

**AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING  
AND ENTREPRENEURIAL DEVELOPMENT  
FACULTY OF AGRICULTURE EDUCATION  
ASANTE MAMPONG**

**GROWTH AND YIELD RESPONSE OF OKRA (*Abelmoschus esculentus* L.  
Moench) TO DIFFERENT TYPES OF INORGANIC FERTILIZER,  
PLACEMENT AND TOP DRESSING**

**ANGELINA POKUA MANSA**

**2025**

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AND TOP DRESSING**

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**A THESIS IN THE DEPARTMENT OF CROP AND SOIL SCIENCES  
EDUCATION, FACULTY OF AGRICULTURE EDUCATION, SUBMITTED TO  
THE SCHOOL OF GRADUATE STUDIES, IN PARTIAL FULFILMENT OF THE  
REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY IN CROP  
SCIENCE.**

**SEPTEMBER 2025**

## DECLARATION

### Candidate's Declaration

I, hereby declare that this thesis is the results of my own original work and that no part of it has been presented for another degree at this university or elsewhere.

**Name:** Angelina Pokua Mansa

Signature: ..... Date: .....

### Supervisor's Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

**Principal Supervisor's Name:** Prof. Harrison Kwame Dapaah

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Lastly, to my children Vanessa Frimpomaa Osei, Venolia Frimpomaa Osei and Nana Yaa Serwaa Osei for their love.

## **DEDICATION**

This thesis is dedicated to God, for His divine guidance, unwavering presence, and blessings that have illuminated my path and granted me the strength to persevere.

I also dedicate this work to my dear husband, Nana Osei Amoako and my dear daughters Vanessa Frimpomaa Osei, Venolia Frimpomaa Osei and Nana Yaa Serwaa Osei for their support.

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## LIST OF ABBREVIATION/ACRONYMS

|      |  |
|------|--|
| AS   | Ammonium Sulphate                        |
| CP   | Cooper Pergler                           |
| EC   | Electrical Conductivity                  |
| EU   | European Union                           |
| MoP  | Muriate of Potash                        |
| MRR  | Marginal Rate of Return                  |
| NARI | National Agricultural Research Institute |
| NPU  | net protein utilization                  |
| OC   | Organic Carbon                           |
| OM   | Organic matter                           |
| PER  | protein efficiency ratio                 |
| RAE  | Retinol Activity Equivalent              |
| WAP  | weeks after planting                     |

## ABSTRACT

The experiment was conducted at the Multipurpose Crop Nursery research site at the Mampong Campus of the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development during the major (March to July) and minor (August to November) rainy seasons of 2023. The objective of this study was to determine the effects of different types of inorganic fertilizer, placement and top dressing on the growth and yield of okra. The experiment was arranged in a Randomized Complete Block Design (RCBD) with three (3) replications. The treatments were: (i) No fertilizer (control), (ii) Yara Activa + No top dressing + Hill placement, (iii) Yara Activa + No Top dressing + Side placement, (iv) Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top dressing + Hill placement, (v) Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  + Side placement, (vi) NPK (20-10-10) + No top dressing + Hill placement, (vii) NPK (20-10-10) + No top-dressing + Side placement, (viii) NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top dressing + Hill placement and (ix) NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top dressing + Side placement. The results show that, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  Top dressing + Hill Placement and NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement flowered and podded earlier. Generally, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement and NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement produced the highest plant height, canopy width, number of leaves and branches per plant and dry shoot weight. Generally, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement and NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement produced the highest fruit diameter, length and fruit yield. Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement and NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement are recommended for consideration for possible adoption for higher growth, development and yield and profitability of okro production in the transition zone of Ghana.

## CHAPTER ONE: INTRODUCTION

### 1.1 Background of the Study

Okra (*Abelmoschus esculentus* L. Moench) is an important vegetable crop that is consumed globally. It belongs to the Malvaceae family. Okra also known as lady's finger, Gombo (French), Miyan gro (Hausa), and Mana (Dagbani), is a commercial traditional vegetable crop grown mostly in the tropical and subtropical regions (Ghodia *et al.*, 2015; Singh *et al.*, 2018; Romdhane *et al.*, 2020). It is commonly planted for its immature green fruits, which are served raw, roasted, or fried as a vegetable. It is frequently used in soups and sauces. The fruits may be preserved through dehydration or pickling. It contains vitamin C and other minerals, such as phosphorus, calcium, and potassium, and has a higher concentration of thiamine, riboflavin, and niacin than many vegetables (Barnes-Svarney & Svarney, 2015; Khan *et al.*, 2017). It also contains carbohydrates, dietary fiber, fats, and proteins.

Ghana produces about 100,000 metric tonnes of okra each year, but India is the world's top producer (Yahaya *et al.*, 2021). In recent years, biotic and abiotic challenges, such as climate change, pest infestation, and disease, have impacted okra production in the Northern region, prompting farmers to combine dry season irrigation, fertiliser, and pesticide treatment in order to increase yield (Oppong-Sekyere *et al.*, 2020; Yahaya *et al.*, 2021; Bellwood-Howard *et al.*, 2018).

### 1.2 Problem Statement and Justification

According to Gloria *et al.* (2017), fertilizers either increase soils inherent fertility or replenish the chemical elements lost to harvesting, grazing, leaching, or erosion. The low yields of okra from farmers fields are often not due the crops low yielding potential, but the result of a number of factors, such as insect pests and diseases, lack of high yielding varieties, poor soil fertility, lack of quality seeds of high yielding varieties and application

of low fertilizer rates (Kizito *et al.*, 2019). Among the several factors, fertilizer management has the greatest impact on the growth, development, and yield of okra (Akhter *et al.*, 2019; Mugtadir *et al.*, 2019). As a result of extensive cultivation, most Ghanaian agricultural soils contain virtually little organic material (Asabere *et al.*, 2018). Therefore, Okra growers rely mostly on inorganic fertilizers to supply vital minerals for increased yields (Miaha *et al.*, 2020). In addition, the majority of farmers broadcast their fertilizer granules during application, leaving them vulnerable to run-offs and volatilization and leaching losses. Consequently, the yields of okra obtained by farmers are significantly below the potentials of the types cultivated (NARI, 2013). The average output of okra in farmer's fields was 2.9 tons per hectare (NARI, 2013) instead of at least 6 t/ha as cited by Oppong-Sekyere *et al.* (2011).

The application of fertilizers improves soil physical and chemical qualities and boosts its biological activities (Ge *et al.*, 2010). Soil nutrient deficiency is regarded as one of the most significant obstacles to sustainable crop development. For every crop to achieve a high level of production and quality yield, appropriate management must ensure the availability of key nutrients in the correct amounts. Consequently, the management of fertilizer, particularly potassium and phosphorus, has a significant impact on the growth, development, and output of okra (Singh *et al.*, 2019; Selim, 2020). Phosphorus and potassium fertilizers play a significant influence on the yield and quality of okra fruits. The application of 190 kg/ha and 200 kg/ ha of NPK fertilizer resulted in the highest growth and output of okra in Nigeria (Mandloi, 2022). By the application of NPK fertilizer, okra growth and yield increased significantly (Rahman and Ferdousi, 2012). According to Adiaha *et al.* (2016), ring and band methods of fertilizer application make nutrients more accessible and available to plants. With regards to plant growth and development, crop response to NPK fertilizer varies based on application rates and the

method of application used. The ring application method of fertilizer considerably improved okra plant height, leaf area, root length, and leaf number. (Gul et al, 2015; Mokrani & Tarchoun, 2018).

### **1.3 Objectives of the Study**

#### **1.3.1 Main Objective**

The main aim of the study was to determine the effects of different types of inorganic fertilizer, placement and top dressing on the growth and yield of okra.

#### **1.3.2 Specific Objectives**

The specific objectives were to:

1. Evaluate the phenology and growth performance of okra as affected by different inorganic fertilizers and their placement and top dressing.
2. Assess the yield and yield components of okra as influenced by different inorganic fertilizers and their placement and top dressing.
3. Evaluate the profitability of okra production as affected by different inorganic fertilizers and their placement and top dressing.

## CHAPTER TWO: LITERATURE REVIEW

### 2.1 Origin and Distribution of Okra

The geographical origin of okra is contested, having South Asian, Ethiopian, and West African advocates. The existence of the claimed parents in South Asia is cited by proponents of a South Asian ancestry. Contrary to this, the absence of a term for okra in ancient Indian languages suggests that it reached there during the Christian era. However, confusion between Okra and *Abelmoschus caillei* (L.) Moench (West African okra) puts doubt on the veracity of these claims. Egyptians and Moors of the 12th and 13th centuries adopted the Arabic term 'bamay' for the plant, indicating that it originated in the east (Okereke *et al.*, 2017; Saxena *et al.*, 2023). The plant may have invaded south west Asia via the Red Sea or the strait to the Arabian Peninsula, as opposed to the Sahara or India (Okereke *et al.*, 2017). In one of the earliest reports, a Spanish Moor who visited Egypt in 1216 describes the inhabitant's cultivating okra and eating the sensitive, young pods with meal (NRC, 2006). From Arabia, the plant expanded throughout the Mediterranean Sea's coastlines and to the east. By 1658, when its existence was documented in Brazil, okra had been brought to the Americas by slave ships patrolling the Atlantic (Green, 2016).

It is believed that the Portuguese corrupted "Gumbo" to signify quin-gombo, the original name for the plant in the Congo and Angola region of Africa. Okra appears to have originated in what geobotanists refer to as the Abyssinian center of origin of cultivated plants, a region that includes modern-day Ethiopia, the mountainous or plateau portion of Eritrea, and the eastern, more elevated portion of the Anglo-Egyptian Sudan (Osei-Assibey, 2014). It is uncertain how okra was transported from Ethiopia to North Africa, the eastern Mediterranean, Arabia, and India. Although it has been widely farmed in Egypt for many centuries, no trace of it has ever been discovered in any ancient Egyptian

monuments or artifacts. The absence of ancient Indian names for it since the arrival of the Spanish Moors shows that it arrived in India after the beginning of the Christian era (Benvenisti, 2000). Okra is suited for cultivation in both backyard gardens and on big commercial farms (Singh *et al.*, 2018). India, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Burma, Japan, Malaysia, Brazil, Ghana, Ethiopia, Cyprus, and the southern United States cultivate it economically. India ranks first in the world with about 0.35 million hectares of land producing 3.5 million tons (70 percent of the total world production) of okra. It is widely cultivated in India due to its simple cultivation, consistent yield, and resilience to varied moisture conditions (Sarkar *et al.*, 2022).

## **2.2 Botany of Okra**

Okra is a robust, upright annual plant that grows to a height of 4 meters and has spirally arranged leaves with leaf blades measuring up to 50 cm in diameter and being more or less deeply 3-5- and 7-lobed. The bloom is axillary and solitary, while the leaves are alternating and frequently palmately 5-lobed (Osei-Assibey, 2014; Umeri *et al.*, 2023; Blancke, 2016). Okra plants have an unpredictable growth pattern. Pods of okra contain numerous, grey to black seeds. Generally, okra seeds germinate roughly 5-7 days after sowing, and seedlings may have three to four leaves per plant and reach a height of 12 to 18 cm in one to two weeks. The okra vegetative stage lasts between three and four weeks after seed germination, after which the commencement of bud and bloom development occurs. The leaves are larger and there are more than eight of them on a plant. The distance between leaves on the stem is longer. In the leaf axils are yellow, single flowers. Typically, okra blooms between 40 and 90 days following sowing (Diizyaman, 2010; Idowu *et al.*, 2022). Continual flowering is strongly dependent on biotic and abiotic stress. Blooming and flowering commencement are delayed at higher temperatures. The

number of vegetative internodes is positively correlated with temperature (Wingler, 2012; Susila *et al.*, 2018; Kumar *et al.*, 2019). Typically, the plant will produce its first flowers one to two months after being planted. The fruit is a capsule that develops rapidly following flowering. The flower blooms each morning. The fruits or pods of this plant are green, cylindrical to pyramidal capsules. 5-35 cm in length and 1-5 cm in width. Vegetative growth ceases shortly after anthesis on the seed crop, with all assimilates being allocated to the reproductive plant parts. Okra is mostly propagated from seeds and matures in 90-100 days (Osei-Assibey, 2014).

### **2.3 Climatic and Soil Requirements for Okra Growth**

Okra is a tropical vegetable. The plant requires warm weather and ample sunlight. It thrives in a variety of soil types, but it grows best in well-drained sandy and clay loam soil that is rich in organic matter (Reddy, 2012; Singh, 2018; Osei-Assibey, 2018). The plant thrives in a climate with a long, warm growing season that lasts throughout the year, as long as the soil is fertile and there is sufficient moisture. It thrives at a maximum average temperature of 35 degrees Celsius and a minimum average above 18 degrees Celsius. Seeds will only germinate in soils that are relatively warm. The ideal temperature range for germination, growth, and fruit setting is 25 to 30 degrees Celsius. There is no germination below 16 degrees Celsius, and a monthly average temperature range of 20 degrees Celsius to 30 degrees Celsius is ideal for plant growth, flowering, and pod development. Okra is tolerant of a wide range of precipitation; nevertheless, supplemental irrigation may be necessary up until the fruiting time if rainfall is insufficient to ensure vigorous growth. The majority of cultivars are well-adapted to altitudes of 500 meters and higher. The crop can be cultivated in soils with pH values between 4.5 and 7. It may be grown at altitudes ranging from sea level to 30 meters. You can plant okra twice a year. Okra demands a lengthy, warm, and humid phase of growth. It can be grown well

in hot, humid regions. It is vulnerable to low temperatures. For regular growth and development, temperatures between 24 and 28 degrees Celsius are desirable. At 24 °C, the first flower bud may form in the third leaf axil, whereas at 28 °C, it may form in the sixth leaf axil. The emergence of flower buds in the sixth leaf axil is not necessarily followed by a delay in time, because at higher temperatures the plants grow more quickly and the higher position is attained sooner. Even if it delays ripening, a greater temperature nevertheless promotes plant development. At temperatures over 40 °C–42 °C, flowers may dry out and fall, resulting in yield losses. Beyond this range, germination will be delayed, and weak seeds may not germinate at all (Maduagwuna *et al.*, 2019; Dilruba, 2008; Asamoah, 2016; Hayamanesh, 2018; Mohammadi *et al.*, 2018).

Okra is propagated by seeds and matures in 90 to 100 days. It is normally an annual plant with a sturdy, upright, and variably branched stem. The height of okra ranges from 0.5 to 4.0 meters. It has alternating leaves that are typically palmately five-lobed and axillary blooms that are solitary. The okra plant grows indefinitely and flowers continuously, although its growth is greatly dependent on biotic and abiotic stress. Typically, the plant begins to produce its first flower between one and two months following seeding. After the development of flowers, the fruit grows rapidly, with significant increases in length, height, and diameter. This occurs four to six days after pollination. At this point, the fruit is often harvested for food. Okra is harvested while the fruits are immature and have a high mucilage content, but before they become excessively fibrous. The production of fiber typically begins on the sixth day following fruit formation and increases rapidly beginning on the ninth day. Depending on the kind, season, and soil qualities, the okra plant blooms and bears fruit indefinitely. Regular harvesting promotes prolonged fruiting, necessitating daily harvesting in environments with robust growth (Santos *et al.*, 2019; Barnwal *et al.*, 2017; Musara *et al.*, 2015).

## **2.4 Importance of Okra**

Okra is more of a diet food than a staple; it is mostly farmed for its immature young fruits and consumed raw, boiled, or fried as a vegetable. It is a typical soup and sauce component. The fruits may be preserved by dehydration or pickling (Vandebroek & Voeks, 2018; Elkhalfa *et al.*, 2021). The leaves are sometimes used as a spinach or cattle feed alternative, the stem fibers for cable, the mucilages for medical and industrial reasons, and the seeds as a coffee substitute (Alemu-Bayu, 2020). The seeds of okra contain a substantial amount of high-quality oil and protein. The vegetable okra is rich in vitamins and minerals. It is exceptionally abundant in calcium (70-90 mg/100 g) and other minerals (Yamaguchi, 2012). Oil has been produced on a limited scale from okra seeds. Lipid components contribute significantly to the nutritional and gustatory value of practically all food kinds. Nature supplies a variety of lipids with distinct chemical and functional qualities (Anwar *et al.*, 2010; Akinoso *et al.*, 2023).

## **2.5 Varieties of Okra**

Okra cultivars vary in terms of plant height, yield potential, and number of days to maturity. Depending on the cultivar, pods can be smooth or ridged, and their form can be stout or thin. Color of pods varies. It could be red, green, or almost white. Some cultivars generate pods of larger size that are still delicate. The lack of spines on the leaves and stems of spineless cultivars makes harvesting them less irritating. Private and commercial breeders continue to improve current varieties by creating hybrids, although new okra types are rarely introduced in contrast to other vegetables. In general, hybrid okra produces greater yields, although their seeds are more expensive than those of established types (Asaduzzaman, 2013; Asamoah, 2016).

Table 2. 1: Varieties of Okra

| Country          | Name of Cultivar   |
|------------------|--|
| Ghana            | Indiana, Asontem, Torkor, Manipeali, Saloni(F1).   |
| Senegal          | Lima(F1), POP-11(Emerald) Lolli, Volta, Indiana, PoP-12(landrace).                           |
| Mali             | Yelen, Sabalibougou, Cleson, Spineless, Keleya.  |
| Cote d'Ivoire    | Perkins Long Pod, Hire, Tomi ( <i>A. caillei</i> ), Koto.                                    |
| Cameroon<br>Togo | Volta, Emerald, Gombo Cafeier, Gombo Local ( <i>A. caillei</i> ), Konni (purified landrace). |
| Nigeria          | V-35, White Velvet, Spineless, Clemision, LD 88, Lady's Finger, Ex-Borno.                    |
| Niger            | Konni, Volta, Terra (purified landrace).   |

## 2.6 Potentials of Okra

### 2.6.1 Okra Potential for Livelihood Enhancement

Okra has the potential to improve the livelihoods of farmers and numerous urban and rural communities. When the potential of okra is harnessed, both small- and large-scale growers as well as all members of the okra value chain will thrive. The EU and Asia have a substantial market for Ghanaian vegetables, and okra is no exception. This, when exploited, will result in the country obtaining the foreign currency it so desperately needs. An increase in the amount of okra exported will also enhance the lives of small-scale farmers (Oppong-Sekyere *et al.*, 2020).

