UNIVERSITY OF EDUCATION, WINNEBA

EFFECT OF DIFFERENT PLANT SPACING AND DIFFERENT RATES OF UREA FERTILIZER APPLICATION ON THE GROWTH AND YIELD OF OKRA (*Abelmoschus esculentus* (L.)

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BY

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AUGUST, 2022

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DECLARATION

STUDENT'S DECLARATION

I, Samuel Anim, hereby declare that this work is the effort and results of my research for the award of the degree. However, work done by others that I used has been correctly cited and acknowledged.

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SAMUEL ANIM DATE

SUPERVISORS' DECLARATION

I hereby declare that the preparation and presentation of this project work were supervised following the guidelines for supervision of Dissertation as laid down by the University of Education, Winneba.

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DR. BERNARD EFFAH DATE

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DEDICATION

I dedicate this thesis to my wife, Adoma Matilda for nursing me with affections, and love and for her dedicated partnership for success in my life.

ABSTRACT

An ideal plant spacing and fertilizer doses for okra's [*Abelmoschus esculentus (L.) Moench*] contributes its performance and output. An experimental study was conducted at the Department of Crop and Soil Sciences, Faculty of Agriculture Education, College of Agriculture Education of Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Mampong-Ashanti campus, to evaluate the effect of different plant spacing and different rates of urea fertilizer application on the growth and yield of okra variety *Asontem*. Three different plant spacing (S1 = 60 cm x 40 cm, S2 = 60 cm x 50 cm, and S3 = 60 cm x 60 cm) and three different rates of urea fertilizer (N1 = 0 kg N ha^{-1}, N2 = 46 kg N ha^{-1}, and N3 = 69 kg N ha^{-1}) were used in the experiment. The experiment was conducted in a 3 x 3 factorial arrangement in a Randomized Complete Block Design (RCBD) with three replications. Superior results were seen from the widest plant spacing (60 cm x 60 cm) and the highest rate of urea fertilizer (69 kg N ha^{-1}) applied in the vegetative growth, and yield components of okra. Nonetheless, the tallest plant height and maximum pod yield per hectare were achieved with the closest plant spacing (60 cm x 40 cm) treated with a higher rate of urea fertilizer application (69 kg N ha^{-1}). Farmers are then advised to cultivate okra variety *Asontem* at a plant spacing of 60 cm x 40 cm with a higher rate of urea fertilizer at 69 kg N ha^{-1} for optimum pod yield per hectare.

ABBREVIATION

N	Nitrogen
P	Phosphorus
K	Potassium
WAS	Weeks After Sowing
DAP	Days After Planting
g	gram
ha	hectare
Cm	centimeter
Kg	kilogram
ANOVA	Analysis of Variance
GEN STAT	General Statistics
RCBD	Randomized complete block design

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Okra [*Abelmoschus esculentus* (L.) Moench] is a popular crop due to its easy cultivation, dependable yield adaptability to varying moisture conditions, and soil types, and is also tolerant to wide variation in rainfall. It is one of the most important warm-season fruit vegetables grown throughout tropical countries. It is also recognized as one of the world's oldest cultivated crops (Paththinige *et al.,* 2008). Okra (*Abelmoschus esculentus*) was originally classified as a member of the genus *Hibiscus*, later classifications reassigned it under *Abelmoschus* and differentiated with copious features from the genus *Hibiscus*.

Abelmoschus esculentus is native to Asia and *Abelmoschus caillei*, to Africa. These two are the most cultivated okra varieties (AdeOluwa and Kehinde, 2011). The *A. esculentus* is almost grown all over the world and accounts for 95% of okra cultivated, whereas the *A. caillei* accounts for 5% of the total world production (Ahiakpa *et al.,* 2017).

Okra thrives well in most soil types from sandy loam, loam, and or clay soils with a pH range of 5.8-8.0 (Madisa *et al.,* 2015). It is sensitive to frost, heat, drought, and waterlogging (Mane *et al.,* 2019). Okra shows wide adaptability and is cultivated either as a home garden crop or on a commercial scale (Reddy *et al.,* 2017).

Okra is a popular vegetable in every market in tropical Africa because of the health benefits it provides as well as the economic potential for peasant farmers (Amissah, 2015).

In Ghana, the crop serves as a cash crop for farmers who cultivate it and a source of nutrition for farmers themselves and those that consume it (Agbaglo *et al.,* 2020).

The versatility of okra cannot be overemphasized since all plant parts are fully utilized. The immature pods contain 86% water, 2.2% protein, 10% carbohydrate, 0.2% fat, and vitamins A, B, and C. It is a good source of calories (4550 k cal kg^{-1}) for human consumption (Amissah, 2015). Its immature green pods are consumed as a vegetable and are also being employed in various culinary preparations such as soups and stews (Ishfaq *et al.,* 2022).

Okra is primarily grown as a vegetable crop, but due to its high oil content of 20% to 40%, it has the potential to be grown for oil extraction (Demelie *et al.,* 2020). It is used for medicinal purposes as a plasma replacement or expander of blood volume (Elkhalifa *et al.,* 2021). The fruit's mucilage can bind bile and cholesterol-carrying toxins that are generated by the liver. Since the plant is so versatile, it is used in a range of dishes (Agbaglo, 2017).

The roots and stems of okra are used for clarification of sugarcane juice from which sugar or brown sugar is prepared (Banvasi *et al.,* 2020). Its seeds are roasted, ground, and used as a substitute for coffee in some countries (Gemede *et al.,* 2015). Mature fruits and stems contain crude fibers which can serve as a raw material in the paper industry (Tomar *et al.,* 2020).

According to Bationo *et al.,* (2018) declining soil fertility is one of the factors to low yield per hectare in Okra cultivation for smallholder farmers in Ghana. Low soil fertility due to monoculture to them is considered one of the major causes of declining per capita food production. Continuous monocultures of okra reduce yields and soil nutrients, especially nitrogen (Goshu *et al.,* 2015).

Due to small land areas and high prices of fertilizers, farmers try to increase plant population per unit area for maximum yield (Bake *et al.,* 2017)

Okra requires the optimum population density for optimal plant growth and seed yield according to Amanga *et al.,* (2017). The right nutrients, moisture, and sunlight for optimum growth and productivity are equally influenced by plant spacing (Hassan and Ali, 2015). The ideal plant density for a given crop is sufficient to achieve the optimal leaf area index to intercept the maximum solar radiation usable for photosynthesis (Paranhos *et al.,* 2016). In this sense, the plant stand affects the penetration of solar radiation and the balance between the growth of vegetative parts and fruits. Thus, changes in plant population or increased availability of solar radiation indirectly affect the distribution of dry matter among plant organs (Casini, 2012). Therefore, emphasis must be given to increasing the per hectare yield of okra by adopting proper spacing.

The spacing used for growing okra varies depending on the interest of the producer, with recommendations for high and low population densities such as 90 cm × 30 cm, 100 cm × 50 cm, and 150 cm × 50 cm, the latter with two plants per hole (Charles *et al.,* 2019). The use of proper spacing is very important since it affects flowering, branching, yield per plant, and total yield in hectares (Omovbude and Udensi, 2018).

Therefore, it is important to optimize plant spacing depending on local climatic conditions and varieties to promote the yield of okra (Makinde, 2014). Due to the importance of plant spacing for okra plant growth and seed production, the current experiment was conducted at Asante Mampong to evaluate the effect of different plant spacing and different rates of chemical fertilizers (Urea) application on the growth, yield, and yield components of okra variety *Asontem*.

1.2 Problem Statement

The challenges confronting farmers in okra production that have resulted in low yield include incorrect plant spacing (Kitila *et al.,* 2011), use of unimproved varieties (Nganga, 2017), and low levels of soil fertility due to continuous crop production on the same piece of land (Ayambire *et al.*, 2019).

The problem of low yields for farmers is further aggravated by the low or no use of fertilizers. Although some work has been done by Ogundare *et al.,* (2015) on the effects of different spacing and urea fertilizer application rates on fruit nutrient composition, growth, and yield of okra, the exact nutrient requirements and suitable spacing for the production of high-quality okra yield remain undetermined. This study, therefore, attempts to evaluate the effect of different plant spacing and rates of different urea fertilizer applications on the growth and yield, and yield properties of the okra variety, *Asontem*.

1.3 Justification

This study is to find out the effect of using different plant spacing and different levels of urea fertilizer on the growth and yield of okra to help increase the yield of farmers in okra production. This will hopefully lead to improved okra yield and marketability. Again, employment generation in the production areas and marketing will also increase. These will eventually increase the profit margin of the farmers which will intend to reduce poverty by improving the livelihood of the farmers.

1.4 Objectives of the Research

1.4.1 *Main Objective*

The main objective of the study is to assess the effects of different plant spacing and different rates of urea fertilizer application on the growth, yield, and yield components of *Asontem* okra at an experimental field at the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Asante Mampong campus.

1.4.2 *Specific objectives*

The specific objectives were to:

1. Determine the influence of different plant spacing and different rates of urea fertilizer application on vegetative growth.

2. Assess the effect of different plant spacing and different rates of urea fertilizer application on yield components of okra.

3. Evaluate the interactive effect of the different plant spacing and the different rates of urea fertilizer application on the growth yield and yield components of okra variety '*Asontem*'.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Botany of Okra

2.1.1 *Origin*

The origin of okra is a point of contention. Okra was originally recorded in Egypt in 1216 A.D., but other agronomists, such as Nikolai Vavilov, verified the crop to have been farmed in tropical regions of Africa, including Ethiopia; thus, Ethiopia is regarded as the center of origin for okra and its wild relatives (Saini *et al.,* 2020). Even though okra has been widely farmed in Egypt for hundreds of years, no evidence of okra has been discovered in Ancient Egypt's ancestral monuments or remains (Sousa and Raizada, 2020). Okra was disseminated from Ethiopia to the Northern part of Africa, the Mediterranean, Arabian, and India in the year 1300 BC. Little information is readily available about the history and distribution of the crop due to the fastness of the spread from Ethiopia to the rest of the world (Agbaglo, 2017). Other scientists have proposed that okra originated from countries such as India, West Africa, Ethiopia, Tropical Asia, Pakistan, and Burma (Benchasri, 2012).

In West Africa, the higher diversity of okra is cited by advocates, although the confusion between okra, *Abelmuschus esculentus,* and A*belmoschus caillei* (L.) Moench (West African okra) casts doubt on these claims (Kumar *et al.,* 2018). Chauhan, (2018) did reveal that the crop had been discovered in Brazil by the year 1658. And that the crop had been introduced to America and other parts of the world by slaves migrating from Africa through the Atlantic slave trade.

2.1.2 *Botany*

Okra is a semi-woody, fibrous herbaceous perennial with an inaccurate growth habit, according to morphological research (Kumar *et al.*, 2020). It has tall stem and various branches that grow to a height of 0.5 m to 4.0 m (Agbaglo *et al.*, 2020).

