* 2013). The bacteria can survive on crop debris and various weeds and can be transmitted by thrips. *Pantoea ananatis* disease can be prevented by ensuring good control of the thrips and onion fly populations. Again, keeping weeds down will help reduce the bacteria populations.

2.9.4 Onion Yellow Dwarf Virus

The first symptoms of the onion yellow Dwarf disease can be seen on the youngest leaves. The virus can be transferred by people and farm machinery. Also, it can be spread by insects such as the peach-potato aphid and other aphids. The leaf becomes pale grey with yellow streaks forming around the veins (Ahmed and Elhassan, 2013). The leaves sometimes become crinkled and flattened and tend to fall over. In infected onion setts, the plants remain small, the foliage is curly, yellow, striped and bent.

Onion Yellow Dwarf disease can be prevented by keeping the crops free from aphids. Again, removing infected plants from vegetative propagated planting material of *Allium* varieties can prevent the spread of the disease. Onions should not be grown in the close vicinity of other *Allium* crops to prevent infection (Ahmed and Elhassan, 2013).

2.9.5 Iris Yellow Spot Virus

The virus is transmitted by the onion thrips *(Thrips tabaci)*. The virus can thrive on various host plants such as over wintering onions, iris, alstroemeria and leeks, as well as in infected thrips (Hafez *et al.,* 2014). The initial symptoms of the disease include diamond shaped lesions on leaves and scales. Lesions often, but not always, have a green centre. Only seedlings can be killed by the virus. Severely infected onion plants show a stunted appearance. Infected plants are more susceptible to other stress factors.

Iris Yellow Spot Virus can be prevented by effectively controlling thrips; by ensuring a healthy crop and good weed management thrips population can be reduced considerably (Hafez *et al.,* 2014).

2.9.6 Thrips

Thrips infection starts with pale green dots on the leaf that turn into silver grey blotches. Thrips are small, pale brown elongated insects that are mainly found in the leaf axils on the youngest leaf tissue of the inner leaves (Nautilus, 2013). Their population can increase explosively, especially during hot, dry weather. An average temperature increase from 15ºC to 20ºC doubles the population. The population consists of: 1-3% adult thrips, 15-30% larvae, 60-75% eggs. Thrips can cause severe damage on neck and scales of the bulb (Nault and Hessney, 2011).

Thrips suck the leaf tissue resulting in white to grey spots and death of the damaged tissue. Damaged leaves are more susceptible to secondary pathogens.

Controlling thrips is difficult above a temperature of 25ºC. It is therefore important to start pest control at an early stage (from a soil temperature of approx.11.5ºC). Regularly inspect the shafts of a number of plants and/or use blue sticky traps between the plants to indicate the size of the population. Applying treatment at a temperature below 25ºC and with low intensity sunlight is necessary as the insect avoids bright sunlight. Ensure a healthy, vigorously growing crop. Since thrips also live on many types of weeds, effective weed control can considerably reduce the infection pressure. Also, adjuvants, insect adhesives and attractants can help to control thrips that are difficult to reach (Leach, 2016).

2.9.7 The Leek Moth's Larvae

The leek moth's larvae feed on leaves creating transparent areas (windows) resulting in the formation of hole in the leaves. The leek moth is an inconspicuous moth. The moth eggs which are dirty white in colour are laid on the leaf. After an average of eight days the eggs hatch and the greyish white to green larvae begin to bore into the leaf (Bosco and Tavella, 2010).

The caterpillars are present from the middle of May until the middle of September, with a short interruption in June. The leek moth prefers warm, dry summers. Besides onions, other crops from the *Allium* family serve as host plant for this insect (Bosco and Tavella, 2010).

2.9.8 Onion Leaf Miner

The adult female onion leaf miner punctures the leaf and lays her eggs inside. The larvae hatch out after a few days and go through a number of different stages before becoming a fully grown leaf miner (De Sibio and Rossi, 2012). The neck and head of the onion can be damaged by the leaf miner. Since the leaf miners have a wide range of host plants, including many weeds. Removing plant debris and applying weed contro1 measures considerably reduces the chance of infection.

2.10 Harvesting

Bulbing usually takes place within 12 to 18 weeks. Onion tops should have broken over before harvest and the neck should be collapsed and dry (Kinoshita *et al.*, 2018). Bulb onion harvest time can begin with onion tops naturally fall over and become brown. This is usually 100 to 120 days after planting, depending on the cultivar. Onion harvest time should be early in the morning when temperatures are not too hot. Knowing how to harvest onions is also important, so as to avoid damage to the plants or onion bulbs. Harvesting should be done by carefully pulling or digging onions up from the ground with the tops intact and gently shaking the soil from around the bulbs (Kinoshita *et al.*, 2018).

2.11 Storage

Once harvested, storing onion bulbs becomes necessary. Onions must first be dried before they can be stored. To dry onions, spread them out on a clean and dry surface in a well-ventilated location, such as a garage or a shed. Onions should be cured for at least two to three weeks or until the tops necks are completely dry and the outer skin on the onion becomes slightly crispy (Poldma *et al.* 2012). Dried onions should be stored in a wire basket, crate or nylon bag in a place where the temperature is between 0 °C- 4 °C. Humidity levels should be between 65 and 70 percent for best results (Poldma *et al.*, 2012). If the location is too damp, rotting may occur. Most onions can be kept for up to three months if dried and stored properly.

2.12 Nutritional Requirement of Onion

Nitrogen, phosphorus, and potassium are often referred to as primary macronutrients because of the large quantities taken up from the soil relative to other essential nutrients. Most horticultural crops are grown on farms that are intensively cropped i.e. one or more cultivated crops are grown on the land each year and the crop residue are not enough to replace the nutrients taken up annually (Kwaghe *et al.,* 2017). Therefore, to increase productivity of a crop, balanced supply of essential elements is mandatory. The source of this element can either be inorganic or organic fertilizer.

Onions are weaker than most other crop plants in extracting nutrients from the soil, especially the immobile types, because of their shallow and low branched root system; hence, they require and often respond well to additional fertilizers (Kwaghe *et al.,* 2017).

2.13 Sources and Nutrient Contribution from Organic Manure

Trewavas (2007) identified sources of organic manure to include animal manure such as cow dung, poultry manure, horse, sheep, pig, and goat droppings as well as plant residues such as hay, legume, non-legume, straw, alfalfa pellets and seaweed. Christo and Onuh (2008) indicated that, both plant and animal sources of organic manure contain macro and micronutrients.

Plants and animals are the major sources of organic manure. Organic manure is bulky and consist of farm yard manure, green manure and compost. Organic manures are good sources of organic matter. They are relatively low in nutrient therefore they must be applied at high rates. Organic matter acts as storehouse for nutrients (nitrogen, phosphorus, sulphur, boron, zinc), increases cation exchange capacity, provides energy for microorganism activity, increases water-holding capacity, reduces the effect of compaction, buffers the soil against rapid changes in acidity, alkalinity and salinity and stabilizes structure and improves tilth (Beah, 2014).

Pinto *et al.* (2016) reported that poultry manure which is a source of organic manure, has a significant amount of nitrogen. Cattle manure obtained during the rainy season when there is abundant green grass for cattle to graze has the highest percentage of plant nutrients than those obtained during the dry season (Dunjana *et al.,* 2012). Pinto *et al*. (2016) asserted that animal and plant wastes at various stages of decomposition constitute soil organic manure. Soil organic manure is derived from dead plant roots, crop residues, green manure, dead soil microorganisms and farmyard manure (Pinto *et al*., 2016).

Plant materials such as straw and dry leaves, garden waste and green manure are forms of organic manure that are mostly used by farmers to improve soil fertility. Green manure can be derived from leguminous crops, which are grown as cover crops and ploughed into the soil (Talgre *et al*., 2012).

High nitrogen content can damage crops (Sincik, 2016). The amount of nitrogen in manure depends on the type of animal, how they are fed, the amount of bedding mixed with the manure and the storage and collection methods. Controlling application rates is difficult to impossible with manure, but in most cases, the nutrients are released slowly enough that it does not cause problems. If large amounts of fresh poultry manure are applied to already fertile soil, there may be enough nitrogen to damage the roots of young plants (Sincik, 2016).

Odour is a major challenge with manure application. Incorporating manure into the soil will reduce the odour, but this is possible only where the soil can be tilled. For topdressing, compost the manure should be composted first. Proper carbon/nitrogen ratios are important to control odour. Horse manure has about the right ratio. Cow and chicken manure will need added carbon. This can be done by mixing equal amounts of manure and high-carbon material, like bedding, straw, leaves or sawdust (Ali *et al*., 2015).

A study conducted by Agyarko and Adomako (2007) on the use of manure on vegetable farms in Sissala, Birim and Shama districts revealed that, bulkiness and problems of transporting the manure to the farm is a major concern to most of the farmers. Most farmers also stated that manure may cause damage to crops, not readily available, attract a lot of insects and enhances weed growth.

2.14 Effect of Organic Manure on Physical and Chemical Properties of Soil

Organic manure from both plants and animals are good sources of organic matter. Beah (2014) stated that a high soil organic matter status leads to improved structural stability, lower bulk density and balance between fine and coarse pores. These properties results in ease of root penetration, erosion resistance and good soil moisture properties: available water capacity and permeability, combined with adequate aeration. When there is a decline of organic matter, it may lead to degradation of these properties with consequences such as capping formation and reduced water holding capacity (Beah, 2014).

Addition of organic manure improves the physical and chemical properties of soil. Vaidya *et al.* (2009) reported that those soils treated with organic manure recorded higher level of organic matter, available potassium and phosphorus, exchangeable calcium, magnesium content than soils without manure treatment. Again, pH and water holding capacity of the soils treated with organic manure were also enhanced. Organic manure improves soil structure through adequate soil holding capacity, aeration and drainage which encourage good root formation and plant growth. Again, organic manure promotes biological activities; nutrient exchange capacity and organic matter content that decreases soil erosion. In crop production, soils must be loose enough to allow root penetration and seedling emergence.

Application of manure had positive effects on soil organic carbon (SOC) (Gulser *et al.*, 2015). In a study on the effect of organic manure on tomato, manured soils recorded a significant decrease in bulk density and were attributed to the increase organic matter of the soil and increased water holding capacity (Agbede, 2010).

Effective tillage practices have been found to be beneficial by minimizing soil hardening or bulk density, improving soil porosity, infiltration, soil water storage and root development. Tillage reduces soil bulk density by breaking the aggregates into smaller particles and increasing aeration. It enhances rapid root elongation with depth, induces a high root density in the subsoil and increases final yield (Agbede, 2010). According to Agbede (2010) combination of soil tillage method and organic manure application involved in crop production affect soil physical conditions, nutrient availability, growth and yield of crops.

Application of organic manure increases porosity and water holding capacity (Adeleye *et al.*, 2010) and also improves and ameliorates several properties such as bulk density, total porosity, penetration resistance and cohesion force. Organic manure amendment improves soil moisture content which could be due to the colloidal and hydrophobic nature of the organic manure (Adeleye *et al.*, 2010).

Organic manure is known to contain macro and micro elements and substances that support growth, development and yield of crops. Among the sources of animal manure used as amendments, poultry manure is reported to have higher values of nitrogen and other nutrients than cattle, pig, grasscutter, goat and rabbit manure. Animal manures generally produce NPK and exchangeable cations such as Ca and Mg and other nutrients for crop growth (Mahmoodaba *et al.*, 2010).

Application of organic manure increases soil organic carbon, N.P.K, Ca, and Mg than soils amended with NPK inorganic fertilizer alone (Indira and Annadurai, 2016). Increase in N.P.K, Ca and Mg is due to the high organic carbon contents observed in the manure. These nutrients increase is due to the type of organic carbon in the manure.

2.15 Effect of Poultry Manure on Soil Physico-Chemical Properties and Crop Performance

Poultry manure, one of the main sources of animal manure has a great potential for soil fertility maintenance and improvement of organic matter. It also improves soil structure and soil biological life if it is applied in the right amount. Due to the high cost of inorganic fertilizers, most farmers and vegetable growers have shifted to the use of poultry droppings to fertilize the soil since it has great influence on soil fertility. Poultry manure is known to contain the highest nitrogen content among the common farmyard sources of manure such as cow dung, sheep, goat, rabbit and horse droppings (Boateng *et al.,* 2009).

Poultry manure improves water holding capacity, improved soil microbial activity, and helps to improve upon both the physical and chemical properties of the soil when applied appropriately (Indira and Annadurai, 2016). Addition of poultry manure to the soil reduces soil bulk density and makes appreciable difference in the root growth of crops (Boateng *et al.,* 2009). The reduction in bulk density creates improvement in soil total porosity.

Pezzolla *et al.* (2013) reported significantly greater soil organic matter in plots treated with organic manure. In their study, plots with poultry manure used as soil amendments had high amounts of available phosphorus and potassium, exchangeable calcium, organic matter and magnesium content than cow dung than and the control plots. Adeleye *et al.* (2010) observed that poultry manure treated plots had higher available P, exchangeable Mg and CEC when compared to other plots treated with pig manure or cow dung at the end of the second planting season. The concentration of nutrients in the plots treated with the different animal manures was in the order of poultry manure >pig manure > cow dung.

Poultry manure has been used worldwide for crop improvement and yield. Poultry manure is essential due to the fact that it has been used successfully on wide variety of crops either as a single animal plant nutrient source or in combination with commercial fertilizers. Adekunle (2013) recorded significant increase in the number of leaves of per plant of okra on poultry manure treated plots compared to the control.

Higher grain yield and biomass of maize was recorded when poultry manure (6-8 tonnes/ha) was applied than NPK fertilizer applied alone. This was attributed to the enhancement of good physical properties of the soil and higher nutrient release (Boateng *et al.*, 2009). Boateng *et al.,* (2009) again reported that higher yield of maize was obtained with 10 tons/ha of poultry manure than with adequate application of N and P inorganic fertilizers.

According to Agyarko and Adomako (2007), application of poultry manure and neem leaves recorded heavier mean root and shoot weight of carrot per plant than the untreated soil. They further indicated that the mean root length per plant (carrot) and mean root diameter with poultry manure plots were significantly longer and wider respectively than the untreated soil.

Ojo *et al*. (2015), reported of higher yields of okra due to the application of poultry manure than NPK. Dapaah (2017) also observed significant increase in plant height, bulb weight, and bulb diameter and bulb yield of onion in poultry manure treated plot than the control.

Poultry manure supply micro nutrients and trace elements not contained in inorganic fertilizer. It is a reservoir of nutrients, released during humification that is eventually made available to the growing plants. Poultry manure can be used to ameliorate the amount of toxic compound produced by the chemical fertilizers. Poultry manure increase the organic matter (OM) content of soil and in turn releases the soil nutrients in available form for the use of the plants.

Agbede (2010) observe that poultry manure enable the soil to hold more water, improves the drainage and organic acids that help to dissolve soil nutrients and then make them available for the crops. Poultry manure contains essential nutrient elements association with high photosynthetic activities and thus promotes root and vegetable growth (Boateng *et al.*, 2009). Mina *et al.* (2011) observed that the highest yield of onion bulbs was obtained with the application of poultry manure.

Zakari *et al.* (2014) reported that the three types of organic manures (poultry dropping, FYM, Cow dung) used in the study significantly increased yield and yield components of garlic. The use of poultry dropping as organic manure at 7.5-10 t /ha recorded optimum yield attributes and yield of garlic.

2.16 Effect of Cow Dung on Physical and Chemical Properties of Soil

Cow dung is basically made up of digested grass and grain. Cow dung is high in organic materials and rich in nutrients. It contains about 3 percent nitrogen, 2 percent phosphorus, and 1 percent potassium (3-2-1 NPK) (Yasmin *et al.*, 2016).

In addition, cow dung contains high levels of ammonia and potentially dangerous pathogens. For this reason, it is usually recommended that it should be cured or composted prior to its use as cow manure. Composting cow dung has several benefits, which include eliminating harmful ammonia gas and pathogens (like E. coli), as well as weed seed and also add generous amounts of organic matter to the soil when applied (Yasmin *et al*., 2016).

Applications of cured cow dung to the soil improve its moisture-holding capacity. This allows less irrigation of crop plants, as the roots of plants can use the additional water and nutrients whenever needed. Additionally, it will improve aeration, helping to break up compacted soils. Composted cow dung also contains beneficial bacteria, which convert nutrients into easily accessible forms so they can be slowly released without burning tender plant roots (Alwaneen, 2016).

2.17 Effect of Inorganic Fertilizers (NPK 15:15:15) on Soil Physico-Chemical Properties and Crop Performance

Inorganic fertilizers are used to provide soil nutrients in order to maintain optimum soil fertility and healthy growth of plants and quality yield. Application of N, P and K fertilizer in acid soil and nutrient depleted soil resulted in change in pH from 5.1 to 5.3 and from 6.2 to 5.8 respectively (Adeniyan *et al*., 2011).

Rahman and Akter (2013) reported that the use of phosphorus fertilizer in combination with N and K raised the soil P content in all the fractions such as saloid P, Al-P, Fe-P, Ca-P and total P in soil. The increase was more at higher rates of P addition along with higher doses of N and K compared to differential combinations of N, P and K. Chemical fertilizers help crops to withstand stress conditions and in some cases these were used to correct plant nutrients deficiencies (Rahman and Akter , 2013).

Maximum net returns in crop production can adequately be sustained with adequate fertilizer program that will supply the amounts of plant nutrients needed. NPK fertilizers are required greatly by crops for healthy development and crop quality. Nitrogen is the most limiting factor for production of crops on soils around the world. Nitrogen is the most important element in the nutrition of compositing micro flora since it is required for the simulation of carbon substrate in organic waste. Phosphorus is the next element after N that limits crop production in the tropical regions and indeed most regions of the world (Kumar and Saritha, 2017) .

Balemi (2010) stated that inadequate P supply will lead to decreased synthesis of Ribonucleic Acid (RNA), the protein maker, leading to decreased growth. Grain yield is often drastically reduced with P deficiency (Balemi, 2010). Potassium is required in small amount but in soil it is required in large amount by many crops and it is important for maintaining the osmotic potential and rigidity of plant cells; hence it plays a vital role in water relations in water uptake in plants (Scanlan *et al*., 2015).

2.18 Effect of Organic Manure and Inorganic Fertilizer Combination on Crop Performance

Nutrient combination to support and sustain crop growth is very important due to the rising cost of chemical fertilizers and the bulkiness and unavailability of organic manure. Complementary use of organic manures and mineral fertilizers has been proven to be a sound soil fertility management strategy in many countries of the world (Biramo, 2018).

According to Faladun *et al.* (2015), high crop yield can be obtained with judicious and balanced NPK fertilization combined with organic manure amendment. Again, Naher and Paul (2017) reported that a system which integrates different practices of soil fertility maintenance, the use of mineral fertilizer, organic manures and intercropping can provide fast growth and good ground cover which allows the roots to exploit soil nutrients at various depths.

Application of Poultry manure and NPK fertilizer on yield and yield components of crops under different cropping systems revealed that, application of NPK and poultry manure significantly increased grain yield as well as other parameters. It was recorded that complementary application gave the higher values than the other treatments, the trend in both locations was NPK plus poultry manure > NPK> poultry manure> no fertilizer (Naher and Paul, 2017).

According to Blay Cyril (2014), the combination of poultry manure and inorganic fertilizer increased plant height, number of leaves per plant, number of plantlets per plant and bulb yield in shallot. This was observed when they studied the optimum levels of poultry manure, inorganic fertilizer and combined effect on the yield of shallot grown on sandy soils in Ghana.

An integrated nutrient management of organic manure in combination with NPK promotes growth and yield of crops than sole NPK and organic manure (Falodun *et al*., 2015). Comparative evaluation of poultry manure and NPK fertilizer on growth and yield of yam in Southwestern Nigeria revealed that the best growth and yield performance of yam was observed under complementary use of poultry manure and NPK. This was attributed to the increased nutrient use efficiency of both macro and micro nutrients from poultry manure and other growth substances such as hormones and macro nutrient from NPK (Agbede *et al*., 2017).

Hossain *et al.* (2018) observed that incorporation of organic manure every year along with recommended dose of NPK fertilizer have been found to produce higher cocoyam and sweet potatoes, leaf numbers and yields than the NPK treatment alone.

The response of crops to combination of organic manure and inorganic fertilizer application as compared to sole source of nutrient showed that the mixture of organic and inorganic fertilizer result in increased yield beyond those achieved with inorganic fertilizer alone (Mahanthesh *et al*., 2009).

Falodun *et al*. (2015) indicated that application of chemical fertilizer and organic manure significantly increased nutrient uptake and yield of onion on moderately acidic soil. Again, Abdullah (2008) reported that combination of 50% inorganic N through organic manure and rest of the N and P through chemical fertilizer was most useful for obtaining maximum harvest index and yield of onion on sandy loam soil.

The integration of inorganic fertilizer and organic manure has also been reported to be more beneficial than the use of either mineral fertilizer or organic manure alone, especially in intensive agricultural production. Nutrient use efficiency was maximized through the combination of organic manure and mineral fertilizer (Nweke and Nsoanya 2013).

Poldma *et al*. (2012) in their research to investigate the response of onion to the application of organic fertilizer, inorganic fertilizer or their combination showed that greater plant height, foliage weight, bulb diameter, bulb yield and bulb weight were produced by organic plus inorganic fertilizer in both years than organic or inorganic fertilizer treatments alone. The application of organic plus inorganic fertilizer at half their recommended rates increased onion bulb yield and reduced field defects.