### 2.6.2 Nutritional and Health Potential

Okra is a significant source of calcium, potassium, vitamins, and minerals that are typically absent from the diets of the impoverished in developing nations. Potassium, sodium, magnesium, and calcium are present in the seeds of the pods. It has been stated that zinc, iron, nickel, and manganese are present. The calorie content per 100 grams of okra is 20g. Fresh pods are practically high in fiber, fat-free, and contain a variety of

minerals, including 10 to 20 percent folate, 30 percent of the necessary levels of vitamin C (16 mg to 29 mg), and around 5 percent vitamin A (14 to 20 RAE) (Singh *et al.*, 2014; Woldetsadik *et al.*, 2022; Rahman, 2014; Butnariu & Butu, 2015).

The seed of okra is composed of oligomeric catechins and flavonol derivatives, while the mesocarp is predominantly composed of hydroxycinnamic and quercetin derivatives. The seeds and pods include biological components such as quaternary derivatives, catechin oligomers, hydroxycinnamic derivatives, and abundant phenolic chemicals. In addition to its high carbohydrate content, proteins, glycol-protein, and additional dietary components enhance the nutritional value of okra. Fresh okra pods are the most significant vegetable source of viscous fiber, an essential dietary component for lowering cholesterol (Osei, 2015; Asamoah, 2016). Seven-day-old okra pods contain the maximum quantity of nutrients (Sami *et al.*, 2019). Okra is reported to be beneficial for genitourinary problems, chronic dysentery, and the prevention of spermatorrhea. It has been observed that okra is effective in treating ulcers and relieving hemorrhoids. Proteins have a vital role in human nutrition. A protein's biological value is determined by its amino acid composition, quantities, and digestion by humans. Due to its sturdy character, dietary fiber, and specific seed protein balance of both lysine and tryptophan amino acids (unlike the proteins of cereals and pulses), okra has been dubbed "the ideal villager's vegetable" (Abbas, 2021; Gemedede *et al.*, 2019).

The amino acid composition of Okra seed protein is comparable to that of soybean, the protein efficient ratio is greater than that of soybean, and the amino acid pattern of the protein makes it a suitable addition to diets based on legumes or grains (Yao *et al.*, 2021). According to Nnamezie *et al.* (2021) and Gemedede *et al.* (2015), okra seed is rich in high-quality protein, particularly in terms of its content of essential amino acids relative to other plant protein sources, and has therefore played an important role in the human diet.

Young, immature okra pods are significant as fresh fruits and can be consumed in a variety of ways. One can boil, fry, or sauté fruits. The composition of okra pods per 100 g edible portion (81 percent of the product as purchased, ends clipped) is as follows: water 88.6 g, energy 144.00 kJ (36 kcal), protein 2.10 g, carbohydrate 8.20 g, fat 0.20 g, fibre 1.70 g, Ca 84.00 mg, P 90.00 mg, Fe 1.20 mg, -carotene 185.00 g, riboflavin 0. The composition of 100 g of edible "Okra" leaves is as follows: water 81.50 g, energy 235.00 kJ (56.00 kcal), protein 4.40 g, fat 0.60 g, carbohydrates 11.30 g, fibre 2.10 g, calcium 532.00 mg, phosphorus 70.00 mg, iron 0.70 mg, ascorbic acid 59.00 mg, beta carotene 385.00 g, thiamin 0.25 mg, riboflavin 2. Carbohydrates are primarily present as mucilage (Idowu *et al.*, 2022). Long chain molecules having a molecular weight of approximately 170,000 that are composed of sugar units and amino acids.

The primary constituents are galactose (25%), rhamnase (22%), galacturonic acid (27%), and amino acids (11%). The mucilage is particularly water-soluble. Its solution in water possesses an intrinsic viscosity of approximately 30%. Potassium, Sodium, Magnesium, and Calcium are the most abundant minerals in pods, which comprise approximately 17 percent seeds. Additionally, the presence of Iron, Zinc, Manganese, and Nickel has been detected (Moyin-Jesu, 2007). Fresh pods are low in calories (20 per 100 g), almost fat-free, high in fiber, and contain various beneficial nutrients, such as approximately 30 percent of the necessary levels of vitamin C (16 to 29 mg), 10 to 20 percent of folate (46 to 88 mg), and around 5 percent of vitamin A. (14 to 20 RAE). Both pod skin (mesocarp) and seeds contain 80 mg of zinc per gram (Vincente *et al.*, 2014; Gemede *et al.*, 2015). Okra seed consists primarily of oligomeric catechins (2.5 mg/g of seeds) and flavonol derivatives (3.4 mg/g of seeds), whereas the mesocarp consists primarily of hydroxycinnamic and quercetin derivatives (0.2 and 0.3 mg/g of skins). Pods and seeds contain an abundance of phenolic chemicals with important biological qualities, such as

quartering derivatives, catechin oligomers, and hydroxycinnamic derivatives (Dubey & Mishra, 2017). These characteristics, together with the food's high carbohydrate, protein, glycol-protein, and other dietary element content, increase this food's significance in the human diet. West African dried okra sauce (pods blended with other ingredients) contains no beta carotene (vitamin A) or retinol (Dubey *et al.*, 2017). However, fresh Okra pods are the most significant source of viscous fiber, an essential dietary component for lowering cholesterol. Green veggies are rich in chlorophyll. It has been suggested that chlorophyllin, a key component of chlorophyll, has substantial health advantages (Solymosi & Mysliwa-Kurdziel, 2017). In general, fruits and vegetables have demonstrated the basic helpful features, notably in the field of giving outstanding health and nutritional qualities in the prevention and delay of the onset of chronic diseases and the provision of vitamins and enzymes required for appropriate bodily function (Aman *et al.*, 2005).

Table 2. 2: Composition Per 100 g of Edible Portion of Okra

| Constituent | Composition | Constituent   | Composition |
|-------------|-------------|---------------|-------------|
| Moisture    | 89.6 g      | Minerals      | 0.7 g       |
| Protein     | 1.9 g       | Carbohydrate  | 6.4 g       |
| Fat         | 0.2 g       | Calcium       | 66 mg       |
| Fibre       | 1.2 g       | Iron          | 0.35 mg     |
| Calories    | 35 g        | Potassium     | 103 mg      |
| Phosphorus  | 56 mg       | Thiamine      | 0.07 mg     |
| Sodium      | 6.9 mg      | Nictonic acid | 0.6 mg      |
| Sulphur     | 30 mg       | Vitamin C     | 13 mg       |
| Riboflavin  | 0.1 mg      | Magnesium     | 53 mg       |
| Oxalic acid | 8 mg        | Copper        | 0.19 mg     |

Source: (Gopalan *et al.*, 2007).

## 2.7 Okra Seed as Potential Edible Oil and Flour Source

The oil content of okra seeds ranges from 20 to 40 percent. The bark fibre is simple to remove. It is white to golden in colour, robust, but somewhat gritty (Gemedé *et al.*, 2015). Tests conducted in China indicate that an alcohol extract of Okra leaves can eliminate oxygen free radicals, alleviate renal tubular-interstitial disorders, decrease proteinuria, and enhance renal function (Hu *et al.*, 2014; Wahyaningsih *et al.*, 2021; Ong *et al.*, 2021). Okra seed can be dried, and the dried seeds can be used to make vegetable curds or roasted and crushed for use as a coffee ingredient or alternative (Gemedé *et al.*, 2015). The yield of okra seed oil is comparable to the majority of oil seed crops, with the exception of oil palm and soybean. In addition, Okra seed oil may have hypocholesterolemic properties. The potential for widespread Okra planting for both edible oil and cake is very great. Additionally, cereal flour could be fortified with okra seed flour. For example, adding "Okra" meal to maize ogi enhances its protein, ash, oil, and fiber content (Gemedé, 2020). In nations such as Egypt, okra seed flour has been combined with maize flour for a very long time to produce higher-quality dough. Before recommending the widespread ingestion of okra seed flour, however, it would be prudent to conduct long-term rodent/animal feeding trials (Gemedé, 2020) 60 to 70% of okra seed oil consists of unsaturated fatty acids. According to reports, okra seeds are an abundant source of tryptophan (94 mg/g N) and sulphur-containing amino acids (189 mg/g N). This combination makes okra seeds extraordinarily beneficial for combating human malnutrition (Moosavi *et al.*, 2018).

Okra seed protein has a net protein utilization (NPU) value comparable to that of many cereals (with the exception of wheat), a seed oil output comparable to that of most oil seed crops with the exception of oil palm and soybean, and a high protein efficiency ratio (PER). Okra has a strong cultivation potential for edible oil and cake on a wide scale.

According to Adalakun *et al.* (2008), okra seed flour can be used to enrich cereal flour. In countries such as Egypt, okra seed flour has been used to complement maize flour for quite some time to increase dough quality (Aderonke *et al.*, 2014).

## **2.8 Nutritional Benefit of Okra**

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### **2.8.1 Effect of Nitrogen Fertilizer on Okra**

One of the factors limiting okra production is the nutrient concentration of the soil, particularly low levels of nitrogen. N-fertilizer accounts for up to fifty percent of all nitrogen inputs, and its availability plays a significant influence in determining the crop yield of farmers. This has been ascribed to the inability to cheaply subsidize its position in the plant. It has been observed that N application considerably improves okra growth (Shahbaz *et al.*, 2014), dry matter partitioning (Kayode & Adeoye 2021), and fruit yield (Shahbaz *et al.*, 2014). (Akanbil *et al.*, 2010). Nitrogen is an essential ingredient and a crucial factor in agricultural plant growth and development. It contributes to the synthesis of chlorophyll, proteins, nucleic acids, hormones, and vitamins, as well as cell division and elongation. Several researchers have observed an increase in okra green pod yield from 56 to 150 kg/ha with the application of nitrogen (Ahmed *et al.*, 2020; Reddy & Ulaganathan, 2015). According to Coutinho-Miranda *et al.* (2022), 100 kg/h of nitrogen fertilizer improves the growth, development, and output of okra. The findings of Khan *et al.* (2013) regarding the effect of nitrogen and phosphorus on the growth and development of okra were same. It is the most frequent nutrient deficiency in soils, contributing to decreased crop production worldwide. Nitrogen may affect the semiochemicals and nutritional properties of plants, as well as the behavioural traits of herbivores (Islam *et al.*, 2017). In general, the N content of host plants is regarded an

indicator of food quality and a factor in herbivore host selection (Quintero & Bower, 2018). A sufficient nitrogen supply is connected with high photosynthetic activity, vigorous vegetative development, and dark green leaf color (Kaur *et al.*, 2016). Nitrogen is partitioned in the crop as phenols and amino acids (protein), resulting in very succulent foliage that is prone to disease and pest infestation (Doughari, 2015). It is theorized that increases in N levels in plants can increase populations of herbivorous invertebrates that feed on those plants. Depending on the bug species and host plants, such increases in insect pest populations on their hosts might come from a variety of mechanisms in response to increasing N levels. Changes in the N content of Poinsettias grown with ammonium nitrate, for instance, boosted the fertility of the whitefly *Bemisia tabaci* (Genn) and attracted more individuals to lay eggs on them. Included among the compounds known to affect pest activity are sugars, enzymes, phenols, and alkaloids (Baah, 2014; Medina-Ortega, 2011).

When crop plants have sufficient access to the necessary nutrients, these compounds that confer resistance or tolerance to insect pests are produced. N-fertilization may reduce plant resistance to insect pests by increasing the nutritional quality of host plants and decreasing the quantities of secondary metabolites (Baah, 2014). N treatments boosted the rate of population expansion of green peach aphid on potatoes, and this increase was positively associated with amino acid contents in the leaves (Ali *et al.*, 2023). High quantities of nitrogen prevent glycoalkaloid production, which inhibits potato insect pests (Rousselin *et al.*, 2016). Alyokhin *et al.* (2015), investigating interactions between fertilizer regimes and host-plants resistance in tomatoes, found that the survival of Colorado potato beetles and adult emergence increased with higher amounts of fertilizer and was associated with decreases in trichome- and lamellar-based beetle resistance, as a result of the improved nutritional quality of the host plant. In addition to improvements

in the survival rates of Colorado potato beetles from the first instar to the adult stage in tomato plants receiving high levels of nitrogen, nitrogen may also accelerate insect development and enhance pupal biomass.

### **2.8.2 Effect of P and K on Crop Growth**

A study has shown that phosphorus content of 0-10 mg/kg is considered low, 10-20 mg/kg medium and greater than 20 mg/kg as high (Zhao *et al.*, 2019). Compared to Phosphorus and Potassium, Nitrogen has received more attention in studies related to plant nutrition. This is because in addition to its role in the formation of proteins, nitrogen is an integral part of the chlorophyll molecule. An adequate supply of nitrogen is therefore associated with vigorous vegetative growth and a deep green colour of plants. Except in virgin and very fertile soils where significant responses may not be obtained, nitrogen applied at the correct levels together with adequate amounts of phosphorus and potassium has beneficial effect on productivity of crops (Murthy *et al.*, 2015).

Yield increase was due mainly to greater fruit set as mean fruit weight was only affected slightly by the high N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O rates (Guo *et al.*, 2022). The nutrients also improved fruit quality of okra. Increasing the rate to 180:180:180kg/ha gave no advantage (Bhende *et al.* 2015). Investigating into egg plant nutrition on irrigated land, it was observed that egg plant receiving nitrogen and phosphorus each at 180kg/ha yielded 35% more than the control (Nemati *et al.*, 2024). Studies on the response of egg plant variety Trakeits to rates of mineral fertilization and method of application was carried and it was reported that, mineral fertilizers raised the yield by 52% (Oyewole *et al.*, 2014). Studies have shown that the combined application of P and K can lead to increased plant growth, fruit yield, and quality in okra (Agyarko *et al.*, 2013). NPK 20:10:10 fertilizer, which contains P and K, at a rate of 200 kg/ha, consistently gave higher pod number, length, and pod yield per plant than other treatments (Oa *et al.*, 2018). Also, Babatola (2013) reported that

the application of 12kg/ha NPK 15:15:15 fertilizer gave the best growth and yield of okra but the fertilizer had no significant effect on physical properties of okra e.g. firmness, colour, disease incidence and weight loss in storage.

### **2.8.3 Effect of Hill and Side Placements of Fertilizers on Crop Growth**

The placement of nutrients is an important issue in nutrient management because placement strongly influences the subsequent availability of nutrients (Selim, 2020). Studies have shown that hill placement, where fertilizer is applied in small mounds beside each plant, can be more efficient for okra than side placement, especially in drier conditions (Anim, 2022). Hill placement can lead to increased pod number and yield compared to broadcast or side placement methods of application (Ibrahim et al., 2015), due to the concentrated availability of nutrients to the plant roots. However, the optimal fertilizer placement method can vary depending on factors like soil type, climate, and irrigation practice. Side placement can improve seedling establishment and early growth. It also reduces fertilizer loss through runoff or leaching compared to broadcast application method (Cheng *et al.*, 2020).

The effectiveness of integrated use of mineral and organic amendments in improving crop yields and maintaining soil fertility has been well documented, but the availability of the resources for achieving these positive effects remains a major challenge, especially in the Sahelian countries. The main sources of organic amendments such as crop residue are used for other purposes and thereby limiting their availability for use as soil amendments. Animal manure is the most common organic resource for smallholder farmers but its availability in sufficient quantities is also a major challenge (Jouzi et al., 2017).

## **2.9 Economics of Fertilizer Use**

While agronomic fertilizer research frequently focuses on optimizing response or reversing nutrient depletion in soils, economics of fertilizer considerations are necessary for drawing conclusions and recommending fertilizer to farmers (Sheahan *et al.*, 2013). Unfortunately, after determining a suitable fertilizer dose for recommendation to smallholder farmers, the majority of fertilizer micro-dose trials-plus-demonstrations lack agronomic and economic evaluations (Blessing, 2014). Sheahan *et al.* (2013) stated that smallholder farmers attempt to maximize returns per unit of input since they are unable to acquire sufficient amounts of fertilizer and other inputs to optimize crop output at the recommended levels. Application of a unit of fertilizer is economical if the value of the increase in crop output attributable to the quantity of fertilizer added exceeds the cost of the fertilizer applied. If a unit of fertilizer does not raise yield sufficiently to cover its cost, its application is not economically viable and will not provide a profit even after a constant yield rise (Sommer & Knudsen, 2021). However, it is only possible to maximize net profits from inputs invested with optimal investment, accurate decisions, and favorable weather. For economic study of fertilizer use, the two most important factors to consider are that the output increase attributable to fertilizer and the correlations between fertilizer cost and produce price (Burke *et al.*, 2017).

## **2.10 Fertilizer Use Efficiency**

Enhanced FUE includes the optimum fertilizer supply, adequate rate and diagnostic procedures, optimal fertilizer application method and timing, balanced fertilization, nutrient interrelationships, integrated nutrient management, crop sowing timing, and exploitation of residual nutrients. Since a greater fertilizer use efficiency is always related with a lower fertilizer rate, cultural activities intended to promote integrated nutrient management will help to reduce the quantity of fertilizer applied to crops, hence

enhancing fertilizer use efficiency (Srinivasarao, 2021; Barlog *et al.*, 2022). However, maximizing profitability requires not just reducing fertilizer consumption per unit of land, but also lowering expenses per unit of crop production through increased yields. Therefore, economic study of fertilizer use is required.