The main stem of the plant is continuous with the tap root which tappers rapidly. The plant has a long taproot with multiple fibrous roots that spread out in all directions in the rhizosphere. The depth reached by the tap root depends on the soil type and moisture (Adekunle, 2011; Tripathi *et al.*, 2011). The leaves are large, alternate, chordate, and are divided into 3 – 7 lobes with notched or toothed margins (Adebisi *et al.*, 2007).

The seeds are dicotyledonous, spherical, kidney-shaped, and have epigeal germination (Ara, 2015; Michael *et al.*, 1997). Okra is self-attuned and has both male and female reproductive parts in the same flower (Tanda, 2019). The flowers are born singly in the leaf axis on a peduncle which is about 2.5 cm long. Flowers have a typical Malvaceae organization with 8 – 10 narrow hairy bracteoles forming the epicalyxes which hall off before the fruits mature (Adebisi *et al.*, 2007). The flowers usually open just before daybreak, begin to close about midday, and are closed by mid-afternoon never to open again (Liu, 2005). The pollen grains of the crop are usually quite large, therefore pollination (both self and cross-pollination) is frequently accomplished with the help of insects such as honeybees and humble bees. (Agbaglo, 2017; Joshi *et al.*, 2021). The rate of cross-fertilization on okra is affected by the cultivar and ecology (Tripathi *et al.*, 2011).

The fruit is a capsule and may be dark green, red, or white which is ridged round, pointed, or pyramidal and about 10 – 25 cm and 2 – 3 cm wide upward pointed hairs when young. About 30 – 80 dark green or grey spherical seeds are found in each Okra plant takes 90-100 days from planting to fruiting depending on the cultivar, and soil condition (Fufa, 2019). Its fruits, fruit length, and diameter increase dramatically between the 4th and 6th days, but it is at this stage that okra is typically harvested for use. Starting on the 9th day, okra plants begin to produce a lot of fiber, and depending on the variety, season and soil moisture okra plants can produce fruit indefinitely (Bayu, 2020; Aseffa, 2019). Although fruiting is delayed by excessively high temperatures, the plant develops quicker, but temperatures between 40ºC and 42ºC cause blossom abortion (Tripathi *et al.*, 2011).

2.2 Varieties of Okra

Generally, three types of okra are available. They are tall green, dwarf green, and lady's finger. Tall green; this variety of okra plant develops to a height of 10 to 40 cm; it grows upright and is unable to spread its leaves, but all of the stems are erect; features big leaves borne from petioles; pods appear in the plant's axil and on a short stem, and the pods are green in color. Dwarf green; this variety of okra grows to a height of 51 cm to 107 cm, is bushy, and has small leaves on slender or weak petioles. The pods are green in color. Lady's finger; this okra type reaches a height of around 90 cm. It seems to be densely branched and bushy; the leaves are enormous and carried on a long petiole, with the bottom leaves reaching up to 60 cm in length. The colour of the plant is light. This cultivar is distinguished from others by the colour of its pods. When suitable for the market, pods can reach a length of 10cm to 13cm; when fully grown, they can reach 15 cm to 25 cm. A thick layer of silky hair covers the fruit.

Each of these varieties is sub-divided in terms of length and colour of the pods resulting in many more varieties (Agbaglo, 2017). Aside from these factors, plant height, fruit size, fruit colour, and time of maturity either early or late maturing contributes to differences in okra varieties (Amissah, 2015). In Ghana, varieties that can be found includes Quim Bombo, *Asontem*, Nkuruma hene, Nkuruma tia, Lady's finger, Legon fingers, Labadi dwarf, Torkor, Saloni, Enidaso, and Clemson Spineless (Ahiakpa *et al.,* 2013). Emerald, Jade, Burmese Okra, Louisiana Short, Alabama Red, Star of David, Spineless Jokoso, LD 88, V-35, Ex Borno, and Silver Queen Okra are exotic cultivars.

Clemson Spineless is a spineless type that matures in 55 to 58 days. It has a medium-dark green stem and angular pods that are 12-15 cm long (Mkhabela *et al.,* 2021). The stems are hairy and woody when mature and the leaves alternate up to 30 cm in length (Katende, 2006). Emerald is another spineless cultivar that takes almost two months to maturity and has dark green, smooth, spherical pods. Lee is a semi-dwarf cultivar with no spines that produces dark brilliant green, angular, straight pods in 55 to 58 days. Annie Oakley is a spineless hybrid cultivar that matures in 53 to 55 days and has beautiful green, angular pods. Prelude is a spineless, open-pollinated cultivar with dark green, glossy pods that are fluted. It matures in 50-55 days and produces significantly more than Clemson Spineless. (Lamont, 1999; Wehner, 1999).

Asontem is another okra variety that is well-branched, not very voluminous and has dark green leaves. Its fruit is quite short, broad with pointed ends, cylindric, light green and slightly ribbed. *Asontem* takes 60 to 70 days after planting to maturity depending on the crop location and the climatic conditions. This okra cultivar is a popular local material among farmers in and around the region in Ghana.

The seeds are planted in April, during the major cropping season (March to July) and repeated in August, during the minor season (August to November)(Bortey and Dzomeku, 2016).

Abelmoschus has four domesticated species that are known in Africa, South and East Asia and the Southern United States. The most extensively grown variety is *esculentus*. *Abelmoschus caillei* (West African okra) which has a long production cycle is also grown in the humid zone of West and Central Africa (Sani *et al.,* 2019). A. *manihot* plants do not usually bloom, and this variety is frequently planted in Papua New Guinea for its leaves. (Kumar *et al.,* 2010).

2.3 World Okra Production

Okra can grow in subtropical and tropical climates all over the world (Ravishankar *et al.,* 2018; Kumar *et al.,* 2010). It is suitable for use as a garden crop as well as a commercial crop (Gemede *et al.,* 2015). Okra is grown commercially in India, Iran, Ethiopia, Turkey, Western Africa, Ghana, Japan, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Myanmar, Malaysia, Thailand, Brazil, Cyprus, and the United States of America (Benjawan *et al.,* 2007; Benchasri, 2012).

India is the top country in okra production in the world. As of 2020, the okra production in India was 6.37 million tons which accounted for 62.26% of the world's okra production. Nigeria, Mali, Pakistan, and Cote d'Ivoire are the other top four countries that contributed massively to the world's production. This represents 28.99% of 10.5 million tons of the world's okra produced. 1.83 million tons, 659 thousand tons, 280 thousand tons, and 188 thousand tons were produced by the top four countries respectively.

Ghana's okra production of 67 thousand tons was ranked 9th in the world and it is among the remaining countries whose production accounted for 8.75% of okra produced in the world (http://knoema.com/results/agriculture-indicators-production+okra (accessed on 17 February, 2022).

2.4 Okra Production in Ghana

Okra is Ghana's fourth most popular vegetable produced after garden eggs, pepper, and tomatoes. It is primarily grown for its succulent fruits as an early maturing crop Production, marketing, and consumption of okra are all done in Ghana's ten regions (Oppong-Sekyere *et al.,* 2011; Abla, 2015; Jain *et al.,* 2012). Brong-Ahafo, Ashanti, Northern, Volta, Greater Accra, and Central regions according to (Ahiakpa *et al.,* 2014) are some of the regions within which it is primarily grown. Okra, spicy peppers and eggplant are all resistant to high temperatures, making them easy to grow (Aleem *et al.,* 2020).

2.5 Importance of Okra

2.5.1 *Importance of Okra to Human Health*

Okra has been used as a vegetable and dietary supplement for a long time. It is in fact, suitable for a variety of medical and industrial purposes in addition to its nutritional purpose (Benchasri, 2012). Nutritionally, one hundred grams of edible okra contain moisture 89.6 g, minerals 0.7 g, Protein 1.9 g, carbohydrates 6.4 g, fat 0.2 g, calcium 66 mg, fiber 1.2 g, calories 35, potassium 103 mg, phosphorus 56 mg, magnesium 53.0 mg, and sodium 6.9 mg. Okra seed is known to be rich in high-quality protein, especially concerning its content of essential amino acids relative to other plant protein sources (Hassan and Ali, 2015).

The amino acid composition of okra seed protein is comparable to that of soybean, the PER (Protein Efficiency Ratio) is higher than that of soybean and the amino acid pattern of the protein renders it an adequate supplement to the legume or cereal-based diets (Adetuyi *et al.*, 2012).

Carotene, folic acid, polyphenolic chemicals, thiamine, niacin, vitamin C, riboflavin, oxalic acid, and amino acids are bioactive compounds that are all present in okra pods (Roy *et al.*, 2014). Its fruit contains flavonoids that act like antioxidants and neutralize free radicals, which are harmful by-products of biological metabolism; responsible for the deterioration of body cells, including those that are responsible for eyesight. Therefore okra consumption protects one's vision (Ilmi *et al.*, 2020; Kaparapu *et al.*, 2020).

Okra seeds contain primarily oligomeric catechins, polyphenolic compounds, flavonol derivatives, protein (i.e., high lysine levels), and oil fraction (its derived oil is rich in palmitic, oleic, and linoleic acid) (Arapitsas, 2008).

Soluble fibers and insoluble fibers are two types of fibers found in okra. Insoluble fibers are helpful for the intestines because they keep the intestinal tract healthy while soluble fibers assist lower cholesterol levels and the risk of heart disease. It also aids in the prevention of cancer, particularly colorectal cancer (Gemede *et al.*, 2015;(Butt and Sultan, 2011).

Abeesculin, a new ribosome-inactivating protein (RIP) isolated from mature plants, is used as immunotoxins, abortifacients, and antiviral agents in pharmacological and therapeutic applications (Begum *et al.*, 2011). Okra has also been known to replace discovered plasma or increase blood volume (Elkhalifa *et al.*, 2021). Among the

Abelmoschus, A. manihot type has been known to control fertility and childbirth, and it also stimulates lactation in women (Rewatkar *et al.*, 2010).

2.5.2 *Importance of Okra to Industry*

Apart from their nutritional worth, the root and matured stem and fruit of the okra which contains crude fiber are used in the paper industry (Makdoomi *et al.*, 2018). The seeds of okra contain about 20% – 40% of the oil (Gemede *et al.*, 2015). Therefore, okra production on a large scale is considerably induced to produce large quantities of oilseeds due to the high oil content (Singh and Sharma, 2022). This can supplement the increasing demand for vegetable oils by the human populace (Aminu *et al.*, 2019). *Abelmoschus moschatus* seeds have fragrant seed oil, hence cultivated for use in the fragrance industry (Kumar *et al.*, 2010). The seeds can also be roasted, crushed, and used as a caffeine-free substitute for coffee (Aseffa, 2019). Okra seed powder is used as a substitute for aluminum salts in water purification (Roy *et al.*, 2014). Anwar *et al.* (2010) also did reveal that oil in the okra seed can be used to efficiently create biodiesel because the seeds contain 21.72 percent crude oil, according to studies of various cultivars (Kumar *et al.*, 2019).