Damse *et al*. (2014) conducted an experiment on integrated nutrient management in garlic and found that application of 75:40:40:40 kg NPK + 7.5 t/ha FYM + 3.5 t/ha poultry manure produced better bulb yield (150.41 q /ha) and benefit cost ratio. Thus, application of reduced dose of chemical fertilizers along with combination of two or three organic manures was found to be beneficial for garlic.

Kumar *et al.* (2014) observed the maximum plant height, number of green leaves, fresh weight of bulb, number of cloves/bulb, diameter of bulb and yield of garlic q /ha occurred under 25% f FYM + 75% NPK. Seran *et al.* (2010) reported that the application of half fold of the of inorganic fertilizer and compost at the rate of 4 t /ha gave profitable yield (4.75 t /ha) and this combination possibly reduced the cost of production in the cultivation of onion.

Mandal *et al.* (2009) reported that the application of 50% vermicompost + 50% NPK recorded maximum plant height, neck diameter, bulb polar and equatorial diameter, whole plant weight, average bulb weight and bulb yield of onion over other treatments.

2.19. Effect of Organic Manure and Inorganic Fertilizer Combination on Soil Physical and Chemical Properties

There is the need to combine the use of organic and inorganic fertilizers to reduce high cost of chemical fertilizers and unavailability of large quantities of manure. Complementary use of organic and inorganic fertilizers as soil nutrient management holds the key to sustainable agricultural productivity and has proven to be a sound fertility management strategy in many parts of the world. The practice enhances crop yield and has a greater beneficial residual effect than manure or inorganic fertilizer alone (Tabitha *et al.*, 2018). The use of organic and inorganic fertilizers have been found to improve soil physical conditions as asserted by Agbede *et al.* (2017) by reducing bulk density and temperature and increasing porosity and water content. The combined effect of the use of organic and inorganic fertilizers does not only reduce bulk density and improve water holding capacity but allows nutrient to be available throughout the growing period by reducing leaching. In this wise, as the inorganic fertilizers quickly release the major nutrients, the organic manure releases both major (NPK) and micro-nutrients and other growth promoting substances for continuous growth. These bind the soil together to retain a lot of moisture which improves soil productivity including improving water infiltrability, soil structure and soil moisture retention (Agegnehu and Amede, 2017).

Chemical fertilizers alone according to Agbede *et al.* (2017) most of the time increases soil acidity, nutrient leaching, nutrient unbalance and degradation of soil physical properties and organic matter status. Contribution of organic manure and inorganic fertilizer provides best values of total acidity, vitamin content, dry matter and NPK, Fe, Me, Zn Cu, Ni and Pb contents of fruits (Shivanand, 2002) .

Hossain *et al.* (2018), clearly showed the importance of the integrated use of inorganic fertilizer and farm yard manure for overall improvement of soil fertility. Most horticultural crops are grown on lands that are intensively cropped, i.e. one or more cultivated crops are grown on the land each year and the crop residues are not enough to replace the organic matter lost annually.

Cyril (2014) indicated that application of organic nutrient like farm yard manure, compost or green manure in combination with inorganic fertilizer improved soil physical properties and cation exchange capacity, exchangeable calcium, and availability of N, P, K and Zn, Mn, Cu and Fe. Cyril (2014) also demonstrated that uptake of nitrogen, phosphorus, potassium and zinc, manganese, copper, and iron increased significantly by crops when 50 percent of organic in combination with 50 percent inorganic fertilizers were applied. Similar results by Agbede (2010) suggested that application of organic manures increased uptake of N, P and K over application of inorganic fertilizers alone. Besides supplying plant nutrients and improving physico-chemical and biological properties of soil, application of farm yard manure along with recommended level of inorganic fertilizers help maintain the organic matter in the soil (Appireddy *et al.*, 2008).

2.20 Economic Analysis of Manure and Inorganic Fertilizer

Gopinath *et al*. (2008) evaluated the effect of different sources and rates of organic manures (farmyard manure, vermicompost and poultry manure) on yield of garden pea and observed that the application of farmyard manure 20 t/ ha gave the highest net returns followed by 15 t /ha. The net benefit-cost ratio was, however, the highest with poultry manure 3 t /ha (9.1) followed by 6 t /ha.

Adediran (2018) in another study observed that the most profitable practice was the two split applications of 2 t /ha compost enriched with 30 kg N/ ha. The treatment produced a favourable benefit: cost ratio (1.9:1) and increased net returns.

In another study maximum net return and benefit to cost ratio (2.4) was obtained in farmyard manure + poultry manure along with mulch treatment followed by farmyard manure + biofertilizers along with mulch treatment in garden pea (Baswana and Rana, 2007).

Srivastava *et al*. (2009) found that the additional income over the control was maximum with the application of NPK fertilizers, followed by pea straw incorporation + NPK fertilizers but the integration of 20 t/ha farmyard manure + rest NPK through fertilizers proved to be most useful in terms of yield along with minimization of chemical fertilization.

Bairwa *et al.* (2009) reported that okra fruit yield increased 29.30% along with highest benefit: cost ratio (3.19) for the treatment comprising of 60% recommended dose of NPK through inorganic fertilizers + neem cake at 0.6 t/ha + vermicompost at 1 t/ ha + Azotobacter + phosphate solubilizing bacteria. Meena *et al.* (2016) also observed that the highest rice equivalent yield and maximum net profit from rice-table pea-onion sequence were recorded with the application of 100% recommended nitrogen dose through poultry manure. Application of farmyard manure 10 t/ha + recommended NPK gave highest net returns compared to other treatments (Gopinath *et al.*, 2011).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental Site

The field experiment was carried out at the Multipurpose Crop Nursery of the College of Agriculture Education, University of Education, Winneba, Mampong- Ashanti campus located in the forest-savannah transitional zone of Ghana. Two experiments were conducted: the first experiment was carried out in the minor rainy season from September to December, 2016 and the second from May to August 2017 in the major rainy season.

Mampong-Ashanti has bimodal rainfall pattern with the major rainy season occurring from March to July and minor rainy season from September to November. Between the two seasons is a short dry spell in August. The soil at the project site is of the Bediese series of the savannah Ochrosol. The FAO classification of the soil at the experimental site is of Chromic Luvisol. The soil is sandy loam, well drained with thin layer of organic matter with characteristic deep yellowish red colour, friable and free from stones (SRI, 1999). The pH ranges from 6.5-7.0 (Asiamah *et al*., 1993). It is permeable, and has moderate water holding capacity (Asiamah *et al*.,1993). The site has an altitude of 457.5m above sea level and occurs within latitude 7º and 8º North of Equator and longitude 1º and 24º' West of the Greenwich (GSS, 2010).

3.2 Experimental Design and Treatments

3.2.1 Experimental design

A Split Plot Design arranged in a Randomized Complete Block Design (RCBD) with three (3) replications was used. Each block contained 2 main plots, to which two varieties were assigned (Bawku Red, Red Creole). Each main plot was split into 6 sub-plots, to which five fertilizer treatments and a control (without any amendment) were assigned (Fig.3.1). The experimental unit was two onion (*Allium cepa*) varieties (Bawku Red and Red Creole).

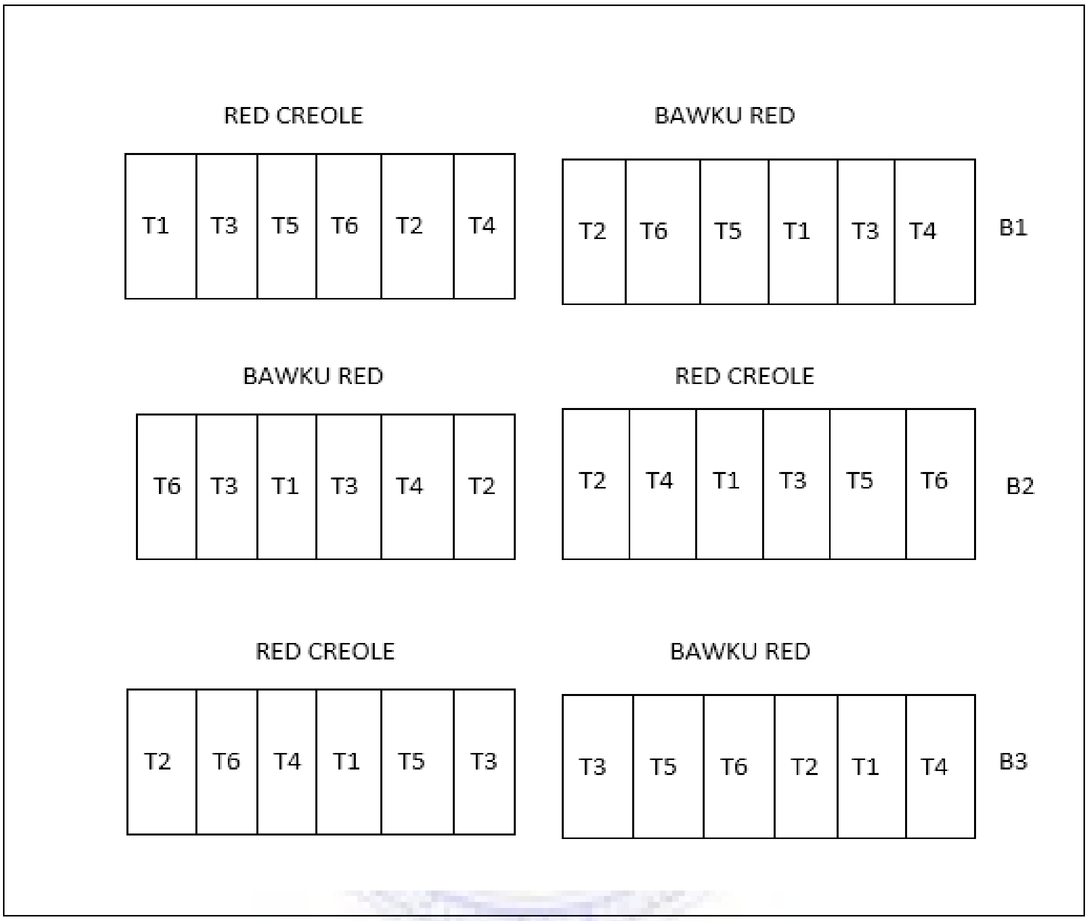

Fig. 3.1 ***Split -Plot field layout used in the experiment***

3.2.2 *Treatments*

The treatment combinations are indicated in Table 3.1.

Table 3.1.*Treatments for the experiment*

Treatments	Inorganic Fertilizer (NPK 15-15-15)	Poultry Manure (PM)	Cow Dung (CD)
T1 (sole CD)	-	-	10 t/ha
T2 (Sole PM)	-	10 t/ha	-
T3 (Sole NPK 15:15:15)	300 kg/ha	-	-
T4(1/2CD+1/2NPK(15:15:15)	150 Kg/ha	-	5 t/ha
T5(1/2PM+1/2NPK 15:15:15)	150 kg/ha	5 t/ha	-
T6 (Control- no fertilizer)	-	-	-

3.3 Organic Manure Preparation

Two weeks old Poultry Manure from a deep litter system of housing and Cow Dung from the cattle kraal were collected from the animal farm at the College of Agriculture Education Mampong Campus. The poultry manure and cow dung were heaped under shade for two weeks and covered with plantain leaves, supported by sticks to minimise the volatization of N through Ammonia gas.

3.4 Soil Sampling

Soil samples were randomly taken from all the treatments in each block and mixed thoroughly treatment by treatment before a sample was taken to represent each treatment for the chemical analysis.

3.5 Determination of Soil Physical Properties

3.5.1 Bulk Density

The bulk density was determined by using the core method (Blake, 1965). The samples of undisturbed soil were taken from the selected sites at a depth of 0 – 15cm using the core sampler. The samples were weighed before and after drying in an oven at a temperature of 105 °C for 24 hours.

Bulk Density was then calculated by using the formula:

$$\text{Bulk density } (\text{g cm}^{-3}) = \frac{M_1}{V_1}$$

Where M_1 is the weight of the undisturbed oven-dried soil sample and V_1 is the volume of the soil which is equal to the volume of the core sampler.

3.5.2 Gravimetric moisture content

The method by Gardner et al.(2001) was used to determine the moisture content. Samples of soil weighing about 100g were taken randomly from the various treatments on the site at 0-15cm depth using the soil auger. The samples were weighed before subjecting them to oven drying at 105°C for 24 hours. These were weighed again after oven drying. Gravimetric moisture was then calculated by using the formula:

$$(\theta)g = \frac{(M_1 - M_2)}{M_2} \times 100$$

Where θg is soil gravimetric moisture, M_1 is the mass of soil before oven drying

M_2 is the mass of soil after oven-drying (FAO, 2008).

3.5.3 Total Porosity

Soil total porosity was determined using the formula

$T = (1\text{-}BD/PD) \times 100$ (Hillel, 1980)

Where T = Total porosity, BD = bulk density and PD = particle density = 2.65g/cm^3.

3.6 Soil Chemical Analysis

Soil samples were taken from all the treatments in each block and mixed thoroughly treatment by treatment before a sample was taken to represent each treatment for the analysis.

3.6.1 Cation Exchange Capacity (CEC)

4 g (for medium to fine textured) air-dry soil was weighed into a 40-ml centrifuge tube, and 33- ml 1 N sodium acetate trihydrate solution, stopper tube we're added and shaken for 5 minutes. The stopper was removed from tube and centrifuge at 3000 rpm until supernatant liquid is clear. The supernatant was decanted as completely as possible and discarded. It was repeated with 33-mL portions of 1 N sodium acetate trihydrate solution, a total of four times, and discarding the supernatant liquid each time. 33-ml 95% ethanol, stopper tube, were added and shaken for 5 minutes, the tube was unstopped and centrifuged until the supernatant was clear and decant. The sample was washed with 33 ml portions of 95% ethanol, for a total of three times, discarding the supernatant liquid each time. The electrical conductivity (EC) of the supernatant liquid from the third washing was less than 400µS/cm.

The adsorbed sodium was replaced from the sample by extraction with three 33-ml portions 1 N ammonium acetate solution. It was shaken for 5 minutes each time, and centrifuged until supernatant liquid is clear. Three supernatant liquids were decanted as completely as possible into a 100-ml volumetric flask, to bring to volume with 1 N ammonium acetate solution, and mixed well. A series of suitable Na standards were run, and a calibration curve drawn. The samples (soil extract) were measured and the emission readings taken by a Flame Photometer. Sodium (Na) concentration was calculated according to the calibration curve.

CALCULATION

For Cation Exchange Capacity in soil:

$$\text{CEC (meq/100 g)} = \text{meq/L Na (from calibration curve)} \times \frac{A}{WT} \times \frac{100}{1000}$$

Where: A = Total volume of the extract (ml)

Wt = Weight of the air-dry soi1 (g)

3.6.2 Soil pH

Soil pH was determined by the use of the pH meter. The pH meter was calibrated using two buffer solutions, 10.0g of soil sample was placed in a 50-ml beaker and 20ml of $CaCl_2$ solution was added. The soil was allowed to absorb the $CaCl_2$ solution without stirring. It was then stirred thoroughly for 10 seconds using glass rod. The suspension was stirred for 30 minutes. The pH was recorded on the calibrated pH meter (IITA, 1979; FAO, 2008).

3.6.3 Organic Carbon / Organic Matter

The Walkley-Black (1934) method was used. 1g of soil was weighed and placed in a 250 ml. Erlenmeyer flask. Then, under the hood, 5 ml of potassium dichromate and 10 ml of concentrated sulphuric acid were added. The solution was allowed to rest for 3 hours. Then 75-100 ml of deionized water, 2-3 drops of ferroin were added and titrated with Mohr's salt. At the same time a blank with 5 ml of dichromate and 10 ml of sulphuric acid were prepared.

CALCULATION: the result could be expressed as organic carbon or as organic matter.

$$\text{O.C\%} = \frac{(b-a) \times N x f x 0.39}{W}$$

Where: b = ml of Mohr's salt used for the blank

a = ml of Mohr's salt used for the sample

N = normality of Mohr's salt

F = normality correction factor

W = weight of the sample

Percent organic matter was calculated after the determination of organic carbon (Walkley and Black, 1934). $\% \, O.M = \% \, O.C. \times 100/58, \quad \% \, O.C \times 1.724$

3.6.4 Total Nitrogen

1g of soil sample was weighed and placed in a Kjeldahl flask. 0.7g of copper sulphate, 1.5g of K_2SO_4 and 30ml of $0.1MH_2SO_4$ was added. The set up was heated gently until frothing ceased. It was then boiled briskly until the solution was clear and digested for 30 minutes. The flask was removed from the heater and cooled, 50ml of water was added and was transferred to a distilling flask. 20 – 25ml of standard acid (0.1MHCl) was placed in the receiving conical flask to get an excess of at least 5ml of the acid. 3 drops of methyl red indicator was added and enough water was added to cover the end of the condenser outlet tubes. Tap water was run through the condenser before 30ml of 35 percent NaOH in the distilling flask was added. The content was heated to distil the ammonia for about 30 – 40 minutes. The receiving flask was removed and the outlet tube was rinsed into the receiving flask with a small amount of distilled water. The excess acid was titrated in the distillate with 0.1MNaOH. The blank was determined on reagents by using the same quantity of standard acid in a receiving conical flask. (Jackson, 1962).

Calculation was done as follows to determine the percent N.

$$\text{Percent N} = \quad 1.401\frac{(V_1M_1 - V_2M_2) - (V_3M_1 - V_4M_2) \times df}{W}$$

Where: V_1= millilitres of standard acid put in receiving flask for samples

V_2= millilitres of standard NaOH used in titration

V_3= millilitres of standard acid put in receiving flask for blank

V_4= millilitres of standard NaOH used in titrating blank

M_1= molarity of standard acid

M_2= molarity of standard NaOH

W= weight of sample taken (1g)

df= dilution factor of sample (FAO, 2008)

3.6.5 Nitrate Nitrogen (NO_3- $^-$N)

5g of soil was placed in an Evlenmeyer flask and 25ml of nitrate – extracting solution was added and shaken for 10minutes. 0.2g of $Ca(OH)_2$ was added and shaken for 5minutes. 0.5g of $MgCO_3$ was added and shaken for 10 – 15minutes. The set up was allowed to settle for few minutes and filtered through No. 42 filter paper. 10 ml of clear filtrate was pipetted into a 100-ml beaker and was evaporated to dryness on a hotplate at low heat in a fumehood. The residue was allowed to cool and 2ml of phenoldisulphonic acid was added to the residue and covered quickly and allowed to stand for 15minutes. 16.5ml of cold water was added and the beaker was rotated to dissolve the residue. To get the yellow stable colour, 15ml of dilute NH_4OH was slowly added until the solution was distinctly alkaline after the beaker was cooled. 16.5ml of water was added and mixed thoroughly. The concentration of NO_3 – N at 415 nm was read using the standard curve (FAO, 2008).

3.6.6 Available Phosphorus

Bray's method (1945) was used.

The preparation of the standard curve was done by Bray's method No. 1. The extraction process was carried out by adding 50ml of the bicarbonate extractant to a 100-ml conical flask containing 2.5g of soil sample. 1g of activated carbon was added and shaken for 30minutes on the mechanical shaker and filtered.

The development of the colour was carried out by Bray's method No.1 and the calculation was done by the standard curve with fresh molybdate reagent. The colour was measured photometrically at 660nm wavelength. The concentration of P was calculated as:
mgP/kg Soil= mgPkg^{-1} in Solution ×50, (Bray and Kurtz 1945).

3.6.7 Available Potassium

This was determined by the use of the photometric method (FAO, 2008). The standard curve was carried out by setting up the flame photometer by atomizing 0 and 20 Ug K/ml solutions alternatively to reading of 0 and 100. The extraction process was carried out by adding 25ml of ammonium acetate extractant to a conical flask fixed with a wooden rack containing 5g of soil sample. It was shaken for 5minutes and filtered. The potash in the filtrate was determined with the flame photometer %K= (a-b) × M/Factor. a=MgK/ml in Sample, b=MgK/ml in blank, M=moisture concentration factor. Factor=200/Dil. factor (Toth and Prince, 1949).

3.6.8 Exchangeable Calcium and Magnesium

Five (5) grams of air-dried soil sample was put in a 150-ml conical flask and 25ml of neutral normal ammonium acetate solution was added mechanically shaken for 5minutes and was filtered through No.1 filter paper. An aliquot of 5ml was taken and 3 crystals of carbamate and 5ml of 16percent NaOH solution and 40mg of indicator powder was added. The set up was titrated with 0.01N EDTA solution until the colour changed gradually from orange-red to reddish-violet (purple). A drop of EDTA solution was added at 5-10 seconds since the change of colour was not instantaneous and the end point was compared with a blank reading (IITA, 1979).

The calculation was:

If N_1 is normality of Ca^{2+}/Mg^{2+} and V_1 is volume of aliquot taken and N_2V_2 are the normality and volume of EDTA used, respectively, then:

$N_1V_1=N_2V_2$

$$N_1 = \frac{N_2V_2}{V_1} = \frac{\text{Normality of EDTA} \times \text{Vol. of EDTA}}{\text{ml of aliquot taken}}$$

3.6.9 Potassium (K)

The AAS was set up and standardized, followed by the preparation of the standard curve. An acid-digest 1g of plant sample was made up to 100ml and kept for estimation range of 5-10 g K/ml. A blank sample was prepared in the same way without adding plant digested material. An aliquot of 5ml was taken for estimation and made up of 100ml and atomized on the calibrated AAS. The absorbance was recorded against each sample and the concentration of K was observed from the standard curve (FAO, 2008).