### **2.11 Fertilizers used for Vegetable Production in Ghana**

According to Olaleye (2020), the importation of compound fertilizers into Ghana greatly exceeds that of straight fertilizers. Ammonium Sulphate (AS) and Muriate of Potash (MOP) are the second most important imported fertilizers (Rajitha, 2018; Kholkute, 2014). The quantities of urea, single super phosphate, and triple super phosphate fertilizers that are imported into Ghana are almost negligible. Addo *et al.* (2021) reported on a variety of conventional fertilizers, including NPK 15:15:15, NPK 20:20:0, Sulphate of Ammonia, and Urea, utilized for soil amendment in some of Ghana's most important tomato-growing regions. Cattle dung, sheep manure, and chicken manure are the most common types of manures utilized by farmers; among the three sources of manure, poultry manure has the highest concentration of essential plant-growth elements N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, CaO, and MgO. For good plant growth, poultry manure contains a high ratio of nitrogen and phosphorus. 30 percent of the nitrogen in poultry litter is in the form of urea or ammonium, making it readily available to crops roots (Haruna, 2011; Ashworth *et al.*, 2020).

Inorganic fertilizers significantly influence the growth, yield, and nutrient uptake of okro, also known as okra, by providing essential macro- and micronutrients directly to the plant. These fertilizers, typically containing nitrogen (N), phosphorus (P), and potassium (K), are critical for boosting agricultural productivity, particularly in soils with low fertility. However, their continuous or excessive application can lead to environmental

issues, soil degradation, and nutrient imbalances, necessitating integrated nutrient management approaches.

Studies have consistently shown that inorganic fertilizers can enhance various growth parameters in okro (Afrad *et al.*, 2021; Olaniyi *et al.*, 2010). For instance, the application of recommended doses of fertilizers, including NPK, has been observed to significantly increase plant height, number of leaves per plant, and leaf area. In one experiment, 100% of the recommended dose of fertilizers (RDF) combined with organic foliar spray significantly improved growth attributes and fruit yield. Another study highlighted that an application of 75% RDF + 25% N through neem oil cake resulted in maximum plant height (136.41 cm), number of leaves per plant (20.98), and leaf area (321.52 cm<sup>2</sup>) in okro. Similarly, the use of NPK 15:15:15 fertilizer at various rates, including 5g, 10g, and 15g, demonstrated positive effects on vegetative growth parameters such as shoot fresh weight, dry weight, plant height, leaf number, and stem girth (Uwuigbe, 2023).

The positive impact of inorganic fertilizers on okro yield is well-documented. Research indicates that the application of inorganic NPK fertilizers can lead to substantial increases in the number of pods per plant, pod length, pod girth, pod weight, and ultimately, the total fruit yield. For example, a combination of chemical and organic N fertilizers yielded the highest crop yield (7.08 t/ha/yr) in a study on purple farmland soil, surpassing the yields from organic N fertilizers (5.68 t/ha/yr) or chemical N fertilizers alone (6.41 t/ha/yr).

## **2.12 Effect of Fertilizer Elements on Fruit Quality**

### **2.12.1 Nitrogen**

According to Di-Vittori *et al.* (2018), excessive nitrogen at the pre-harvest stage can diminish fruit firmness. Produce that has been weakened by a high nitrogen concentration or mechanical damage is especially sensitive to postharvest infections (El-Ramady *et al.*, 2015).  $\text{NH}_4$ 's negative impacts on tomato output have frequently been linked to fruit rot at the blossom end (Hagassou *et al.*, 2019; Riboldi, 2018). Regarding fruit quality, an  $\text{NH}_4$  +-N-dominated nitrogen supply may significantly increase the incidence of blossom-end rot, an effect attributed to a suppression of calcium uptake by the increased external  $\text{NH}_4$  + concentrations (Weerasinghe *et al.*, 2013). Zhang *et al.* (2019) found that when the ammonium fraction was 0.25, total and fruit dry weight increased. Parisi *et al.* (2022) observed that a high nitrogen input (250 kg ha<sup>-1</sup>) reduced the pH, soluble solids, glucose and fructose contents, and the ratio of reducing sugars to total solids in tomato fruit. Incorporating a portion of nitrogen in the form of  $\text{NH}_4$ -N may improve fruit quality by raising the concentration of sugars and organic acids compared to nitrate-only (Petropoulos *et al.*, 2018). The addition of reduced nitrogen forms, such as ammonium or organic nitrogen, improves the flavor of tomato fruits (Halbert-Howard *et al.*, 2021).

### **2.12.2 Potassium**

Potassium improves fruit shape, minimizes ripening problems, and increases acid content (Sardans & Penuelas, 2021). (Raddatz *et al.*, 2020). Potassium promotes resistance to pests and diseases, as well as to drought and frost stressors. High potassium concentrations in tomato fruit induced the development of organic acids that limit calcium availability and cell membrane permeability. Potassium fertilization improves the color of fruit. Moreover, it raises the concentrations of citric and malic acids, total solids, sugars, and carotene in tomato fruits, hence enhancing their storage quality.

Potassium accumulates more than other dietary components, resulting in a high need for this mineral (Rawat *et al.*, 2016; Constan-Aguilar *et al.*, 2015). Potassium's antagonistic effect on the uptake of other nutrients, such as Ca, N, or Mg, is the primary cause for concern when potassium levels are increased in a nutritional solution. It has been found that a high K: Ca ratio increases blossom end rot (Wakeel, 2013). Potassium is also involved with carbohydrate chemistry, plant ionic balances, and fruit quality (Zorb *et al.*, 2014). Potassium provides resistance to pests and diseases, as well as drought and frost stressors (Wang *et al.*, 2013).

### **2.12.3 Calcium**

Shoulder check crack is another physiological issue that contributes to the loss of fruit quality. An increased calcium supply may lessen its incidence (Kumar *et al.*, 2021). In recent years, calcium has garnered a great deal of attention due to its beneficial benefits; in particular, it can delay ripening and senescence, reduce respiration, improve shelf life, increase firmness, and minimize physiological problems (Salahshoor & Guo, 2012). Calcium promotes fruit softening due to its critical role in cell wall formation and influence on cell membrane integrity. Hocking *et al.* (2016) discovered that calcium-based nutrition (calcium chloride) delayed the ripening of fruits (strawberries) and increased the fruit's firmness at harvest and during storage. Inadequate Calcium availability will boost the manufacture of carotenoids, the pigments responsible for the tomato's fruit color. Apple has been treated commercially with calcium to enhance its shelf life and minimize post-harvest problems (Gago *et al.*, 2016). Calcium is essential for preserving the structural and functional integrity of plant membranes, as well as for stabilizing cell walls, regulating ion transport and selectivity, and activating cell wall enzymes.

#### **2.12.4 Magnesium**

Magnesium, a significant component of cell walls, is essential for photosynthesis and, consequently, for plant life in general (O'Neill & York, 2018). Magnesium is not directly implicated in tomato fruit quality; however, in the case of severe magnesium insufficiency, fruit size and general appearance may be diminished (Martinez *et al.*, 2020). However, an increase in magnesium supply above the normal suggested levels may significantly increase the incidence of blossom end rot if it is not accompanied by a proportional increase in calcium supply. Magnesium appears to additionally stabilize the ribosomal particles in the configuration required for protein synthesis, and it is expected to have a similar stabilizing action in the nucleus matrix (Suh *et al.*, 2014; Costan *et al.*, 2020).

#### **2.12.5 Sulphur**

The application of sulphur in the form of several fertilizers (ammonium, sodium, potassium, and calcium sulphates) considerably improved the lycopene content of fruits and the red color of tomato homogenate in both cultivars. Although it had a very similar effect on the lycopene content of tomato fruits in both cultivars, the effect on plant growth and fruit yield was cultivar-dependent. Higher sulphur dose increased fruit yield in cultivar *ejk*, but lowered fruit output in cultivar *Proton* (Zelená *et al.*, 2009; Caruso *et al.*, 2019; Quansafi, 2022).

## **CHAPTER THREE: MATERIALS AND METHODS**

### **3.1 Experimental Site**

The major and minor season experiments was conducted at the Multipurpose Crop Nursery of the Crops and Soil Science Education Department, at the Mampong Campus of the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development in 2023. Asante Mampong is located within Ghana's transitional zone at 07°04'N, 01°24'W and its elevation is 457.5 m above sea level. The precipitation pattern is bimodal, described as major and minor rainy seasons. The major rainy season is usually occur between April and July, and the minor rainy season is from September and November (Freebairn & Zillman, 2002). The soils at the experimental site belongs to the Savannah Ochrosol type, which is part of the Bediesi series and are classified as Chromic Luvisol according to the FAO/UNESCO (1990) classification.

### **3.2 Experimental Design and Treatments Application**

The experimental design was a Randomized Complete Block Design (RCBD) with three (3) replications. The treatments are shown in Table 3.1. Each plot size measured 3 m x 3 m. The plant spacing of 50 cm x 50 cm was used. The okra variety used was Asontem, there were 36 plants per plot.

The land was both tilled and harrowed. The field was outlined, lined, and staked before planting was done. The experimental area was 27 by 9 meters in size (243 m<sup>2</sup>). The area was separated into three separate blocks. Each block was subdivided into nine plots, and 1 meter was left between the blocks and plots.

Table 3. 1: Treatment used in the study

| Treatment | Description  |
|-----------|--|
| 1.        | No fertilizer application (Control)  |
| 2.        | Yara Activa + No top-dressing + Hill placement   |
| 3.        | Yara Activa + No top-dressing + Side placement   |
| 4.        | Yara Activa + (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top-dressing + Hill placement    |
| 5.        | Yara Activa + (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top-dressing + Side placement    |
| 6.        | NPK (20-10-10) + No top-dressing + Hill placement  |
| 7.        | NPK (20-10-10) + No top-dressing + Side placement  |
| 8.        | NPK (20-10-10) + (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top-dressing + Hill placement |
| 9.        | NPK (20-10-10) + (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top-dressing + Side placement |

(NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>: Sulphate of ammonium (or Ammonium sulphate)

### 3.3 Land Preparation, Sowing and Management Practices

The land was ploughed and harrowed. Three seeds were sown and later thinned to 2 seedlings per stand one week after emergence.

Basal application of Yara Milla Activa (23-10-5 NPK+2MgO+3S +0.3Zn) and NPK (20-10-10) fertilizers was done at 7 days after planting directly onto the soil surface when the plants were actively growing.

. Yara Milla activa (23-10-5 NPK+2MgO+3S +0.3Zn) was applied at the recommended rate of 450kg per hectare while NPK (20-10-10) fertilizer was applied at the recommended rate of 500kg/ha (Haro, 2022). Top-dressing with Sulphate of ammonia (21N) was done at a rate of 250kg/ha (Maalekuu & Oponng-Sekyere, 2022).

**Top- dressing:** The fertilizers were applied directly onto the surface at the base of plants when the plants were actively growing.

**Hill placement:** Opening pockets were made around the base of a plant and fertilizers were placed in each pocket, which was then covered with soil.

**Side placement:** Fertilizers were placed using drills, and fertilizer were placed in furrows near the seed row during planting.

Weed control was primarily done by hand-hoeing. Occasionally, supplementary irrigation was done using rubber hose or watering can. Insect pests were controlled during the experimental period using Golan XL (ai-Acetamiprid 200g/L) at 5ml/20L of water and sprayed at each 2 weeks intervals as recommended by the manufacturer. Diseases were controlled with Copper Oxychloride (0.3%) fungicide at 3ml per litre of water using CP15 knapsack sprayer.

### **3.4 Data Collected**

#### **3.4.1 Initial Soil Analysis**

Initial soil samples were taken from a depth of 0-15 cm and 15-30 cm to assess the physical and chemical parameters of the soil prior to planting. The physical and chemical properties determined were the texture, pH, Electrical Conductivity (EC), Organic Carbon (OC), Nitrogen (N), Phosphorus (P) and Potassium (K).

#### **3.4.2 Phenology**

Phenological data included percentage plant establishment, days to 50% emergence, days to 50% flowering, and days to 50% podding. The 50% days to emergence, flowering and podding were determined when 50% of plants in the two central harvestable rows had emerged from the day of planting, produced at least one flower or one pod.

### **3.4.3 Growth Data**

#### **Plant height**

Plant height (*cm*) was measured from the soil level to the apical tip of three tagged plants from the two central rows per plot at 4 weeks after planting (WAP) and repeated at two weeks intervals.

#### **Stem Diameter**

Stem diameter (*cm*) was measured with a pair of Vernier caliper at from the substrate level of the three tagged plants from the two central rows of each plot at 4 weeks after planting and repeated at two weeks intervals.

#### **Number of Leaves Per Plant**

The number of leaves was determined by counting all fully opened leaves on three tagged plants from the two central rows per plant at 4 weeks after planting(4WAP) and repeated at two weeks intervals. The number of leaves per plant was obtained by dividing the total number of leaves by three.

#### **Number of Branches Per Plant**

The number of branches was determined by counting all branches on the three tagged plants from the central rows per plot at 4 WAP and dividing by three. This measurement was repeated at two weeks intervals.

**Plant Canopy Spread (cm)**The canopy width per plant was measured at the widest part of the canopy from the three tagged plants in the two central rows per plot at 4 weeks after planting(4WAP) and repeated at two weeks intervals.

### **Chlorophyll Content of leaf**

The chlorophyll content of the 5<sup>th</sup> leaf on the three tagged plants from the two central rows per plot was measured using chlorophyll meter (SPAD-502 meter) at 4 weeks after planting (4WAP) and was continued at two weeks intervals.

### **Dry Shoot Weight**

The dry shoot weight of two plants selected from the second and fifth rows per plot was determined from the 4<sup>th</sup> week to the 10<sup>th</sup> week after planting. The sampled plants were cut at ground level leaving the roots in the soil. The shoot made up of the stem, the branches and the leaves were then chopped into pieces, enveloped and dried in an oven at 80 degrees per Celsius for 72 hrs until constant weight was obtained.

### **3.4.4 Yield and Yield Components**

#### **Fruit Diameter (cm)**

The fruit diameter was measured from five (5) randomly sampled fruits per plot. A pair of calipers was used to measure the diameter at the center of the fruit.

#### **Fruit Length (cm)**

The fruit length was measured from five (5) randomly sampled fruits per treatment. A ruler was used to measure the length.

#### **Weight of Fruits Per Plot**

An electronic weighing scale was used to weigh all harvested fruits from the 2 central rows per plot.

### **3.4.5 Economic Benefit**

Partial budget analysis was carried out to determine the profitability of okra production under the various treatments. The Benefit:Cost ratio and Marginal Rate of Return (MRR) were used to determine the profitability of using the various treatments. The MRR was calculated using the formular:

$$\text{Marginal Rate of Raturrn (MRR)} = \frac{\text{Change in net benefit}}{\text{Change in total variable cost}} \times 100$$

### **3.4.6 Statistical Analysis**

The data collected were subjected to the Analysis of variance (ANOVA) using Genstat 15<sup>th</sup> Edition Statistical Package. The means that showed significant differences were separated at 5% probability rate using Tukey's Honestly Significant Difference (HSD) test.

## CHAPTER FOUR: RESULTS

### 4.1 Initial Soil Chemical and Physical Characteristics

Table 4.1 shows the chemical properties of the soil samples collected at depths of 0-15 cm and 15-30 cm for both major and minor season experiments. At a depth of 0-15 cm, organic carbon (OC) was relatively very low (Appendix 1), it measured 0.95% and 1.15% for major and minor seasons, respectively (Table 4.1). Organic matter (OM) was relatively high (Appendix 1) as it recorded 1.65% and 1.75% for major and minor seasons, respectively; and sodium (Na) was normal at 1.15 cmol/kg and 1.50 cmol/kg. The total nitrogen was also low (0.19% and 0.17% at the two respective depths), potassium (K) was also relatively low (0.52 cmol/kg and 0.45 cmol/kg at the two respectively depths) and phosphorus (P) was relatively very high (177.7 mg/kg and 160.24 mg/kg) (Table 4.1). However, the pH measured shows the soil was slightly acidic (5.1) for both seasons. Magnesium (Mg) was at moderate level (1.65 cmol/kg and 1.50 cmol/kg) when measured at the two depths.

At a depth of 15-30 cm, the organic carbon (OC) contents were 0.70% and 0.69% for the major and minor seasons, respectively. Organic matter (OM) content was high (Appendix 1) (1.24% and 1.20% for major and minor seasons, respectively), while sodium (Na) was normal (1.05 cmol/kg and 1.10 cmol/kg for major and minor seasons respectively) (Table 4.1). Total nitrogen content was measured at 0.17% and 0.22% for major and minor seasons respectively, potassium (K) content was low (0.41 cmol/kg and 0.40 cmol/kg for major and minor seasons respectively); magnesium (Mg) content was at moderate (2.56 cmol/kg and 1.95 cmol/kg); and phosphorus (P) was high (143.8 mg/kg and 142.8 mg/kg for major and minor seasons respectively). (Table 4.1 and Appendix 1). The soil was classified as Sandy loam for the top 0-15 cm for the two seasons.

Okra thrives best in well-drained loamy or sandy-loam soils. The optimal soil pH for okra growth typically ranges between 6.0 and 6.8. High organic matter content is crucial for soil health and okra productivity.