2.6 Diseases of Okra

2.6.1 *Southern blight (Sclerotium rolfsii)*

Southern blight is a serious disease produced by the soil-borne fungus *Sclerotium rolfsii*, which affects a wide range of crops including vegetables, fruits, field crops, ornamentals, and turf grasses (Ünal *et al.*, 2019). The disease development is aided by favorable conditions such as rainy conditions, acidic soils, and warm weather (24°C - 35°C). *Sclerotium rolfsii* can infect any portion of the plant, particularly those that come into contact with the soil or those that are close to the ground.

The growth of the disease on okra is aided by a warm and humid climate. *Sclerotium rolfsii*, a fungus, infects the roots and lower stems of the okra plant, causing progressive wilt symptoms. When conditions are favorable, the fungus mycelium can be observed around the point where the collar. In just a few days, a considerable amount of white sclerotia forms which becomes brown over time and grows to the size of one millimeter to two millimeters in diameter. The fungus can survive and function as a survival structure for this fungus for many years since it survives saprophytically. The movement of the pathogen *Sclerotium rolfsii*-infested soil infects other soils as well (Agbaglo, 2017).

2.6.2 *Damping-off (Pythium spp.)*

Damping-off kills most seedlings either before or shortly after the emergence of the okra seedlings (Sarkar *et al.,* 2022). The amount of pathogen present and the surrounding environment such as high humidity, moist soils, overcrowding, and compacted soils are favorable conditions for the fungus to thrive (Tripathi *et al.,* 2011). The okra plant is more susceptible to pre-emergence damping-off when the soil is cool. If okra seeds assault the seedling before it emerges, the seedling will fall to the ground and perish. When the attack hits the okra seedling around the collar region, the tissues beneath the water-soaked lesion become mushy. When the pathogen infects the crop at or below the soil line, young seedlings of okra can collapse over and die (Raid and Palmateer, 2006).

2.6.3 *Verticillium wilt (Verticillium albo-atrum)*

Verticillium wilt is a fungal disease that causes little yellowing symptoms of the lower and older leaves of the okra crop. This disease is caused by the fungus *Verticillium albo-atrum*.

Plants affected show signs of wilting during the mid-day when the temperature is quite high. The wilt progresses from the lower leaves to the top leaves until the plant finally dies. Discoloration of the vascular bundles can be seen when the bottom portion of the stem is cut longitudinally. The rapid growth and progression of *Verticillium* wilt are aided by high pH soils (Raid and Palmateer, 2006).

2.6.4 *Blossom blight*

Blossom blight is the most common okra disease, caused by the fungus *Choanephora cucurbitarum.* A cottony growth containing fungal fruiting bodies that are dark in colour, covers the blossoms and sometimes very little pods. These pods do not develop. Throughout periods of excessive humidity, which occur often during the growing season, the disease is most severe. On okra, no effective fungicides have been licensed for control. However, avoiding over-application of fertilizer and over-irrigation late in the evening and planting in poor portions or shady parts of the field would be the best control option according to Quilty and Cattle (2010).

2.7 Effects of Plant Spacing on the Growth and Yield of Okra

Plant spacing is one of several factors that contribute to low okra production per hectare. It has been discovered that proper plant spacing can result in maximum okra fruit yield Maurya *et al.* (2013) by affecting blooming, the number of leaves per plant, fruit per plant, and crop productivity per hectare as a whole (da Silva Nunes *et al.,* 2018). Consequently, inappropriate plant spacing can result in low yield and poor-quality fruits (Norman *et al.*, 2019). Da Silva Nunes *et al.* (2018) reported that the plant spacing for okra production varies according to the producer's system of conduction and interest but for increased land production of okra.

Maurya *et al.* (2013) reported the crop should be spaced between 60 cm to 80 cm apart in one row and 20 cm to 30 cm between the crops. Other authors have reported a plant spacing ranging from 20 cm to 40 cm between plants and 30 cm to 60 cm between rows for okra production (Gemechu, 2018).

It has been reported that optimum plant population is the key element for higher yields of okra, as plant growth and yield are affected by intra and inter-row spacing (Amjad *et al.*, 2001). This, therefore, has called for several kinds of research to be carried out globally to determine the appropriate spacing for the optimum yield of okra.

In this regard, Moniruzzaman *et al.* (2007) have reported 60 cm × 30 cm apart as the plant spacing for okra since it yielded the highest (2.86 tons ha^{-1}) when plants were spaced at that when they conducted a field experiment on okra with four different spacing (60 cm × 30 cm, 60 cm × 40 cm, 60 cm × 50 cm, and 60 cm × 60 cm) to determine the best plant spacing. Their results showed that the plants in the closest spacing (60 cm × 30 cm) grew taller, had an increase in seed yield per hectare but a reduction in the number of mature fruits per plant, length and diameter of mature fruit, number of seeds per fruit, 100-seed weight, and seed yield per plant. The maximum number of mature fruits per plant (26.70) was recorded from the widest spacing (60 cm × 60 cm), maximum fruit length (17.67 cm), and fruit diameter (1.98 cm). The lowest number of matured fruits was obtained from the closest spacing (60 cm × 20 cm) and produced fruits of the lowest length (15.90 cm) and diameter (1.80 cm). The highest number of seeds per fruit (62.2) and 100-dry seed weight (64.71 g) was recorded in the widest spacing (60 cm x 60 cm) identically followed by 60 cm x 50 cm spacing (59.9 g and 63.95 g, respectively). The highest seed yield per plant was obtained from the widest spacing (60 cm x 60 cm) closely followed by 60 cm x 60 cm spacing (83.10 g).

Bake *et al.* (2017) experimented to assess suitable combinations of sowing dates 10th (D1), 20th (D2), and 30th June (D3) at ten days interval and three spacing 60 cm × 45 cm, 60 cm × 60 cm, and 60 cm× 75 cm planting distances and their effects on various quantitative and qualitative attributes of okra. Their results showed that for days to 50% flowering the wider plant spacing (60 cm × 75 cm) exhibited the minimum number of days. The highest number of fruits per plant was achieved in closer spacing (60 cm × 45 cm), while maximum fruit length, fruit width, average fruit weight (g), fruit yield per plant, and fruit yield (g/ha) were attained in intermediate spacing (60 cm × 60 cm).

To find out the appropriate spacing and weeding regimes for okra production in Rivers State, Nigeria, Omovbude and Udensi (2018) used three spacing (60 cm x 15 cm, 60 cm x 20 cm, and 60 cm x 30 cm) and three weeding regimes [no weeding, weekly weeding, and twice at 3 and 7 weeks after planting (WAP)] in their experiment. They realized that as plant spacing increased, plant height decreased at various levels of spacing in each of the sampling intervals. The tallest plants were obtained from okra grown at the closer spacing of 60 cm x 15 cm in all sampling intervals, while plants spaced at 60 cm x 30 cm had the shortest plant. The highest value in terms of leaf area index and the number of fruits were obtained from okra spaced at 60 cm x 15 cm while the lowest was from plants spaced at 60 cm x 30 cm. the highest pod yield per plant was produced by plants spaced at 60 cm x 30 cm than other spacing.

To assess the effect of inter-row spacing (IRS) and rates of nitrogen (N) fertilizer on growth, yield components, and yield of okra crop, Gemechu, (2018) conducted research at Assosa, Western Ethiopia using three inter-row spacing (30 cm, 45cm, and 60 cm) and five rates of nitrogen (N) fertilizer (0, 23, 46, 69 and 92 kg N ha^{-1}). Gemechu realized that days to 50% flowering and pod setting of okra increased with the increased inter-row spacing from 30 cm to 60 cm. Flowering and pod setting in okra were delayed in plants grown at 60 cm inter-row spacing. However, plants at an inter-row spacing of 45 cm and 60 cm did not show a significant difference in the number of days required to attain 50% flowering. The delayed pod setting in plants at a row spacing of 60 cm was significantly different from days to pod setting in plants at a row spacing of 30 and 45 cm. Plants attained significantly highest height both at flowering (104.15 cm) and end of crop harvest (173.92 cm) due to 30 cm inter-row spaced, which was in reduction by about 20.68% and 15.99% compared to wider inter-row (60 cm) spaced plants at flowering (82.61) and end harvest (146.11) respectively.

The height of plants tends to reduce as inter-row spacing increases, however, the height of plants measured at flowering and end of crop harvest did not show significant differences at an inter-row spacing of 45 and 60 cm. The canopy of okra plants attained the maximum spread (97.77 cm) at an inter-row spacing of 60 cm whereas plants at a narrow inter-row spacing of 30 cm had canopy spread reduction by about 30.68% compared to the use of 60 cm inter-row spacing.

The maximum duration of harvest in days (32.73) and a maximum number of harvests (8.33) were observed in plants at an inter-row spacing of 60 cm while the minimum duration/period of harvest (26.13 days) and a minimum number of harvests (6.60) were observed in plants at 30 cm inter-row spacing. The duration and number of harvests increased by about 25.26 % and 26.21 % due to inter-row spaced at 30 cm as compared to 60 cm inter-row spaced plants respectively.

Agba *et al.* (2018) in their experiment to find out the effect of spacing and NPK 20:10:10 fertilizer on the growth and yield of okra in the years 2015 and 2016 in Nigeria, revealed that okra sown at a closer intra-row spacing of 60 cm x 15 cm gave a taller plant height (57.58 cm in 2015 and 59.34 cm in 2016), fewer number of branches, the highest leaf area index (2.0231 in 2015 and 2.3529 in 2016) and the highest pod yield (8.26 t/ha) and (8.03 t/ha) per hectare in the year 2015 and 2016 respectively. However, with the wider intra-row spacing of 60 cm x 60 cm the highest leaf growth rate (1.4032 g/m^2/day in 2015 and 1.6145 g/m^2/day in 2016) and stem (2.8740 g/m^2/day in 2015 and 3.166 g/m^2/day in 2016) dry matter accumulation rate. Days to attain 50% flowering was earlier (40.78 and 40.83), and fresh pod yield per plant (14.43 and 14.56) was higher in wide intra-row okra spacing of 60 cm x 60 cm than in other intra-row spacing.

Bishnoi *et al.* (2019) studied the effect of different spacing on growth, fruit quality, and yield of okra. The experiment was conducted at the farm of Sh. Jagdish Parshad at village Rampura, Teh. Abohar, Dist. Fazilka. Three different spacing 30 cm x 15 cm, 45 cm x 15 cm and 60 cm x 15 cm were used for experimentation. From the experiment, it was observed that the average maximum plant height (47.85 cm), number of pods per plant (1.35), and pod length (6.9 cm) were recorded in spacing (60 cm x 15 cm) and average minimum plant height (42.36 cm) and number of pods per plant (1.10) were observed in spacing (45 x 15 cm). But average minimum pod length (6.3 cm) was observed in spacing (30× 15 cm).