3.7 Planting Materials and Nursing of Seeds

Seeds of Bawku Red and Red Creole onion varieties were obtained from Savanna Agricultural Research Institute (SARI). The two varieties were chosen because they have high yield capacity, resistant to diseases, have a longer post-harvest shelf life and they grow well in locations that have full sun as well as medium rain (Pal, 2014). They are very hardy and therefore, they require moderate water and can also grow well in places that have intense cold temperatures. They can do well in clay, loamy, or sandy soil with pH range between 6.0 to 7.0 and therefore can be grown at weak acidic or neutral areas (Pal, 2014).

Two nursery beds of 5.0 m length and 1.0 m width for each onion variety were marked out and cleared. The land was tilled manually with hoe thoroughly and made into a fine tilth. Seeds of the two onion varieties were drilled into rows of 15 cm apart on September 10, 2016 for the minor rainy season and April 20, 2017 for the major rainy season.

3.8 Land Preparation, Manure Application and Planting

The experimental field was marked out, ploughed, disked and harrowed to a fine tilth. A total land size of 191.75 square meters was marked out. There were two main plots. Each main plot was made up of 6 sub-plots. Each plot measured 1.2 m^2 with 0.5 m between plots. The treatments were replicated 3 times with 1.0 m left between blocks. Well composited poultry manure and cow dung were incorporated into respective treatment plots before the transplanting of onion seedlings. Healthy and vigorous growing seedlings were selected 30 days after nursing and transplanted in the field. This was done late in the afternoon to reduce the risk of desiccation and poor establishment after being hardened by increasing watering interval. Each plot was made up of four rows with ten plants per row giving a plant density of

40 plants per plot. The distance between each plant in a row was 15 cm and the distance between rows was 20 cm.

3.9 Agronomic Practices

NPK 15:15:15 was applied at full rate of 300 kg/ha as sole treatment and at half rate of 150 kg/ha as a supplement to organic manured plot. The NPK fertilizer was applied 5 cm away from the plant by side placement two weeks after transplanting the seedlings.

The plants were regularly irrigated twice in a day, depending on the weather condition, till the first signs of neck break when irrigation interval was extended to 10 days till 70% maturity. All plants received the same amount of water. Hoeing of the weeds was done two weeks after transplanting and every two weeks before bulbing to keep plots free from weeds during the growth period. The paths between the blocks and plots were weeded with cutlass and hoe four times during the experimental period in both seasons.

Earthening- up was done every two weeks after the seedlings have established to cover exposed roots by watering. The inter-rows were stirred up with hand fork at two weekly intervals throughout the growing period to improve aeration for enhancement of growth of the crop (Ali et al., 2014). Deltameterine and Malathion were used to control pests. This was done twice; 2 weeks after transplanting and 6 weeks after transplanting.

3.10 Data Collection and Statistical Analysis

3.10.1 Plant Sampling and data collection

Data were collected on vegetative, yield and yield components. In the case of vegetative data 5 randomly tagged plants from the two middle rows were selected for determination of plant height, number of leaves per plant, bulb diameter, percentage crop establishment, shoot fresh weight, shoot dry weight average bulb dry weight and average bulb fresh weight . Yield and yield components data were taken from the harvestable area for determination of number of plants harvested, number of bulbs per plot, marketable bulb yield, unmarketable bulb yield and total bulb yield.

3.10.1.1 Plant height

Five plants per plot were randomly selected from the middle rows and tagged for data collection. Plant Height was taken with a metre rule, from the base of the plant to the apex of the longest leaf at 2 weeks after transplanting and 2 weeks interval and the mean estimated (Dapaah, 2014).

3.10.1.2 Number of leaves per plant

The total number of leaves per plant was counted on sampled plants from the two middle rows at 2 weeks after transplanting and at two weeks interval and the mean estimated (Dapaah, 2014).

3.10.1.3 Percentage Plant Establishment

Plants within the middle rows that have successfully established were counted 4 weeks after transplanting and expressed as a percentage (Dapaah, 2014).

CALCULATION

$$\%\ \text{Plant Establishment} = \frac{Ps}{Pt} \times 100\%$$

Where Ps= plants that had successfully established, Pt=total number of plants within the harvestable area.

3.10.1.4 Shoot fresh weight

This refers to the above ground fresh biomass of the plant, which was harvested by cutting five randomly selected plants taken from each plot, from the crown and measured with an electronic weighing scale and the average recorded (Dapaah, 2014).

3.10.1.5 Shoot dry weight

This refers to the above ground biomass of the plant, which was oven dried at a temperature of 78 degrees Celsius for 48 hours until a constant weight was obtained. The aboveground biomass was harvested by cutting five randomly selected plants taken from each plot from the crown and chopped into small 1-2 cm cubes, mixed thoroughly, and a sub-sample each weighing 100 gram weighed. The exact weight of each sub-sample was determined and recorded as fresh weight. Each subsample was placed in a paper bag and put in an oven until a constant dry matter was attained. Each sub-sample was then immediately weighed and recorded as dry shoot weight (Lemma and Shimeles 2003).

3.10.1.6 Bulb fresh weight per plot

The average bulb fresh weight of five randomly selected mature bulbs per plot was measured using electronic weighing scale and the mean estimated. This was done at harvest (Lemma and Shimeles 2003).

3.10.1.7 Bulb dry weight per plot

Five bulbs were randomly selected from each plot and chopped into small 1-2 cm cubes, mixed thoroughly, and a sub-sample each weighing 100 gram was weighed using electronic weighing scale. The exact weight of each sub-sample was determined and recorded as fresh weight. Each subsample was placed in a paper bag and put in an oven at 78 degrees Celsius for 48 hours until a constant weight was attained. Each sub-sample was then immediately weighed and recorded as dry bulb weight (Lemma and Shimeles 2003).

3.10.1.8 Total Dry Biomass

This was determined by measuring the shoot and bulb dry weights of sample plants using electronic weighing balance. This was done at harvest (Dapaah, 2014).

3.10.1.9 Bulb Diameter

The mean bulb diameter of five randomly selected bulbs from the middle rows was measured at the maximum wider portion of matured bulbs using veneer caliper. This was done at harvest (Dapaah, 2014).

3.10.1.10 Number of plants at harvest per plot

The total number of plants at harvest per plot from the middle rows was counted and the mean recorded (Dapaah, 2014).

3.10.1.11 Number of bulbs per Plot

The total number of bulbs per plot from the two middle rows was counted at harvest and the mean estimated. `

3.10.1.12 Unmarketable Bulb Yield

The total weight of unmarketable bulbs that were under sized (< 60 g), diseased, decayed and bulbs from plants with physiological disorder such as thick neck and split was measured from the two middle rows per plot at final harvest and expressed in t/ ha (Lemma and Shimeles 2003).

3.10.13 Marketable Bulb Yield

This referred to the weight of healthy and marketable bulbs from 60 g and above (Lemma and Shimeles 2003). This parameter was determined from the two middle rows per plot at final harvest and expressed as t/ ha.

3.10.1.14 Total Bulb Yield

The total bulb yield was determined from the two middle rows per plot as a sum weight of marketable and unmarketable yields that was measured in kg per plot and finally converted into t /ha (Dapaah, 2014).

3.10.1.15 Days to Maturity

Days to maturity refers to the number of days from seedling transplanting to a day at which more than 80% of the plants in a plot showed yellowing/senescence of leaves or attained physiological maturity. This was determined when 80% of the plants within the two middle rows were seen with senescence of leaves and stem. These were counted for the different treatments and recorded (Dapaah, 2014).

3.10.1.16 Harvest index

At harvest, plants from the two middle rows of each plot were harvested and separated into bulb and vegetative parts and their separate weights taken for estimation of the harvest index. It was estimated as the ratio of the bulb yield to the total plant biomass yield (Dapaah, 2014).

3.10.2 Statistical Analysis

Data collected were subjected to Analysis of Variance (ANOVA) using GENSTAT VERSION 11. Significant means obtained were separated by Least Significant Difference (LSD) method at 5% significance level.

3.11 Benefit/Cost Analysis of Treatments

Benefit/Cost analysis was done to determine the relative economic benefit of the applied treatments using 2016 and 2017 annual market prices. The yields were adjusted by 10% downwards due to management level variability between a researcher and a farmer (CIMMYT, 1988). Costs of farm services were taken at Mampong market in Mampong Municipality of the Ashanti Region of Ghana. This was due to the location of the study and also all inputs were obtained from there. Capital costs such as land, water and management charges, interests on operational capital, depreciation of machinery and equipment, and other overhead costs were not considered because of so many years of depreciation and their insignificant values.

The economic indicators used were;

3.11.1 Gross Benefit

This is the product of the adjusted yield (t/ha) and the sale prices. It was calculated by multiplying the yield in t/ha by the market price.

3.11.2 Net Benefit

It is the gross benefit less total variable cost. It was determined by subtracting the total cost of production from the gross benefit.

3.11.3 Benefit: Cost Ratio (BCR)

The Benefit: Cost Ratio (BCR) defines the profitability of a treatment. This was determined as the Gross Benefit of yield divided by the Cost of production.

CHAPTER FOUR

RESULTS

4.1 Climatic Conditions

All climatic data were from at the Mampong Meteorological Station. In 2016, the maximum average temperature during the experiment was 31.1^{0}C and the minimum was 22.8^{0}C. The average total rainfall from August to December 2016 was 136.3mm. The average relative humidity in 2016 season from August to December recorded a minimum of 63.6% and maximum of 71.0% (Tables 4.1a and b)

In 2017 cropping season, the average total rainfall was 156.4mm, which was higher than rainfall recorded in 2016 cropping season. The maximum average temperature was 31.0 ^{0}C and the minimum was 23.0^{0}C. The maximum temperature in 2016 cropping season was higher than that in 2017 cropping season. However, the minimum temperature in 2017 cropping season was higher than that in 2016 cropping season.

The 2016 cropping season was drier than the 2017 cropping season since the experiment was in the minor rainy season. The average minimum relative humidity in 2017 was 67.2% and a maximum was 96.0%. The relative humidity in 2017 cropping season was higher than the relative humidity in 2016 cropping season. The differences in climatic conditions could be attributed to the fact that the period of the experiment in 2016 was in the minor rainy season as against the major season in 2017.

Table 4.1a. ***Climatic data for 2016 minor rainy season***

Month	Rainfall(mm)	Min. tem.(^{0}C)	Max. tem.(^{0}C)	Min. Rel. Hum. (%)	Max. Rel. Hum. (%)
August	55.1	22.1	28.4	72	68
September	32.9	22.4	29.7	71	78
October	209.4	22.7	31.5	64	77
November	64.0	23.6	33.1	57	75
December	24.0	23.3	32.6	54	58
Aver. Value	77.1	22.8	31.1	63.6	71

Source: Mampong Metrological Station.

Table 4.1b. ***Climatic data for 2017 major rainy season***

Month	Rainfall(mm)	Min. tem.(^{0}C)	Max. tem.(^{0}C)	Min. Rel. Hum.(%)	Max. Rel. Hum. (%)
April	98.8	24.0	33.6	59	95
May	201.0	23.6	32.9	62	95
June	250.8	23.0	30.6	70	98
July	139.3	22.4	29.2	72	96
August	91.8	22.0	28.5	73	96
Av. Value	156.3	23.0	31.0	67.2	96.0

source: Mampong Metrological Station

4.2 Nutrient Levels of Organic Manure Used in the Experiment

Table 4.2 shows the nutrient content of poultry manure and cow dung used in the study. Poultry manure had the higher nitrogen (N), total phosphorus (P) and total magnesium (Mg). Cow dung had the higher calcium (Ca) content. The pH of both poultry manure and cow dung was slightly above neutral.

Table 4.2 ***Chemical properties of poultry and cattle manure used in field studies***

Property	pH	Ca%	Mg%	P%	K%	N%
Chicken manure	8.3	0.94	1.32	1.39	0.63	2.0
Cow dung	7.5	2.7	0.91	0.7	0.53	1.61

4.3 Soil Physical Characteristics after Treatment Application Two Weeks After Transplanting (2WAT)

In both 2016 and 2017 cropping seasons, the 300 kg/ha NPK treatment recorded higher bulk density than the sole manure and their combinations with NPK (Tables 4.3a and 4.3b). However, all the treated plots recorded lower bulk density than the control. The sole poultry manure, sole cow dung and their combination with NPK recorded the highest total porosity. Also all the treated plots recorded higher total porosity than the control in both seasons.

In both seasons, the 10 t/ha PM and the 10 t/ha CD produced the greatest gravimetric moisture content than their combination with NPK and the sole NPK treatment. All the treated plots recorded increased gravimetric moisture content over the control (Tables 4.3a and 4.3b). Total porosity and gravimetric moisture content were higher in 2017 than in 2016. However, bulk density in 2016 cropping season recorded an increase over that in 2017 cropping season.

Table 4.3a ***Soil physical properties at experimental site after organic manure and NPK application, 2016.***

Treatment	Bulk Density(g/cm^3)	Total Porosity(%)	Gravimetric Moisture content(%)
10 t/ha CD	1.22	53.96	10.59
10 t/ha PM	1.20	53.50	10.65
300 kg/ha NPK	1.30	50.94	10.12
5 t/ha PM+150 kg/ha NPK	1.24	52.83	10.16
5 t/ha CD+150 kg/ha NPK	1.25	53.21	10.4
Control(no fertilizer)	1.40	47.17	8.44

Table 4.3b ***Soil physical properties at experimental site after organic manure and NPK application, 2017.***

Treatment	Bulk Density(g/cm^3)	Total Porosity(%)	Gravimetric Moisture content(%)
10 t/ha CD	1.21	54.69	11.54
10 t/ha PM	1.12	54.90	11.65
300 kg/ha NPK	1.31	52.04	11.13
5 t/ha PM+150 kg/ha NPK	1.20	54.38	11.26
5 t/ha CD+150 kg/ha NPK	1.14	53.90	11.14
Control(no fertilizer)	1.41	49.17	8.94

4.4 Soil Chemical Properties at the Experimental Site

From Tables 4.4a and 4.4b, for both 2016 and 2017 cropping seasons, it can be deduced that the soi atl 0-20cm was acidic. Organic matter content and nitrogen level were low under general conditions. The cation levels in the background soil recorded lower values per soil analytical data interpretation guide of CSIR-Soil Research Institute (Appendix A). Available P and K were low from the results obtained from the background soil. The low levels of the cations (Mg, Ca, K and Na) had an effect on the total exchangeable bases (TEB) and the effective cation exchange capacity (ECEC) which shows low base saturation of 69.4% and 68.3 % respectively.

4.5. Soil Nutrient Levels after Treatments

In both 2016 and 2017 cropping seasons, the soil pH for treated plots recorded an increase over the control (Tables 4.4a and 4.4b). The manured treated plots and their combination gave higher levels of organic carbon, percentage total nitrogen and organic matter content than the sole NPK and the control (Tables 4.4a and 4.4b). The 10 t/ha PM and the 5 t/ha PM + 150 kg/ha NPK recorded higher Ca and Mg levels while the sole 300 kg/ha NPK recorded the highest K level among the exchangeable bases in both seasons. The sole poultry manure and cow dung as well as their combination with NPK gave an increase in TEB than the sole NPK and the control in both cropping season.

Additionally, results both sites (Tables 4.4a and 4.4b) indicated that the treated plots gave higher ECEC levels than the control. The sole poultry manure and its combination with NPK gave the highest ECEC levels. Again, results from both seasons (Tables 4.4a and 4.4b) indicated that all the treated plots had higher base saturation levels than the control. The 10 t/ha PM and the 300 kg/ha NPK gave higher available P and K than the control in both cropping seasons (Tables 4.4a and 4.4b). All the treatments recorded higher organic carbon and organic matter levels in 2017 cropping season than in 2016 cropping season. However, total nitrogen was higher in 2016 cropping season than in 2017 cropping season.

Table 4.4a Soil ***Chemical Properties after Treatments Application, 2016***

Treatment	pH, H_2O 1:25	Org. C %	Total N,(%)	Org. M (%)	Exch. Cations (me/100g)				T.E.B	Exch. A(Al+H)	E.C.E.C me/100 g	Base Sat (%)	Available	
					Ca	Mg	K	Na					P ppm	K ppm
10 t/ha CD	6.59	0.83	0.08	1.44	4.01	2.00	0.04	0.03	6.08	0.50	6.58	97.30	49.8	13.3
10 t/ha PM	6.25	0.91	0.09	1.56	4.67	2.94	0.04	0.02	7.67	0.10	7.77	98.71	181	14.5
300 kg/ha NPK	6.11	0.73	0.07	1.37	3.20	1.34	0.06	0.03	4.62	0.30	5.55	83.24	152	15.8
5 t/h CD+ 150 kg/ha NPK	6.19	0.80	0.08	1.44	3.74	1.60	0.04	0.02	5.40	0.15	5.55	97.30	62.9	13.4
5 t/haPM+ 150 kg/ha NPK	6.34	0.91	0.08	1.56	4.67	4.07	0.05	0.03	7.8	0.10	7.93	98.74	146	13.9
Control (no fertilizer)	5.17	0.63	0.06	1.25	3.20	2.14	0.03	0.02	5.39	0.15	4.92	69.4	44.9	9.48

Table 4.4b ***Soil Chemical Properties after Treatments Application, 2017***

Treatment	pH, H_2O 1:25	Org. C (%)	Total N(%)	Org. M (%)	Exch. Cations (me/100g)				T.E.B	Exch. A(Al+H)	E.C.E.C me/100g	Base Sat (%)	Available	
					Ca	Mg	K	Na					P ppm	K ppm
10 t/ha CD	6.95	0.89	0.07	1.54	4.51	2.93	0.04	0.02	6.18	0.52	6.78	97.10	48.8	14.3
10 t/ha PM	6.25	0.96	0.07	1.65	4.67	2.00	0.05	0.02	6.67	0.16	7.17	97.81	183	14.4
300 kg/ha NPK	6.12	0.79	0.06	1.36	3.20	1.34	0.07	0.03	4.12	0.20	5.85	82.34	154	15.9
5 t/h CD+ 150 kg/ha NPK	6.21	0.82	0.07	1.64	4.74	1.69	0.04	0.02	5.45	0.15	5.15	97.60	61.9	13.4
5 t/ha PM+ 150 kg/ha NPK	6.54	0.94	0.07	1.61	4.67	4.00	0.06	0.03	7.70	0.17	7.39	98.72	147	13.1
Control (no fertilizer)	5.16	0.65	0.05	1.35	3.40	2.34	0.04	0.02	5.49	0.13	4.27	68.3	44.9	9.36

4.6 Vegetative Parameters

4.6.1 Number of Leaves

There were marked differences in the number of leaves per plant in 2016 and 2017 crop seasons. For Bawku Red in 2016 cropping season, the sole poultry manure and sole cow dung showed a steady growth from 2 to 8 WAT. The sole poultry manure and its combination with NPK recorded the greatest number of leaves per plant at 4 and 6 WAT and these were significantly ($P<0.05$) higher than the control. All the treated plots recorded greater number of leaves per plant than the control at 10 WAT (Fig.4.1a). For Red Creole in 2016 cropping season, all the treated plots showed a steady increase in leaf numbers throughout the growing period. The poultry manure produced the greatest number of leaves at 4 WAT and was significantly ($P<0.05$) higher than the control. At 6 WAT, the sole poultry manure again produced the greatest number of leaves per plant, though similar to its combination with NPK. At 4 to 10 WAT all the treated plots recorded greater number of leaves per plant than the control (Fig. 4.1a).

For Bawku Red in 2017 season, the sole poultry manure recorded the greatest number of leaves per plant at and 6 WAT and was significantly ($P<0.05$) different from the control. From 2 to 10 WAT, all the treated plots recorded higher number of leaves per plant than the control (Fig.4.1b).

For Red Creole in 2017 season, the sole poultry manure and its combination with NPK recorded a steady increase in leaf number throughout the growth period. The 10 t/ha PM and the 10 t/ha CD treatments recorded the highest number of leaves per plant from 4 WAT to 6 WAT and these were significantly ($P<0.05$) higher than the control. From 2 to 10 WAT, all the fertilized treatments recorded higher number of leaves per plant than the control treatment. (Fig.4.1b).