Table 4. 1:Initial Soil Chemical and Physical properties of the Experimental Locations.

| <b>Nutrient</b>     | <b>Major Rainy Season</b> |                 | <b>Minor Rainy Season</b> |                 |
|---------------------|---------------------------|-----------------|---------------------------|-----------------|
|                     | <b>0-15 cm</b>            | <b>15-30 cm</b> | <b>0-15 cm</b>            | <b>15-30 cm</b> |
| Organic Carbon (%)  | 0.95                      | 0.70            | 1.15                      | 0.69            |
| Organic Matter (%)  | 1.65                      | 1.24            | 1.75                      | 1.20            |
| Total nitrogen (%)  | 0.19                      | 0.17            | 0.17                      | 0.22            |
| K (cmol/kg)         | 0.52                      | 0.41            | 0.45                      | 0.40            |
| Na (cmol/kg)        | 1.15                      | 1.05            | 1.50                      | 1.10            |
| Mg (cmol/kg)        | 1.65                      | 2.56            | 1.50                      | 1.95            |
| Available P (mg/kg) | 177.65                    | 143.78          | 160.24                    | 142.80          |
| pH                  | 5.1                       | 4.9             | 5.1                       | 4.7             |
| Soil Texture        | Sandy Loam                | Clay Loam       | Sandy Loam                | Clay Loam       |

#### 4.2 Rainfall, Relative Humidity and Temperature

The rainfall and relative humidity measured during the experimental period for the major cropping season (March, 2023 to July, 2023) and the minor cropping season (August, 2023 to December, 2023) are shown in Table 4.2. During the major cropping season, 784 mm of rainfall was recorded from March, 2023 to July, 2023 with the highest peak in April. Mean monthly relative humidity of 90.4 % and 63.0% was recorded for 6:00 hrs and 15:00 hrs respectively. The average minimum and maximum temperature were 22.76 °C and 31.72 °C, respectively (Table 4.2).

During the minor cropping season, a total rainfall of 786.9 mm was recorded from August, 2023 to December, 2023 with the peak in October and August. However, no rainfall was recorded in December. The average relative humidity for 6: 00 hrs and 15:00

hrs was 88.0% and 61.6% respectively from August, 2023 to December, 2023 (Table 4.2). The mean minimum and maximum temperature were 22.82 and 31.84, respectively (Table 4.2).

Optimal growth of okra typically occurs in warm environments. Research indicates that ideal temperatures for okra range from 25°C to 35°C 4. Elevated temperatures, especially during critical growth stages, can negatively impact physiological processes and reproductive traits in plants, potentially leading to reduced yield 6. For instance, high day/night temperatures above 35/17°C.

Table 4. 2: Climatic Data for the major and minor cropping seasons of 2023

| Month                     | Total Rainfall (mm) | Mean Relative Humidity (%) |          | Monthly Temperature (°C) |      |      |
|---------------------------|---------------------|----------------------------|----------|--------------------------|------|------|
|                           |                     | 6:00 hrs                   | 15:00hrs | Min                      | Max  | Mean |
| <b>Major Rainy Season</b> |                     |                            |          |                          |      |      |
| Mar                       | 57.8                | 88                         | 55       | 23.1                     | 33.8 | 28.5 |
| Apr                       | 258.8               | 91                         | 59       | 22.7                     | 33.3 | 28.0 |
| May                       | 71.3                | 90                         | 60       | 23.2                     | 32.8 | 28.0 |
| Jun                       | 198                 | 92                         | 70       | 23                       | 30.3 | 26.7 |
| Jul                       | 198.9               | 91                         | 71       | 21.8                     | 28.4 | 25.1 |
| <b>Total</b>              | <b>784.8</b>        |                            |          |                          |      |      |
| <b>Mean</b>               |                     | 90.4                       | 63       | 22.8                     | 31.7 | 27.3 |
| <b>Minor Rainy Season</b> |                     |                            |          |                          |      |      |
| Aug                       | 213.4               | 93                         | 74       | 22.5                     | 29   | 25.8 |
| Sep                       | 196                 | 92                         | 69       | 22.4                     | 30.6 | 26.5 |
| Oct                       | 286.4               | 90                         | 62       | 23                       | 32   | 27.5 |
| Nov                       | 91.1                | 91                         | 59       | 23.5                     | 33.1 | 28.3 |
| Dec                       | 0                   | 74                         | 44       | 22.7                     | 34.5 | 28.6 |
| <b>Total</b>              | <b>786.9</b>        |                            |          |                          |      |      |
| <b>Mean</b>               |                     | 88                         | 61.6     | 22.8                     | 31.8 | 27.3 |

### **4.3 Phenology of Okra**

#### **4.3.1 Days to 50% Emergence**

The results of days to 50% emergence for both the major and minor seasons are presented in Table 4.3. On the average days to 50% emergence ranged from 5-7 days for both seasons. Different fertilizer types, top-dressing and fertilizer placement did not significantly affect days to 50% emergence in both seasons (Table 4.3).

#### **4.3.2 Days to 50% Flowering**

The results of days to 50% flowering for both major and minor seasons are presented in Table 4.3. On the average days to 50% flowering ranged from 56-61 days and 56-62 days for the major and minor seasons, respectively. Different fertiliser types, top dressing and fertiliser placement significantly ( $P < 0.05$ ) affected days to 50% flowering during both seasons. During the major season, NPK (20-10-10) + No top-dressing + Hill placement recorded the highest number of days to 50% flowering (61 days) which was significantly different ( $P > 0.05$ ) from NPK + Top-dressing Hill placement (56 days) (Table 4.3). During the minor season, the longest period taken for 50% flowering was observed in the plants treated with Yara Activa + Top-dressing + Hill placement (62 days) which was significantly different ( $P < 0.05$ ) from Yara Milla Activa + Top dressing + Hill Placement which took fewer (56) days and the control plants also took 57 days to attain 50% flowering (Table 4.3). Days to 50% flowering was not significantly ( $P > 0.05$ ) affected the different seasons as indicated in Table 4.3.

Table 4. 3: Effect of different fertilizer types, top-dressing and fertilizer placement on days to 50% emergence and days to 50% flowering in the major and minor cropping seasons in 2023

| Treatment   | Days to 50% Emergence |              | Days to 50% Flowering |              |
|---|-----------------------|--------------|-----------------------|--------------|
|   | Major Season          | Minor Season | Major Season          | Minor Season |
| No fertilizer(control)  | 6                     | 5            | 60                    | 61           |
| Yara Activa + No top dressing + Hill placement  | 6                     | 6            | 58                    | 58           |
| Yara Activa +No Top dressing + Hill placement   | 5                     | 5            | 58                    | 56           |
| Yara Activa +(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top dressing + Hill placement    | 5                     | 6            | 58                    | 62           |
| Yara Activa+(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> + Side placement                  | 7                     | 6            | 60                    | 60           |
| NPK (20-10-10) + No top dressing +Hill placement  | 6                     | 7            | 61                    | 59           |
| NPK (20-10-10) + No top-dressing + Side placement   | 6                     | 6            | 57                    | 57           |
| NPK(20-10-10) + (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top dressing + Hill placement | 5                     | 6            | 60                    | 58           |
| NPK(20-10-10)+ (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top dressing + Side placement  | 5                     | 5            | 56                    | 60           |
| HSD (0.05)  | NS                    | NS           | 4.28                  | 5.47         |
| CV (%)  | 11.63                 | 15.52        | 2.48                  | 3.22         |
| Seasonal (HSD=0.05)<br>× Season (HSD=0.05)  |                       | NS           |                       | NS           |

*HSD= Fisher's Least significant difference (P>0.05) difference (5%), CV (%)= coefficient of variation, NS= Not significant*

### 4.3.3 Days to 50% Podding

Days to 50% podding for both major and minor seasons are presented in Table 4.4. Different fertiliser types, top dressing and fertiliser placement did not significantly ( $P>0.05$ ) affect days to 50% podding during the major cropping season, but significantly ( $P<0.05$ ) affected days to 50% podding during minor season (Table 4.4). During the minor cropping season, days to 50% podding for NPK (20-10-10) + No top-dressing + Side placement podded late (75 days) and this was significantly ( $P<0.05$ ) different from the Yara Mila Activa + Top dressing + Hill Placement which took only 69 days to pod after sowing (Table 4.4). Thus, the Yara Milla Activa + Top dressing + Hill Placement resulted in early fruiting of the plants, preferable trait in vegetable.

Table 4. 4: Effect of different fertilizer types, top-dressing and fertilizer placement on Days to 50% podding in the major and minor cropping seasons in 2023

| Treatment  | Days to 50% Podding |              |
|--|---------------------|--------------|
|  | Major Season        | Minor Season |
| No fertilizer(control)   | 72                  | 74           |
| Yara Activa + No top dressing + Hill placement   | 73                  | 74           |
| Yara Activa + No Top dressing + Side placement   | 73                  | 69           |
| Yara Activa + (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top dressing + Hill placement    | 72                  | 73           |
| Yara Activa + (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> + Side placement                 | 73                  | 74           |
| NPK (20-10-10) + No top dressing +Hill placement   | 72                  | 71           |
| NPK (20-10-10) + No top-dressing + Side placement  | 70                  | 75           |
| NPK (20-10-10) + (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top dressing + Hill placement | 74                  | 70           |
| NPK (20-10-10) + (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top dressing + Side placement | 71                  | 73           |
| HSD (0.05)   | NS                  | 5.61         |
| CV (%)   | 2.76                | 2.66         |

Seasonal (HSD=0.05) =

× Season (HSD=0.05) =

*HSD= Fisher's Least significant difference ( $P>0.05$ ) difference (5%), CV (%) = coefficient of variation, NS= Not significant*

## 4.4 Growth of Okra

### 4.4.1 Plant Height

The results of plant height for both the major and minor seasons are presented in Figure 4.1. Different fertiliser types, top dressing and fertiliser placement significantly ( $P < 0.05$ ) affected plant height of okra at 4 to 10 WAP during both major and minor rainy seasons, except at 6 WAP during the minor season.

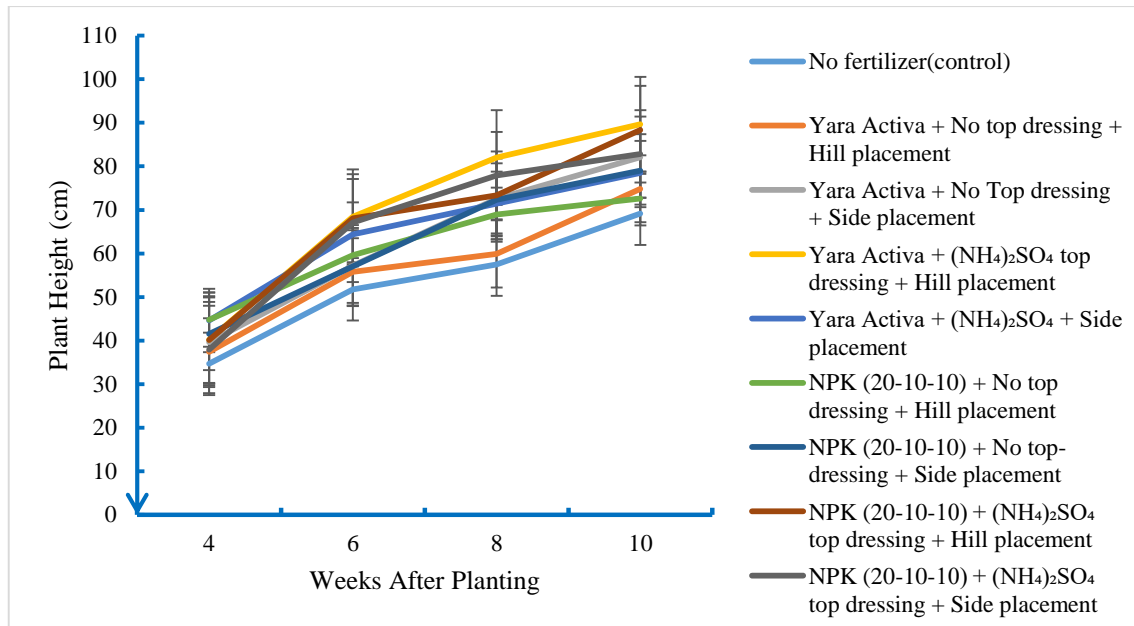
During the major season, the tallest plants were recorded on Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  Top dressing Hill placement from 6 to 10 WAP, while the control plants (no fertilizer) were the shortest plants. At 4 WAP, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top dressing + hill placement plants were 44.78 cm tall, followed by Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement plants (44.62 cm), followed by NPK (20-10-10) + No top-dressing + Side placement (41.56 cm) and NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (40.11 cm), which were all significantly ( $P < 0.05$ ) taller than the plants treated with NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement and No fertilizer (control) (37.96 cm and 34.66 cm respectively) (Figure 4.1a). At 6 WAP, during the major season, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement produced the tallest plants at 68.41 cm, followed by NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (68.09 cm), which were all significantly ( $P > 0.05$ ) taller than the plants from the control plants, the Yara Activa + No top-dressing + Hill placement, Yara Milla Activa + Top dressing + Hill Placement and the NPK (20-10-10) + No top-dressing + Side placement which were 51.76 cm, 55.79 cm, 57.20 cm and 57.00 cm, respectively (Figure 4.1a). At 8 WAP, during the major cropping season, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement also produced the tallest plants again (82.00 cm) tall, followed

by the NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing (52.9 cm) + Side placement treated plants (72.9 cm), followed by NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing (54.3) + Hill placement treatment (73.83 cm) which were both significantly ( $P>0.05$ ) taller than the control plants (57.46 cm), Yara Activa + No top-dressing + Hill placement treated plants (59.90 cm) and Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement treated plants (71.47 cm) (Figure 4.1a). The Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement at 10 WAP, again produced the tallest plants (89.67 cm), which was followed by NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement plants (88.36 cm), and these were significantly ( $P<0.05$ ) taller the control plants (69.12 cm), the Yara Activa + No top-dressing + Hill placement treated plants (74.84 cm), NPK (20-10-10) + No top-dressing + Hill placement treatment (76.80 cm) and NPK (20-10-10) + No top-dressing + Side placement (61.06 cm) (Figure 4.1a).

During the minor season, the tallest plants were recorded on NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  Top dressing Hill placement while the shortest plants were recorded on NPK (20-10-10) + No top-dressing Side placement (Figure 4.1b). At 4 WAP, NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement as 61.33 cm followed by YaraMilla Activa + Top dressing + Hill Placement which recorded 61.03 cm which were significantly ( $P>0.05$ ) taller than the plants from the control plots (52.99 CM) and NPK (20-10-10) + No top-dressing + Hill placement (54.36 CM) (Figure 4.1b). At 8 WAP, a similar trend observed during the major season continued, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement treatment produced the tallest plants again (85.09 cm) followed by NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement which were averagely 85.91 cm tall which were significantly ( $P<0.05$ ) taller than the plants from the NPK (20-10-10) +

No top-dressing + Side placement (53.54 cm) (Figure 4.1b). The NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top dressing + Hill placement had the tallest plants (90.3 cm) at 10 WAP, followed by Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  Top dressing Hill placement (84.67 cm) which were highly significant ( $P>0.05$ ) from No fertilizer (control) (77.29 cm), Yara Activa+ $(\text{NH}_4)_2\text{SO}_4$  +Side placement (82.02 cm) and Yara Activa + No Top dressing +Hill placement (80.02 cm) (Figure 4.1b).