The average maximum number of leaves per plant (15.77) and some flowers per plant (0.55) were observed in spacing (45 cm x 15 cm) and the average minimum number of leaves per plant (13.32) and some flowers per plant (0.42) were observed in spacing (60 cm x 15 cm).

Bulo *et al.* (2019) at Sam Higgin bottom University of Agriculture, Allahabad carried out a field experiment to assess different plant spacing (T1 - 45 cm x 15 cm, T2 - 50 cm x 20 cm, T3 - 55 cm x 25 cm, T4 - 60 cm x 30 cm, T5 - 65 cm x 35 cm, T6 - 70 cm x 40 cm, T7 - 75 cm x 45 cm and T8 - 80 cm x 50 cm) on growth and yield of okra under subabul (*Leucaena leucocephala*) based alley cropping system. Results from their research showed that plant height was inversely proportional to plant spacing whereas the number of leaves per plant, number of branches per plant, number of fruits per plant, fruit weight per plant (g), and yield per plant (g) were directly proportional to plant spacing. Therefore, with a decrease in plant spacing from 80 cm x 50 cm to 45 cm x 15 cm, maximum plant height was found with the closest plant spacing. However, for yield (t/ha) T4 (60 cm x 40 cm) gave the highest value of 5.793. In terms of T5, T6, and T7, the wider spacing of 75 cm x 45 cm T7 had the highest number of leaves per plant (14.789), number of branches per plant, number of fruits per plant (12.13), fruit weight per plant (14.620 g) and yield per plant (202.02 g) but had the least value 4.543 tons for yield per hectare.

Another field research was undertaken at the Department of Crop Protection, School of Agriculture, Njala University to evaluate the effect of plant spacing, growth and yield, and profitability of okra variety, Clemson spineless, production in Sierra Leone from 2017 to 2018 main cropping seasons.

Five levels of plant spacing (50 cm × 40 cm, 60 cm × 30 cm, 60 cm × 40 cm, 70 cm × 30 cm, and 70 cm × 40 cm) as treatments were adopted with three replications. Their study revealed that 50 cm x 40 cm plant spacing significantly produced taller plants of heights 66.0 cm and 74.66 cm in both the 2017 and 2018 main cropping seasons respectively than all other plant spacing treatments. It also had the widest leaf area values (472.00 cm and 545.33 cm) for both 2017 and 2018 respectively. They further stated that decreasing the plant population significantly increased the yield and also the number of pods of okra. Hence, the minimum number of matured okra pods and pod weight being recorded from plants with the closest plant spacing of 50 cm x 40 cm in both the 2017 and 2018 cropping seasons. The widest plant spacing 70 cm x 40 cm produced the narrowest leaf area (191.00 cm and 158.50 cm respectively) at 4 and 8 weeks after planting and the shortest plant height (43.66 cm and 46.33 cm) during the 2017 and 2018 okra cropping seasons. Nevertheless, the wider plant spacing significantly yielded the maximum number of matured pods per plant, increased the number of pods by 108% in 2017 and 113% in 2018 as compared to 50 cm x 40 cm plant spacing in both cropping years. The lowest matured pod yield of okra ha^{-1} was obtained from plant spacing 70 cm x 40 cm in both years. The highest pod yield ha^{-1} (6.34 and 7.35) was produced with a plant spacing of 60 cm x 40 cm which was statistically at par with 70 cm x 30 cm plant spacing during the 2017 and 2018 cropping seasons (Norman *et al.*, 2019).

Two-row spacing of 60 cm x 40 cm and 60 cm x 50 cm were used to study okra's yield response to the different methods of fertilizer application (i.e. through fertigation tank and by manual application). Results showed that the response of the okra crop was considered a better combination of 60 cm x 50 cm through the fertigation method compared to manual application.

Yield attributes such as pod weight, pod length (11.02 cm), and pod perimeter (14.25 cm) were also observed to be best in the spacing of 60 cm x 50 cm. Similarly, plant characteristics namely plant height (39.16 cm), root depth, and lateral distribution of roots were also found to be highest (Tejaswini *et al.*, 2021).

2.8 Effects of Nitrogen Fertilizers Application on the Growth and Yield of Okra

Fertilizer is one of the most significant crop inputs since it boosts productivity and increases yield number and quality (Muhammad *et al.,* 2020). Nitrogen is the second most absorbed nutrient by vegetables, and it is a critical macronutrient throughout plant growth and development. This nutrient's appropriate management aids in vegetative growth and productivity. In okra's growth, nitrogen gives a better response in terms of fruit production as well as yields (Zubairu *et al.,* 2017). Nitrogen shortage leads to delayed plant growth, thin stems, and less leaf expansion; excess deficiency causes restrictions as it promotes the saline effect in the soil, resulting in nutritional imbalance. Excess deficit causes constraints as it promotes the saline effect in the soil, resulting in nutritional imbalance. Furthermore, it can cause oxidative damage to essential cellular components such as lipids, proteins, DNA, and RNA, as well as reduce plant development and yield, by prolonging the vegetative cycle of the plant and delaying blooming (De Souza Medeiros *et al.,* 2018).

Brar and Singh, (2016) have stipulated that the supply of nitrogen for crop production can have an impact on the crop's performance. As a result, crop nitrogen supply and demand must be synchronized. Nitrogen depletion and/or scarcity signal that the crop will either be unable to maintain its leaf area expansion rate or its leaf and plant nitrogen concentration. Either of these factors will have an impact on crop growth and economic product production. The source of nitrogen, soil type, and environmental conditions have been reported by Hofman and Cleemput, (2004) to influence its availability to plant's performance.

The required amount of nitrogen for the highest fruit output, as reported in numerous publications and journals according to Brar and Singh, (2016), ranges from 120 to 200 kg/ha for okra crops. On the other hand, De Souza Medeiros *et al.,* (2018) have reported nitrogen quantities ranging from 60 to 180 kg ha^{-1} depending on the soil fertility of the producing region.

The specific nitrogen need of a crop, which fluctuates according to environmental variables, soil, and climate according to Brar and Singh, (2016) must be assessed by a field trial. In this regard, in comparison to a control, nitrogen (90 kg ha^{-1}) by vermicompost and urea considerably increased plant height, branch per plant, and leaf area of okra (Garhwal *et al.,* 2007). With the treatment of 150 kg NPK ha^{-1}, the maximum plant height, leaf area, root length, number of leaves, and yield of okra were achieved (Omotoso and Shittu, 2007). The treatment of 140 kg N ha^{-1} and 100 kg P ha^{-1} greatly improved the plant height and leaf area of okra (Singh *et al.,* 2008).

Firoz (2009) reported 100 kg N ha^{-1} as the required nitrogen for okra after obtaining the highest yield of 16.73 t ha^{-1} at Hill Agricultural Research Station, Khagrachari. The experiment was conducted to assess the effect of different rates of nitrogen (60, 80, 100, and 120 kg ha^{-1}) in combination with phosphorus (80, 100, and 120 kg ha^{-1}) on the growth and yield of okra during the rainy season. The report again showed that increasing the rate of nitrogen fertilizer up to 120 kg ha^{-1} increased plant height, the highest number of fruits per plant (20.6), and the percentage of branched plants (40%). And that increased percentage of branched plants led to an increased yield of okra.

Nitrogen fertilizer rate, 60 kg N/ha recorded the shortest plant height (1.30 m), the minimum percentage (24%) of branched plants, and the lowest number of fruits per plant (14.1). However, when nitrogen fertilizer was applied at 120 kg per hectare, the yield decreased, but it was at par with 100 kg N/ha. The differences in yield among four nitrogen levels were attributable to the difference in pods per plant and the weight of pods per plant. As the number and weight of fruits were higher in the plant from 100 kg N/ha, the ultimate fruit yield was higher in those plants.

Ekwu *et al.* (2010) also conducted a field experiment at the faculty of Agriculture and Natural Resources Management's experimental farm to assess the effects of different nitrogen rates (0, 70, 140, 210 kg N ha^{-1}) and mulching (grass mulch) on okra vegetative development and green pod yield. The nitrogen rate of 140kg ha^{-1} produced the most branches and leaves but days to 50% flowering were prolonged and shortest where nitrogen was omitted according to their findings.

Uddin *et al.* (2014) experimented to evaluate the different doses of nitrogen on the growth and yield of okra (BARI Dherosh-1). The experiment consisted of four levels of nitrogen viz. N0: 0, N1: 110, N2: 120, and N3: 130 kg N/ha using Randomized Complete Block Design with three replications. Maximum plant height (86.2 cm), number of leaves (43.8/plant), leaf length (28.8 cm), petiole length (23.1 cm), stem diameter (2.3 cm), internode length (14.3 cm), number of branches (4.0/plant), fruit length (16.8 cm), fruit diameter (1.9 cm), number of flower buds (29.4/plant), weight of individual fruit (11.6 g), fresh weight of leaves (298.4 g/plant), dry matter content of leaves (12.0%) and yield (7.1 kg/plot and 16.4 t/ha) was found from N2 whereas minimum from N0.

Amanga *et al.* (2017) reported that the application of nitrogen at the rate of 46 and 69 kg N ha^{-1} led to the longest days 50.40 and 51.40 to 50% flowering respectively as compared to the control treatment, which gave the least days to flowering (46.33) of okra plant at Gambella region, Western Ethiopia. Nitrogen application at 69 kg N ha^{-1}

recorded the longest number of days to pod setting (54.33) while the control level (0 kg N ha^{-1}) recorded the lowest days to pod setting 49.93. Maximum plant height (63.41 cm) was recorded from the application of a nitrogen fertilizer level of 23 kg N ha^{-1}, whereas the minimum plant height was recorded from the rest of the nitrogen fertilizer levels. The application of nitrogen rates at 23 kg N ha^{-1} also resulted in the maximum length of the pod-bearing zone (54.03) and the maximum number of leaves per plant (15.91). However, an increase in the rate of nitrogen beyond 23 to 46 and 69 kg N ha^{-1} resulted in a significant reduction in the length of pod bearing zone to 49.23 (8.9%) and (46.84) 13.28%, respectively, compared to 23 kg N ha^{-1} application.

De Souza Medeiros *et al.* (2018) evaluated the growth and yield of okra (Santa Cruz cultivar) under different nitrogen rates (N1 = 0, N2 = 40, N3 = 80, N4 = 120, N5 = 160, and N6 = 200 kg ha-1) and irrigation facilities using post-treated domestic wastewater in Paraíba state, Brazil. The effects of treatments on the growth and production variables of okra plants were evaluated. The increment in the nitrogen rates significantly influenced only the leaf area of the okra plants. However, a nitrogen rate of 200 kg ha^{-1} promoted the highest yield of okra production (1,273.53 g), increased leaf area, and the number of fruits (38). The maximum rate of nitrogen promoted greater cell division and the formation of more tissues, which resulted in greater leaf expansion, an increase in the root system, and the relationship between the leaf area and photosynthesis, which consequently influence fruit production.