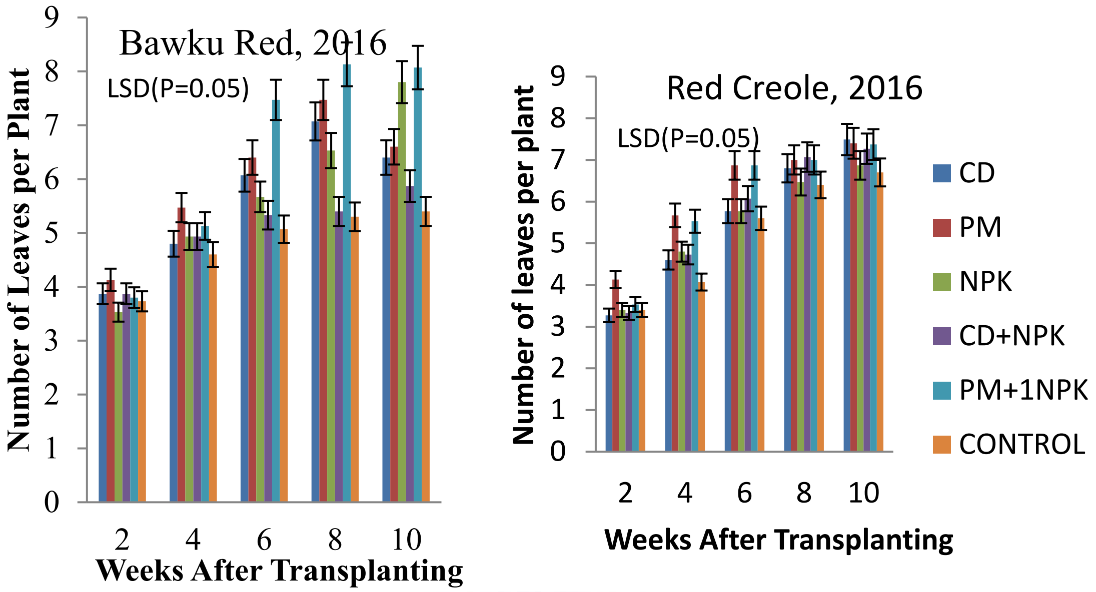

Fig.4.1a. ***Effect of organic and inorganic fertilizers on onion number of leaves, 2016.***

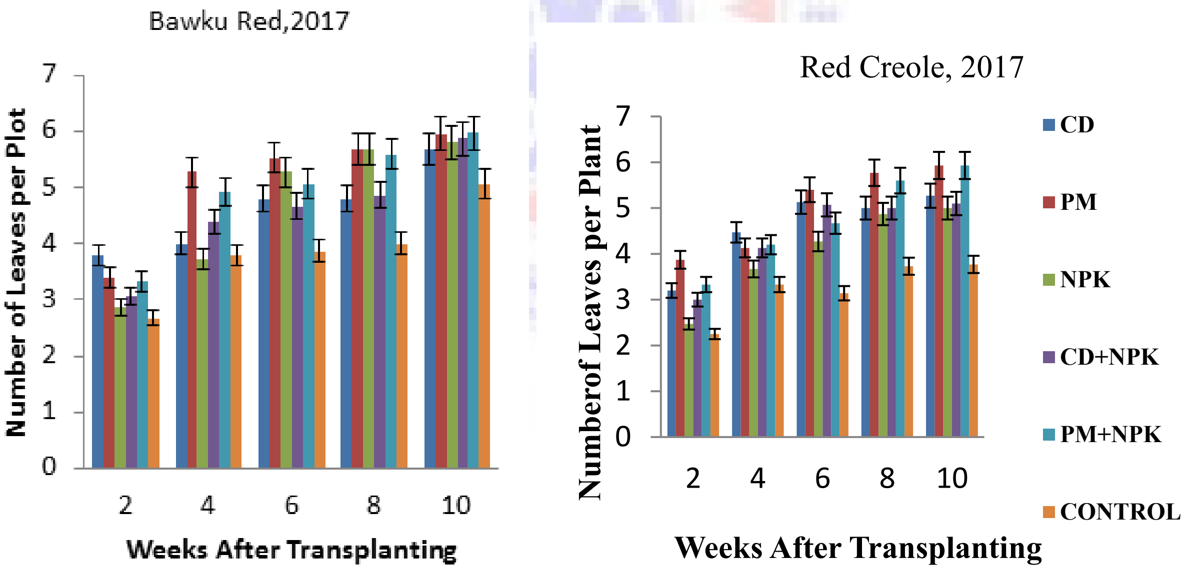

Fig.4.1b. ***Effect of organic and inorganic fertilizers on number of leaves, 2017 season***

4.6.2 Plant Height

There were observed differences in plant height in 2016 and 2017 cropping season.

For Bawku Red in 2016 cropping season, the sole poultry manure and its combination with NPK recorded a steady increase from 2 to 10 WAT. The 10 t/ha PM and 5 t/ha PM +150 kg/ha NPK produced the tallest plants at 4 WAT and was significantly ($P<0.05$) different from the control. At 6 WAT, the 5 t/ha PM +150 Kg/ha NPK produced the highest plant height (44.08cm) which was significantly ($P<0.05$) different from the control. All the treated plots recorded taller plant height at 10 WAT than the control (Fig. 4.2a). For Red Creole in 2016 cropping season, the sole poultry manure treated plots recorded the tallest plants at 4 and 6 WAT, which was significantly ($P<0.05$) different from the rest of the treated plots and the control.

In 2017 cropping season, the sole poultry manure and its combination with NPK produced the tallest plant at 4 WAT for both varieties, which were significantly ($P<0.05$) different from the control. At 6 WAT, the 10 t/ha CD gave the tallest plant for Bawku Red and was significantly different ($P<0.05$) from the control but not significantly ($P>0.05$) different from the 5 t/ha PM +150 kg/ha NPK. However, the sole poultry manure gave the tallest plants for Red Creole at 6 WAT and was significantly ($P<0.05$) higher than the control but was at par with its combination with NPK. At 8 WAT and 10 WAT, the sole NPK and its combination with cow dung recorded the tallest plants. Also, all the treated plots recorded taller plants than the control from 4 WAT to 10 WAT for both varieties (Fig. 4.2b).

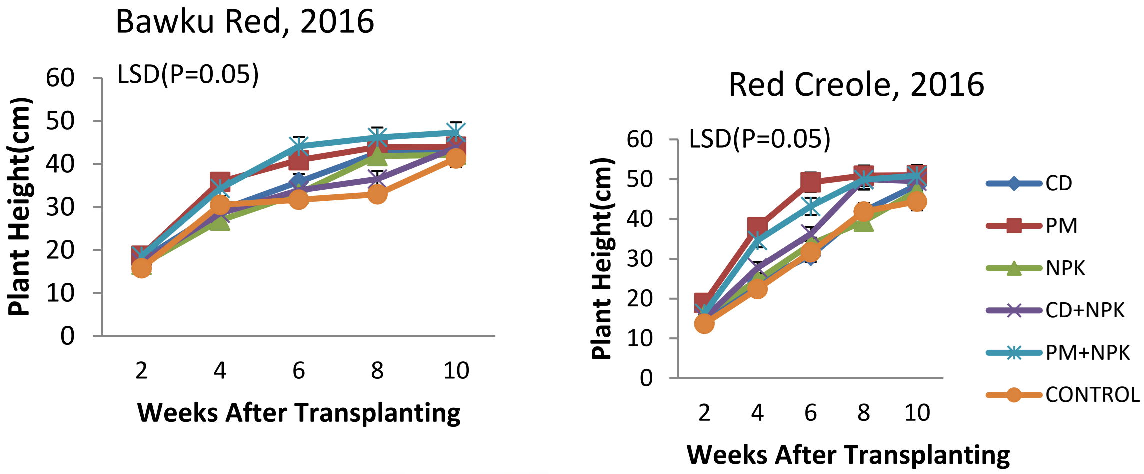

Fig.4.2a. *Effect of organic and inorganic fertilizer on plant height, 2016*

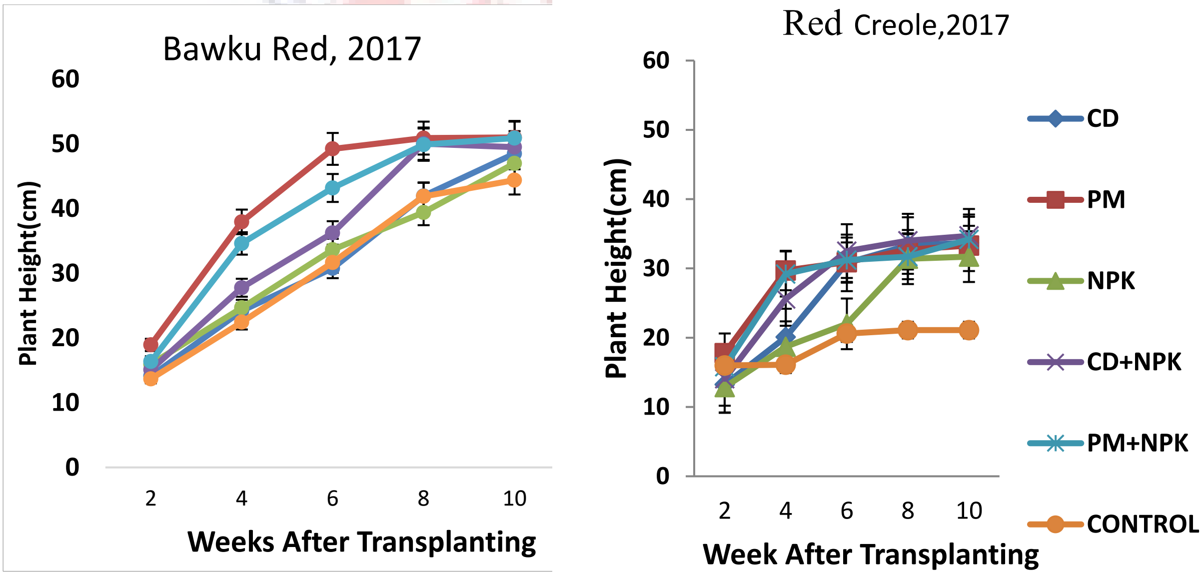

Fig.4.2b. *Effect of organic and inorganic fertilizers on onion plant height, 2017.*

4.6.3 Effect of Manure and Inorganic Fertilizer on Shoot fresh Weight and Shoot dry Weight

For Bawku Red in 2016 cropping season, the 5 t/ha PM +150 Kg/ha NPK recorded the greatest fresh shoot weight, and this was significantly (P <0.05) different from the control but not significantly (P>0.05) different from the 5 t/ha CD +150 Kg/ha NPK. Also, all the sole treatments recorded greater fresh shoot weight than the control (Table 4.5). For Red Creole, The 5 t/ha CD +150 Kg/ha NPK recorded the greatest fresh shoot weight followed by the 10 t/ha PM, and these were significantly ($P < 0.05$) different from the control. The rest of the of the treated plots all gave higher fresh bulb weight for both varieties in both cropping seasons than the control (Table 4.5).

In 2017 cropping season, the 5 t/ha PM +150 kg/ha NPK recorded the greatest fresh shoot weight for Bawku Red variety. However, the 10 t/ha PM gave the highest fresh shoot yield for Red Creole, and this was significantly ($P < 0.05$) different from the control. All the sole treatments and treatment combinations gave higher fresh shoot weight for both varieties in both cropping seasons than the control (Table 4.5).

For Bawku Red in 2016 cropping season, the 5 t/ha PM +150 kg/ha NPK recorded significantly ($P < 0.05$) higher dry shoot weight than the 10 t/ha PM, the 300 kg/ha NPK, the 5 10t/ha CD and the control, but was not significantly ($P > 0.05$) different from the 5 t/ ha CD + 150 kg/ha NPK (Table 4.5). The 5 t/ha PM +150 kg/ha NPK recorded significantly ($P < 0.05$) higher dry shoot weight than the control and the rest of the treatments for Red Creole in 2016 cropping season (Table 4.5)

In 2017 cropping season, the sole poultry manure and its combination with NPK recorded significantly ($P < 0.05$) higher dry shoot weight than the control for both varieties (Table 4.5)

Table 4.5 ***Effect of Manure and Inorganic Fertilizer on Shoot Fresh Weight and Shoot dry Weight , 2016 and 2017.***

Treatments		Shoot fresh weight(g)		Shoot dry weight(g)	
		2016	2017	2016	2017
BAWKU RED	10 t/ha CD	53.0	58.2	3.50	8.54
	10 t/ha PM	66.0	66.8	4.32	9.69
	300 kg/ha NPK	74.7	56.8	4.90	7.89
	5 t/ha CD+ 150 kg/haNPK	86.0	67.5	5.63	6.05
	5 t/ha PM+150 kg/ha NPK	92.0	78.8	6.33	9.54
	Control	61.0	43.4	4.00	5.40
RED CREOLE	10 t/ha CD	135	83.2	9.00	7.89
	10 t/ha PM	206	113	8.00	10.1
	300 Kg/ha NPK	186	62.4	7.00	7.99
	5 t/ha CD+ 150 kg/haNPK	246	96.2	7.00	8.74
	5 t/ha PM+150 kg/haNPK	141	99.8	10.00	9.76
	Control	127	43.8	6.00	6.60
	LSD(P=0.05)	44.3	43.5	1.71	2.27
	C V (%)	30.8	0.98	30.7	26.4
	V×T Interaction	0.62	0.62	0.68	0.52

4.7 Phenological Parameters

4.7.1 Percentage Crop Establishment, Number of Plants at Harvest and Days to Maturity

In 2016 cropping season, the sole poultry manure and its combination with NPK recorded the highest crop establishment for both varieties, which was significantly ($P<0.05$) different from the NPK and the control (Table 4.6). All the treated plots recorded greater percentage plant establishment than the control for both varieties.

In 2017 cropping season, the 5 t/ha PM +150 kg/ha produced the greatest percentage crop establishment and this was significantly ($P <0.05$) different from the 10 t/ha CD and the control for Bawku Red. The 10 t/ha PM recorded the greatest percentage crop establishment for Red Creole and this was significantly ($P <0.05$) different from the control (Table 4.6).

For Bawku Red in 2016 cropping season, the 10 t/ha PM and the 5 t/ha PM +150 kg/ha NPK recorded the greatest number of plants at harvest and were significantly ($P<0.05$) different from the control. For Red Creole in 2016 cropping seasons, the 10 t/ha PM recorded the greatest number of plants at harvest, which was significantly ($P<0.05$) different from the control but was not significantly ($P >0.05$) different from the 300 kg/ha NPK and the 5 t/ha PM +150 kg/ha NPK (Table 4.6).

In 2017 cropping season, the 5 t/ha PM +150 kg/ha NPK recorded the greatest number of plants at harvest for both varieties with the control recording the lowest.

In 2016 cropping season, the sole poultry manure took longer days to attain physiological maturity for both varieties, which was significantly ($P<0.05$) different from the control.

However, the combined poultry manure and NPK treated plots took shorter days to attain physiological maturity for both varieties, which was significantly (P<0.05) different from the control. Again in 2017 cropping season, the 10 t/ha PM took the longest days to reach physiological maturity for both varieties. However, the 5 t/ha PM+150 kg/ha NPK took shorter days to attain physiological maturity for the two varieties in 2017 cropping season

(Table 4.6).

Table 4.6 ***Effect of Manure and Inorganic Fertilizer on Percentage Crop Establishment ,*** ***number of plants per plot and days to maturity, 2017 and 2018***

Treatment		Percentage plant Establishment		Number of plants Per plot		Days to Maturity	
		2016	2017	2016	2017	2016	2017
BAWKU RED	10 t/ha CD	89.7	89.0	15.0	11.0	114	96.0
	10 t/ha PM	96.0	93.3	16.0	10.0	118	110
	300 kg/ha NPK	85.3	86.3	14.0	8.00	111	97.0
	5 t/ha CD+ 150 kg/haNPK	87.3	92.7	13.0	9.00	107	93.0
	5 t/ha PM+150 kg/ha NPK	96.0	100	16.0	12.00	105	75.0
	Control	83.5	68.7	11.0	8.00	110	105
RED CREOLE	10 t/ha CD	81.3	96.0	13.0	12.0	116	110
	10 t/ha PM	92.0	100	16.0	12.0	117	111
	300 kg/ha NPK	81.3	97.3	14.00	11.0	111	98.0
	5 t/ha CD+ 150 kg/haNPK	83.3	95.3	14.00	12.0	108	98.0
	5 t/ha PM+150 kg/haNPK	92.4	99.3	15.0	13.0	106	96.0
	Control	75.0	71.3	10.0	9.00	109	104
	LSD (P=0.05)	9.80	8.09	2.90	2.34	1.88	19.3
	C V (%)	9.2	7.5	15.8	16.0	1.4	16.2
	V×T Interaction	0.98	0.73	0.62	0.84	0.55	0.58

4.8 Yield and Yield Components

4.8. 1 Marketable Bulb Yield, Unmarketable Bulb Yield and Total bulb yield

For Bawku Red in 2016 cropping season, the 5 t/ha PM+150 kg/ha NPK amended plot produced a significantly ($P<0.05$) higher marketable bulb yield than the 10 t/ha CD, the 5 t/ha CD +150 kg/ha and the control. However, there was no significant ($P>0.05$) difference between the 10 t/ha PM and 300 kg/ha NPK. All the treated plots recorded significantly ($P<0.05$) higher marketable bulb yield than the control for Bawku Red in 2016 cropping season. For Red Creole in 2016 cropping season, the sole poultry manure recorded the highest marketable bulb yield and was significantly ($P<0.05$) different from the sole cow dung, sole NPK and the control (Table 4.7).

In 2017 cropping season, the 5 t/ha PM +150 kg/ha NPK gave the highest marketable bulb yield for Bawku Red whereas the sole poultry manure gave the highest for Red Creole, and these were significantly ($P<0.05$) different from the control for both onion varieties (Table 4.7).

In 2016 cropping season, the control recorded the highest unmarketable bulb yield for Bawku Red. The 10 t/ha PM recorded the highest unmarketable bulb yield for Red Creole and this was significantly ($P<0.05$) different from the 5 t/ha CD +150 kg/ha NPK and the control.

In 2017 cropping season, the control again, recorded the highest unmarketable bulb yield for Bawku Red whereas the 10 t/ha PM recorded the highest unmarketable bulb yield for Red Creole (Table 4.7). In both 2016 and 2017 cropping seasons, the combined poultry manure and NPK treatment recorded the highest total bulb yield (9.67 t/ha and 9.42 t/ha respectively) for

Bawku Red, whereas the sole poultry manure gave the highest bulb yield (12.10 t/ha and 9.43 t/ha respectively) for Red Creole, and these were significantly ($P<0.05$) different from the control in both cropping seasons. Again the sole NPK recorded a significantly ($P<0.05$) higher total bulb yield than the control for Bawku Red in both cropping seasons.

Table 4.7 ***Effect of Manure and Inorganic Fertilizer on Marketable Bulb Yield, Unmarketable Bulb Yield and Total Bulb Yield, 2016 and 2017***

Treatments		Marketable bulb yield(t/ha)		Unmarketable bulb Yield(t/ha)		Total Bulb Yield (t/ha)	
		2016	2017	2016	2017	2016	2017
BAWKU RED	10 t/ha CD	4.96	4.63	1.43	1.15	6.39	5.78
	10 t/ha PM	6.86	6.83	1.42	1.23	8.28	8.06
	300 Kg/ha NPK	6.38	6.00	0.86	0.50	7.24	6.50
	5 t/haCD+ 150 kg/haNPK	6.64	5.23	1.27	1.41	7.91	6.65
	5 t/haPM+150 kg/haNPK	8.44	7.63	1.22	1.79	9.67	9.42
	Control	1.16	1.07	1.25	1.15	2.41	2.31
RED CREOLE	10 t/ha CD	4.69	1.53	1.96	1.77	6.64	3.30
	10 t/ha PM	9.20	8.50	2.87	1.93	12.1	9.43
	300 Kg/ha NPK	3.86	2.20	1.70	1.55	5.56	3.75
	5 t/haCD+ 150 kg/h NPK	4.99	2.67	1.55	1.12	6.54	3.78
	5 t/haPM+150 kg/haNPK	6.64	5.23	1.27	1.41	7.91	7.27
	Control	1.18	1.07	0.89	0.97	2.07	1.04
	LSD(P=0.05)	3.34	2.76	0.91	1.02	3.28	2.51
	C V (%	51.3	51.4	48.1	60.2	19.1	35.6
	V×T Interaction	0.55	0.10	0.38	0.58	0.34	0.07

4.8.2 Total Biomass and Harvest Index

In 2016 cropping season, the 5 t/ha PM +150 kg/ha NPK produced significantly ($P<0.05$) higher total biomass than the control for both varieties (Table 4.8).

In 2017 cropping season, the 5 t/ha PM +150 kg/ha recorded the greatest total biomass than the control for Bawku Red, whereas the 10 t/ha PM recorded the greatest for Red Creole, and these were significantly ($P<0.05$) different from the control (Table 4.8). All the sole treatments and treatment combinations recorded greater total biomass than the control for both varieties in 2017 cropping seasons (Table 4.8)

For Bawku Red in 2016 cropping season, the sole cow dung and sole poultry manure recorded significantly ($P<0.05$) greater harvest index than the control. For Red Creole, the sole cow dung recorded significantly ($P<0.05$) greater harvest index than the control.

In 2017 cropping season, the 5 t/ha CD +150 kg/ha recorded the greatest harvest index for Bawku Red variety while the 5 t/ha PM +150 kg/ha recorded the greatest harvest index for Red Creole, and these were significantly ($P<0.05$) different from the control (Table 4.8). All the sole treatments and treatment combinations recorded greater total biomass than the control for both varieties in both cropping seasons (Table 4.8).