(a) Major Season



(B) Minor Season

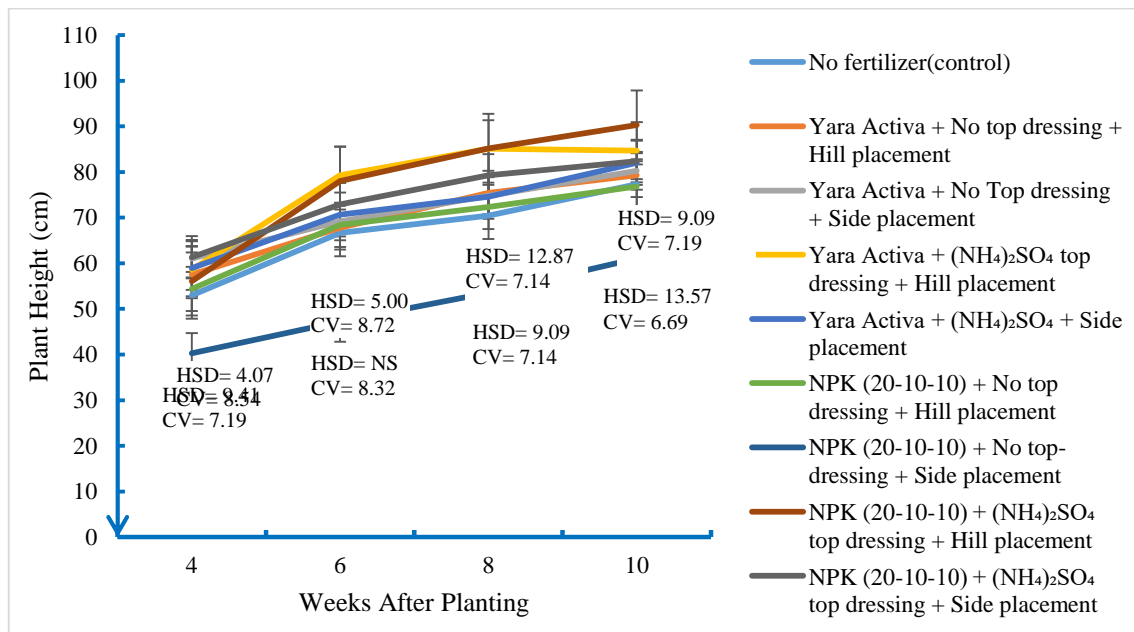


Figure 4. 1: Effect of different fertilizer types, top-dressing and fertilizer placement on plant height in the major (a) and minor (b) cropping seasons in 2023

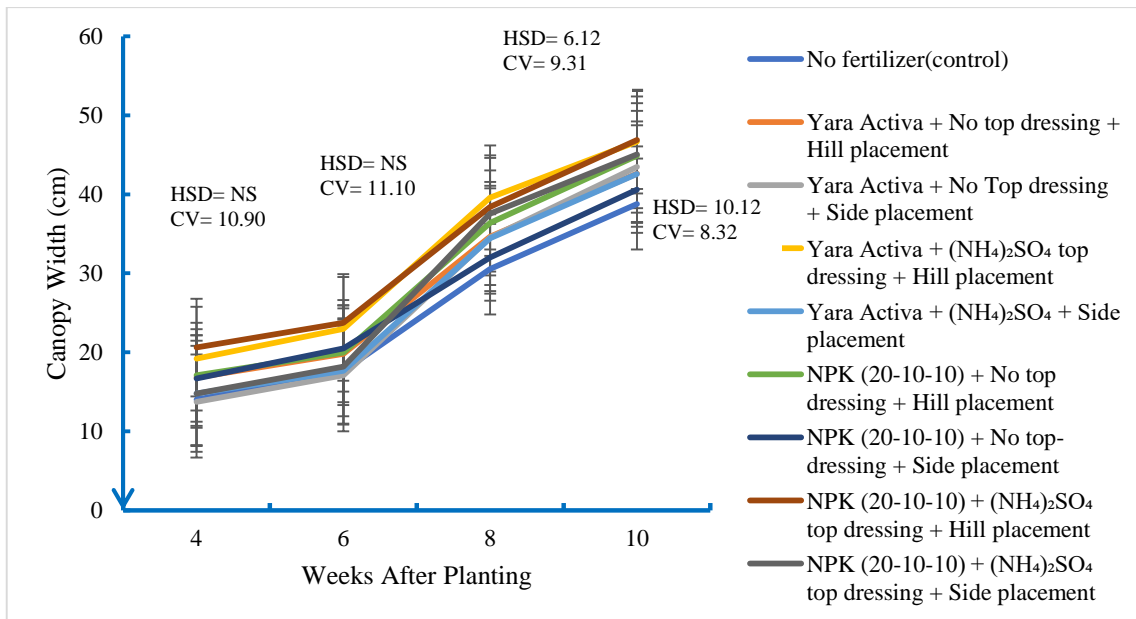
#### 4.4.2 Canopy Width

The results of canopy width for both the major and minor seasons are presented in Figure 4.2 respectively. Different fertiliser types, top dressing and fertiliser placement significantly ( $P < 0.05$ ) affected canopy width of okra at 4 to 10 WAP during both major and minor rainy seasons, except at 4 and 6 WAP during the major season. During the major season, the widest canopy was recorded on plants treated with Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  Top dressing + Hill placement at 4 and 8 WAP, NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top dressing + Hill placement at 6 and 10 WAP (Fig. 4.2a). At 8 WAP, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement gave the widest canopy as 39.60 cm, followed by NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (38.41 cm), followed by NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement (37.56 cm) which were significantly ( $P < 0.05$ ) wider than the canopies of plants under the control plots (No fertilizer) and NPK (20-10-10) + No top-dressing + Side placement treated plants. At 10 WAP, NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement treated plants had the widest canopy (46.89 cm), followed by Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement treatment (46.68 cm) which were significantly ( $P < 0.05$ ) wider than the canopies of the control plants (38.77 cm) (Fig. 4.2a).

During the minor season, the widest canopy, at 4 WAP, was recorded on plants treated with Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (49.08 cm) followed by the NPK (20-10-10) + No top-dressing + Hill placement and NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement treatments with 48.26 cm and 48.05 cm respectively, which were statistically ( $P < 0.05$ ) from T1 (42.38 cm), Yara Milla Activa + Top dressing + Hill Placement (40.24 cm) and NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement

(40.60 cm) (Fig. 4.2b). At 6 WAP, during the minor season, the widest canopy was recorded on plants treated with NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (55.49 cm) followed by NPK (20-10-10) + No top-dressing + Hill placement and Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (49.24 cm) and (48.02 cm) respectively, which were statistically ( $P < 0.05$ ) wider than the control plants (43.17 cm) and the Yara Activa + No top-dressing + Hill placement treated plants (44.73 cm) (Fig. 4.2b). At 8 WAP, during the minor season, a similar trend observed during the major season continued, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement recorded the widest canopy again as 69.99 cm followed by NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement which recorded canopy width of 69.99, followed by NPK (20-10-10 SOA top-dressing + Hill placement which recorded canopy width of 67.95 cm which were highly significant ( $P > 0.05$ ) from Yara Milla Activa + Top dressing + Hill Placement recording a canopy width of 58.54 cm and NPK (20-10-10) + No top-dressing + Side placement which also had 51.90 cm (Fig. 4.2b).

(a) Major Season



(b) Minor Season

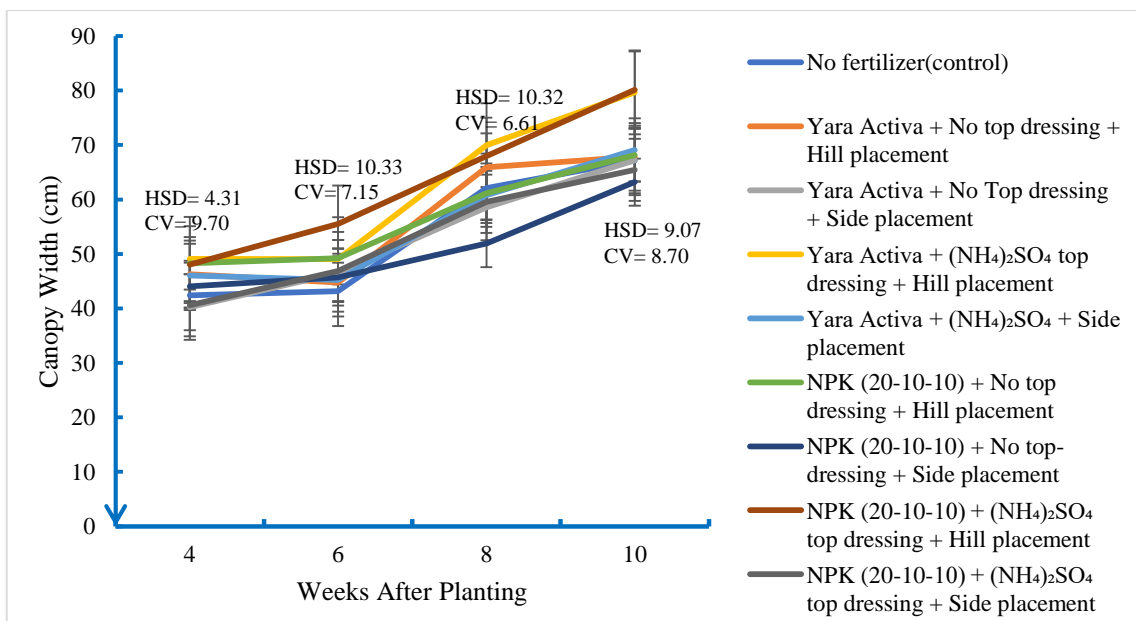


Figure 4. 2: Effect of different fertilizer types, top-dressing and fertilizer placement on canopy width in the major (a) and minor (b) cropping seasons in 2023

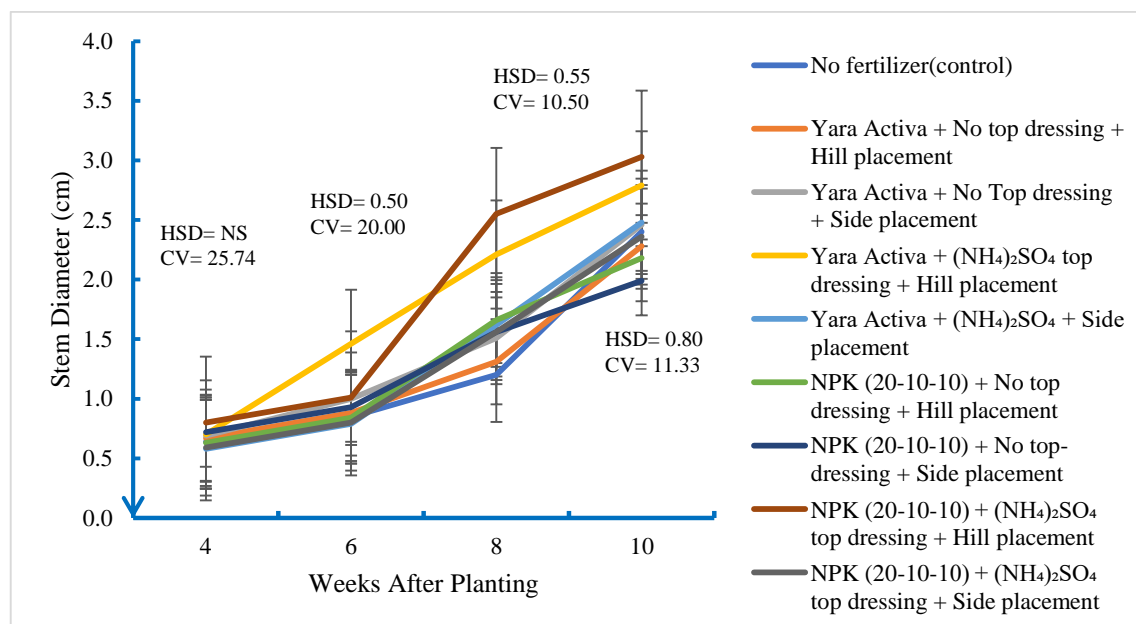
#### 4.4.3 Stem Diameter

The results of stem diameter during major and minor cropping seasons are presented in Figure 4.3. Different fertiliser types, top dressing and fertilizer placement method significantly ( $P < 0.05$ ) influenced stem diameter from 6 WAP to 10 WAP at in seasons, except at 6 WAP during the minor season.

In the major cropping season, NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  Top dressing + Hill placement method resulted in the largest stem diameter from 8 to 10 WAP, while No fertilizer (control) and NPK (20-10-10) + No top dressing + Hill placement treatments produced smaller stem diameter at 8 and 10 WAP, respectively (Figure 4.3a). At 6 WAP, during the major cropping season, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement gave the highest stem diameter of 1.46 cm, followed by NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (1.01 cm) and these were significantly ( $P > 0.05$ ) different from plants treated with Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement (0.7 cm), NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement (0.80 cm) and no fertilizer (control) (0.85 cm) (Figure 4.3a). At 8 WAP, NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement led to the widest stem diameter (2.55 cm), followed by Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (2.21 cm), which were significantly ( $P > 0.05$ ) different from no fertilizer (control) (1.20 cm) and Yara Activa + No top-dressing + Hill placement (1.31 cm). At 10 WAP, NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement gave the widest stem diameter (3.03 cm), followed by Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (2.79 cm), which were significantly ( $P > 0.05$ ) different from NPK (20-10-10) + No top-dressing + Side placement (1.97 cm) (Figure 4.3a).

In the minor season experiment, at 8 WAP, NPK (20-10-10) + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Hill placement treated plants had the widest stem diameter (3.10 cm) and this was significant (P>0.05) greater than plants from the control plots (1.9 cm). Yara Activa + No top-dressing + Hill placement (1.76 cm) and NPK (20-10-10) + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Side placement (2.0 cm) (Figure 4.3b).

(a) Major Season



(b) Minor Season

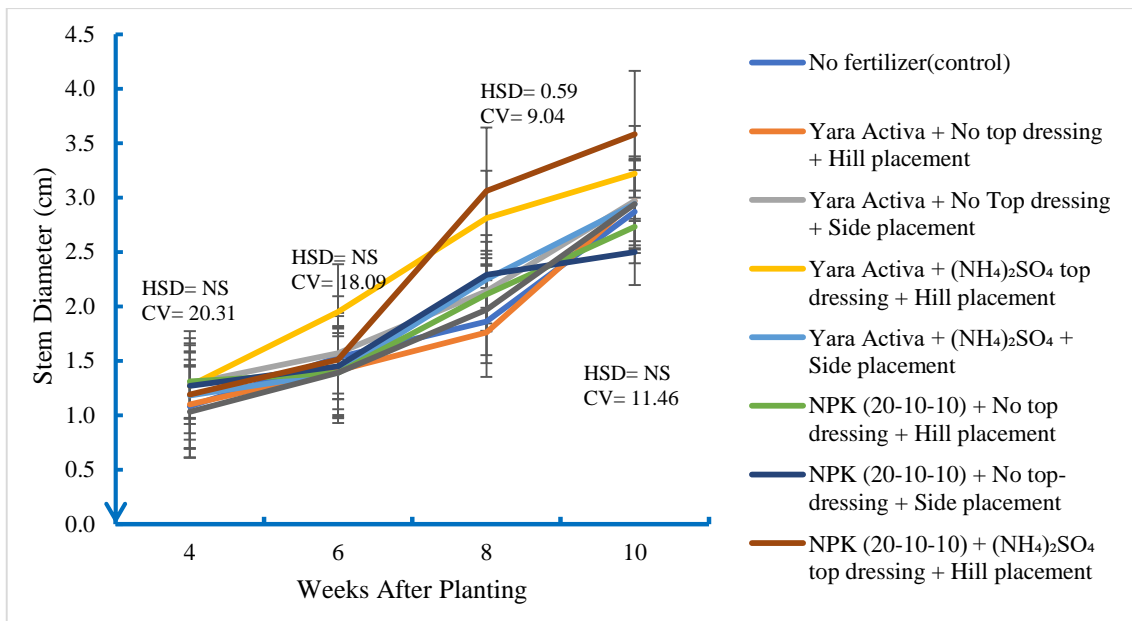


Figure 4. 3: Effect of different fertilizer types, top-dressing and fertilizer placement on stem diameter in the major (a) and minor (b) cropping seasons in 2023

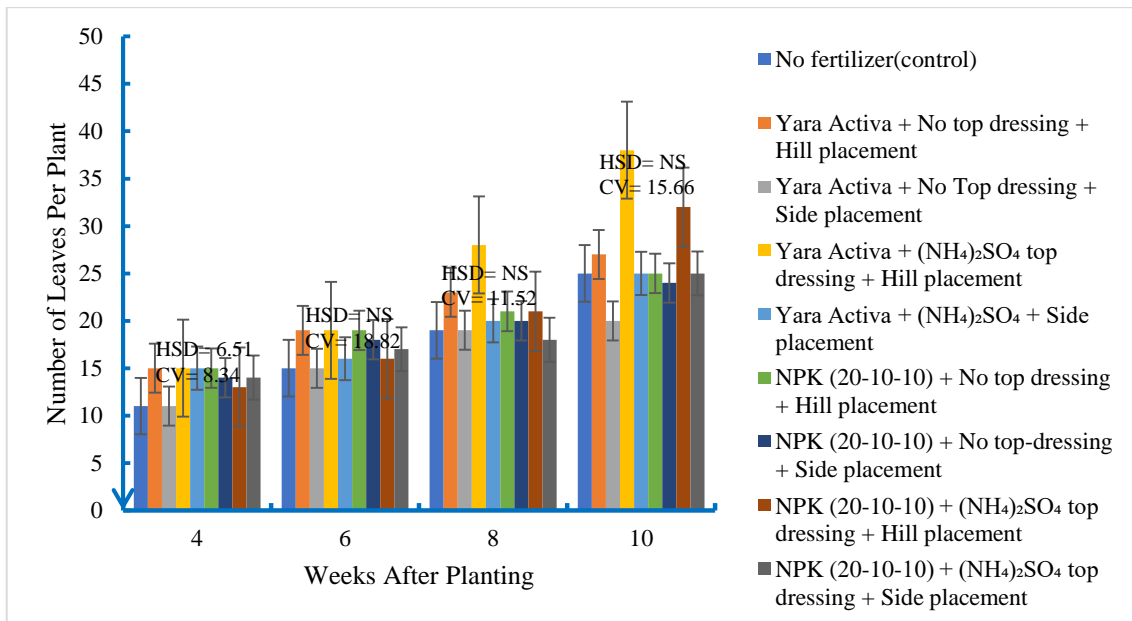
#### 4.4.4 Number of Leaves Per Plant

The results of number of leaves during major and minor cropping are presented in Figure 4.4. Different fertiliser types, top dressing and fertilizer placement did not significantly ( $P>0.05$ ) influence number of leaves from 4 to 6 WAP during both seasons and also at 8 WAP during the major season experiment, but significantly ( $P>0.05$ ) influence number of leaves at only 8 WAP during the minor season at 10 WAP during both seasons (Figure 4.4a).

In the major cropping season, plants treated with Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement method produced the highest number of leaves (34 leaves/plant) at 10 WAP. The NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement plants produced 32 leaves per plant which was significantly ( $P>0.05$ ) more than the plants from control plots (25 leaves per plant). However, during the minor season experiment, the NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement treated plants gave the highest number of leaves (33 leaves per plant), followed Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (29 leaves per plant) which were highly ( $P>0.05$ ) greater than those from the control plots (18 leaves per plant) (Fig. 4.4a).

In the minor season, at 8 WAP, the NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement treated plants produced averagely 29 leaves per plant as the highest number of leaves which was significantly ( $P>0.05$ ) more than control plants which produced on the average, 17 leaves per plant (Fig. 4.4b).