Gemechu (2018) having applied nitrogen fertilizer at a rate of 69 kg N ha^{-1} significantly increased the period of harvesting (33.89 days) and some harvests (8.67) of local okra variety by name ‘Bamia’ at Assosa Agricultural Technical Vocational Education and Training College, Benishangul Gumuz Regional State. The further report showed that the increase in nitrogen application rate from 0 to 46 and 0 to 69 kg Nha^{-1} led to the longest days to 50% flowering (51.40 days), prolonged the duration of 50% pod set by 7.6 % as compared to the control treatment, which gave least days to flowering (46.33). The application of the 69 kg N ha^{-1} increased the flowering date by 10.94% as compared to the control. The application of a nitrogen fertilizer rate of 46 kg N ha^{-1} significantly increased the number of leaves per plant by 16.81% compared to the number of leaves per plant recorded to control plots. Nevertheless, applying more nitrogen beyond 46 kg ha^{-1} did not favour the production of a greater number of branches.

Rahman *et al.* (2020) also observed that the application of 150 kg N ha^{-1} to okra variety BARI Dherosh-2 in rooftop garden produced the highest leaf breadth (37.49 cm), number of leaves plant per plant (62.07), number of branches planted per plant (9.87), number of nodes plant per plant (24.20), number of internodes plant per plant (23.87), fruit petiole length (5.76 cm), fruit length (13.20 cm) and fruit diameter (2.11 cm), number of fruits plant per plant (24.10), single fruit weight (16.59 g), yield plot per plot (3.80 kg) and yield ha^{-1} (13.89 t). However, the application of 180 kg N ha^{-1} recorded the highest plant height (123.20 cm), leaf length (30.17 cm), and stem base diameter (3.25) in those growth parameters.

The results of a field study undertaken during the Kharif season of 2011-12 at Horticulture Research Farm, Department of Horticulture, College of Agriculture, Sehore using four-level of Nitrogen (N1-75 kg ha^{-1}, N2-100 kg ha^{-1}, N3-125 kg ha^{-1}, N4-150 kg ha^{-1}) and three levels of gibberellic acid, GA3 (G1-0 ppm, G2-50 ppm, G3-100 ppm) showed that 150 kg N ha^{-1} and 100 ppm concentration of GA3 used as seed treatment was the best treatment for obtaining higher fruit yield of okra. The results on growth parameters indicated that an increase in the levels of nitrogen from 75 to 150 kg/ha significantly increased the plant height at 30 days after sowing (DAS) from 10.60 cm to 16.41 cm; plant spread at 30 DAS from 11.80 cm to 18.80 cm; stem diameter at 30 DAS from 0.23 cm to 0.34 cm; and the average leaves per plant at 30 DAS from 6.93 to 8.55 while the minimum values were recorded under the treatment N1G1 (N-75 kg/ha + GA3-0 ppm). In terms of the yield characteristics, the length of fruit (21.08 cm), the girth of fruit (2.59 cm), the weight of fruit (17.36 g), and yield per hectare (83.15 g) were recorded as a maximum under the treatment N4G3 (N-150 kg/ha + GA3-100 ppm) while treatment N1G1 (N-75 kg/ha + GA3-0 ppm) recorded minimum. The dry weight of 100 g fruits of okra was found maximum of 10.42 under the treatments combinations N4G3 (N-150 kg/ha + GA3-100 ppm) and a minimum of 9.81 under the treatments combinations N1G1 (N- 75 kg/ha + GA3-0 ppm) (Verma *et al.*, 2020).

Four doses of goat manure compost (0, 5, 10, 15, and 20 tons ha^{-1}) were used on okra plants spaced at 60 cm x 40 cm; 70 cm x 40 cm; 80 cm x 40 cm to evaluate their effect on the growth at observed age 14, 28 and 42 days after planting (DAP) and yield of okra plants. The results showed that plant spacing 80 cm x 40 cm had an independent effect on the number of flowers (10.89), number of fruits, and fruit weight (1.28 g), as well as goat manure compost dose on plant height at 42 DAP, number of leaves at 14 DAP and 42 DAP, stem diameter at 28 DAP, number of fruits and fruit weight (Nurmas *et al.*, 2021).

2.9 Effects of Plant Spacing and Nitrogen Fertilizer Application on the Growth and Yield of Okra

Uddin *et al.* (2014) carried out a study entitled "Impact of nitrogen and spacing on the growth and yield of okra". The applications of nitrogen at 100 kg ha^{-1} to plant spaced at 60 cm x 30 cm recorded higher yield attributes of the number of nods per plant, leaves per plant, internodes length, plant height, and pod length, number of pods per plant, fruit yield per plant and total green pod yield per hectare. Nitrogen application up to 125 kg ha^{-1} significantly decreases the days to 50% flowering. The pod weight, pod length, the number of nodes per plant, the number of pods per plant, fruit yield per plant, and total green pod yield per hectare increased higher with the optimum plant-to-plant spacing of 15 cm. The results revealed the interaction between nitrogen level and plant density was present in the case of plant growth and yield contributing characteristics of okra. Although the highest-level interaction of 100 kg N ha^{-1} with a plant to plat spacing of 15 cm produced a high number of nods per plant, pod weight, pod length, number of pods per plant, pod yield per plant, and total green pod yield per hectare and the days to 50% flowering decreased was recorded with 125 kg N ha^{-1} and plant to plant spacing 20 cm.

Brar and Singh (2016) also recommended 100 kg ha^{-1} used on a plant-to-plant spacing of 15 cm on okra to have resulted in higher yield attributes per hectare in their investigation entitled "Impact of nitrogen and spacing on the growth and yield of okra". Their treatments for the experiment were three nitrogen doses viz. 75, 100, and 125 kg ha^{-1} and three plants to plant spacing viz. 10 cm, 15 cm, and 20 cm.

Their research proved that a treatments combinations of 125 kg ha^{-1} nitrogen with a spacing of 20 cm proved to be the overall best treatment which increased leaves per plant (24.6), number of pods per plant (40.2), number of nodes per plant (37.1), the maximum pod length of 10.3 cm and lowest days to 50% flowering (45.3days) from other combination of treatments. The maximum internode length of 3.30 cm was produced by the combined effect of 125 kg ha^{-1} and spacing of 10 cm which was significantly higher than all other combinations. The maximum total green pod yield

(77.6 g ha^{-1}) was produced by the combined effect of 125 kg ha^{-1} and 15 cm spacing which was significantly higher than all other combinations.

Amanga *et al.,* (2017) have reported that growing okra at plant spacing 45 cm x 30 cm (74,047 plants ha^{-1}) with a nitrogen rate of 46 kg N ha^{-1} does have a significant influence on the growth and yield components of okra. Results from their experiment showed that maximum dry pod yield (16.65 t ha^{-1}), highest fresh pod yield (46.14 t ha^{-1}), and above-ground biomass yield (119.34 t ha^{-1}) were attained when okra variety, 'Amula' was grown in Gambella area, Western Ethiopia. The maximum length of green pods (29.01 cm) was recorded from the interaction between plant spacing 60 cm x 40 cm and nitrogen application rate of 46 kg N ha^{-1} pod diameter (3.27 cm) was attained with plant spaced at 60 cm x 30 cm and from the nitrogen application rate of 46 kg N ha^{-1}. However, the minimum dry pod yield was recorded from plant spacing 60 cm x 40 cm and all the applied nitrogen fertilizer rates. The highest number of branches was recorded from plants spaced 45 cm x 30 cm and 60 cm x 30 cm when nitrogen was applied at 46 kg N ha^{-1}.

Gemechu, (2018) assessed the effect of inter-row spacing (IRS) and rates of nitrogen (N) fertilizer on growth, yield components, and yield of okra crop at Assosa, Western Ethiopia. The experimental treatments consisted of three inter-row spacing (30 cm, 45 cm, and 60 cm) and five rates of nitrogen (N) fertilizer (0, 23, 46, 69, 92 kg N ha^{-1}). Results indicate that nitrogen applied at 92 kg N ha^{-1} to okra crop grown at an inter-row spacing of 60 cm recorded the maximum number of branches per plant (3.00), the maximum number of tender fruits per plant (23.99), the weight of tender fruit per plant (25.67 g) and the maximum fruit yield (0.46 kg). Meanwhile, the maximum number of branches per plant was in statistical parity with the row spacing of 45 cm in combination with 69 kg N ha^{-1} and 92 kg N ha^{-1}; and inter-row spacing of 60 cm with the application of 46 and 69 kg N ha^{-1}. The highest number of tender fruit due to the combined effect of IRS/N at 60 cm/92 kg N ha^{-1} had statistical parity at 60 cm/69 kg N ha^{-1}, 60 cm/69 kg N ha^{-1} and 60 cm/23 kg N ha^{-1}. However, the minimum number of branches per plant (0.67) and weight of tender fruit (15.88 g) were obtained from 30 cm inter-row spacing without nitrogen fertilizer application (control).

Nurmas *et al.* (2021) investigated the impact of plant spacing (60 cm x 40 cm; 70 cm x 40cm; 80 cm x 40 cm) and goat manure composition (0, 5, 10, 15, and 20 tons ha^{-1}) on the okra (*Abelmoschus esculentus* L.) crop on food security. Their results revealed a spacing of 80 cm x 40 cm in combination with compost doses of goat manure 20 tons ha^{-1} to have a favorable interaction in the variable height of plants (13.67 cm) at 14 DAP (days after planting) and 32.85 cm at 28 DAP, the number of leaves 28 DAP, stem diameter (5.73 cm) at 42 DAP, and fruit weight (39.20 g).

2.10 Maturity and Harvesting

According to Quilty and Cattle (2010), Okra pods are young fruits that are harvested at a rapid rate. Three to seven days after bloom, harvesting takes place. It's time to pick okra when the pods are substantial and the fruit is bright green with little seeds. The pod turns pithy and harsh after that period, and the green hue and mucilage content decrease. Okra pods should be soft and fibrous, and the color should match the varietal (generally bright green). The fragile pods are frequently broken during harvest, especially along the ridges, resulting in unsightly brown and black discoloration.

Okra is harvested when its length reaches 5 cm to 7.6 cm to obtain the tender texture; however, the fruit length depends on the variety. The picking time’s extent will increase the length, diameter, and okra fruit weight Fruit length and diameter of okra genotypes varied from 5.00 cm to 25.00 cm and 1.90 to 260 cm respectively according to Saifullah and Rabbani (2009).