Table 4.8. ***Effect of Manure and Inorganic Fertilizer on Total Biomass and Harvest Index, 2016 and 2017***

Treatments		Total biomass(g)		Harvest index	
		2016	2017	2016	2017
BAWKU RED	10 t/ha CD	15.00	14.86	0.67	0.34
	10 t/ha PM	16.33	13.01	0.74	0.43
	300 kg/ha NPK	14.00	14.59	0.55	0.46
	5 t/ha CD+ 150 kg/ha NPK	18.00	12.97	0.57	0.49
	5 t/ha PM+150 kg/ha NPK	19.67	17.69	0.64	0.46
	Control	12.00	9.370	0.54	0.33
RED CREOLE	10 t/ha CD	18.67	11.89	0.63	0.34
	10 t/ha PM	18.30	16.83	0.54	0.34
	300 Kg/ha NPK	17.00	13.62	0.55	0.42
	5 t/ha CD+ 150 kg/ha NPK	19.67	15.89	0.57	0.48
	5 t/ha PM+150 kg/ha NPK	23.00	15.62	0.57	0.36
	Control	15.00	7.730	0.53	0.32
	LSD (P=0.05)	3.05	5.26	0.098	0.15
	C V (%)	21	32.3	18.1	29.5
	V×T Interaction	0.69	0.69	0.62	0.92

4.8.3 Fresh Bulb Weight and Dry Bulb Weight per Plot at Harvest

In 2016 cropping season, 5 t/ha PM +150 kg/ha NPK recorded the greatest fresh bulb weight (100.7g) for Bawku Red which was significantly ($P<0.05$) different from the control and the rest of the treatments. There was no significant ($P>0.05$) difference between the 10 t/ha PM and the 300 kg/ha NPK for fresh bulb weight as recorded in Bawku Red. The 10 t/ha PM gave the greatest fresh bulb weight (94.0g) for Red Creole and this was significantly ($P<0.05$) different from the 300 kg/ha NPK and the control (Table 4.9). All the sole treatments and their combination with NPK gave a greater fresh bulb weight than the control for Red Creole in 2016 (Table 4.9).

In 2017, the 5 t/ha PM +150 kg/ha recorded the significantly ($P <0.05$) greater fresh bulb weight than the 5 t/ha CD+150 kg/ha and the control for Bawku Red, whereas the 10 t/ha PM recorded the greatest fresh bulb weight for Red Creole, which was significantly ($P <0.05$) different from the 300 kg/ha NPK and the control treatment (Table 4.9).

In 2016, the combined poultry manure and NPK treated plots recorded significantly greater bulb weight than the control for Bawku Red variety, where as the sole poultry manure recorded the greatest dry bulb weight for Red Creole, and these were significantly ($P<0.05$) different from the control (Table 4.9).

In 2017, the 5 t/ha PM +150 kg/ha produced the greatest dry bulb weight for both Bawku Red and Red Creole onion varieties. All the sole treatments and treatment combinations produced greater dry bulb weight than the control for both varieties in both seasons (Table 4.9).

Table 4.9 ***Effect of Manure and Inorganic Fertilizer on Bulb Fresh and Dry Weights, 2016 and 2017***

Treatments		Mean fresh Bulb Weight per Plot(g)		Mean dry Bulb Wgt. per Plot(g)	
		2016	2017	2016	2017
BAWKU RED	10 t/ha CD	58.7	51.6	5.68	5.32
	10 t/ha PM	64.8	48.2	6.27	4.97
	300 Kg/ha NPK	60.7	42.9	5.88	6.69
	5 t/ha CD+ 150 kg/haNPK	56.7	35.6	5.49	5.93
	5 t/ha PM+150 kg/haNPK	100.7	67.3	9.80	8.15
	Control	58.3	33.8	5.68	4.32
RED CREOLE	10 t/ha CD	49.3	40.5	4.8	4.13
	10 t/ha PM	94.0	67.8	9.21	5.63
	300 Kg/ha NPK	50.9	32.5	4.89	5.63
	5 t/ha CD+ 150 kg/haNPK	80.8	49.2	7.48	5.15
	5 t/ha PM+150 kg/ha NPK	88.5	58.9	8.26	8.92
	Control	45.6	12.8	4.19	4.09
	LSD(P=0.05)	19.78	23.3	2.72	3.39
	C V (%)	33.8	43.3	23.2	48.9
	V×T Interaction	0.21	0.45	0.68	0.86

4.8.4 Bulb Diameter, and Number of Bulbs per Plot

In 2016 cropping season, the 5 t/ha PM+150 kg/ha NPK recorded the largest bulb diameter (4.87cm) for Bawku Red, but this was not significantly ($P>0.05$) different from the sole treatments. All the sole treatments and their combinations recorded significantly ($P<0.05$) greater bulb diameter than the control for Bawku Red. Also, the 5 t/ha PM +150 kg/ha NPK recorded significantly ($P <0.05$) larger bulb diameter than the control for Red Creole, but this was not significantly (P>0.05) different from the 10 t/ha PM and the 5 t/ha CD + 150 kg/ha NPK. All the treated plots recorded significantly (P<0.05) higher bulb diameter than the control (Table 4.10).

In 2017 cropping season, the combined poultry manure and NPK treatment recorded significantly (P<0.05) greater bulb diameter than the control for Bawku Red variety while the sole poultry manure gave the highest bulb diameter for Red Creole, and this was significantly(P<0.05) different from the control. All the amended plots gave higher bulb diameter than the control for both varieties (Table 4.10).

In 2016 cropping season, the combined poultry manure and NPK treatment produced the greatest number of bulbs per plot for Bawku Red, and this was significantly (P<0.05) different from the sole NPK and its combination with cow dung and the control . However, the sole poultry manure gave the highest number of bulbs per plot for Red Creole, and this was significantly (P<0.05) different from the sole cow dung, the treatment combination and the control (Table 4.10)

In 2017 cropping season, the highest number of bulbs per plot was in response to the 5 t/ha PM +150 kg/ha NPK, and this was significantly (P<0.05) higher than the control for both varieties. Also all the sole treatments and treatment combinations gave higher number of bulbs per plot than the control (Table 4.10).

Table 4.10 Effect *of Manure and Inorganic Fertilizer on Bulb Diameter and Number of Bulbs per Plot, 2016 and 2017*

TREATMENTS		Bulb diameter(cm)		No. of bulbs per Plot	
		2016	2017	2016	2017
BAWKU RED	10 t/ha CD	4.23	1.93	13.0	10.00
	10 t/ha PM	4.78	1.63	15.0	9.00
	300 kg/ha NPK	4.18	1.83	12.0	8.00
	5 t/ha CD+ 150 kg/haNPK	3.51	1.20	12.0	9.00
	5 t/ha PM+150 kg/haNPK	4.87	2.73	16.0	11.0
	Control	3.17	1.03	10.0	8.00
RED CREOLE	10 t/ha CD	3.51	1.23	13.0	11.3
	10 t/ha PM	4.68	2.10	13.0	12.0
	300 kg/ha NPK	3.38	1.40	14.0	11.0
	5 t/ha CD+ 150 kg/haNPK	4.24	1.25	11.0	11.0
	5 t/ha PM+150 kg/haNPK	4.78	1.79	13.0	13.0
	Control	2.16	0.77	9.00	11.0
	LSD(P=0.05)	0.69	0.87	2.4	2.44
	C V (%)	14	46.6	13.7	19.3
	V×T Interaction	0.52	0.62	0.68	0.89

4.9 Bulb Yield

There were differences in yield of onion in two seasons of experimentation (Table 4.11). Total bulb yields recorded by the treatments in 2016 cropping season were higher than the bulbs yields recorded by the treatments in 2017 cropping season for both varieties. In 2016 cropping season, the mean bulb yield was 7.12 t/ha and 6.80 t/ha for Bawku Red and Red Creole respectively. In 2017, mean bulb yield were 6.6 t/ha and 5.31 t/ha for Bawku Red and Red Creole respectively (Table 4.11).

Table 4.11 ***Effect of Crop Season on Bulb Yield***

	Treatments	**Bulb Yield(t/ha), 2016**	**Bulb Yield (t/ha),2017**
Bawku Red	CD	6.39	5.78
	PM	8.28	8.06
	NPK	7.24	6.50
	1/2CD+1/2NPK	7.91	6.65
	1/2PM +1/2NPK	9.67	9.42
	Control	3.41	3.31
Red Creole	CD	6.64	3.30
	PM	12.1	9.43
	NPK	5.56	3.75
	1/2CD+1/2NPK	6.54	3.78
	1/2 PM+1/2NPK	7.91	7.27
	Control	2.07	1.04
	LSD (P=0.05)	3.94	2.91
	CV (%)	19.3	34.6
	V×T Interaction	0.31	0.06

4.10 Economic Considerations

4.10.1 Cost of Treatments

For both onion varieties in both seasons, the sole manure treatments attracted the lowest total variable cost (GhC 425 per plot), while their combination with NPK costed GhC 535. The sole

NPK attracted the highest total variable cost (GhC 750 per plot). All the amended plots attracted higher total variable cost than the control (Table 4.12a and 4.12b).

4.10.2 Gross and Net Benefit of Treatments

For Bawku Red in 2016 and 2017, the 5 t/ha PM +150 kg/ha NPK accrued the highest gross benefit and net benefit than the control and the rest of the treatments. The accrued the lowest gross and net benefits than the rest of the treatments for Bawku Red in both seasons (Table 4.12a and 4.12b). For Red Creole in 2016 and 201, the 10 t/ha PM resulted in the highest gross benefit and net benefit followed by the 5 t/ha PM +150 kg/ha NPK. All the treated plots recorded higher gross and net benefit than the control (Table 4.12a and 4.12b).

4.10.3 Benefit: Cost Ratio of Treatments

For both Bawku Red and Red Creole varieties in 2016 and 2017, the 10 t/ha PM NPK accrued the highest benefit cost ratio (BCR) followed by the 5 t/ha PM +150 kg/ha NPK. (Table 4.12a and 4.12b).

Table 4.12a *Economics of Treatments Used in the Experiment, 2016*

	Treatment	GBY (t/ha)	AY(t/ha)	TVC(GhC)	GB (GhC/ha)	NB (GhC/ha)	BCR
Bawku Red	CD	6.39	5.75	425	9200	8775	21.6
	PM	8.28	7.45	425	11920	11495	28.0
	NPK	7.24	6.52	750	10432	9682	13.9
	1/2CD+1/2 NPK	7.91	7.12	535	11392	10857	21.3
	1/2PM+1/2 NPK	9.67	8.70	535	13920	13385	26.0
	Control	2.41	2.17	300	3472	3175	11.5
Red Creole	CD	6.64	5.98	425	9568	9143	22.6
	PM	12.1	10.89	425	17428	17003	41.0
	NPK	5.56	5.00	750	8000	7250	10.7
	1/2CD+1/2 NPK	6.54	5.89	535	9424	8889	17.6
	1/2PM+1/2 NPK	7.91	7.17	535	11392	10857	21.3
	Control	2.07	1.86	300	2976	2676	9.9

GBY=Gross Benefit Yield, AY=Adjusted Yield, TVC= Total Variable Cost, NB=Net Benefit and BCR= Benefit Cost Ratio

Table 4.12b *Economics of Treatments Used in the Experiment, 2017*

	Treatment	GBY(t/ha)	AY(t/ha)	TVC (GhC)	GB (GhC/h)	NB (GhC/h)	BCR
Bawku Red	CD	5.79	5.20	425	8320	7895	19.6
	PM	8.06	7.25	425	11600	11175	27.3
	NPK	6.50	5.85	750	9360	8610	12.5
	1/2CD+1/2 NPK	6.65	5.99	535	9584	9049	17.9
	1/2PM+1/2 NPK	9.42	8.48	535	13568	13033	25.4
	Control	2.31	2.08	300	3326	3026	11.0
Red Creole	CD	3.30	2.97	425	4752	4327	11.2
	PM	9.43	8.48	425	13568	13143	31.9
	NPK	3.75	3.38	750	5408	4658	7.2
	1/2CD+1/2 NPK	3.78	3.40	535	5440	4905	10.2
	1/2PM+1/2 NPK	7.27	6.54	535	10464	9929	19.6
	Control	1.04	0.93	300	1488	1188	5.0

GBY=Gross Benefit Yield, AY= Adjusted Yield, TVC= Total Variable Cost, NB=Net Benefit and BCR= Benefit Cost Ratio.

CHAPTER FIVE

DISCUSSION

5.1 Physical Properties of Soil

From Tables 4.3a and 4.3b, it can be clearly seen that the soil bulk density was highest in the -control plot. High bulk density has negative effects on soil properties. Soils with high bulk density are mostly compact with poor aeration. As a result, the pore spaces in the soil cannot hold much water and these speeds up erosion which leads to poor water storage. The sole manure treated plots and their combination with NPK recorded significant decrease in bulk density.

The decrease in bulk density of the manure treated plots and their combination with NPK might be linked with the increase in organic matter content of the soil. This led to easy root penetration due to the decrease in compaction of the soil, improved porosity and improved aeration that helped the roots to permeate well. Addition of organic matter leads to improved structural stability and lower bulk density. These leads to easy root penetration, erosion reduction and good soil moisture properties such as available water holding capacity and permeability, combined with adequate aeration (Khairuddin *et al*., 2018).

The addition of organic manure to the soil, in the above treatments lowered the soil bulk density after the amendment. The treatments made the soil moist and loose therefore the pore spaces were increased hence improvement of water storage over the control. These findings are in line with Mbah *et al*. (2004) and Adeleye *et al*. (2010), that addition of organic manures improve physical properties such as moisture content, aeration and total porosity, and also reduces penetration resistance and cohesion force.

5.2 Chemical Properties of Soil

The manure added organic matter to the soil and this might have provided supplemental nutrients of exchangeable cations such as K, Ca, Mg and Na in the top soil. The cation exchange capacity levels increased due to the manure application. This supports the work done by Frempong *et al.* (2006) and Ramos *et al.* (2018) that addition of organic manure increases organic matter content which in turn increases the levels of Ca, K and Mg. In a study to determine the effects of organic matter and nutrients in manure on soil organic matter dynamics and crop production, Eghball *et al.* (2002) reported significantly greater soil organic matter levels in plots treated with organic manure. In the current study, poultry manure gave the higher organic matter content compared to the other treatments. The addition of organic manure might have provided supplementary exchangeable cations such as K, Ca and Mg in the top soil (Ramos *et al.*, 2018).

The application of manure affected the soil pH by reducing the soil acidity in the treated plots. The increase in pH due to the sole manure and their combinations with NPK might be due to the addition of organic matter to the soil and thus confirming the statement made by Narmabuye *et al.* (2008) that organic matter adds basic plant nutrients to the soil which may raise the pH of the soil.

Liu *et al.* (2013) observed that application of organic manure increases organic carbon, N,P, K, Ca and Mg than soils amended with NPK inorganic fertilizer alone and the increase is due to the high organic carbon contents observed in the type of organic carbon used. The present study showe that the organic carbon contents of the poultry manure and the cow dung were higher than the NPK alone (Table 4.4). In an experiment to evaluate the comparative effect of poultry manure and NPK fertilizer on soil physical and chemical properties, Agbede *et al.*

(2017), observed a general increase in soil organic carbon and other nutrients by poultry manure than the sole NPK and the control. They reported that high contents of N,P,K, Ca and Mg in the soil were products of high organic carbon contents observed. This result is in an agreement with the results of Vaidya *et al.* (2009).

The organic carbon content of poultry manure was also found to be higher than that of the cow dung. This is in an agreement with the assertion of Gulser *et al*. (2015) that differences in the organic carbon is due to the kind of organic manure used. The high content of wood litter in poultry manure results in its high organic carbon content.

Generally, the addition of organic manure (cow dung and poultry manure) brought improvement in the levels of various nutrients than the NPK and the control. The study also showed increase levels of total nitrogen, available phosphorus and available K due to addition of the organic manure. The percent base saturation was increased. This is in conformity with the finding of Adeleye *et al*. (2010), who observed an increase in soil pH, organic matter, total nitrogen, available phosphorus, exchangeable cations and percent base saturation due to addition of poultry manure.

Also the organic manure and their combination with NPK recorded an increase in pH, total nitrogen, organic carbon and exchangeable cations over the control. The ECEC, base saturation and the available P and K were high in the manure plus NPK treated plots than the control. He indicated that application of organic nutrient like farm yard manure, compost or green manure in combination with inorganic fertilizer improved soil physical properties and cation exchange capacity, exchangeable calcium, and availability of N, P, K and Zn, Mn, Cu and Fe. Shivanand (2002) also demonstrated that uptake of nitrogen, phosphorus, potassium and zinc, manganese, copper, and iron increased significantly by crops when 50 percent of organic manure in combination with 50 percent inorganic fertilizers were applied. Similar results by Tolanur (2002) suggested that application of organic manures in combination with inorganic fertilizers increased uptake of N, P and K over application of inorganic fertilizers alone.

5.3 Vegetative Parameters

5.3.1 Number of Leaves and Plant Height

The increase in the number of leaves and plant height as well as the steady growth in response to sole poultry manure as recorded in Red Creole in 2016 may be attributed to the release of macro and micro nutrients by poultry manure during the course of microbial decomposition (Dapaah, 2014). The improvement in plant height and number of leaves with application of poultry manures might also be due to better moisture holding capacity and favorable soil conditions (Agbede *et al*., 2017). Poultry manure, besides supplying major nutrients (N, P and K) also supplied secondary elements such as Ca, Mg and S. Poultry manure also contains uric acid having 60 per cent nitrogen, which changes rapidly to ammonical form and hence efficiently utilized for better plant growth. In the chemical properties, poultry manure lowered the soil acidity. This was achieved through the liberation of carbon dioxide and organic acid during decomposition. Again, its decomposition products may give rise to natural complexing agents that solubilize the nutrients already present in soil and make them available to the plant (Agbede *et al*., 2017).

This is in line with the results of Iazuddin and Chandrasekhar (2000), Meena *et al.* (2015) and Soremi *et al*. (2017) who reported that there was higher release of nutrients from added organic sources such as poultry manure.

The increase in plant height and the number of leaves per plant by Bawku Red in response to the combination of Poultry manure and NPK in both cropping seasons may be attributed to enhanced release of macronutrients from the added source of N, P and K as well as release of nutrients on mineralization and changes in the physico-chemical properties of soil due to application of organic carbon in the form of poultry manure thereby improving the soil nutrients status. The balanced addition of NPK ensured that nutrients in the form of N, P and K were readily available in soluble forms for plant growth and development. It is well established that nitrogen is the most indispensable of all mineral nutrients for growth and development of the plant as it is the fundamental constituents of all living matter. It also plays an important role in plant metabolism by virtue of being an essential compound like amino acids, protein, nucleic acids, enzymes, co-enzymes and alkaloids (Ben, 2016).

The higher levels of N released after mineralization of poultry manure promotes vegetative growth of plants (Shiyam *et al*., 2017). Like nitrogen, phosphorus is also a nutrient that is needed by plants in relatively large quantities for normal plant growth. Plants obtain their internal energy from P-containing compounds, mainly adenosine diphosphate (ADP) and adenosine triphosphate (ATP). This indicates that inadequate P supply will lead to decreased synthesis of Ribonucleic Acid (RNA), the protein maker culminating into depressed growth. Phosphorus is a component of the complex nucleic acid structure of plants, which regulates protein synthesis. Phosphorus is therefore, important in cell division and development of new tissues. Phosphorus deficiency therefore leads to a stunted growth with a limited root system and thin stem (Yang, 2017).

The response to potassium fertilization in terms of overall improvement in growth attributes is further supported by the fact that potassium provides the ionic environment for metabolic processes in the cystosol, and as such function as a regulator of various processes including growth regulation (Kumar, 2018). These findings are in line with the findings of Amujoyebge *et al.* (2007) and Cyril (2014) who reported that application of organic and inorganic fertilizers supply plant nutrients for crop growth, plant height and leaves and affect plant physiological process which is very instrumental in crop yield.

5.3.1 Shoot Weight

The highest fresh shoot weight in 2016 cropping season and dry shoot weight in 2017 cropping season in response to 5t/ha Poultry Manure and 150 kg/ha NPK combination may be attributed to the contribution of organic manure to the increase in new leaf formation, leaf width, leaf length, leaf area and extended activity of older leaves .This is in line with the findings of Abd El-Samad *et al.* (2011) who reported that the increment in vegetative growth parameters of onion plants in response to nitrogen was probably due to the positive role nitrogen plays in increasing photosynthesis through improving leaf area index and chlorophyll contents and uptake of other mineral nutrient, thereby resulting in higher vegetative growth.

The increase in shoot fresh and dry weight yield of the onion plants may also be attributed to the role manure and NPK combination play in supplying not only nutrients but also organic carbon that can be a source of energy for soil biota that improve soil health and soil chemical characteristics. This result is also in agreement with the findings of Gulser *et al.* (2015)

5.4 Phenological Properties of Onion

The significantly high percentage crop establishment and number of plants per plot at harvest recorded by sole poultry manure and its combination with NPK over the control (Table 4.6) may be due to the role poultry manure plays in providing micro and macro nutrients as well as maintaining soil physical characteristics such as reduced bulk density, improved aeration and water holding capacity, and the role of NPK in providing the mineral nutrients of the soil in soluble forms. This is in conformity with the findings of Dapaah (2014), who stated that the high crop establishment indicated possible attainment of optimum plant population density, and that good land preparation coupled with judicious application of both organic and inorganic fertilizers result in a higher percentage crop establishment. Also the regular watering done during the first four weeks after transplanting the seedlings in 2016 cropping season and rainfall received during the first four weeks after transplanting the Onion seedlings in 2017 cropping season might have also contributed significantly to the high percentage crop establishment and the number of plants at harvest per plot in both seasons for all the treatments.

The longer days it took the 10 t/ha PM plots in both varieties to reach physiological maturity as compared to the other treated plots may be linked to the role manure (which contains high amount of nitrogen) plays in promoting vegetative growth before the start of bulb development. This indicates that the nutrients taken up by plant roots from the soil will be used for increased cell division and synthesis of carbohydrate, which will predominantly be partitioned to the vegetative sink of the plants, resulting in plants with a luxurious foliage growth (Boateng *et al*., 2009). This is in line with the suggestion of Hafez and Geries (2018) that nitrogen promotes vegetative and lush growth thereby delaying plant maturity. On the contrary, the combination of organic manure and inorganic fertilizer shortens the maturity days as observed in the 5 t/ha PM+150 Kg/ha NPK treated plot in both varieties. This is in conformity with the findings of Bhati *et al.* (2018) who reported that integration of organic manure with inorganic fertilizers fasten maturity period of the crop.