(a) Major Season



(b) Minor Season

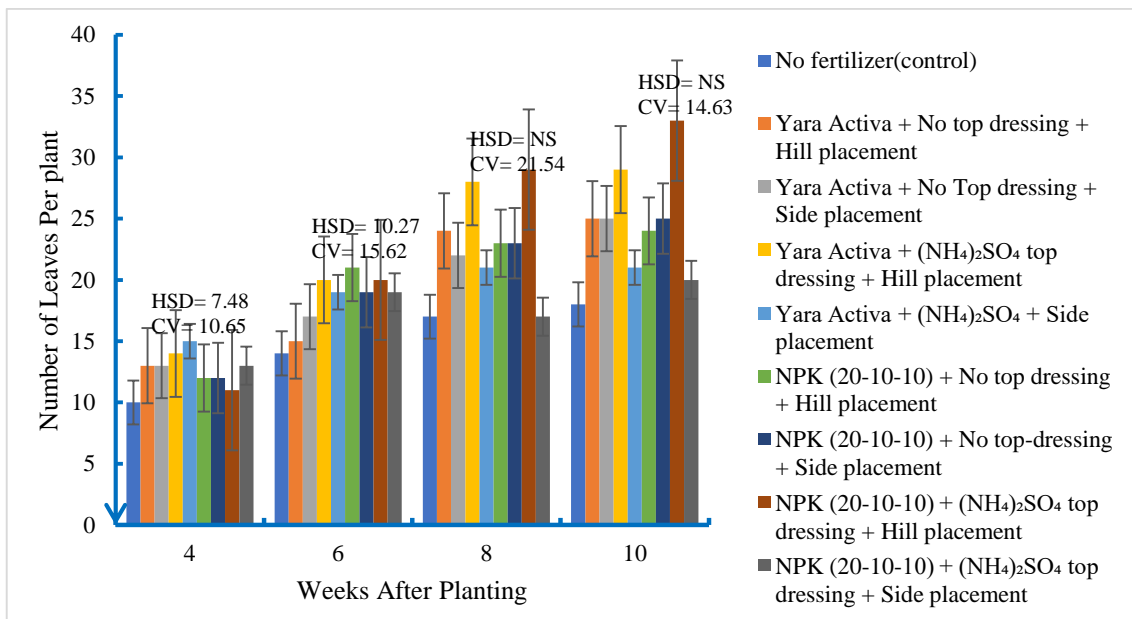


Figure 4. 4: Effect of different fertilizer types, top-dressing and fertilizer placement on number of leaves per plant in the major (a) and minor (b) cropping season in 2023

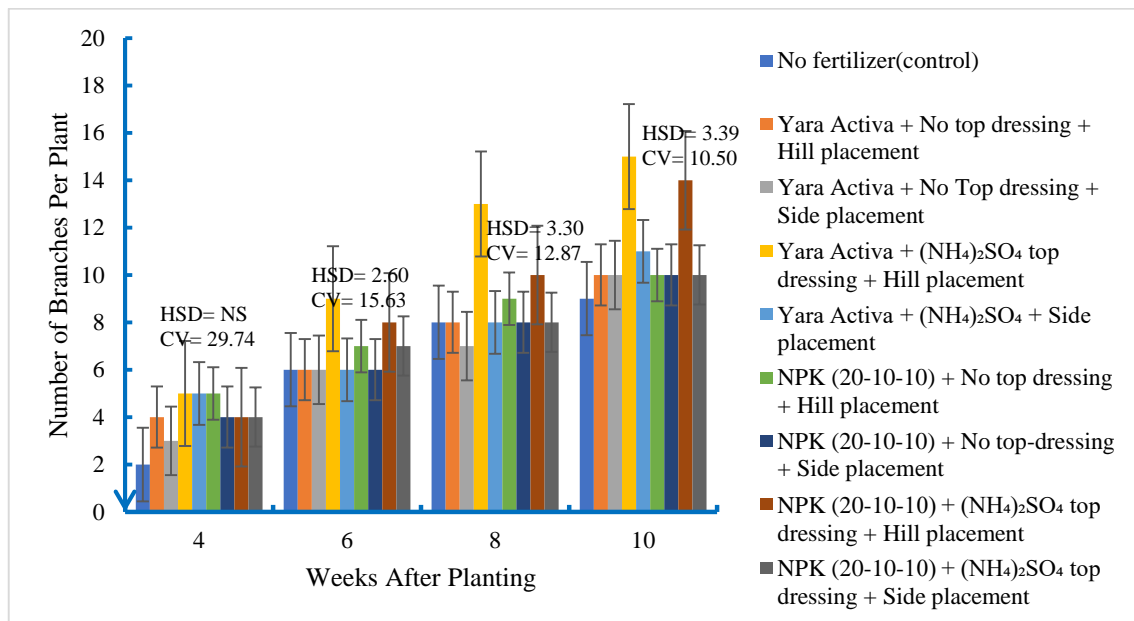
#### 4.4.5 Number of Branches Per Plant

The results of number of branches per plant during major and minor cropping season experiments are presented in Figure 4.5. Different fertilizer types, top dressing and fertilizer placement did not significantly ( $P>0.05$ ) influence number of leaves during 4 WAP at both seasons, during only minor season at 6 and 8 WAP, except during the major season at 6 WAP and 8 WAP, and at both seasons during 10 WAP (Figure 4.5).

In the major seasons, at 6 WAP, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement recorded 9 branches as the highest number of branches which was significantly ( $P>0.05$ ) different from no fertilizer (control), Yara Activa + No top-dressing + Hill placement, Yara Mila Activa + Top dressing + Hill Placement, and NPK (20-10-10) + No top-dressing + Side placement which all recorded 6 branches at 6 WAP (Figure 4.5a). At 8 WAP, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement recorded 13 branches which was highly significant ( $P>0.05$ ) from Yara Mila Activa + Top dressing + Hill Placement (7 branches) all the other treatments apart from NPK (20-10-10) + No top-dressing + Hill placement (9 branches) and NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (10 branches) (Figure 4.5a). At 10 WAP, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement again recorded the highest number of branches as 15 branches, followed by NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (14 branches) which was significantly ( $P>0.05$ ) different from T1 (9 branches) (Figure 4.5a).

In the minor season, at 10 WAP, NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement rather recorded the highest number of branches as 14, followed by Yara Mila Activa + Top dressing + Hill Placement (12 branches) and Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (12 branches) (Figure 4.5b).

(a) Major Season



(b) Minor Season

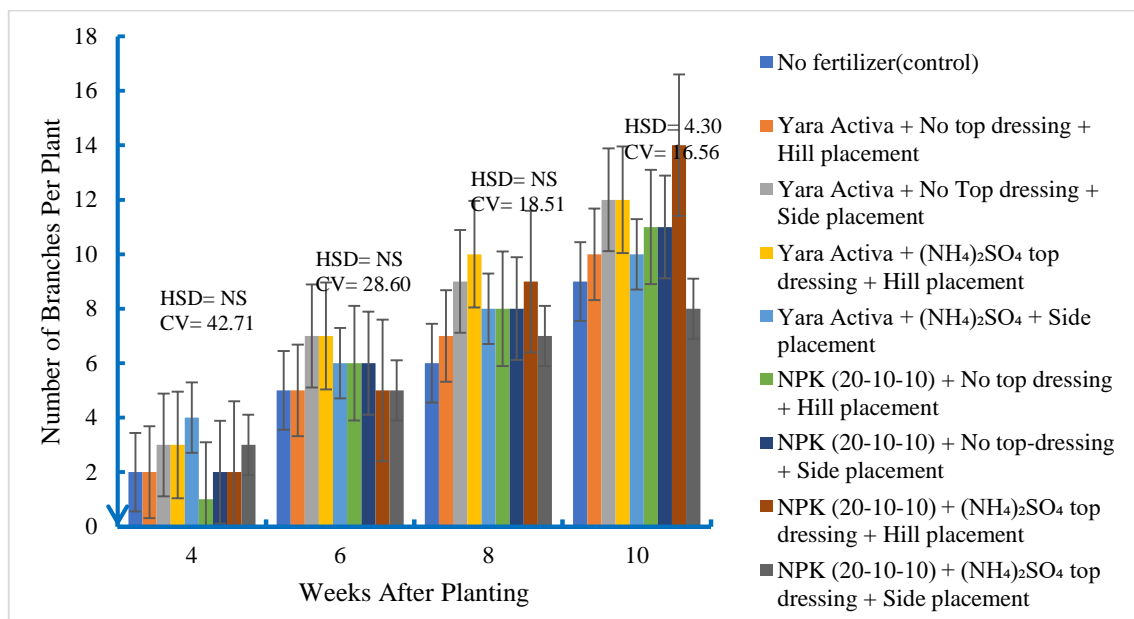


Figure 4. 5: Effect of different fertilizer types, top-dressing and fertilizer placement on number of branches per plant in the major (a) and minor (b) cropping season in 2023

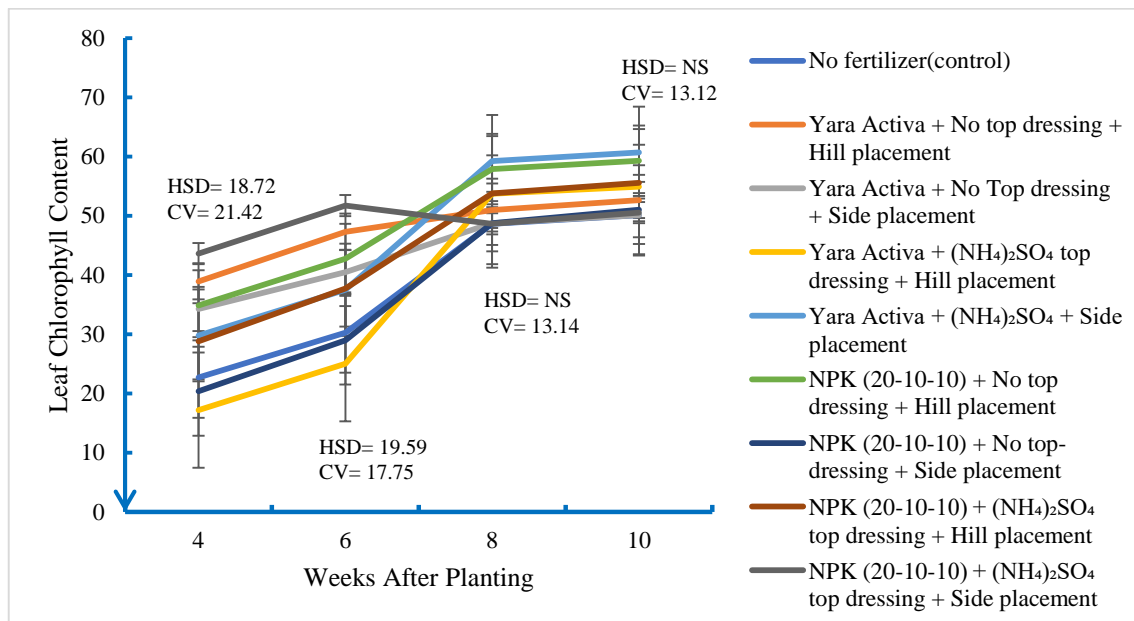
#### 4.4.6 Chlorophyll Content of Leaf

The results of chlorophyll content as influenced by fertiliser types, top-dressing and fertilizer placement during the major and minor cropping in season is presented in Figure 4.6. Different fertilizer types, top dressing and fertilizer placement did not significantly ( $P>0.05$ ) influence number of leaves at 4 WAP at the minor seasons, during both seasons at 8 WAP and during only major season at 10 WAP, but significant ( $P>0.05$ ) differences were observed at 4 WAP during the major season and 10 WAP during the minor season (Fig. 4.6).

In the major season, 6 WAP during both the major and minor seasons, chlorophyll content was higher in NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement (43.60, 51.73 and 51.32, respectively), which was significantly ( $P>0.05$ ) different from that of Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (17.20 at 4 WAP, 25.03 at 6 WAP in the major seasons and no fertilizer (control) (42.32) (Fig. 4.6a).

In the minor seasons, at 10 WAP, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement rather during the minor season recorded the highest chlorophyll content (58.70) and the least was recorded on NPK (20-10-10) + No top-dressing + Hill placement as 43.66 (Figure 4.6b).

(a) Major Season



(b) Minor Season

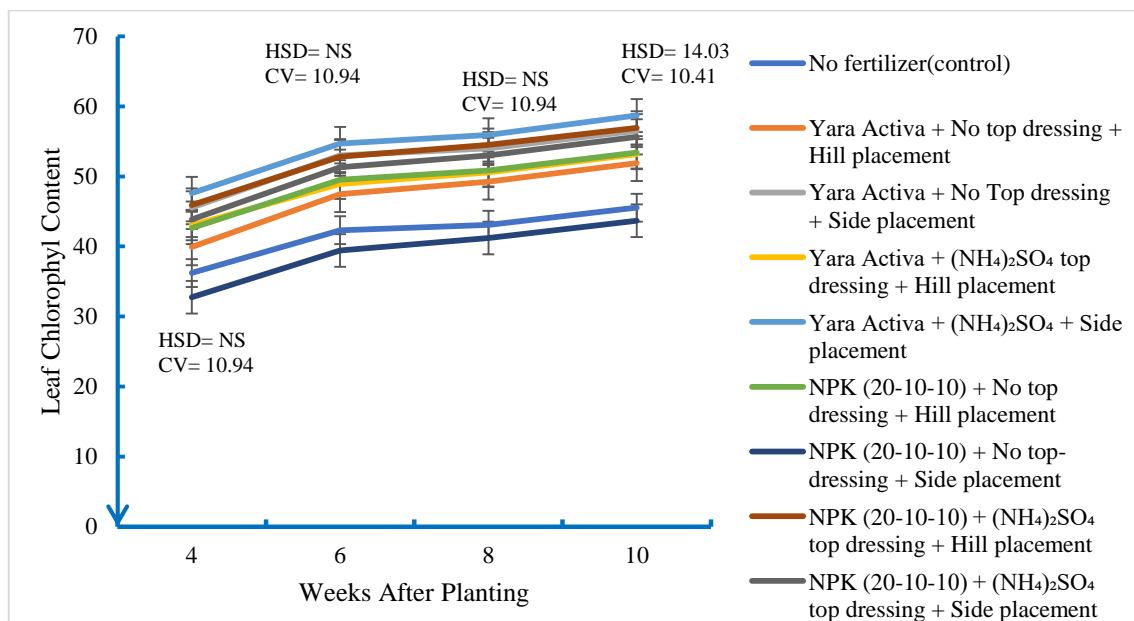


Figure 4. 6: Effect of different fertilizer types, top-dressing and fertilizer placement on leaf chlorophyll content in the major (a) and minor (b) cropping season in 2023

#### 4.4.7 Dry Shoot Weight

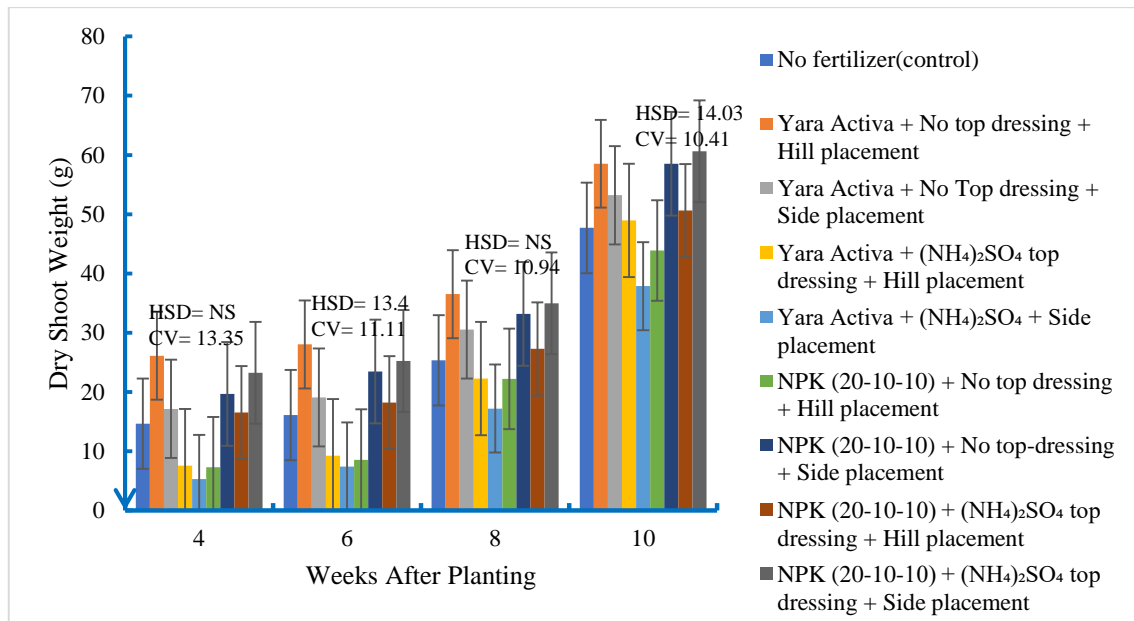
The results of dry shoot weight of okra as influenced by fertiliser type, top-dressing, and fertiliser placement during both major and minor raining season is presented in Figure 4.7. There were significant ( $P < 0.05$ ) differences in dry shoot weight as influenced by the different treatments at 4 to 10 WAP during the major season, but no significant ( $P > 0.05$ ) differences in dry shoot weight were observed at 4 to 10 WAP during the minor season (Figure 4.7)

In the major season, at 4 WAP, the greatest dry shoot was recorded from plots treated with Yara Activa + No top-dressing + Hill placement as 26.11 grammes, followed by NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + SideRow placement which also recorded 23.23 g which were all statistically significant ( $P < 0.05$ ) from the dry shoot weight recorded on Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (7.53 g), and Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement which (5.30 g) (Figure 4.7a) (Figure 4.7a). At 6 WAP, Yara Activa + No top-dressing + Hill placement again had their greatest shoots as greatest shoot weight (26.11 g), followed by NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement (25.23 g), which were all statistically significant ( $P > 0.05$ ) from the dry shoot weight recorded on Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement (7.41 g) and NPK (20-10-10) + No top-dressing + Hill placement (8.55 g) which as the lightest shoot weight. At 8 WAP, Yara Activa + No top-dressing + Hill placement gave the greatest shoots (36.51 g) which was followed by NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement which also recorded 34.97 g which were statistically different from all the other treatment, whereas the lightest weight was observed on Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (22.26 g) (Figure

4.7a). At 10 WAP during the major season. During the major rainy season, the heaviest dry shoot was recorded again on NPK (20-10-10) + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Side placement as (60.63 g), followed by Yara Activa + No top-dressing + Hill placement and NPK (20-10-10) + No top-dressing + Side placement which recorded dry shoot weight of 58.51 g and the lightest weight was recorded on NPK (20-10-10) + No top-dressing + Hill placement as 43.85 g (Figure 4.7a).