Normally, the harvesting of okra takes place first thing in the morning following which it is sold (Booth et al, 1976). Harvesting the crop regularly will boost the yield and encourage development (Varmudy, 2011). Okra pods are normally plucked every other day from the time the first pod is developed (Fajinmi and Fajinmi, 2010). However, a two (2) day picking interval according to Maurya *et al.* (2013) recorded the highest (23.99 tons) yield per hectare for okra variety, Clemson Spineless, when they used a closer spacing of 45 cm x 30 cm. This according to them was significantly higher than any other combination of plant spacing and picking interval. This two (2) day interval of harvesting okra pods had again been affirmed by Falodun and Ogedegbe, (2016) when they conducted a field experiment to assess the response of planting spacing and harvest intervals on the growth of okra yield at the Teaching and Research Farm of the Faculty of Agriculture, University of Benin, Benin City, Nigeria. Their treatments consisted of four planting spacing, 40 cm x 30 cm, 50 cm x 30 cm, 60 cm x 30 cm, and 70 cm x 30 cm, and three harvest intervals of (1 day, 2 days, and 3 days). Their results obtained showed that the spacing of 40 cm × 30 cm gave the highest pod yield (0.58 t/ha) while the two days harvest interval produced the maximum value for pod weight per plant, number of pods, and pod yield (0.54 t/ha)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site and Location

The experiment was conducted at the experimental field of the Department of Crop and Soil Sciences, Faculty of Agriculture, College of Agriculture Education of Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Mampong-Ashanti campus.

Mampong-Ashanti is located north of Kumasi within the transitional zone which is between the Guinea Savanna in the North and the rainforest region in the South. Mampong-Ashanti is at about 457.5 meters above sea level and is located at latitude $7^{\circ}4'$N of the equator and longitude 1° 24'W (Asante *et al.,* 2019). Asante Mampong is 56 Km from Kumasi (http://distancesfrom.com/gh/distance-from-Kumasi-to-Asante-Mampong/DistanceHistory/6569001.aspx (accessed on 17 February, 2022).

The type of soil in Mampong-Ashanti is Savanna Ochrosol, which is derived from the Voltaian sandstone which occurs on the upper and middle slopes of the Catena. The soil according to local classification belongs to the Bediesi series which is well-drained, red, friable, and permeable with moderate water holding capacity and contains a moderate amount of organic matter. It is classified as chronic luvisol in the FAO/ UNESCO legend (Asiamah, 1998).

The soil of the area is suitable for growing many vegetables such as carrots and pepper. It is also used for growing other crops such as yam, cassava, cocoa, maize, and plantain. The vegetation cover of the area is the Savanna type with a lot of grasses. However, the most common weeds that emerged on the field were Cyprus species, *Eleusine indica*, and milk weeds.

3.2 Climatic Information

Total rainfall for the minor and major cropping season of 2020 was 910 mm while the average relative humidity for the minor and major was 79%. The major rainy season starts in Mid-March and ends in July, with a short dry spell in August. The minor season also starts in September and ends in Mid-November. The highest average temperature was 36 $^{\circ}$C in January and the lowest was 29 $^{\circ}$C in July. (Metrological Service Department of Mampong-Ashanti, 2020).

3.3 Preparation of the Experimental Field

The experimental field was slashed, ploughed, and harrowed to a fine tilt. The field was further divided into three (3) replications, replication one (R1), replication two (R2), and replication three (R3) using a tape measure and line (rope) and pegs. Each replication was further demarcated into nine (9) treatment plots of dimension 4.8 m × 3.0 m. Alleys between the replications were 1.0 m while that between the plots was 0.5 m. The total size of the experimental area was 639.6 m^2 (49.2 m × 13.0 m).

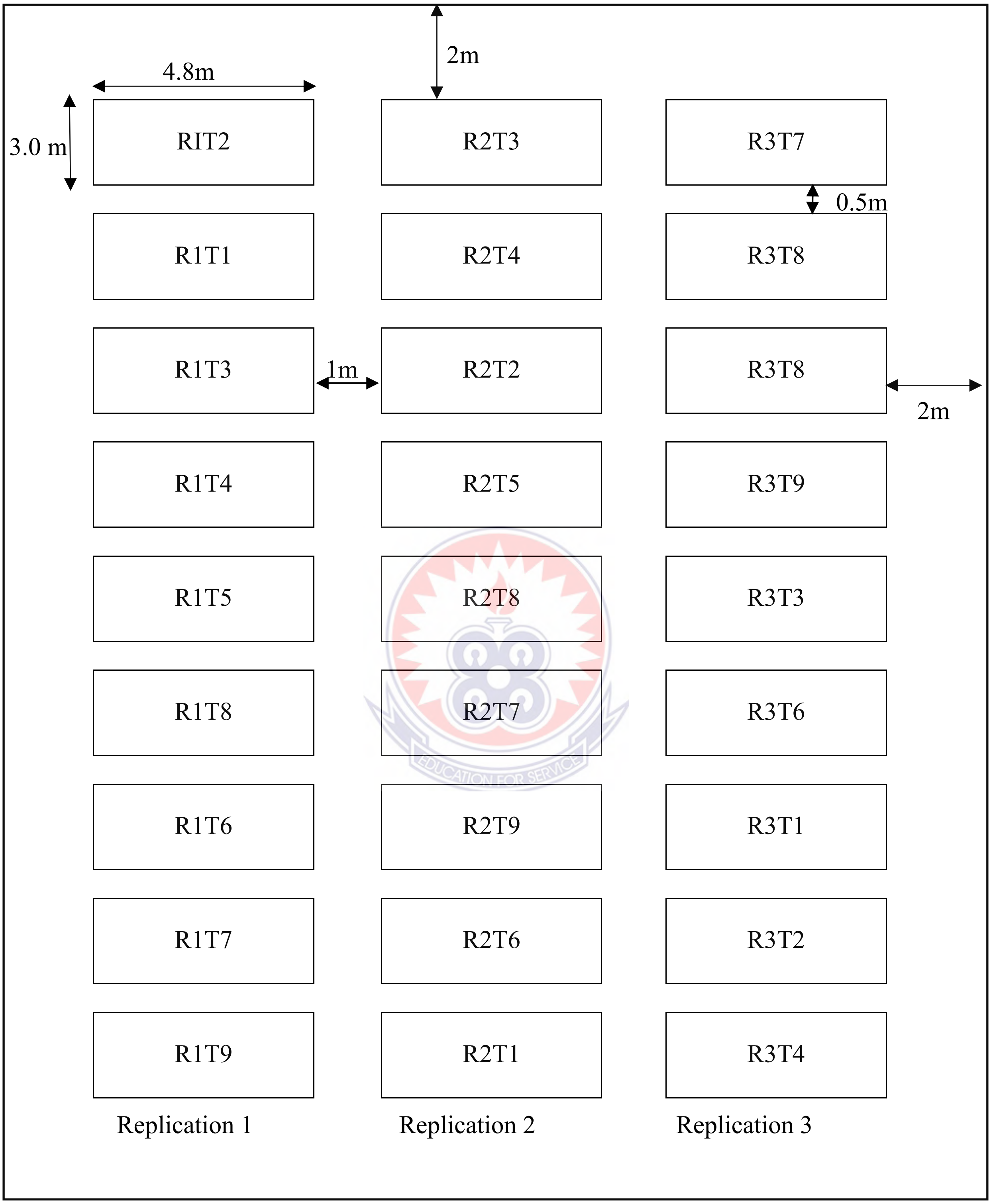

Figure 3.1: Field Layout

3.3.1 *Experimental Design*

The experimental design was a 3 x 3 factorial arrangement in a Randomized Complete Block Design (RCBD) with three (3) replicates. Soil amendments and plant spacing formed the factors. The soil amendments were three (3) different rates of urea as viz. N1 (0 kg N ha^{-1}), N2 (46 kg N ha^{-1}) and N3 (69 kg N ha^{-1}) as recommended by (Amanga *et al.,* 2017). Whilst that of the plant spacing was three (3) namely, S1 (60 cm × 40 cm), S2 (60 cm × 50 cm), and S3 (60 cm × 60 cm) as recommended by Tejaswini *et al.* (2021). In all, there were nine (9) treatments combinations viz, T1 (S2 N1), T2 (S3 N2), T3 (S1 N3), T4 (S2 N2), T5 (S2 N3) T6 (S1 N1), T7 (S1 N2), T8 (S3 N1) and T9 (S3 N3).

3.3.2 *Treatments*

Factor A: Soil amendment

N1 = 0 kg N ha^{-1} (Control)

N2 = 46 kg N ha^{-1} (66 g per plot)

N3 = 69 kg N ha^{-1} (99 g per plot)

Factor B: Plant spacing

S1 = 60 cm × 40 cm

S2 = 60 cm × 50 cm

S3 = 60 cm × 60 cm

Treatment combinations

T1 = S2 N1 (60 cm x 50 cm + 69 kg N ha^{-1})

T2 = S3 N2 (60 cm x 50 cm + 0 kg N ha^{-1})

T3 = S1 N3 (60 cm x 40 cm + 69 kg N ha^{-1})

T4 = S2 N2 (60 cm x 50 cm + 46 kg N ha^{-1})

T5 = S2 N3 (60 cm x 60 cm + 46 kg N ha^{-1})

T6 = S1 N1 (60 cm x 40 cm + 0 kg Nha^{-1})

T7 = S1 N2 (60 cm x 40 cm + 46 kg N ha^{-1})

T8 = S3 N1 (60 cm x 60 cm + 0 kg N ha^{-1})

T9 = S3 N3 (60 cm x 60 cm + 69 kg N ha^{-1})

3.4 Planting Material

An imported and distributed Technisem okra seed (*Asontem*) by Agriseed Limited, Ghana, was bought from the open market and used as received. The seeds had thiram treatment, a 99 % minimum purity, and 80% minimum germination.

3.5 Sowing of Seeds

The okra variety "*Asontem*" seeds were sown directly without prior soaking in water on the 11th day of March, 2022. The sowing was done using a dibber at a seed rate of four (4) seeds per hill at a planting depth of 1.5 cm.

3.6 Cultural Practices

3.6.1 *Thinning Out*

On the 24th day of March, 2022, that is, the thirteenth (13th) day after sowing, seedlings were thinned to one stand per hill. In order not to disturb the roots of the seedling that was left standing, scissors were used to cut the seedlings from the base above the soil level.

3.6.2 *Weed Control*

Regular hoeing and hand pulling of weeds were used to control weeds on the field. Weeds in the vicinity, a five-centimeter radius of the crop's stem were uprooted with the hand while the rest of the field was done with a hoe.

3.6.3 *Irrigation*

Rainy, humid, warm, and dry spell conditions were encountered during the experimental time; thus, watering of the field was done with a rubber hose and watering can occasionally.

3.6.4 *Fertilizer Application*

A white prilled urea fertilizer, marketed and distributed by Afcott Ghana Limited was bought from the open market and used as received. It had total nitrogen of 46% minimum, 1% max of Biuret, 0.50 maximum of moisture, and granulometry 1-4 mm of 90% minimum. This urea fertilizer was applied on the 8th day of April, 2022 at a rate of 0 kg N ha^{-1} (control), 46 kg N ha^{-1} (66 g per plot), and 69 kg N ha^{-1} (99 g per plot). It was further replicated three times on the experimental plots within blocks. To obtain the actual rate to be applied per stand, the various plant populations of 78, 60, and 55 from each plant's spacing S1, S2, and S3 respectively were calculated. Hence, urea fertilizer of quantity of 0.8 g, 1.1 g, and 1.2 g was derived from the 66 g of urea per plot and was applied to plant spacing S1, S2, and S3 respectively. Similarly, the urea rate of 99 g per plot was again calculated to obtain a rate of 1.3 g, 1.7 g, and 1.8 g for plant spacing, S1, S2, and S3 respectively and was applied to each plant per treatment plot.