5.5 Yield and Yield Components of Onion

The significant increase in yield and yield components for both varieties over the control, in both 2016 and 2017 in response to sole poultry manure may be as a result of poultry manure having a material which contains better levels of nutrients and water holding capacity and release macro and micro nutrients during the course of microbial decomposition. Organic matter is also a source of energy for soil micro flora which brings the transformation of soil inorganic nutrients in the form that is readily utilized by growing plant and improves the physical properties of the soil (Agbede *et al*., 2017). The beneficial response of poultry manure to yield and yield components might also be attributed to the availability of sufficient amount of plant nutrients throughout the growth period of crop resulting in plant vigour and yield (Boateng *et al*., 2009). The increased yield and yield attributes with poultry manure might be because of rapid availability and utilization of nitrogen for various internal plant processes for carbohydrates production. Later on these carbohydrates may undergo hydrolysis and get converted into reproductive sugars which ultimately helped in increasing yield. The carbohydrates content due to application of poultry manure might be attributed to balanced C: N ratio and increased activity of plant metabolisms (Dayo -Olagbende, 2018).

Organic manures activating many species of living organisms which release phytohormones which may stimulate the plant growth and absorption of nutrients and thereby increases onion yield (Adeleye *et al*., 2010). Similar result was also reported by Khang *et al.* (2011), Choudhary *et al.* (2013) and Sharma *et al*. (2014).

Again, the significantly high total bulb yield and marketable bulb yield due to the integrated poultry and NPK fertilization (5 t/ha PM + 150 kg/ha NPK) could be attributed to the role of the combined effect of the two treatments in improving the physicochemical structure of the soil and nutrients supplied by their combinations. The NPK promoted faster release of the macro-nutrients which gave the plants good start in growth while the slow release of nutrients by the poultry manure ensures continuous supply of nutrients for the plants (Singh and Kumar, 2016).

The significantly higher total bulb yield recorded by the sole NPK over the control for Bawku Red in both 2016 and 2017 may be explained on the basis that nitrogen fed to plants might have made their rapid growth and acquired healthy green colour due to increased synthesis of chlorophyll for better photosynthesis.

The increase in bulb diameter and bulb weight over the control in response to the poultry manure and NPK either applied alone or in combination may be due to the role of potassium in photosynthesis, protein synthesis, activation of some enzymes and phloem solute translocation of photoassimilates into bulbs thereby increasing the bulb diameter and weight (Hopkins and Huner, 2009). Again, the nitrogen supplied by the NPK is a component of chlorophyll molecule which gives the plant its green colour for enhanced photosynthesis (Hopkins and Huner, 2009).

Mohanty *et al.* (2015) reported that 50% organic and 50% inorganic fertilizer application resulted in maximum yield of onion, improved soil physical and chemical properties. This has the tendency to uplift the livelihood of farmers.

Application of organic nutrient like farm yard manure, compost or green manure in combination with inorganic fertilizer improved soil physical properties and cation exchange capacity, exchangeable calcium, and availability of N, P, K and Zn, Mn, Cu and Fe. Also uptake of nitrogen, phosphorus, potassium and zinc, manganese, copper, and iron increased significantly by crops when 50 percent of organic in combination with 50 percent inorganic fertilizers were applied (Hossain *et al*., 2016). The combined effect of the use of organic and inorganic fertilizers does not only reduce bulk density and water holding capacity but allows nutrient to be available throughout the growing period and reduces leaching. In this wise, as the inorganic fertilizers quickly release the major nutrients, the organic manure releases both major (NPK) and micro-nutrients and other growth promoting substances for continuous growth. These bind the soil together to retain a lot of moisture which improves soil productivity including improving water infiltrability, soil structure and soil moisture retention. These findings are in conformity with the results by Tolanur Frempong *et al*. (2006) and Agbede (2010).

5.6 Effect of Cropping Season on Yield of Onion

Differences were observed in the yield of onion between two cropping seasons of experimentation (Table 4.11). Yields were better in 2016 than in 2017. Since the crop was raised under the identical level of management, resources and cultivation practices, the variation in growth and yield between the two cropping seasons could be the result of weather conditions that prevailed growth, which, in turn, might have influenced the yield. Tesfaye *et. al*. (2018) were of the view that weather condition is a principal input parameter which could bring about year to year variation in productivity of agricultural crops despite consistency of other input parameters and practices of crop husbandry.

The low rainfall, low humidity and high temperature during the 2016 cropping season might have contributed to the high yield. Again, the high rainfall, high humidity and low temperature during the 2017 cropping season might have contributed to the low bulb yield. The seasonal variation in growth and yield could be attributed to the fact that onion thrives best at mild climate with minimum rainfall, optimum temperature and low humidity for bulb formation (Khokhar, 2008).

5.7 Economic Benefits of Treatments

The greater total variable cost recoded by sole NPK treated plots could be linked to the high cost of chemical fertilizers. The lower totals variable cost recorded in the manure treated plots could be ascribed to the low cost of animal manure due to its availability. The lower total variable cost recorded in the manure and NPK combination compared with the sole NPK could be explained on the basis that supplementing chemical fertilizer at half rate with organic fertilizer reduces the cost. This is in line with the findings of Srivastava *et. al.,*

(2009).

The greatest monetary net returns from Bawku Red variety were obtained under the 5 t/ha PM + 150 kg/ha NPK. The greatest monetary net returns from Red Creole variety were obtained under the 10 t/ha PM (Table 4.12a and 4.12b).The higher values of net returns under these treatments over the control and the other treatments could be ascribed to the higher bulb yield obtained under these treatments by the two onion varieties. Similar results have been reported by Choudhary *et al.* (2013) and Damse *et al.* (2014).

The higher benefit cost ratio obtained under the sole poultry manure and its combination with NKP could be due to the low cost of these treatments and the high net returns they recorded. Similar result have been reported by Gopinath *et al.* (2007) and Baswana and Rana (2007)

Results from the economic analysis in 2017 cropping season indicated that for every Ghc 100.00 investment for the production of Bawku Red, the treatments will give the following benefits: 10 t/ha CD - Ghc 1960, 10 t/ha PM- Ghc 2730, NPK- Ghc 1250, 5 t/ha CD + 150 kg/ha-Ghc -1790, 5 t/ha PM + 150 kg/ha- Ghc 2540 and Control- 1,100. Again, for the production of Red Creole, the treatments will give the following benefits: 10 t/ha CD - Ghc 1120, 10 t/ha PM- Ghc 3190, NPK- 720, 5 t/ha CD + 150 kg/ha-Ghc 1020, 5 t/ha PM + 150 kg/ha- Ghc 1960 and Control- 500. Similar economic benefit was indicated in 2016 cropping season for the various treatments for every Ghc100.00 invested in the production of the two onion varieties. The economic analysis showed that the sole poultry manure and its combination with NPK gave higher economic returns for both varieties over the control and the rest of the treatments and could be recommended for onion cultivation.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

From the results of the 2016 and 2017 cropping seasons, the following conclusions were drawn:

- It was observed that, the addition of sole poultry manure and sole cow dung and their combination with inorganic fertilizer used as amendments increased the soil organic matter content as well as increase in soil nutrients such as available P and K, ECEC and total N. These also improved the physical attributes of the soil such as gravimetric moisture content and total porosity as well as reduction in bulk density.
- The vegetative growth of onion recorded marked differences in the two seasons from 4 weeks after transplanting (4 WAT) to 10 weeks after planting (10 WAT). The sole poultry manure and the treatment combination (poultry manure and NPK) were significantly ($P<0.05$) higher at 4 WAT and 6 WAT than the control and other amendments in plant height and number of leaves for Red Creole and Bawku Red respectively.
- With the yield and yield components, the sole poultry manure and its combinations with NPK performed better in terms of bulb diameter, fresh bulb weight, number of bulbs at harvest per plot, marketable bulb yield and total bulb yield for both seasons.
- The 5 t/ha PM+ 150 kg/ha NPK recorded the greatest gross and net benefits for Bawku Red variety while the 10 t/ha PM produced the greatest monetary returns for Red Creole variety.

6.2 Recommendations

- For soil fertility restoration in onion production, sole Poultry Manure (10 t/ha) and in combination with NKP (5 t/ha PM+150 kg/ha NPK) should be used as soil amendment.

- For maximum growth and yield in onion production, Poultry Manure combined with NPK (5 t/ha PM+150 kg/ha NPK) is recommended.
- For maximum profitability in onion production, Poultry Manure (5 t/ha) combined with NPK (150 kg/ha) is recommended for Bawku Red variety while sole Poultry Manure (10 t/ha) is recommended for Red Creole variety.
- For maximum crop yield, heavier bulb weight and wider bulb diameter, the minor rainy season (September to December) is recommended for onion cultivation in the Transitional Zone of Ghana.

REFERENCES

Addai, I. (2014). Effects of Cultivar and B ulb Size on Growth and Bulb Yield of Onion. (Allium cepa L.) in the Northern Region of Ghana. *British Journal of Applied Science & Technology*, 4(14), pp.2090-2099. http://dx.doi.org/10.9734/bjast/2014/8458.

Abdullah A. A. (2008). Effect of vermicompost and vermiwash on the productivity of spinach (Spinacia oleracea), Onion (Allium cepa) and Potato (Solanum tuberosum).World Journal of Agricultural Sciences. 4 (5): 554-557.

Abd El-Samad, E.H., Khalifa, R.Kh. M., Lashine, Z.A., Shafeek, M.R.(2011).Influence of Urea fertilization and foliar application of some micronutrients on growth, yield and bulb quality of onion. Aust. J. Basic Appl. Sci., 5(5): 96-103.

Adediran, J. (2018). An Economic Analysis of Split Application of Organo-mineral Fertiliser on Okra in Humid Forest Zone of Nigeria. *Journal of Horticultural Science and Biotechnology*, 76 (3): 347 — 349.

Adekunle, O. (2013). The Effect of Combined Application of Poultry Manure and Sawdust on the Growth and Yield of Okra. *Journal of Agricultural Science*, 5(10). Available at: http://dx.doi.org/10.5539/jas.v5n10p169.

Adeniyan O. N., Ojo A. O., Akinbode, O. A and Adediran J. A. (2011). Comparative study of different organic manures and NPK fertilizer for improvement of soil chemical properties and dry matter yield of maize in two different soils. *Journal of Soil Science and Environmental Management.* 2(1): 9-13.

Agbede, T. (2010). Tillage and fertilizer effects on some soil properties, leaf nconcentrations, growth and sweet potato yield on an Alfisol in southwestern Nigeria. *Soil and Tillage Research*,110(1),p.25-32. http://dx.doi.org/10.1016/j.still.2010.06.003.

Agbede, T., Adekiya, A. and Eifediyi, E. (2017). Impact of Poultry Manure and NPK Fertilizer On Soil Physical Properties and Growth and Yield of Carrot. *Journal* *of Horticultural Research*, 25(1), pp.81-88. http://dx.doi.org/10.1515/johr-2017-0009.

Agegnehu, G. and Amede, T. (2017). Integrated Soil Fertility and Plant Nutrient *Agricultural Research,* **34**(3): 210-213.

Agyarko, K. and Adomako, W.J. (2007). Survey of the use of organic manure among vegetable farmers in selected districts in Ghana. *Journal of Sustainab Develovelopment Afric.*Vol.9, No.4 2007 ISSN: 1520-5509.

Al-Hassan, S. (2009). Non-traditional vegetable production in the Northern Region of Ghana.*Ghana Journal of Development Studies*, 6(1) http://dx.doi.org/10.4314/gjds . v6i1.48924.

Ali, J. (2016). Effect of sowing dates and phosphorus levels on growth and bulb production of Onion. PAB , 5(3). https://doi.org/10.19045/bspab.2016.50053.

Ali, M., Khan, F., Hossain, M. and Rahman, A. (2015). Preparation of cattle manure compost using saw dust and rice straw. *Bangladesh Journal of Animal Science*, 44(1), p.64. http:// dx.doi.org/10.3329/bjas.v44i1.23145.

Ali, M., Alam, M., Barkotulla, M., Khandaker, S. and Simon, P. (2014). Effect of Earthing up and Level of Irrigation on Yield and Quality Seed Production of Onion. *Progressive Agriculture*, 18(2). Available at: http://dx.doi.org/10.3329/pa.v18i2.18163.

Alwaneen, W. (2016). Cow Manure Composting by Microbial Treatment for using as potting Material: An Overview. *Pakistan Journal of Biological Sciences*, 19(1),pp.1-10 Available at: http://dx.doi.org/10.3923/pjbs.2016.1.10.

Ahmed, M., & Elhassan, S. (2013). Epidemiology and Management of Onion Yellow Dwar Disease in Sudan. Plant Pathology J., 12(4), 162-168. https://doi.org/10.3923/ppj.2013. 162.168.

Appireddy, G., Saha, S., Mina, B., Kundu, S., Selvakumar, G. and Gupta, H. (2008). Effect of organic manures and integrated nutrient management on yield potential of bell pepper (Capsicum annuum) varieties and on soil properties. *Archives of Agronomy and Soil Science*, 54(2), pp.127-137. http://dx.doi.org/10.1080/03650340701836808.

Asiamah, R.D. (1998). Soils and soil suitability of Ashanti Region. Soil Research Institute –CSIR Kwadaso, Kumasi; Technical Report No. 193.

Asiedu, E. K. Hemeng, O. B. Dawuda, M. M. Agbeko, Y and Amponsah, E. K. (2007) Effect of poultry and sheep manure on growth and yield of carrot. Ghana journal of Horticulture (6): 66-69. http://dx.doi.org/10.4314/acsj.v12i2.27672.

Ayoola, O. T. and Adeniyan, O. N., 2006. Influence of poultry manure and NPK fertilizer on yield and yield components of crops under different cropping systems in south west Nigeria. African J. Biotech., 5 (15): 1386- 1392

Bairwa H.L., Mahawer L.N., Shukla A.K., Kaushik R.A. and Mathur S.R. (2009).Response of integrated nutrient management on growth, yield and quality of okra. *Indian J. ag Sci*., 79 (5):381384.

Balemi, T. (2010). Effect of phosphorus nutrition on growth of potato genotypes with contrasting phosphorus effeciency. *African Crop Science Journal*, 17(4) Available at: http://dx.doi.org/10.4314/acsj.v17i4.54304.

Beah, A. (2014). Effect of Organic Manure on Soil Bio physical Properties and Dry Matter Partitioning in Cauliflower. *International Journal of Plant & Soil Science*, 3(9), pp.1044-1054. Available at: http://dx.doi.org/10.9734/ijpss/2014/10953.

Ben M. R. (2016). Effect of Nitrogen Source and Concentration on Growth and Activity of Nitrogen Assimilation Enzymes in Roots of a Moroccan Sorghum Ecotype. Plant, 4(6), p.71. Available at: http://dx.doi.org/10.11648/j.plant.20160406.14.

Bhati, V., Yadav, P., & Kumar, R. (2018). Effect of Levels of Inorganic Fertilizers, Organic Manure and Bio-Fertilizers on Plant Growth Attributes of Onion (Allium cepa L.) cv. N-53 under Hot Arid Region of Western Rajasthan, India. Int.J.Curr.Microbiol.App.Sci, 7(03), 3593-3601. Retrieved June 9, 2019, from 10.20546/ijcmas.2018.703.413

Biramo, G. (2018). The Role of Integrated Nutrient Management System for Improving Crop Yield and Enhancing Soil Fertility under Small Holder Farmers in Sub-Saharan Africa: A Review Article. *Modern Concepts & Developments in Agronomy*, 2(5). Available at: http://dx.doi.org/10.31031/mcda.2018.02.000547 .

Blake, G.R., 1965. Bulk Density. In: Methods of Soil Analysis, Part 1. Physical and Mineralogical Properties Including Statistics of Measurement and Sampling, Black, C.A. (Ed.). *American Society Agronomy Inc., Madison, Wisconsin, USA.*, pp: 374-377.

Boateng, S., Zickermann, J. and Kornahrens, M. (2009). Poultry manure effect on growth and yield of maize. *West African Journal of Applied Ecology*, 9(1). Available at: http://dx.doi.org/10.4314/wajae.v9i1.45682

Bosco, L., & Tavella, L. (2010). Population dynamics and integrated pest management of Thrips tabaci on leek under field conditions in northwest Italy, 135(3), 276-287. https://doi.org/10.1111/j.1570-7458.2010.00991.x

Bray, R. And Kurtz, L. (1945). Determination of Total, Organic, And Available Forms of Phosphorus In Soils. *Soil Science*, 59(1), pp.39-46.

Carr, E., Zaid, A., Bonasera, J., Lorbeer, J. and Beer, S. (2013). Infection of Onion Leaves by Pantoea ananatis Leads to Bulb Infection. *Plant Disease*, 97(12), pp.1524-1.Available at: http://dx.doi.org/10.1094/pdis-06-12-0597-re.

Choudhary, B.S., Soni, A.K. and Khaswan, S.L. (2013). Growth, yield and quality of garlic (*Allium sativum* L.) as influenced by different nutrient management practices. *Annals of Agricultural Research,* **34**(3): 210-213.

Choudhary, M.K. and Chandra, A. (006). Effect of integrated nutrient management on yield and yield attributing characters in okra and residual effect on succeeding crop radish. *Indian Journal of Arid Horticulture,* **1**(1): 25-27.

Christo, E. and Onuh, M. (2008). Influence of Different Types of Organic Manure on Yield and Nutrient Content of Fluted Pumkin (*Telfairia occidentalis* Hook F). *Journal of Agriculture and Food Sciences*, 3(2).http://dx.doi.org/10.4314/jafs.v3i2.41634.

Chope, G. and Terry, L. (2010). Effect Of Curing At Different Temperatures. On Phytohormone And Biochemical Composition Of Onion 'Red Baron' During Long-Term Postharvest Storage. *Acta Horticulturae*, (877), pp.699-705. Available at: http:// dx.doi.org/10.17660/actahortic.2010.877.92.

CIMMYT (International Centre for Maize and Wheat Improvements (1988).*From Agronomic data for farmer recommendation: an economic training manual*. Completely revise edition-Mexico-D.F.

Colina-Coca, C., de Ancos, B. and SÃ¡nchez-Moreno, C. (2013). Nutritional Composition of Processed Onion: S-Alk(en)yl-l-cysteine Sulfoxides, Organic Acids, Sugars, Minerals, and Vitamin C. *Food and Bioprocess Technology*, 7(1), pp.289-298. Available at: http://dx.doi.org/10.1007/s11947-013-1150-4 .

Cyril, C. (2014). Vegetative Growth and Yield Response of Amaranthus cruenthus to Arbuscular Mycorrhizal Fungi (AMF), Poultry Manure (PM), Combination of AMF-PM and Inorganic Fertilizer. AJEA , 4(6), 665-https://doi.org/10.9734/ajea/2014/5439

Dapaah, H. (2014). Influence of Poultry Manure and NPK Fertilization on Growth, Yield and Storability of Onion (*Allium cepa L.*) Grown Under Rain-fed Conditions. *American Journal of Experimental Agriculture*, 4(8), pp.866-878. Available at: http://dx.doi.org/10.9734/ajea/2014/7526 .

Damse, D.N., Bhalekar, M.N. and Pawar, P.K. 2014. Effect of integrated nutrient management on growth and yield of garlic. *The Bioscan*, **9**(4): 1557-1560.

Darabi, A. (2016). The Study of Effect of Planting Date and Density on Marketable

Yield and Bulb Characteristics of an Onion Population from Behbahan. *Journal of Crop production and processing*, 5(18), pp.301-314. Available at: http://dx.doi.org/10.18869/acadpub.jcpp.5.18.301.

Dayo-Olagbende, G., Ayodele, O. and Ogunwale, G. (2018). Effect of the Application of Poultry Manure and Wood Ash on Maize (*Zea mays* L.) Performance. *Journal of Horticulture and Plant Research*, 4, pp.11-16.

De Sibio, P. and Rossi, M. (2012). Oviposition of a leaf-miner on Erythroxylum tortuosum (Erythroxylaceae) leaves: hierarchical variation of physical leaf traits. *Australian Journal of Botany*, 60(2), p.136. Available at: http://dx.doi.org/10.1071/bt11268

Dhananivetha, M., Amnullah, M., Arthanari, P. and Mariappan, S. (2017). Wee management in onion: A review. *Agricultural Reviews*,(OF). http://dx.doi.org/10.18805/ag.v0iof.7311.

Doe, J. (2018). Crop Response to Salinity Regulated by Soil Texture. *CSA News*, 63(8), p.9. Available at: http://dx.doi.org/10.2134/csa2018.63.0805.

Downes, K., Chope, G. and Terry, L. (2009). Effect of curing at different temperatures on biochemical composition of onion (*Allium cepa L.*) skin from three freshly cured and cold stored UK-grown onion cultivars. *Postharvest Biology and Technology*, 54(2), pp.80-86. Available at: http://dx.doi.org/10.1016/j.postharvbio.2009.05.005

Dunjana, N., Nyamugafata, P., Shumba, A., Nyamangara, J. and Zingore, S. (2012). Effects of cattle manure on selected soil physical properties of smallholder farms on two soils of Murewa, Zimbabwe. *Soil Use and Management*, 28(2), pp.221-228. Available at: http://dx.doi.org/10.1111/j.1475-2743.2012.00394.x.