In the minor season, at 6 WAP, Yara Activa + No top dressing +Hill placement recorded the heaviest dry shoot (25.9 g), which was significant from NPK (20-10-10) +No top dressing +Hill placement (13.1 g) (Figure 4.7b).

(a) Major Season



(b) Minor Season

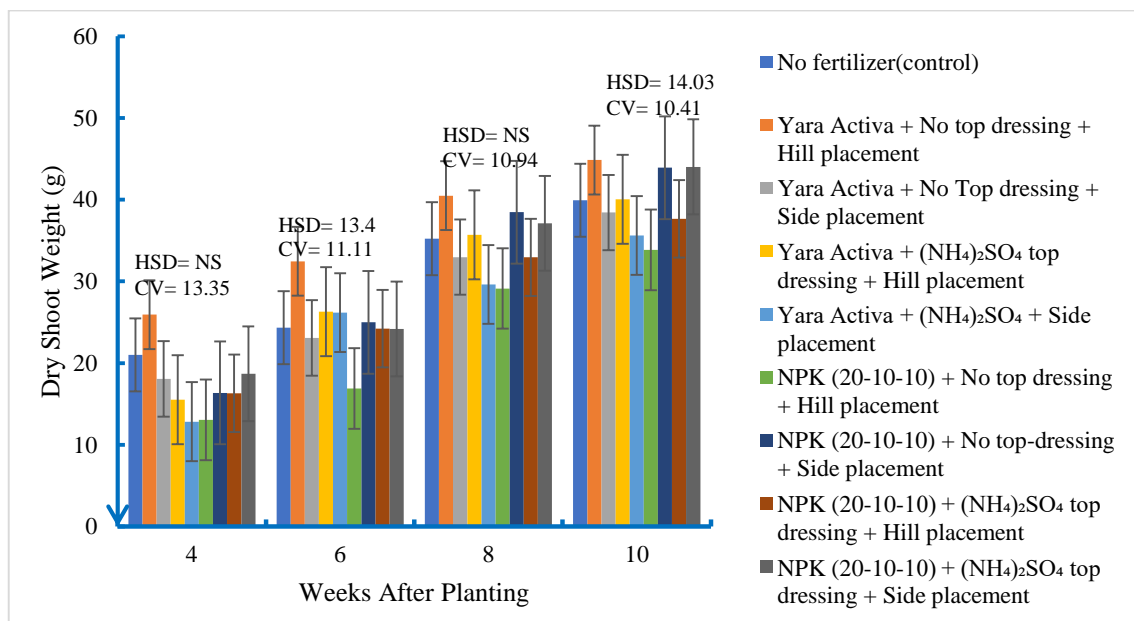


Figure 4. 7: Effect of different fertilizer types, top-dressing and fertilizer placement method on dry shoot weight on dry shoot weight in the major (a) and minor (b) cropping season in 2023

## **4.5 Yield and Yield Components**

### **4.5.1 Fruit Diameter**

The results of the treatments on fruit diameter of okra is presented in Table 4.5. Fruit diameter was significantly affected by the treatments during both major and minor seasons. In the major season, plants treated with Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (4.5 cm) had the widest fruit, which differed significantly ( $P < 0.05$ ) from NPK (20-10-10) + No top-dressing + Side placement (3.3 cm). The widest fruit diameter during the minor season was recorded from plants treated with Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement plots (3.5 cm), while the least diameter was recorded on NPK (20-10-10) + No top-dressing + Side placement (2.7 cm).

### **4.5.2 Fruit Length**

The results for fruit length of okra as influenced by fertiliser type, top-dressing and fertilizer placements are presented in Table 4.5. The different treatment significantly ( $P > 0.05$ ) influenced fruit length of Okra during both major and minor seasons. In both the major season, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement produced the longest fruit (11.5 cm), while in the minor season NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top dressing + Hill placement recorded the highest fruit length (11.0 cm) NPK (20-10-10) + No top-dressing + Side placement recorded the shortest fruit length (7.0 cm and 5.4 cm, in both the major and minor seasons, respectively (Table 4.5).

Table 4. 5: Fruit Diameter and Fruit Length as affected by Different Fertilizer types, Top-dressing and Fertilizer Placement

| Treatment  | Fruit Diameter      |              | Fruit Length |              |
|--|---------------------|--------------|--------------|--------------|
|  | Major Season        | Minor Season | Major Season | Minor Season |
| No fertilizer(control)   | 3.7                 | 3.3          | 7.7          | 8.0          |
| Yara Activa + No top dressing + Hill placement   | 4.0                 | 3.1          | 7.4          | 5.0          |
| Yara Activa + No Top dressing + Side placement   | 3.3                 | 3.4          | 8.2          | 6.4          |
| Yara Activa + (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top dressing + Hill placement    | 4.5                 | 3.2          | 11.5         | 10.3         |
| Yara Activa+ (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> + Side placement                  | 3.5                 | 3.5          | 8.3          | 6.8          |
| NPK (20-10-10) + No top dressing +Hill placement   | 3.8                 | 2.8          | 7.3          | 6.0          |
| NPK (20-10-10) + No top-dressing + Side placement  | 2.0                 | 2.7          | 7.0          | 5.4          |
| NPK (20-10-10) + (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top dressing + Hill placement | 4.1                 | 2.8          | 7.2          | 11.0         |
| NPK (20-10-10) + (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top dressing + Side placement | 3.6                 | 2.9          | 7.5          | 6.3          |
| HSD (0.05)   | 1.8                 | 0.6          | 4.0          | 4.8          |
| CV (%)   | 17.58               | 6.92         | 16.96        | 23.05        |
|  | Season HSD (0.05)   |              | 0.33***      |              |
|  | x Season HSD (0.05) |              | 0.25***      |              |

### 4.5.3 Fruit Yield

The fruit yield of okra as influenced by fertiliser type, top-dressing and fertilizer placement method is presented in Table 4.6. The fruit yield ranged from 1.57-5.41 t/ha and 2.70-4.05 t/ha for the major and minor seasons, respectively. In the major season, the highest fruit yield (5.41 t/ha) was obtained with the application of Yara Activa + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Hill placement, while NPK (20-10-10) + No top-dressing + Side placement produced the least fruit yield (1.57 t/ha). Similarly, in the minor season, Yara Activa + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Hill placement gave the greatest fruit yield (4.05 t/ha), while NPK (20-10-10) + No top-dressing + Side placement treatment resulted in the least fruit yield (2.70 t/ha). Averaged across both seasons, Yara Activa + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Hill placement produced 121% more fruit yield than the NPK (20-10-10) + No top-dressing + Side placement treatment (Table 4.6).

Table 4. 6: Fruit Yield as affected by Different Fertilizer types, Top-dressing and Fertilizer Placement

| Treatments  | Fruit Yield (t/ha)  |              |
|---|---------------------|--------------|
|   | Major Season        | Minor Season |
| No fertilizer(control)  | 4.54                | 2.96         |
| Yara Activa + No top dressing + Hill placement  | 1.84                | 2.83         |
| Yara Activa +No Top dressing + Side placement   | 3.66                | 3.15         |
| Yara Activa +(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top dressing + Hill placement    | 5.41                | 4.05         |
| Yara Activa+(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> + Side placement                  | 3.89                | 3.19         |
| NPK (20-10-10) + No top dressing +Hill placement  | 3.09                | 2.82         |
| NPK (20-10-10) + No top-dressing + Side placement   | 1.57                | 2.70         |
| NPK(20-10-10) + (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top dressing + Hill placement | 3.27                | 3.86         |
| NPK(20-10-10)+ (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> top dressing + Side placement  | 3.59                | 2.89         |
| HSD (0.05)  | 0.92                | 0.65         |
| CV (%)  | 9.25                | 7.03         |
|   | Season (HSD=0.05)   | 0.15***      |
|   | x Season (HSD=0.05) |              |

HSD=Tukey's honestly significant (P>0.05) difference (5%), CV=coefficient of variation

#### 4.6 Partial Budget Analysis

The partial budget analysis was done for both major and minor cropping seasons and the results are shown in Tables 4.7 and Table 4.8. The adjusted fruit yield was obtained by deducting 10% of the fruit yield from the total fruit yield and then used to calculate the gross farm gate benefits.

The benefit to cost ratio showed that the application of Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement gave the highest ratio of 20.7 and 15.34.1 for major and minor seasons, respectively, followed by Yara Activa + No top dressing + Hill placement (17.5) treatment while the NPK (20-10-10) + No top-dressing + Hill placement gave 15.1 in the major season. The NPK (20-10-10) + No top dressing + Side placement treatment had the least benefit-cost ratio of 7.2 the major season (Table 4.7).

In the minor season experiment, NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement and by Yara Activa + No top dressing + Hill placement produced the second highest benefit-cost ratio of 14.8 and 14.9 in the major season, respectively. The least benefit to cost ratio of 10.9 was obtained from the NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement treated plots in the minor season experiment (Table 4.8).

In the minor season, the marginal rate of returns indicated that all the treatments were dominated by the no fertilizer (control), except the NPK (20-10-10) + No top dressing + Hill placement. The MRR of NPK (20-10-10) + No top dressing + Hill placement over the no fertilizer (control) was GHS 249.57 indicating that in adapting the NPK (20-10-10) + No top dressing + Hill placement, for every one (1) cedi cost incurred, the farmer gains an additional (extra) 248.57 cedis, compared with the control.

In the minor season, the MRR results indicated that NPK (20-10-10) + No top dressing + Hill placement, NPK (20-10-10) + No top dressing + Side placement and Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement were all dominated by the no fertilizer

(control), treatment (Table 4.8). However, Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  no top-dressing + Hill placement had a MRR of 425.74%, indicating that for every cedi (GHS1.00) cost incurred in the application of Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  no top-dressing + Hill placement, a farmer can gain an additional return of GHS 424.74 (Table 4.8). The Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  No top-dressing + Hill placement also dominated all the other treatments (Table 4.8).

Table 4. 7: Partial Budget Analysis for Major Cropping Season

|  | Treatment                  |  |  |  |  |  |  |  |  |
|--|----------------------------|--|--|--|--|--|--|--|--|
|  | No fertilizer<br>(control) | Yara Activa<br>+ No top-<br>dressing +<br>Hill<br>placement    | Yara Activa<br>+ No top-<br>dressing +<br>Hill<br>placement    | Yara Activa<br>+<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Hill<br>placement | Yara Activa<br>+<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Side<br>placement | NPK (20-<br>10-10) + No<br>top-dressing<br>+ Hill<br>placement   | NPK (20-<br>10-10) + No<br>top-dressing<br>+ Side<br>placement   | NPK (20-<br>10-10) +<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Hill<br>placement | NPK (20-<br>10-10) +<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Side<br>placement |
| <b>GROSS FARM BENEFITS</b>             |                            |  |  |  |  |  |  |  |  |
| Fruit Yield (t/ha)                     | 4.54                       | 1.84   | 3.66   | 5.41   | 3.89   | 3.09   | 1.57   | 3.27   | 3.59   |
| Adjusted yield (10%)                   | 4.086                      | 1.656  | 3.294  | 4.869  | 3.501  | 2.781  | 1.413  | 2.943  | 3.231  |
| Farm Gate Price (GHS/t)                | 7850                       | 7850   | 7850   | 7850   | 7850   | 7850   | 7850   | 7850   | 7850   |
| <b>Total Gross Benefit (GHS)</b>       | 32075.1                    | 12999.6  | 25857.9  | 38221.65   | 27482.85   | 21830.85   | 11092.05   | 23102.55   | 25363.35   |
| <b>TOTAL VARIABLE COST</b>             |                            |  |  |  |  |  |  |  |  |
| Cost of Fertilizers                    | 0                          | 1373.8   | 1373.8   | 1736.3   | 1736.3   | 1336.3   | 1336.3   | 1698.8   | 1698.8   |
| Cost of Fertilizer Application         | 0                          | 22   | 22   | 22   | 22   | 22   | 22   | 22   | 22   |
| <b>Total Variable Cost (GHS)</b>       | 0.0                        | 1395.8   | 1395.8   | 1758.3   | 1758.3   | 1358.3   | 1358.3   | 1720.8   | 1720.8   |
| <b>Net Benefit (GHS)</b>               | 32075.1                    | 11603.8  | 24462.1  | 36463.3  | 25724.5  | 20472.5  | 9733.7   | 21381.7  | 23642.5  |
| <b>BENEFI: COST RATIO</b>              | 0.0                        | 8.3  | 17.5   | 20.7   | 14.6   | 15.1   | 7.2  | 12.4   | 13.7   |
| <b>MARGINAL RATE OF RETURN (MRR)</b>   |                            |  |  |  |  |  |  |  |  |
| <b>MRR</b>                             | No fertilizer<br>(control) | NPK (20-<br>10-10) + No<br>top-dressing<br>+ Hill<br>placement | NPK (20-<br>10-10) + No<br>top-dressing<br>+ Side<br>placement | Yara Activa<br>+ No top-<br>dressing +<br>Hill<br>placement  | Yara Activa<br>+ No top-<br>dressing +<br>Hill<br>placement  | NPK (20-<br>10-10) +<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Hill<br>placement | NPK (20-<br>10-10) +<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Side<br>placement | Yara Activa<br>+<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Side<br>placement     | Yara Activa<br>+<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Hill<br>placement     |
| <b>Total Variable Cost (TVC) (GHS)</b> | 0.0                        | 1358.3   | 1358.3   | 1395.8   | 1395.8   | 1720.8   | 1720.8   | 1758.3   | 1758.3   |
| <b>Net Benefit (NB) (GHS)</b>          | 32075.1                    | 20472.5  | 9733.7   | 11603.8  | 24462.1  | 21381.7  | 23642.5  | 25724.5  | 36463.3  |
| <b>MRR ([ΔNB/ΔTVC] × 100)</b>          |                            | D*   | D*   | D*   | D*   | D*   | D*   | D*   | 341.9  |

Table 4. 8: Partial Budget Analysis for Minor Cropping Season

|  | Treatment                  |  |  |  |  |  |  |  |  |
|--|----------------------------|--|--|--|--|--|--|--|--|
|  | No fertilizer<br>(control) | Yara Activa<br>+ No top-<br>dressing +<br>Hill<br>placement    | Yara Activa<br>+ No top-<br>dressing +<br>Hill<br>placement    | Yara Activa<br>+<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Hill<br>placement | Yara Activa<br>+<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Side<br>placement | NPK (20-<br>10-10) + No<br>top-dressing<br>+ Hill<br>placement   | NPK (20-<br>10-10) + No<br>top-dressing<br>+ Side<br>placement   | NPK (20-<br>10-10) +<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Hill<br>placement | NPK (20-<br>10-10) +<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Side<br>placement |
| <b>GROSS FARM BENEFITS</b>             |                            |  |  |  |  |  |  |  |  |
| Fruit Yield (t/ha)                     | 3.0                        | 2.8  | 3.2  | 4.1  | 3.2  | 2.8  | 2.7  | 3.9  | 2.9  |
| Adjusted yield (10%)                   | 2.7                        | 2.5  | 2.8  | 3.6  | 2.9  | 2.5  | 2.4  | 3.5  | 2.6  |
| Farm Gate Price (GHS/t)                | 7850.0                     | 7850.0   | 7850.0   | 7850.0   | 7850.0   | 7850.0   | 7850.0   | 7850.0   | 7850.0   |
| <b>Total Gross Benefit (GHS)</b>       | 20912.4                    | 19994.0  | 22254.8  | 28613.3  | 22537.4  | 19923.3  | 19075.5  | 27270.9  | 20417.9  |
| <b>TOTAL VARIABLE COST</b>             |                            |  |  |  |  |  |  |  |  |
| Cost of Fertilizers                    | 0.0                        | 1373.8   | 1373.8   | 1736.3   | 1736.3   | 1336.3   | 1336.3   | 1698.8   | 1698.8   |
| Cost of Fertilizer Application         | 0.0                        | 22.0   | 22.0   | 22.0   | 22.0   | 22.0   | 22.0   | 22.0   | 22.0   |
| <b>Total Variable Cost (GHS)</b>       | 0.0                        | 1395.8   | 1395.8   | 1758.3   | 1758.3   | 1358.3   | 1358.3   | 1720.8   | 1720.8   |
| <b>Net Benefit (GHS)</b>               | 20912.4                    | 18598.1  | 20858.9  | 26854.9  | 20779.0  | 18565.0  | 17717.2  | 25550.1  | 18697.0  |
| <b>BENEFIT: COST RATIO</b>             | 0                          | 13.3   | 14.9   | 15.3   | 11.8   | 13.7   | 13.0   | 14.8   | 10.9   |
| <b>MARGINAL RATE OF RETURN (MRR)</b>   | 0                          | 2.8  | 3.2  | 4.1  | 3.2  | 2.8  | 2.7  | 3.9  | 2.9  |
| <b>MARGINAL RATE OF RETURN (MRR)</b>   | No fertilizer<br>(control) | NPK (20-<br>10-10) + No<br>top-dressing<br>+ Hill<br>placement | NPK (20-<br>10-10) + No<br>top-dressing<br>+ Side<br>placement | Yara Activa<br>+ No top-<br>dressing +<br>Hill<br>placement  | Yara Activa<br>+ No top-<br>dressing +<br>Hill<br>placement  | NPK (20-<br>10-10) +<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Hill<br>placement | NPK (20-<br>10-10) +<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Side<br>placement | Yara Activa<br>+<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Side<br>placement     | Yara Activa<br>+<br>(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub><br>top-dressing<br>+ Hill<br>placement     |
| <b>Total Variable Cost (TVC) (GHS)</b> | 0.0                        | 1358.3   | 1358.3   | 1395.8   | 1395.8   | 1720.8   | 1720.8   | 1758.3   | 1758.3   |
| <b>Net Benefit (NB) (GHS)</b>          | 20912.4                    | 18598.1  | 20858.9  | 20779.0  | 26854.9  | 18565.0  | 17717.2  | 18697.0  | 25550.1  |
| <b>MRR ([ΔNB/ΔTVC] × 100)</b>          |                            | D*   | D*   | D*   | 425.7  | D*   | D*   | D*   | D*   |

## CHAPTER FIVE: DISCUSSION

### 5.1 Phenology

The plants treated with NPK (20-10-10) + No top-dressing + Hill placement delayed in obtaining days to 50% flowering during the major seasons and the application of Yara Milla Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement also delayed days to 50% flowering in minor season (62 DAS). The plants that were treated with Yara Milla Activa + Top dressing + Side Placement also produced pods earlier (71 days) than the other treatments during the major season and Yara Milla Activa + No top dressing + Side Placement (69 days) during minor season. The 23-10-5 NPK+2MgO+3S +0.3Zn in the Yara Milla Activa and 20-10-10 formulation of the NPK might have enhanced cell disintegration and reintegration of more tissues resulting in luxuriant phenology and thereby increased the growth of okra and other morphological characters (Wasis, 2019) to reach fruiting earlier. Also, primarily mediated through its balanced nutrient composition, which supports various physiological processes critical for plant development. Ekwere & Efreteui (2021), in their study reported that nutrients composition such as nitrogen, potassium and phosphorus led to fewer days to fruit formation in okra.