3.6.5 *Control of Pests and Diseases*

Pests like white flies (*Bemisia tabaci*), Red cotton bug (*Dysdercus koenigii*), grass hoopers, green stink bug (*Acrosternum hilare*), caterpillars, and Flea beetle (*Podagrica spp.*) which were identified were controlled with Goland (Acetamiprid 200g per liter) insecticide that has a stomach action and strong systemic and translaminar activity. It was used as a foliar spray at the rate of 15ml per 15 liters of water. ACP 15-liter knapsack sprayer was used in spraying the insecticide beginning from one (1) week after planting and at every three (3) days intervals until seven days to harvesting (8^{th} week after sowing). The predominant disease encountered was the leaf mosaic virus.

3.6.6 *Harvesting*

Harvesting was done manually by plugging at four days' intervals starting from 13^{th} June 2022 (9th week after sowing) to 2^{nd} June 2022 (12th week after sowing). All five harvestings were done.

3.7 Data Collection and Measurement

Five (5) plants out of the ten (10) plants from the two middle rows were randomly selected and tagged in each plot for observation and results collection. The results collection on vegetative growth indicators such as the number of leaves per plant, plant height, and stem girth were taken at weeks 5, 6, and 7 after sowing while the number of branches per plant was taken at 7, 8, and 9 weeks after sowing. Yield parameters were taken at week 9 to 12 weeks after sowing (WAS).

3.7.1 *Number of Leaves per Plant:*

The number of leaves per plant was recorded by counting the leaves that were fully opened on each of the tagged plants. Mean values were calculated and analyzed.

3.7.2 *Plant Height (cm)*

The plant height of the tagged plants in each plot was measured from the collar region of the stem to the tip of the freshly opened leaf in the apical area using a measuring tape. Mean values were calculated and analyzed.

3.7.3 *Stem Diameter (cm)*

The stem girth of each of the tagged plants was taken at the collar region of the plants using a vernier caliper. The average values were computed and analyzed.

3.7.4 *Number of Branches per Plant*

The number of branches per plant was determined by counting the branches on the tagged plants in each treatment plot and their averages were computed and analyzed. Emerged branches with two or more fully opened leaves were considered branches.

3.7.5 *Number of Fresh Pods per Plant*

The number of pods per plant was counted every four days picking intervals on the tagged plants in each plot for three (3) weeks. The means of the total number of pods obtained from the selected plants were computed and analyzed. All pods per plant were taken at five harvesting times.

3.7.6 *Length of Fresh Pod (cm)*

If the number of pods harvested per plant was either less or equal to five, one pod was selected to represent the respective plant and if the pods per plant obtained were more than five but less than ten, two pods were randomly selected. The length of the pods was recorded by measuring the length of each green pod from the tip to the base of the fruit using a thread and its respective length was measured on a tape measure. Average values were computed and analyzed.

3.7.7 *Fresh Pod Diameter (cm):*

The fresh pod diameter of the randomly selected pod was measured using a vernier caliper and the mean values were computed and analyzed.

3.7.8 *Fresh Pod Weight (g):*

The fresh pod weight of the randomly selected pod(s) from the sampled crops was measured by using a digital balance. The average weight of the pods was calculated, computed, and analyzed.

3.8 Pod Yield (tons/ha):

The fruits within the harvestable area of each plot were harvested and weighed for pod yields per plot. This was converted into pod yield per hectare (kg/ha) using the formula:

$$\text{Pod yield (t/ha)} = \frac{\text{Harvestable Yield } (Kg)}{\text{Harvested area } (m^2)} \times 10000 \text{ m}^2$$

3.9 Data Analysis

Analysis of variance (ANOVA) was carried out on all numerical results using GenStat statistical package, 18th edition. The least significant difference (LSD) at 5 percent was used to compare the treatment means.

CHAPTER FOUR

4.0 RESULTS

4.1 Vegetative Growth Parameters of Okra

4.1.1 *Plant Height*

Figure 4.1 shows plant heights at 5, 6, and 7 weeks after sowing (WAS) as influenced by plant spacing. The result shows that there is a general trend of the plant height decreasing as plant spacing increases. It can be seen that the closer plant spacing (S1) performed better in attaining the tallest plant height relative to the other spacing treatment. Hence, the maximum plant heights of 27.02 cm, 36.91 cm, and 45.98 cm were obtained respectively in closest plant spacing (S1), followed by plant spacing S2, with a plant height of 24.88 cm, 34.21 cm, and 42.58 cm. The minimum plant height of 24.10 cm, 32.60 cm, and 39.54 cm was seen from the widest plant spacing (S3).

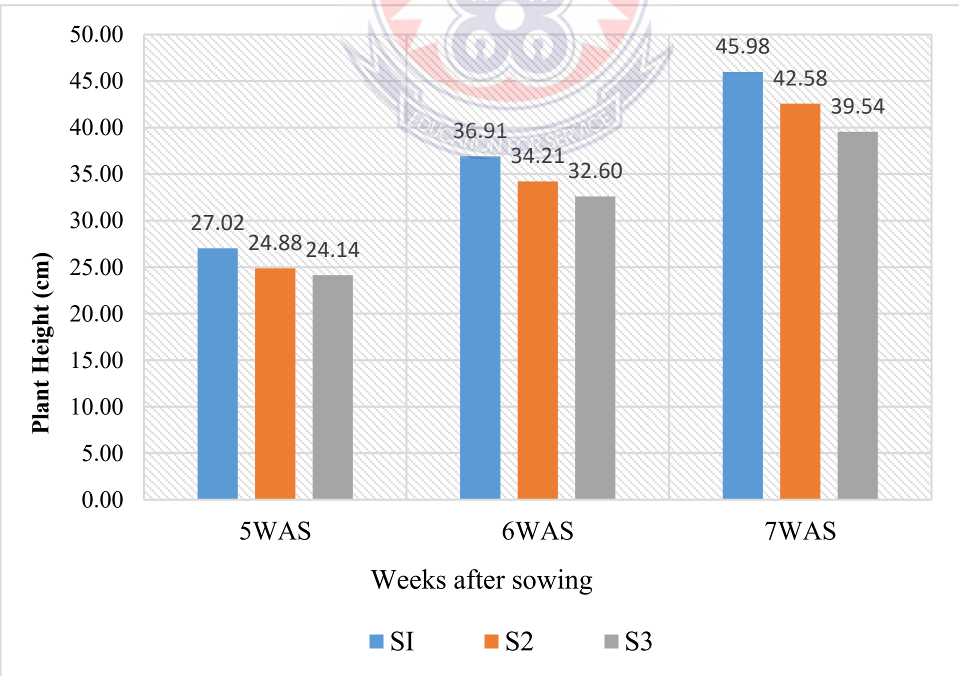

Figure 4.2: Plant height as influenced by plant spacing

Plant height again shows a general trend of gradual increase with the increasing levels of urea fertilizer applied (Figure 4.1). This show that increasing the rates of urea fertilizer application had a direct influence on okra's vegetative growth generally. Urea fertilizer applied at the highest rate (N3) performed better in achieving the maximum plant heights (34.09 cm, 4.68 cm, and 49.16 cm) than the plant heights observed with either N2 or N1 rates of urea applied at 5, 6, and 7 weeks after sowing. The minimum plant height (17.13 cm, 25.02 cm, and 33.94 cm) was found in okra plants that were treated with no urea fertilizer at all (N1).

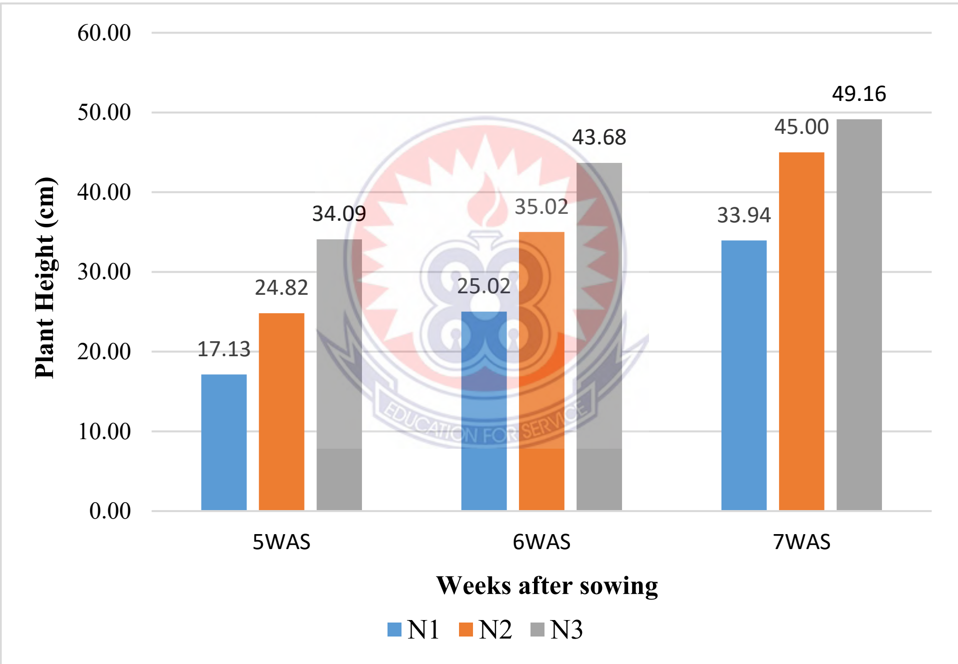

Figure 4.3: Plant height as influenced by different rates of urea fertilizer application

The combined effect of plant spacing and different urea fertilizer applications on plant height is shown in Table 4.2. A significant difference ($P<0.05$) was obtained in the plant heights among the various treatments applied during the growth stages of the plant. Generally, the highest plant height of 38.10 cm, 47.90 cm, and 54.67 cm was found in treatment combination, T3 while the shortest plant height (16.37 cm, 24.10 cm, and 32.20 cm) was observed in treatment combination, T8. However, at 7 weeks after sowing (WAS), plant height measured in the treatments T9 and T2 were not statistically different from each other. A similar observation too was seen for plant heights attained by plants subjected to the treatment combination T7 and T5.