Essilfie, M., Dapaah, H., Darkwa, K., Timpabi, D. and Boateng, D. (2017). Varietal Response of Maize (*Zea mays)* to Integrated Nutrient Management of NPK and Chicken Manure Amendments. *Journal of Experimental Agriculture International*, 18(1), pp.1-13.

Platt E. S. (2003). Garlic Onion & other. Alliums, *AbeBooks.co.uk* - ISBN ... Publisher: Stackpole Books, 2003.

Faladun, E., Ehigiator, J. and Egharevba, R. (2015). Growth and yield of onion as influenced by organic and inorganic fertilizer in Edo rainforest of Nigeria. *Agro-Science*, 12(3), p.15. Available at: http://dx.doi.org/10.4314/as.v12i3.3.

FAO. 2012. The State of Food and Agriculture 012: Investing in agriculture for a be future. Rome.

FAO. 2013. FAOSTAT statistical database (available at faostat.fao.org).

FAO (Food and Agriculture Organization) (2008) Plant Nutrition for Food Security. A Guide for Integrated Nutrient Management. Rome, Italy.

Fouda K. (2017). Response of Onion Yield and Its Chemical Content to NPK Fertilization and Foliar Application of Some Micronutrients. *Egyptian Journal of Soil Science*,0(0), pp.1-12. Available at: http://dx.doi.org/10.21608/ejss.2017.1083 .

Frempong, M.E. Ofosu-Anim, J. and Blay, E.T. (2006). Nutrient Supply Strategies on Growth and Yield and Yield Components of Okro (Abelmoschus esculentus L. Moench). *Ghana Journal of Horticulture Volume 5.*

Gambo, B.A., M.D. Magaji, A.I. Yakubuand and A.U. Dikko, (2008). Effect of FYM, nitrogen, and weed interference on the growth and yield of onion (*Allium cepa* L.) at *Sokoto Rima.Ghana Journal of Development Studies*, 6(1). Available at: http: dx.doi. org/10.4314/gjds.v6i1.48924.

Gardner, C.M.K., D.A. Robinson, K. Blyth and J.D. Cooper, (2001): Soil water content. In: Soil and Environmental Analysis: Physical Methods (K.A. Smith and C.E. Mullins, eds.), Marcel Dekker, New York, pp. 1—64. http://dx.doi.org/10.1093/jee/2.3.236.

Ghana Statistical Service (2010), Population and Housing Census. District Analytical Report, Mampong Municipal.

Ghabel, R., Rajabipour, A., Ghasemi-Varnamkhasti, M., & Oveisi, M. (2010). Modeling the mass of Iranian export onion (Allium cepa L.) varieties using some physical characteristics. Res. Agr. Eng., 56(No. 1), 33-40. https://doi.org/10.17221/23/2009-rae

Gopinath & Mina, Banshi. (2011). Effect of organic manures on agronomic and economic performance of garden pea (Pisum sativum) and on soil properties. *Indian Journal of Agricultural Sciences*. 81. 236-239.

Gupta, R., Srivastava, K. and Pandey, U. (1994). Diseases And Insect Pests Of Onion In India. *Acta Horticulturae*, (358), pp.265-270. Available at: http://dx.doi.org/10.17660/ actahortic.1994.358.43.

Hafez, E., & Geries, L. (2018). Effect of Nitrogen Fertilization and Biostimulative Compounds on Onion Productivity, 51(1). Retrieved June 9, 2019, from 10.2478/cerce-2018-0007

Hafez, E., El-Morsi, A., El-Shahaby, O. and Abdelkhalek, A. (2014). Occurrence of iris yellow spot virus from onion crops in Egypt. *VirusDisease*, 25(4), pp.455-459. Available at: http://dx.doi.org/10.1007/s13337-014-0235-7.

Hillel, D. (1980) Applications of soil physics. Academy Press, New York. pp. 385.

Hopkins, W.G., Hüner, N.P.A. (2009): Introduction to Plant Physiology, 4th Edition. John Wiley and Sons, Inc., Hoboken, USA.

Hossain, M., Islam, M., & Rahaman, M. (2018). Growth Performance and Development Attributes of Mungbean (Vigna radiata L.) as Influenced by Organic Manure and Inorganic Fertilizer. AJAAR , 7(2), 1-13. https://doi.org/10.9734/ajaar/2018/43164

Hu, J. (2019). First Report of Onion Bulb Rot Caused by Pantoea agglomerans in Arizona. Plant Disease , PDIS-10. https://doi.org/10.1094/pdis-10-18-1749-pdn

H. Seran, T. and Brintha, I. (2010). Review on Maize Based Intercropping. *Journal of Agronomy*, 9(3), pp.135-145. http://dx.doi.org/10.3923/ja.2010.135.145.

Iazuddin Ahmed, S. and Chandrasekhar Reddy, K. (2000). Effect of inorganic fertilizers in conjunction with organic manures to onion growth on alfisol in Andhra Pradesh. National symposium on *onion garlic production and post-harvest management. Challenges and strategies.* NHRDF, Nasik, Nov. 19-31, 2000 Pp-86-89.

IITA. (1979). *Determination of exchangeable Ca, Mg, K, Na, Mn and Effective CEC in Soils:* In Selected Methods far Plant Analysis. Manual Series No.1.IITA, Ibadan, Nigeria.

Indira, E. and Annadurai, B. (2016). Impact of Farm Yard Manure and Goat Manure as Organic Amendment on Physico-chemical and Physical Properties of Theri Soil. *International Journal of Plant & Soil Science*, [online] 9(1), pp.1-6. Available at: http:// dx.doi.org/10.9734/ijpss/2016/20519 .

Jackson, M. L. (1962) Soil Chemical Analysis. International Institute for Tropical Agriculture (IITA). Manual Series No.1, 70.

Jayanthi M. and Vaideke A. (2012). A Study on Farmers Problems in Production and Marketing of Onion in Sulur Taluka, Coimbatore District. *Global Journal For Research Analysis*, 3(7), pp.37-39. http://dx.doi.org/10.15373/22778160/july2014/12.

Jayanthi M., Vaideke A., (2014). A Study on Farmer's Problem in Production and Marketing of Onions in Sulur Taluka, Coimbatore District. Global Jornal for Research Analysis, Vol. 3: (7), ISSN 2277- 8160.

Joshi, N. and Sawant, P (2012). Response of Onion (Allium cepa L.) Seed Germination and Early Seedling Development to Salt Level. International Journal of Vegetable Science, 18: 3–19

Kapoulas, N., Koukounaras, A. and Z. (2017). Nutritional quality of lettuce and onion as companion plants from organic and conventional production in north Greece. *Scientia Horticulturae*, 219, pp.310-318.http://dx.doi.org/10.1016/j.scienta.2017.03.027.

Kahsay, Y. (2013). Intra row spacing effect on shelf life of onion varieties (Allium cepa L.) at Aksum, Northern Ethiopia. J. Plant Breed. Crop Sci. ,4(6), 127-136.https://doi.org/10.

5897/jpbcs12.071

Khairuddin, M., Isa, I., Zakaria, A. and Rani, A. (2018). Effect of Amending Organic and Inorganic Fertilizer on Selected Soil Physical Properties in Entisols. *Agrivita Journal of Agricultural Science*, 40(2).http://dx.doi.org/10.17503/agrivita.v40i2.1087 .

Khokhar, K. (2008). Effect of temperature and photoperiod on the incidence of bulbing and bolting in seedlings of onion cultivars of diverse origin. *The Journal of Horticultural Science and Biotechnology*, 83(4), pp.488-496. http://dx.doi.org/10.1080/14620316.2008.11512412 .

Kim, S., Bang, H., & Patil, B. S. (2013). Origin of three characteristic onion (Allium cepa L.) mitochondrial genome rearrangements in Allium species. Scientia Horticulturae, 157, 24-31. https://doi.org/10.1016/j.scienta.2013.04.009

Kinoshita, T., Yamamoto, T., Hamano, M., & Yamasaki, A. (2018). Type of Mulching Film and Planting Date Adapted to a New Onion Cropping Type Using Onion Sets for Early Winter Harvesting in the Northern Tohoku Area of Japan. Engeigaku Kenkyuu, 17(3), 303-309. https://doi.org/10.2503/hrj.17.303

Kondal, K. (2011). Growth Rate of Area, Production and Productivity of Onion Crop in Andhra Pradesh. *Indian Journal of Applied Research*, 4(3), pp.4-6. Available at: http://dx.doi.org/10.15373/2249555x/mar2014/2 .

Kubar, G. (2018). Effect of potassium (K+) on growth, yield components and macronutrient accumulation in Wheat crop. Pure and Applied Biology, 7(4). Available at http://dx.doi.org/10.19045/bspab.2018.700183

Kumar, A., Singh, B., Kumar, D., Kumar, P., Kumar, T., Kumar, S. and Goswami, A. (2014). Effect of balanced fertilizer and planting techniques on growth and yield of garlic (*Allium Sativum* L.). *Annals of Horticulture*, **7**(2): 123-128.

Kumar, U. (2014). Weed management studies in onion (Allium cepa L.). *The Asian Journal Of Horticulture*, 9(2), pp.426-430. http://dx.doi.org/10.15740/has/tajh/9.2/426-430.

Kwaghe, E., Saddiq, A., Solomon, R. and Musa, S. (2017). Integrated Nutrient Management 9on Soil Properties and Nutrient Uptake by Red Onion. *Turkish Journal of Agriculture - Food Science and Technology*, 5(5), p.471. Available at: http://dx.doi. org/10.24925/turjaf.v5i5.471-475.927 .

Kumari, M. and Saritha, J. (2017). Effect of phosphorus fertilizers on oil seed crops. *Agriculture Update*, 12(Special-3), pp.749-754. Available at: (http://dx.doi.org/10.15740/has/au/12.techsear(3)2017/.

Leach, A. B. (2016). Advancing onion thrips (Thrips tabaci) control and onion production with a multi-faceted IPM program. https://doi.org/10.1603/ice.2016.113857

Lee, E., Jang, Y., Kim, C., Choi, I., Kim, Y., Bang, J. and Kim, S. (2008). The Effect of the Period of Low Temperature before Overwinter On Bolting and Flowering in Extremely Early Maturing Onion Varieties. *Acta Horticulturae*,(771), pp.109-113. Available at: http://dx.doi.org/10.17660/actahortic.2008.771.15 .

Liu, E., Yan, C., Mei, X., Zhang, Y. and Fan, T. (2013). Long-Term Effect of Manure and Fertilizer on Soil Organic Carbon Pools in Dryland Farming in Northwest China. *PLoS ONE*, 8(2), p.e56536.http://dx.doi.org/10.1371/journal.pone.0056536.

Li, J., Zhong, X., Wang, F., & Zhao, Q. (2011). Effect of poultry litter and livestock manure on soil physical and biological indicators in a rice-wheat rotation system. Plant Soil Environ., 57(No. 8), 351-356. https://doi.org/10.17221/233/2010-pse

Mahanthesh, B., M. Harshavardhan and M. Raviprasad, (2009). Impact of bio-fertilizers with Management in Tropical Agro-Ecosystems: A Review. *Pedosphere*, 27(4), pp.662 680. Available at: (http://dx.doi.org/10.1016/s1002-0160(17)60382-5.

Mandal, K., Hati, K. and Misra, A. (2009). Biomass yield and energy analysis of soybean production in relation to fertilizer-NPK and organic manure. *Biomass and Bioenergy*, 33(12), pp.1670-1679. Available at http://dx.doi.org/10.1016/j.biombioe.2009.08.010.

Mahmoodaba, M., Amini, S. and Khazaeipou, K. (2010). Using Animal Manure for Improving Soil Chemical Properties under Different Leaching Conditions. *Research Journal of Soil and Water Management*, 1(2), pp.34-37. Available at: http://dx.doi.org/10.3923/rjswm.2010.34.37.

Meena, S., Bairwa, H., Mahawer, L., Meena, M., Chittora, A. and Meena, S. (2016). Effect of integrated nutrient management on growth, yield and quality of onion cv. N-53. *Research on Crops*, 17(3), p.550. Available at http://dx doi.org/10.5958/2348-7542.2016.00092.9.

Meena, A.K., Paliwal, R. and Meena, K.K. (2015). Effect of organic manures and. bio-fertilizers on growth and quality attributes of *kharif* onion (*Allium cepa* L.) in semi-arid region. *Indian Research Journal of Genetics and Biotechnology,* **7**(1):73. —76.

Mia, M., Akter, S., Molla, A. and Rahman, G. (2010). Poultry Manure with Inorganic Nitrogen on Growth and Yield of Onion (*Allium cepa* L.). *The Agriculturists*, 5(1), p.101. Available at: http://dx.doi.org/10.3329/agric.v5i1.5204.

Mina, W. (2011). Institutional Reforms Debate and FDI Flows to MENA Region. *SSRN Electronic Journal*. Available at: http://dx.doi.org/10.2139/ssrn.1806643

Mohanty, A., Behera, P. and Harichandan, S. (2015). Effect of nutrient management on the growth and productivity of onion. *Agricultural Science Digest - A Research Journal*, 35(3), p.241. Available at: http://dx.doi.org/10.5958/0976-0547.2015.00056.7.

M, S. (2016). The Effects of Different Nitrogen Rates on Root Yield and Quality of N and NZ Type Sugar Beet Varieties. OAJAR , 1(1). https://doi.org/10.23880/oajar-16000105

Mohammadi, G. (2013). Alternative Weed Control Methods: A Review. https://doi.org/10.

5772/54164

Naher, M. and Paul, A. (2017). Effect of integrated nutrient management on nutrient uptake and sustainable grain yield in transplanted aman rice. *SAARC Journal of Agriculture*, 15(1), p.43. Available at: http://dx.doi.org/10.3329/sja.v15i1.33149.

Naramabuye, F., Haynes, R. and Modi, A. (2008). Cattle manure and grass residues as liming materials in a semi-subsistence farming system. Agriculture, Ecosystems & Environment, 124(1-2), pp.136-141. Available at: http://dx.doi.org/10.1016/j.agee.2007.08.005.

Nault B. A. Hessney M. L. (2011). Onion thrips control in onion -Trial I, 2010. Arthropod Manag. Trials 36: E51.

Nault, B. A. (2013). Onion Thrips Control in Onion, 2011, 38(1). Retrieved June 9, 2019, from 10.4182/amt.2013.e37

Njue, L., Okemo, P. and Monda, E. (2010). Efficacy of onion (Allium cepa l.) and garlic (*Allium sativum* l.) juice against common pathogens associated with meat. *Journal of Tropical Microbiology and Biotechnology*, 5(1). ahttp://dx.doi.org/10.4314/jtmb.v5i1. 49261.

Nweke IA, Nsoanya LN (2013) Effect of different rates of rice mill Waste on soil chemical properties and grain yield of maize (*Zea mays L.*). International Journal of Agriculture Available at: http://dx.doi.org/10.4182/amt.2013.e37.

Ojo, A., Sokalu, A. and Faramade, A. (2015). Soil Chemical Properties, Growth Parameters and Yield as Affected by Poultry Manure Tea for Okra Production. *British Journal of Applied Science & Technology*, 5(1), pp.104-10. http://dx.doi.org/10.9734/bjast/2015/ 9340.

Okporie, E. (2009). Responses of the tropical onion (*Allium cepa*) to changes in photoperiod. *International Journal of Tropical Agriculture and Food Systems*, 1(4). Available at: http://dx.doi.org/10.4314/ijotafs.v1i4.40940.

Ortega, R. (2015). Integrated Nutrient Management In Conventional Intensive Horticulture. Production Systems. *Acta Horticulturae*, (1076), pp.159-164. Available at: http://dx.doi.org/10.17660/actahortic.2015.1076.18.

Özer, N. (2011). Screening for fungal antagonists to control black mold disease and to induce the accumulation of antifungal compounds in onion after seed treatment. BioControl, 56(2), 237-247. https://doi.org/10.1007/s10526-010-9326-6

Pal Baliyan, S. (2014). Evaluation of Onion Varieties for Productivity Performance in Botswana. *World Journal of Agricultural Research*, 2(3), pp.129-135. Available at: http://dx.doi.org/10.12691/wjar-2-3-8.

Peluffo, S., GonzÃ¡lez Idiarte, H., Borges, A., Arboleya, J. and GalvÃ¡n, G. (2016). Onion sets as planting material for seed production of three cultivars in Uruguay. *Seed Science and Technology*, 44(3), pp.500-513. at: http://dx.doi.org/10.15258/sst.201644.3.04.

Peng, S., He, Y., Yang, S. and Xu, J. (2014). Effect of controlled irrigation and drainage on nitrogen leaching losses from paddy fields. *Paddy and Water Environment*, 13(4), pp.303-312. Available at: http://dx.doi.org/10.1007/s10333-014-0442-2.

Petrovic, B., Kopta, T., & Pokluda, R. (2019). Effect of biofertilizers on yield and morphological parameters of onion cultivars. https://doi.org/10.2478/fhort-2019-0002

Pezzolla, D., Gizzi, S., Zadra, C., Agnelli, A., Roscini, L., & Gigliotti, G. (2013). Changes in the Composition of Soil Dissolved Organic Matter After Application of Poultry Manure, 451-454. https://doi.org/10.1007/978-94-007-5634-2_81

Pinto, R., Brito, L., & Coutinho, J. (2016). Horticultural crop yields and nitrogen uptake response to green manure, farmyard manure compost and organic commercial fertilizer. Acta Hortic., (1146), 25-32. https://doi.org/10.17660/actahortic.2016.1146.3

Põldma, P., Moor, U., Merivee, A., & Tõnutare, T. (2012). EFFECT OF CONTROLLED

ATMOSPHERE STORAGE ON STORAGE LIFE OF ONION AND GARLIC CULTIVARS. Acta Hortic., (945), 63-69.https://doi.org/10.17660/actahortic.2012.945.7

Rahman, M. and Akter, F. (2013). Effect of NPK fertilizers on growth, yield and yield attributes of okra (Abelmoschus esculentus (L.) Moench.). *Bangladesh Journal of Botany*, 41(2). Available at: http://dx.doi.org/10.3329/bjb.v41i2.13436.

Ramos, F., Dores, E., Weber, O., Beber, D., Campelo, J. and Maia, J. (2018). Soil organic matter doubles the cation exchange capacity of tropical soil under no-till farming in Brazil. *Journal of the Science of Food and Agriculture*, 98(9), pp.3595-3602. Available at: http://dx.doi.org/10.1002/jsfa.8881.

Ram, R., & Pathak, R. (2016). Organic Aapproaches for sustainable production of horticultural crops: A review. Prog. Hort. , 48(1), 1. Retrieved June 9, 2019, from 10.5958/2249-5258.2016.00001.4

Rizk, F.A., (1997). Productivity of onion plant (Allium Cepa, L.) as affected by method of planting and NPK application. *Egyptian Journal of Horticulture*, 24(2): 219-238.

Seran TH, Srikrishnah S, Ahamed MMZ.(2010). Effect of different levels of inorganic fertilizers and compost as basal application on the growth and yield of onion (Allium Cepa L.). Journal of Agricultural Sciences. 2010; 5(2):64-70

Scanlan, C., Bell, R. and Brennan, R. (2015). Simulating wheat growth response to potassium availability under field conditions in sandy soils. II. Effect of subsurface potassium on grain yield response to potassium fertiliser. *Field Crops Research*, 178, pp.125-134. Available at: http://dx.doi.org/10.1016/j.fcr.2015.03.019.

Schwertfeger, D. M., and W. H. Hendershot. 2009. Determination of Effective Cation Exchange Capacity and Exchange Acidity by a One-Step BaCl2 Method. Soil Sci. Soc. Am. J. 73:737-743. doi:10.2136/sssaj2008.0009

Sharma and Arpita, (2014), Nutritional Benefits of onion, - Facts for you (Market Survey) —

www.ffymag.com.

Sharma, U., Paliyal, S., Sharma, S. and Sharma, G. (2014). Effects of Continuous Use of Chemical Fertilizers and Manure on Soil Fertility and Productivity of Maize-Wheat under Rainfed Conditions of the Western Himalayas. *Communications in Soil Science and Plant Analysis*, 45(20), pp.2647-2659. Available at:http://dx.doi.org/10.1080/00103624.2014.941854.

Shiyam, J., Garjila, Y. and Bobboyi, M. (2017). Effect of Poultry Manure on Growth and Yield of Maize (*Zea mays Var Praecox)* in Jalingo, Taraba State, Nigeria. *Journal of Applied Life Sciences International*, 10(4), pp.1-6. Available at: http://dx.doi.org/10.9734/jalsi/2017/31972 .

Singh, B. and Kumar, R. (2016). Effect of integrated nutrient management on growth, yield and nutrient uptake of clusterbean under irrigated conditions. *Agricultural Science Digest - A Research Journal*, 35(1). Available at: http://dx.doi.org/10.18805/asd.v35i1.9307.

Singh D.P and Meena S. (2017). Effect of Long Term Application of Fertilizer and Manure on Establish Relationship between Soil Organic Carbon Fractions with Yield of Maize and Wheat Crops under Maize-Wheat Sequence in Heplustepts. *International Journal of Current Microbiology and Applied Sciences*, 6(9), pp.600-606. Available at: http://dx.doi.org/10.20546/ijcmas.2017.609.073.

Singh, S., Shyam, R., Chaudhary, S. and Yadav, L. (2016). Weed management in onion. *Indian Journal of Weed Science*, 48(2), p.199. Available at: http://dx.doi.org/10.5958/0974-8164.2016.00049.6.