### 5.2 Growth

The various treatments significantly ( $P < 0.05$ ) influenced plant height of okra from 4 WAP to 10 WAP. The tallest plants (89.67 cm) were produced at 10 WAP from the plots treated with Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement during the major season, while the shortest plants (69.12 cm) were observed in No fertilizer (control) plots during the major cropping season. During the minor cropping season, the greatest plant height of okra (90.30 cm) was observed in the NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement, plots treated at 10 WAP, while the shortest plants (61.06 cm) were observed in NPK (20-10-10) + No top-dressing + Side placement treated plots. This shows that application of NPK fertilizer

(20-10-10) + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + side placement helped to improve plant height of okra crops during the minor season and the application of Yara Activa (23-10-5 NPK+2MgO+3S +0.3Zn) + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Hill placement also helped to improve plant height of okra crops during the major season. Nitrogen, phosphorus, and potassium contained in the inorganic fertilizer have great effects in plant growth and development.

The seasonal variation might be as result of soil temperature significantly influenceing nutrient availability and root activity (Wang *et al.*, 2021). In warmer seasons, higher soil temperatures can accelerate the decomposition of organic matter, releasing nutrients like nitrogen, phosphorus, and potassium into the soil. However, excessively high temperatures can also lead to nutrient losses through volatilization or leaching. Conversely, lower soil temperatures in colder seasons can slow down decomposition rates, reducing nutrient availability. Soil moisture also affect nutrient solubility and mobility, influencing nutrient uptake by plant roots. Adequate soil moisture is essential for the diffusion of nutrients to the root surface and their subsequent absorption. In dry seasons, limited soil moisture can restrict nutrient availability, while excessive moisture during wet seasons can lead to nutrient leaching and runoff (Cavagnaro, 2016). These results are similar with the findings of Adekiya *et al.* (2019), who reported that the heights of okra plants increased with the application of NPK (20-10-10) fertilizer. Plants need high concentration of these primary nutrients, as any deficiency of the essential nutrients would prevent good plant growth (Oroka *et al.*, 2016). Within the stem resides the cambium where cell division takes place for a growing plant. Stems cannot widen or lengthen without adequate supply of phosphorus element that plays an important role in cell division and leads to the increase in width and length of stems. Thus, sufficient phosphorus supplied by the NPK fertilizer enhanced the heights of the plants.

Different fertiliser types, top dressing and fertiliser placement methods significantly ( $P < 0.05$ ) affected canopy width of okra at 8 to 10 WAP during both major and minor rainy seasons

experiments (Table 4.6). It was observed that, sulphate of ammonia ( $(\text{NH}_4)_2\text{SO}_4$ ) top-dressing + hill placement of fertilizer with either Yara Milla Activa or with NPK produced the widest canopy. For instance, during the major seasons, at Yara Milla Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + hill placement had the widest canopy at 8 WAP, and then at 10 WAP, the NPK +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + hill placement also had the widest canopy. During the minor season, Yara Milla Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + hill placement again recorded the widest canopy width at 8 WAP and NPK +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + hill placement also had the widest canopy at 10 WAP. Similar results were reported by Abdul-Ganiyu *et al.* (2017), where sulphate of ammonia applied as top dressing significantly ( $P < 0.05$ ) produced wider canopy in maize. Agba *et al.* (2018) reported that NPK (20:10:10) produced the widest canopy of okra. However, these results, for canopy width disagrees with that of Makinde *et al.* (2023) who observed lower values with no significant ( $P > 0.05$ ) differences in their study with the application of NPK to okra. Comparatively, wider canopy width observed on the NPK is in accordance with Kareem *et al.* (2020) who observed that in solanaceous plants, increasing N containing fertilizer rates could lead to a corresponding increase in canopy width, leaf area, light-interception and dry matter partition. Nevertheless, application of NPK above 120 kg/ha showed no incremental advantage with respect to leaf area. Besides, the amount of nutrient applied could have influenced the physico-chemical properties and nutrient content of the soil that might have impacted canopy width (Kareem *et al.*, 2020). According to Tanioka *et al.* (2020), canopy or leaf growth is substantially affected by increasing N level and suggested that leaf area might be owing to adequate supply of N for high photosynthetic activity.

Significant variation was recorded at different growth stages of okra due to different fertilizer types, top-dressing and fertilizer placement on the number of branches and number of leaves. At 8 and 10 WAP, the highest number of branches of okra plant (13 and 15 branches) was found from the Yara Milla Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + hill placement. YaraMilla Activa is a

combination of nitrogen (N), phosphorus (P) and potassium (K) designed to optimize crop yield and quality. Nitrogen is an essential macro nutrients and determinant in growth and development of crop plants. Jonah *et al.* (2017) reported that NPK are the most needed macro-nutrients that okra required for proper growth and yield. Akhter (2020) also observed increases in okra yield as a result of NPK (20-10-10) fertilizer application. The variability observed in the number of leaves and number of branches among treatments might be due to effective and efficient uptake and utilization of available nutrients for growth and development of the okra crop.

The no significant ( $P>0.05$ ) differences observed in chlorophyll content as affected by the different treatments, but seasons was significant ( $P>0.05$ ) in chlorophyll content at 4 WAP to 10 WAP. The significant ( $P>0.05$ ) difference in chlorophyll content in okra leaves may be due to weather conditions which affected the role of macro and micro nutrients in the physiological process, cell division and elongation which indirectly affected the tissue formation and consequently vegetative growth and the reproductive stage of the crop. There were more rains during the early stage of the cropping period in the minor season than in the major season. Higher chlorophyll (SPAD) value was recorded in the minor season at 4 WAP content (41.95) and 6 WAP (48.83) whereas minimum Chlorophyll content was observed in major season at 4 WAP (30.06) and 6 WAP (30.06). Maximum Chlorophyll was rather recorded in the major season at 8 WAP content (52.26) and 10 WAP (53.87), whereas minimum Chlorophyll content was observed in minor season at 8 WAP (50.27) and 10 WAP (52.85). Chlorophyll content decreases with increasing levels of water deficits in okra plants (Wakchaure et al., 2023; Adejumo et al., 2019). Bhattacharya (2022) also reported that when plants are under some adverse weather conditions, physiological process of the plant are slowed down that gears towards growth and development.

The maximum dry shoot weight of 58.51 g and 44.85 g for the major and minor seasons, respectively at 10 WAP) was obtained from plants treated with the Yara Activa + No top-dressing + Hill placement method. This treatment consistently produced higher dry shoot weight throughout the study period. The application of Yara Milla without any top-dressing plus the side placement of fertilizer showed an increasing trend in dry shoot weight of okra throughout the cropping period and gave the highest. On the other hand, the application of NPK + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + hill placement of fertilizer recorded least dry shoot weight over the cropping period for the two seasons. The dry shoot weight recorded on NPK plots is an indication of the higher dry matter production with continuous application of Yara Milla + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + side placement of fertilizer.

The results indicated that the development of vegetative characters in okra such as plant height, number of branches and number of leaves was enhanced with the application of Yara Milla Activa + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Hill placement and NPK + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Hill placement, which consequently enhanced shoot fresh weight and dry matter accumulation. The observed increases in crop parameters following application of NPK + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Hill placement and Yara Activa + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Hill placement may be due to the enhancement of soil fertility which promoted the growth of the okra plants.

Low fertilizer application rates have been noted as the main cause of depleted soil nutrients and relatively stagnant crop yields (Alam et al., 2020; Pasley et al., 2019). However, Li et al. (2020) reported that excessive fertilizer inputs in the planting process induce rapid growth and high-yield crops, resulting in low fertilizer efficiency. The N component might have enhanced cell disintegration and reintegration of more tissues resulting in luxuriant vegetative growth and thereby increased the growth of okra and other morphological characters (Wasis, 2019). Conversely, result for shoot and root weight are not in agreement with Kumawat (2018) and Fuseini & Nurideen (2023) who reported lower values in their study. According to Kanneh et

al. (2016) plant growth can be influenced by application of fertilizer in addition to inherent soil fertility. Results of this study further corroborates with that of Olaiya et al. (2015) who recorded similar values when they assessed the impact of poultry manure on fruit yield and yield components of okra.

### **5.3 Yield and Yield Components**

The various treatments markedly affected the fruit diameter of okra in both the major and minor seasons. The treatment with the largest fruit diameter was Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement (1.45 cm), which differed significantly from NPK (20-10-10) + No top-dressing + Side placement (0.66 cm). The largest fruit diameter in the minor season was obtained from the Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Side placement plots, while the least fruit diameter was recorded from the NPK (20-10-10) + No top-dressing + Side placement plots. During the major season, the treatment with the longest fruit length was NPK (20-10-10) +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement which differed considerably from NPK (20-10-10) + No top-dressing + Side placement (1.72 cm). The longest fruit length during the minor season was measured at 4.43 cm on from the Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement treatment, while the least diameter (2.70 cm) was obtained from the NPK (20-10-10) + No top-dressing + Side placement treatment. The fruit yield (kg/ha) of okra, was significantly impacted by fertilizer type, top-dressing, and fertilizer placement. Okra plants treated with Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement produced the highest fruit yield (5.41 t/ha) in the major season and 4.05 t/ha in the minor season, whereas NPK (20-10-10) + No top-dressing + Side placement produced the least yield (1.57 t/ha) in the major season and 2.70 t/ha in minor season. In both seasons, the control (no fertilizer) treatment produced moderate fruit diameter (1.19 cm for major season and 1.05 cm in minor season), fruit length (3.60 cm in the major season and 2.96 cm in the minor season) and fruit yield of okra (4.54 t/ha for major season and 2.96 t/ha for minor season).

The Yara Activa + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Hill placement which produced the highest fruit suggests that it supplied sufficient plant nutrients in contrast to treatment that produced the least. Godia (2014) also attributed fruit number variability observed in okra response to different fertilizer amendments to the possibility of consistent release of nutrients by Yara Milla Activa + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Hill Placement, leading to higher yield. This might also be related to possibility of enhancing stomata conductance, better partitioning of photosynthetic materials towards economic yield and better genetic structure. The current result conforms to findings reported by Ngegba et al. (2020) and Amina et al. (2023).

#### **5.4 Partial Budget Analysis**

The scaling down of the fruit yield by 10% before the determination of partial budget was necessary to avoid overestimation of the returns that farmers are likely to get, since experimental yields are usually higher than farmers yield because of higher management levels, small plot size, better harvesting methods and precision in harvesting (Azumah *et al.*, 2020).

The benefit to cost ratio varied significantly among the different treatments in both cropping seasons. The combination of Yara Activa, (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing, and Hill placement yielded the maximum benefit to cost ratio in both cropping seasons. In addition, all treatment except the control (no fertilizer) had significant benefit to cost ratio (more than 1). The study by Thokal *et al.* (2020) has found variations in benefit to cost ratio attributable to different fertilizer types, top-dressing methods, and fertilizer location in okra cultivation. The increased benefit to cost ratio or net benefit from the NPK + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Hill placement and Yara Milla Activa + (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> top-dressing + Hill placement may be attributed to the increased fruit production, which resulted in augmented revenue generation in respect to low production cost. In the dominance analysis, a treatment is dominated if it has a higher cost of production but a lower net benefit than another (Mutenje *et al.*, 2019).



## CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

### 6.1 Conclusion

- Generally, the application of Yara Activa + SOA top-dressing + Hill placement treatment or NPK (20-10-10) + SOA top-dressing + Hill placement treatment promoted plant growth through increased plant height, wider canopy, more leaves, greater number of branches and dry shoot weight in both seasons.
- Generally, Yara Milla Activa + Top dressing + Hill Placement or NPK (20-10-10) + SOA top-dressing + Side placement treatments promoted early flowering and fruiting of the okra plants.
- The application of Yara Activa + SOA top-dressing + Hill placement or NPK (20-10-10) + SOA top-dressing + Hill placement increased the yield of the okra fruits by enhancing fruit diameter and increasing fruit length in both seasons.
- For profitability of okra production, the application of Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement gave the highest benefit to cost ratio. All the treatment used with the exception of the control (no fertilizer) produced significant benefit to cost ratio. The application of Yara Activa +  $(\text{NH}_4)_2\text{SO}_4$  top-dressing + Hill placement treatment gave the highest marginal rate of returns and therefore more preferable.

### 6.2 Recommendations

The application of Yara Activa + SOA top-dressing + Hill placement and NPK (20-10-10) + SOA top-dressing + Hill placement are recommended for consideration for possible adoption for higher growth, development and yield of okra and profitability in the transition of Ghana.

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## LIST OF APPENDIXES

Appendix 1: Guide to interpretation of soil analytical data in Ghana (Reference?)

| Nutrient                                  | Rank/Grade              |                       |                 |             |
|---|-------------------------|-----------------------|-----------------|-------------|
| <b>Phosphorus, P (ppm), (Bray 1)</b>      |                         |                       |                 |             |
| < 10                                      | Low                     |                       |                 |             |
| 10 – 20                                   | Moderate                |                       |                 |             |
| > 20                                      | High                    |                       |                 |             |
| <b>Potassium, K (pmm)</b>                 |                         |                       |                 |             |
| < 50                                      | Low                     |                       |                 |             |
| 50 – 100                                  | Moderate                |                       |                 |             |
| > 100                                     | High                    |                       |                 |             |
| <b>Calcium, Ca (ppm)/Meg = 0.25 Ca</b>    |                         |                       |                 |             |
| < 5.0                                     | Low                     |                       |                 |             |
| 5.0 – 10.0                                | Moderate                |                       |                 |             |
| > 10.0                                    | High                    |                       |                 |             |
| <b>ECEC (cmol (+)/kg)</b>                 |                         |                       |                 |             |
| < 10                                      | Low                     |                       |                 |             |
| 10 - 20                                   | Moderate                |                       |                 |             |
| > 20                                      | High                    |                       |                 |             |
| <b>Soil pH (Distilled Water Method)</b>   |                         |                       |                 |             |
| < 5.0                                     | Very Acidic             |                       |                 |             |
| 5.1 – 5.5                                 | Acidic                  |                       |                 |             |
| 5.6 – 6.0                                 | Moderately Acidic       |                       |                 |             |
| 6.0 – 6.5                                 | Slightly Acidic         |                       |                 |             |
| 6.5 – 7.0                                 | Neutral                 |                       |                 |             |
| 7.0 – 7.5                                 | Slightly Alkaline       |                       |                 |             |
| 7.6 – 8.5                                 | Alkaline                |                       |                 |             |
| > 8.5                                     | Very Alkaline           |                       |                 |             |
| <b>% Organic Carbon</b>                   | <b>% Organic Carbon</b> | <b>Interpretation</b> |                 |             |
| < 1.0                                     | < 1.5                   | Low                   |                 |             |
| 1.0– 2.0                                  | 1.6 – 3.0               | Moderate              |                 |             |
| 2.0-4.0                                   | 3.0                     | Adequate              |                 |             |
| > 4.0                                     | >3.0                    | High                  |                 |             |
| <b>Nitrogen (%)</b>                       |                         |                       |                 |             |
| < 0.1                                     | Low                     |                       |                 |             |
| 0.1 – 0.2                                 | Moderate                |                       |                 |             |
| > 0.2                                     | High                    |                       |                 |             |
| <b>Exchangeable cations (cmol (+)/kg)</b> | <b>Units</b>            | <b>low</b>            | <b>moderate</b> | <b>High</b> |
| Sodium (Na)                               | (cmol (+)/kg)           | -                     | 0-2             | > 2.0       |
| Potassium (K)                             | (cmol (+)/kg)           | <0.2                  | 0.2 – 0.4       | > 0.4       |
| Calcium (Ca)                              | (cmol (+)/kg)           | < 2.0                 | 2.0-10          | > 10        |
| Magnesium (Mg)                            | (cmol (+)/kg)           | < 1.0                 | 1.0-3.0         | > 3.0       |