Soremi, A., Adetunji, M., Adejuyigbe, C., Bodunde, J. and Azeez, J. (2017). Effects of Poultry Manure on Some Soil Chemical Properties and Nutrient

Bioavailability to Soybean. *Journal of Agriculture and Ecology Research International*, 11(3), pp.1-10. Available at: http://dx.doi.org/10.9734/jaeri/2017/32419.

Sitekhale, H.H.E, s. (2013). Poultry Manure and NPK Fertilizer Application and their Residual Effects on the Yield and Yield Components of Tomato (Lyqcopersiconesculentum. Mill) in two Distinct Ecological zones of Central Southern Nigeria. *IOSR Journal of Agriculture and Veterinary Science*, 3(2), pp.40-47. Available at: http://dx.doi.org/10.9790/2380-0324047.

Srivastava BK, Singh MP, Singh S, Lata S, Srivastava P and Shahi UP. 2009. Effect of integrated nutrient management on the performance of crop under brinjal-pea-okra cropping system. *Indian Journal of Agricultural Sciences,*79 (2): 91-95.

Strike, B. and Vance, A. (2017). Weed management strategies in long-term organic blueberry production systems â€ impact of mulch type and weed control methods on economics. *Acta Horticulturae*, (1180), pp.347-354. Available at: http://dx.doi.org/10.17660/actahortic.2017.1180.47.8

Suwarso, E. and Anggraeni, D. (2017). Inhibitory Effect of Bombay Onion (Allium cepa L.) Extracts on Mitotic Chromosomes. *Indonesian Journal of Cancer Chemoprevention*, 7(2), p.46.http://dx.doi.org/10.14499/indonesianjcanchemoprev7iss2pp46-48.

Tabitha, K., Wilson, T. and Joseph, P. (2018). Effect of Organic and Inorganic Fertilizer on the Soil Chemical Properties of the Rhizosphere in Kiambu County, Kenya. *Asian Research Journal of Agriculture*,7(4), pp.1-13. http://dx.doi.org/10.9734/arja/ 2017/37081.

Talgre, L., Lauringson, E., Roostalu, H., Astover, A. and Makke, A. (2012).   Green manure as a nutrient source for succeeding crops. *Plant, Soil and Environment*, 58(No. 6), pp.275-281. http://dx.doi.org/10.17221/22/2012-pse.

Tendaj, M. and Mysiak, B. (2011). Growth characteristic of Welsh onion (Allium fistulosum

L.) grown from seeds and transplants. *Folia Horticulturae*, 23(1). Available at: http://dx.doi.org/10.2478/v10245-011-0001-x

Tesfaye, M., Belew, D., Dessalegn, Y. and Shumye, G. (2018). Effect of planting time on growth, yield components, seed yield and quality of onion (Allium cepa L.) at Tehuledere district, northeastern Ethiopia. Agriculture & Food Security, 7(1). Available at: http://dx.doi.org/10.1186/s40066- 018-0178-0.

Toth, S. and Prince, A. (1949). estimation of cation-exchange capacity and exchangeable ca, k, and na contents of soils by flame photometer techniques. *Soil Science*, 67(6), pp.439-446. Available at: http://dx.doi.org/10.1097/00010694-194906000-00003.

Trewavas, A. (2007). Organic manure. New Scientist, 195(2616), p.20. Available at: http://dx.doi.org/10.1016/s0262-4079(07)62011-9 .

Vickers, L., Grove, I., & Monaghan, J. (2015). SOIL TYPE AND IRRIGATION AFFECT ONION YIELD AND STORABILITY. Acta Hortic., (1091), 245-251. https:doi.org// 10.17660/actahortic.2015.1091.30

Vu Tien Khang, Patil, H.M. and Gudedhe, N.N. (2011). Effect of integrated nutrient. management on onion yield and soil properties in soybean — onion cropping sequence

Yadav, R.L., Sen, N.L. and Yadav, B.L. (2003): Response of onion to nitrogen and potassium fertilization under semi-arid condition. Indian Journal of Horticulture 60:176-178.

Yang, W. (2017). Effect of nitrogen, phosphorus and potassium fertilizer on growth and seed germination of Capsella bursa-pastoris (L.) Medikus. *Journal of Plant Nutrition*, 41(5), pp.636-644. http://dx.doi.org/10.1080/01904167.2017.1415350.

Yasmin, K., Aziz, M. and Kashem, M. (2016). Effect of Cowdung, NPK and Rhizobium Inocula on Growth and Soil Status of Summer Mungbean (Vigna radiata) in Acid Soil. *International Journal of Plant & Soil Science*, 12(5), pp.1-7. Available at: http://dx.doi.

org/10.9734/ijpss/2016/2749.

Young, A. (1997). *Agroforestry for soil management.* Cab International Wallingford Oxen.urt) 27(5): 3-7.

Walkley, A. and I.A. Black. (1934). An examination of the Degtjareff method of determining. organic carbon in soils: Effect of variations in digestion conditions and of inorganic soil constituents. Soil Sci. 63:251-263. 22.

Zahoor, M. (2016). Effect of organic waste and NPK fertilizer on potato yield and soil fertility. *Pure and Applied Biology*, 5(3). Garlic Clone. *Acta Horticulturae*, (555), pp.243-246. Available at: http://dx.doi.org/10.17660/actahortic.2001.555.36 .

Zakari, S., Miko, S. and Aliyu, B. (2014). Effect of different types and levels of Organic Manures on Yield and Yield Components of Garlic (*Allium sativum* L) at Kadawa, Kano, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 7(1), p.121. Available at: http://dx.doi.org/10.4314/bajopas.v7i1.22.

APPENDICES

APPENDIX A

Guide to interpretation of soil analytical data in Ghana by soil research institute (2009)

Nutrient	Rank / Grade
Phosphorus, P (ppm), (Blay – 1)	
<10	Low
10 -20	Moderate
>20	High
Potassium, K (ppm)	
<50	Low
50 – 100	Moderate
>100	High
Calcium, Ca (ppm) / Mg = 0.25 Ca	
<10	Low
5.0 – 10.0	Moderate
>10	High
ECEC (cmol (+) / Kg)	
<10	Low
10 – 20	Moderate
>20	High

Soil pH (Distilled Water Method)	Very Acidic
<5.0	Acidic
5.1 – 5.5	Moderately Acidic
5.6 – 6.0	Slightly Acidic
6.0 – 6.5	Neutral
6.5 – 7.0	Slightly Alkaline
7.0 – 7.5	Alkaline
7.6 – 8.5	Very Alkaline
>8.5	
Organic Mater (%)	
<1.5	Low
1.6 – 3.0	Moderate
>3.0	High
Nitrogen (%)	
<0.1	Low
0.1 – 0.2	Moderate
>0.2	High
Exchangeable Potassium (cmol (+) / Kg)	
<0.2	Low
0.2 – 0.4	Moderate
>0.4	High

APPENDIX B

ANALYSIS OF VARIANCE ON GROWTH COMPONENTS

2016 CROPPING SEASON

```
Variate: LV_2WAT
Source of variation     d.f.    s.s.    m.s.    v.r.    F pr.
R stratum       2       1.0067  0.5033  4.41
 R.*Units* stratum
T       5       3.68    0.736   6.44    <.001
V       1       0.8711  0.8711  7.63    0.011
T.V     5       1.1289  0.2258  1.98    0.122
Residual        22      2.5133  0.1142
 Total  35      9.2

Variate: LV_4WAT_LV_6WAT
Source of variation     d.f.    s.s.    m.s.    v.r.    F pr.
 R stratum      2       6.0956  3.0478  12.24
R.*Units* stratum
T       5       4.5522  0.9104  3.66    0.015
V       1       0.0011  0.0011  0       0.947
T.V     5       0.7122  0.1424  0.57    0.721
Residual        22      5.4778  0.249
Total   35      16.8389

Variate: LV_6WAT
 Source of variation    d.f.    s.s.    m.s.    v.r.    F pr.
 R stratum      2       2.8772  1.4386  2.98
 R.*Units* stratum
T       5       13.71222.7424   5.68    0.002
V       1       0.2178  0.2178  0.45    0.509
T.V     5       2.4056  0.4811  1       0.443
Residual        22      10.62940.4832
Total   35      29.8422

Variate: LV_8WAT_LV_10WAT
Source of variation     d.f.    s.s.    m.s.    v.r.    F pr.
 R stratum      2       2.6022  1.3011  1.41
 R.*Units* stratum
T       5       9.5789  1.9158  2.08    0.107
V       1       2.6678  2.6678  2.89    0.103
T.V     5       10.88562.1771   2.36    0.074
Residual        22      20.30440.9229
Total   35      46.0389
```

```
Variate: PH_2WAT
 Source of variation          d.f.      s.s.      m.s.      v.r.      F pr.
 R stratum          2         44.765    22.382    5.72
 R.*Units* stratum
T         5         65.852    13.17     3.36      0.021
V         1         19.184    19.184    4.9       0.038
T.V       5         23.111    4.622     1.18      0.35
Residual            22        86.154    3.916
Total     35        239.067
```

```
Variate: PH_4WAT
Source of variation           d.f.      s.s.      m.s.      v.r.      F pr.
 R stratum          2         732.46    366.23    18.23
R.*Units* stratum
T         5         273.08    54.62     2.72      0.046
V         1         19.43     19.43     0.97      0.336
T.V       5         64.49     12.9      0.64      0.67
Residual            22        441.96    20.09
Total     35        1531.43
```

```
Variate: PH_6WAT
 Source of variation          d.f.      s.s.      m.s.      v.r.      F pr.
 R stratum          2         156.55    78.28     2.48
 R.*Units* stratum
T         5         1113.36222.67     7.05      <.001
V         1         17.33     17.33     0.55      0.467
T.V       5         148.57    29.71     0.94      0.474
Residual            22        694.65    31.58
Total     35        2130.46
```

```
Variate: PH_8WAT
 Source of variation          d.f.      s.s.      m.s.      v.r.      F pr.
 R stratum          2         123.61    61.81     2.13
 R.*Units* stratum
T         5         350.61    70.12     2.41      0.069
V         1         159.05    159.05    5.47      0.029
T.V       5         243.76    48.75     1.68      0.182
Residual            22        639.25    29.06
Total     35        1516.29
```

```
Variate: PH_10WAT
Source of variation           d.f.      s.s.      m.s.      v.r.      F pr.
R stratum           2         5108      2554      0.85
R.*Units* stratum
T         5         14214     2843      0.95      0.47
V         1         4487      4487      1.5       0.234
T.V       5         12136     2427      0.81      0.555
Residual            22        65971     2999
Total     35        101917
```

```
Variate: %CROP_ES_PLTS_PT
Source of variation       d.f.     s.s.     m.s.     v.r.     F pr.
 R stratum         2         740.72  370.36  9.22
 R.*Units* stratum
T         5          1066.56213.31  5.31      0.002
V         1          266.78  266.78  6.64      0.017
T.V       5          37.56    7.51      0.19      0.964
Residual             22        883.94  40.18
Total     35         2995.56
```

2017, CROPPING SEASON

```
Variate: NLV_2WAT
 Source of variation       d.f.     s.s.     m.s.     v.r.     F pr.
 R stratum         2         3.2506  1.6253  2.61
 R.*Units* stratum
T         5          4.6214  0.9243  1.48      0.235
V         1          0.3403  0.3403  0.55      0.468
T.V       5          4.2747  0.8549  1.37      0.273
Residual             22        13.70280.6229
 Total    35         26.1897
```

```
Variate: NLV_4WAT
 Source of variation       d.f.     s.s.     m.s.     v.r.     F pr.
 R stratum         2         2.6289  1.3144  2.97
 R.*Units* stratum
T         5          13.81892.7638  6.24      <.001
V         1          0.01      0.01      0.02      0.882
T.V       5          0.8233  0.1647  0.37      0.862
Residual             22        9.7444  0.4429
Total     35         27.0256
```

```
Variate: NLV_6WAT
Source of variation       d.f.     s.s.     m.s.     v.r.     F pr.
 R stratum         2         5.1667  2.5833  3.62
 R.*Units* stratum
T         5          27.48     5.496    7.69      <.001
V         1          3.0044  3.0044  4.21      0.052
T.V       5          0.7556  0.1511  0.21      0.954
Residual             22        15.71330.7142
 Total    35         52.12
```

```
Variate: NLV_8WAT
 Source of variation                d.f.        s.s.        m.s.        v.r.        F pr.
 R stratum              2           16.722      8.361       4.86
 R.*Units* stratum
T           5           6.502       1.3         0.76        0.591
V           1           0.16        0.16        0.09        0.763
T.V         5           1.573       0.315       0.18        0.966
Residual                22          37.864      1.721
 Total      35          62.822
```

```
Variate: NLV_10WAT
 Source of variation                d.f.        s.s.        m.s.        v.r.        F pr.
 R stratum              2           7.172       3.586       2.1
R.*Units* stratum
T           5           9.367       1.873       1.1         0.391
V           1           0.49        0.49        0.29        0.598
T.V         5           3.373       0.675       0.39        0.847
Residual                22          37.608      1.709
Total       35          58.01
```

```
Variate: PH_2WAT
 Source of variation                d.f.        s.s.        m.s.        v.r.        F pr.
R stratum               2           0.484       0.242       0.03
 R.*Units* stratum
T           5           65.119      13.024      1.85        0.145
V           1           1.181       1.181       0.17        0.686
T.V         5           13.454      2.691       0.38        0.856
Residual                22          155.2527.057
Total       35          235.49
```

```
 Variate: PH_4WAT
 Source of variation                d.f.        s.s.        m.s.        v.r.        F pr.
 R stratum              2           194.17      97.08       3.09
 R.*Units* stratum
T           5           796.86      159.37      5.07        0.003
V           1           20.1        20.1        0.64        0.432
T.V         5           30.14       6.03        0.19        0.962
Residual                22          691.03      31.41
Total       35          1732.29
```

```
 Variate: PH_6WAT
 Source of variation                d.f.        s.s.        m.s.        v.r.        F pr.
 R stratum              2           160.01      80.01       2.5
 R.*Units* stratum
T           5           1691.65338.33           10.55       <.001
V           1           1.69        1.69        0.05        0.821
T.V         5           100.32      20.06       0.63        0.682
Residual                22          705.37      32.06
Total       35          2659.04
```

```
Variate: PH_8WAT
Source of variation     d.f.      s.s.      m.s.      v.r.      F pr.
R stratum         2         837.18    418.59    6.47
 R.*Units* stratum
T         5         717.36    143.47    2.22      0.089
V         1         9.4       9.4       0.15      0.707
T.V       5         139.01    27.8      0.43      0.823
Residual            22        1423.1964.69
 Total    35        3126.14

Variate: PH_10WAT
Source of variation     d.f.      s.s.      m.s.      v.r.      F pr.
R stratum         2         803.32    401.66    5.79

R.*Units* stratum
T         5         703       140.6     2.03      0.114
V         1         16.4      16.4      0.24      0.632
T.V       5         139.61    27.92     0.4       0.842
Residual            22        1525.5669.34
Total     35        3187.89

Variate: %_PLT_EST
Source of variation     d.f.      s.s.      m.s.      v.r.      F pr.
 R stratum        2         110.72    55.36     1.22
R.*Units* stratum
T         5         3359.22671.84    14.86     <.001
V         1         215.11    215.11    4.76      0.04
T.V       5         128.56    25.71     0.57      0.723
Residual            22        994.61    45.21
Total     35        4808.22
```

APPENDIX C

ANALYSIS OF VARIANCE ON YIELD AND YIELD COMPONENTS 2016 CROPPING SEASON

```
Variate: MN_FB_WT
Source of variation                 d.f.        s.s.        m.s.        v.r.        F pr.
 R stratum              2           135.7       67.9        0.13
 R.*Units* stratum
T           5           7700.5      1540.1      2.93        0.036
V           1           21          21          0.04        0.843
T.V         5           3811.2      762.2       1.45        0.247
Residual                22          11580.7526.4
Total       35          23249.1
```

```
Variate: DB_WT
Source of variation                 d.f.        s.s.        m.s.        v.r.        F pr.
R stratum               2           7.056       3.528       0.56
 R.*Units* stratum
T           5           101.47220.294           3.24        0.024
V           1           4.694       4.694       0.75        0.396
T.V         5           18.806      3.761       0.6         0.699
Residual                22          137.6116.255
Total       35          269.639
```

```
Variate: TD_BM
 Source of variation                d.f.        s.s.        m.s.        v.r.        F pr.
 R stratum              2           10.72       5.36        0.43
 R.*Units* stratum
T           5           186.89      37.38       2.97        0.034
V           1           69.44       69.44       5.52        0.028
T.V         5           36.56       7.31        0.58        0.714
Residual                22          276.61      12.57
Total       35          580.22
```

```
Variate: HI
 Source of variation                d.f.        s.s.        m.s.        v.r.        F pr.
 R stratum              2           0.011250.005630.47
 R.*Units* stratum
T           5           0.055440.011090.92      0.484
V           1           0.031420.031422.62      0.12
T.V         5           0.041130.008230.69      0.639
Residual                22          0.264010.012
 Total      35          0.40325
```

```
Variate: MBY_t_ha
Source of variation     d.f.    s.s.    m.s.    v.r.    F pr.
 R stratum      2       67.268  33.634  6.1
 R.*Units* stratum
T       5       114.76222.952   4.16    0.008
V       1       11.845  11.845  2.15    0.157
T.V     5       113.65122.73    4.12    0.009
Residual        22      121.31  5.514
Total   35      428.837
```

```
Variate: UMBY_t_ha_TBY_t_ha
Source of variation     d.f.    s.s.    m.s.    v.r.    F pr.
R stratum       2       3.7447  1.8723  2.44
R.*Units* stratum
T       5       3.9522  0.7904  1.03    0.425
V       1       3.3979  3.3979  4.42    0.047
T.V     5       3.2296  0.6459  0.84    0.535
Residual        22      16.90180.7683
Total   35      31.2262
```

```
Variate: TBY_t_ha
 Source of variation    d.f.    s.s.    m.s.    v.r.    F pr.
R stratum       2       46.214  23.107  4.02
 R.*Units* stratum
T       5       120.84724.169   4.21    0.008
V       1       2.555   2.555   0.44    0.512
T.V     5       98.472  19.694  3.43    0.019
Residual        22      126.4395.747
 Total  35      394.526
```

```
Variate: BLB_DIA
 Source of variation    d.f.    s.s.    m.s.    v.r.    F pr.
R stratum       2       3.7818  1.8909  9.84
R.*Units* stratum
T       5       7.0153  1.4031  7.3     <.001
V       1       1.0609  1.0609  5.52    0.028
T.V     5       4.6424  0.9285  4.83    0.004
Residual        22      4.2262  0.1921
Total   35      20.7265
```

2017 CROPPING SEASON

```
 Variate: BLB_DIAM
 Source of variation       d.f.     s.s.     m.s.     v.r.     F pr.
 R stratum        2        1.7413   0.8706   1.72
 R.*Units* stratum
T         5       6.8396   1.3679   2.69     0.048
V         1       0.8281   0.8281   1.63     0.215
T.V       5       1.9366   0.3873   0.76     0.586
Residual          22       11.16830.5077
 Total    35      22.5139
```

```
Variate: HARV_INDX
Source of variation        d.f.     s.s.     m.s.     v.r.     F pr.
 R stratum        2        0.085210.0426     3.36
 R.*Units* stratum
T         5       0.140150.028032.21         0.089
V         1       0.001370.001370.11         0.745
T.V       5       0.020560.004110.32         0.893
Residual          22       0.278660.01267
Total     35      0.52594
```

```
Variate: M_BLB_YLD
 Source of variation       d.f.     s.s.     m.s.     v.r.     F pr.
 R stratum        2        24.855   12.428   2.62
 R.*Units* stratum
T         5       114.01922.804     4.81     0.004
V         1       12.84    12.84    2.71     0.114
T.V       5       56.228   11.246   2.37     0.072
Residual          22       104.2454.738
 Total    35      312.187
```

```
Variate: UM_Blb_Yld
Source of variation        d.f.     s.s.     m.s.     v.r.     F pr.
R stratum         2        0.4569   0.2285   0.42
 R.*Units* stratum
T         5       7.5627   1.5125   2.81     0.041
V         1       3.0276   3.0276   5.63     0.027
T.V       5       1.9199   0.384    0.71     0.62
Residual          22       11.84080.5382
 Total    35      24.8079
```

```
Variate: TL_BLB_YLD
 Source of variation       d.f.     s.s.     m.s.     v.r.     F pr.
 R stratum        2        6.126    3.063    0.67
 R.*Units* stratum
T         5       118.67823.736     5.19     0.003
V         1       3.398    3.398    0.74     0.398
T.V       5       52.044   10.409   2.28     0.082
Residual          22       100.54   4.57
Total     35      280.786
```

```
Variate: No_Blb_plt
 Source of variation     d.f.    s.s.    m.s.    v.r.    F pr.
 R stratum       2       12.056  6.028   1.57
 R.*Units* stratum
T       5       222.47244.494  11.57   <.001
V       1       0.694   0.694   0.18    0.675
T.V     5       22.472  4.494   1.17    0.356
Residual        22      84.611  3.846
 Total  35      342.306

 Variate: FS_WGT1
 Source of variation     d.f.    s.s.    m.s.    v.r.    F pr.
 R stratum       2       1486    743     0.52
 R.*Units* stratum
T       5       29656   5931    4.11    0.009
V       1       100595 100595 69.77   <.001
T.V     5       10962   2192    1.52    0.224
Residual        22      31721   1442
 Total  35      174421
```