Table 4.1: Plant height as influenced by treatment combinations

	Plant Height (cm)		
	5 WAS	6 WAS	7 WAS
Treatment combination			
T1 (60 cm x 50 cm + 0 kg N ha^{-1})	17.53a	26.10a	35.37a
T2 (60 cm x 60 cm + 46 kg N ha^{-1})	25.10b	31.80b	42.00b
T3 (60 cm x 40 cm + 69 kg N ha^{-1})	38.10d	47.90e	54.67d
T4 (60 cm x 50 cm + 46 kg N ha^{-1})	23.90b	35.30c	44.00b
T5 (60 cm x 50 cm + 69 kg N ha^{-1})	31.00c	41.23d	48.37c
T6 (60 cm x 40 cm + 0 kg N ha^{-1})	17.50a	24.87a	34.27a
T7 (60 cm x 40 cm + 46 kg N ha^{-1})	25.47b	37.97c	49.00c
T8 (60 cm x 60 cm + 0 kg N ha^{-1})	16.37a	24.10a	32.20a
T9 (60 cm x 60 cm + 69 kg N ha^{-1})	33.17c	41.90d	44.43b
LSD (5%)	4.81	3.25	3.67
CV (%)	11.0	5.4	5.0

Means followed by or sharing the same letters within a column are not significantly different at a 5% level of significance; CV = coefficient of variation, LSD = least significant difference at 5%; WAS = Weeks after sowing, T = Treatment, N = Nitrogen

4.1.2 *Number of Leaves per Plant*

The number of leaves per plant as influenced individually by plant spacing and different urea fertilizer applications at 5 WAS, 6 WAS, and 7 WAS is presented in Table 4.2. The results show that increasing plant spacing influenced an increase in the number of leaves per plant. Plant spacing S3 recorded the maximum number of leaves (20, 29, and 39) per plant. This is directly followed by S2 with the number of leaves per plant of 18, 27, and 35 while the minimum number of leaves per plant of 17, 24, and 32 were recorded in the closest plant spacing (S1).

Table 4.2: Number of leaves per plant as influenced by treatment combination

	Number of leaves per plant		
	5 WAS	6 WAS	7 WAS
Plant Spacing			
S1 (60 cm x 40 cm)	16.56a	24.22a	31.67a
S2 (60 cm x 50 cm)	18.29b	26.89b	34.78b
S3 (60 cm x 60 cm)	19.53b	29.33c	39.11c
Urea Fertilizer			
N1 (0 kg N ha^{-1})	12.71a	18.18a	24.56a
N2 (46 kg N ha^{-1})	17.44b	26.49b	35.89b
N3 (69 kg N ha^{-1})	24.22c	35.78c	45.11c
LSD (5%)	1.57	1.97	2.89
CV (%)	8.7	7.4	8.2

Means followed by or sharing the same letters within a column are not significantly different at a 5% level of significance; CV = coefficient of variation, LSD = least significant difference at 5%; WAS = Weeks after sowing, S = Plant spacing, N = Nitrogen

Similarly, increasing the urea fertilizer application from N1 to N3 had a significant ($p<0.01$) increase in the number of leaves per plant (Table 4.2). The minimum number of leaves per plant of 13, 18, and 25 were recorded in N1 while the maximum number of leaves per plant of 24, 36, and 45 were recorded in the application of a higher rate of urea (N3).

Figure 4.3 shows the influence of treatment combinations on the number of leaves per plant. The result shows that increasing the rate of urea within spacing treatment influenced the number of leaves per plant. At 5 and 6 weeks after sowing (WAS) treatment combinations, T6 and T8 recorded the same number of leaves per plant of 12 and 19 respectively as the lowest number of leaves per plant among the other treatment combinations. However, at 7 WAS treatment combinations influenced the similar number of leaves per plant that was recorded in T2 and T3. Yet, the number of leaves per plant (24) was recorded lowest in T1. The maximum number of leaves per plant of 27, 40, and 51 were recorded in the T9 treatment combinations throughout the results taken. A significant increase in the number of leaves per plant was recorded in all the treatments during the growth stages of plant growth at 5 WAS, 6 WAS, and 7 WAS.

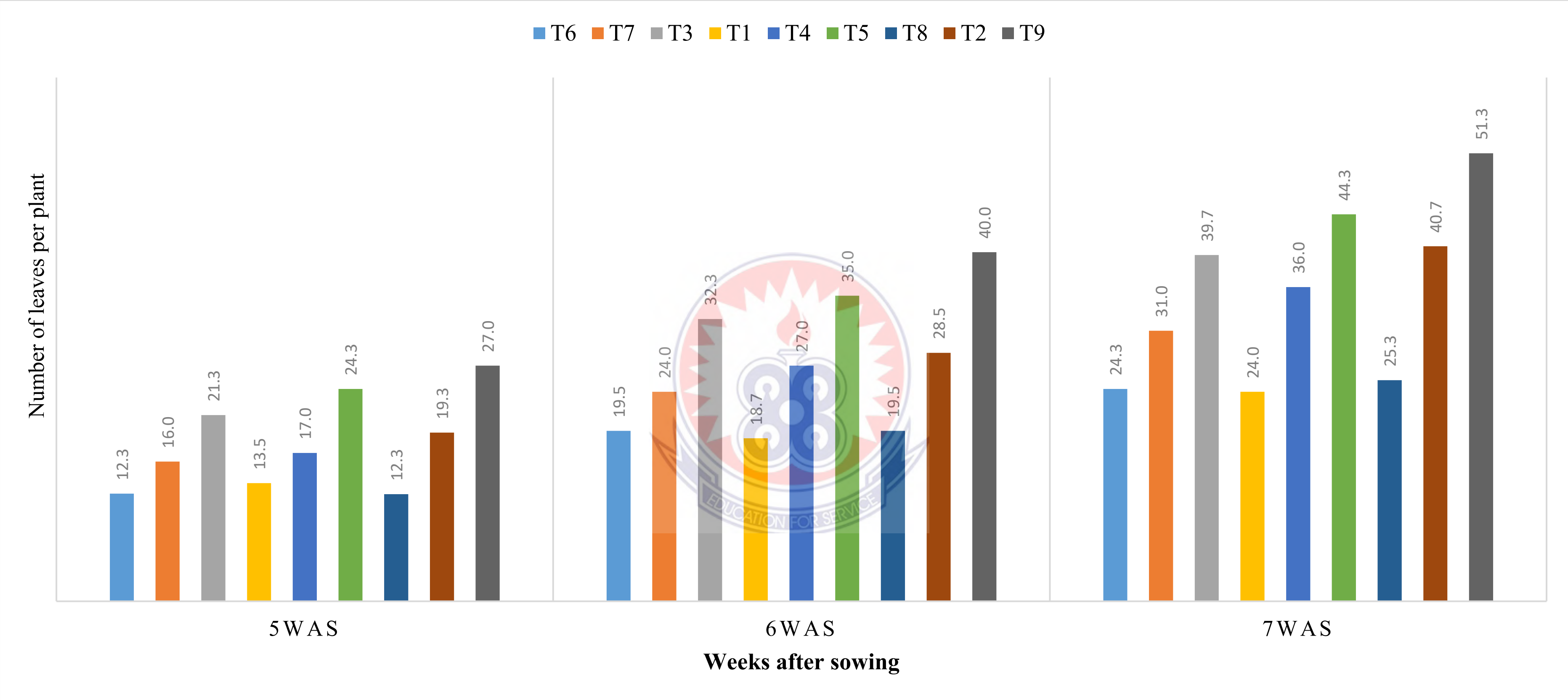

Figure 4.4: Number of leaves per plant as influenced by different rates of urea fertilizer application.

4.1.3 *Stem Diameter*

Figure 4.4 shows the influence of plant spacing on stem diameter. The result shows that increasing the plant spacing correlates with an increase in stem growth of the okra plant at 5 weeks after sowing (WAS), 6 WAS, and 7 WAS. The thickest stem diameter (1.47 cm, 2.13 cm, and 2.63 cm) was recorded in okra plants spaced widely (S3) while the thinnest stem diameter (1.12 cm, 1.41 cm, and 1.68 cm) was recorded in the closest plant spacing (S1) with plants in S2 plant spacing recording the intermediate stem diameter (1.22 cm, 1.63 cm, and 2.11 cm).

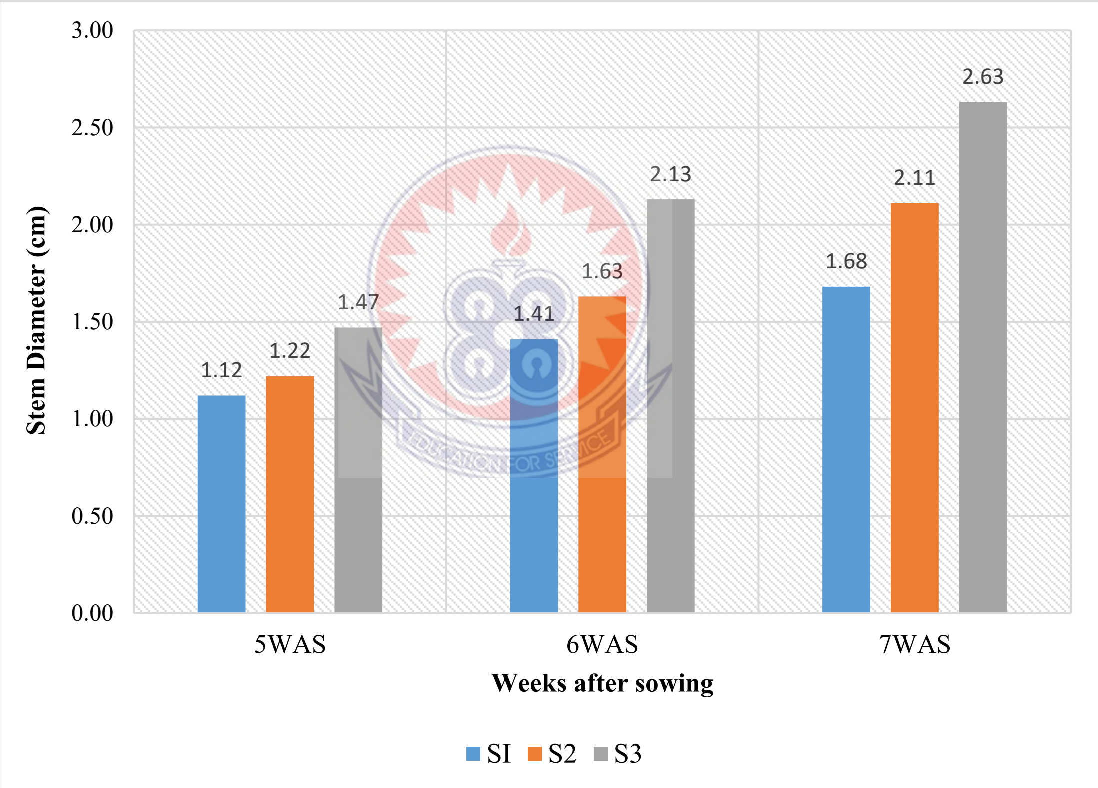

Figure 4.5: Stem diameter as influenced by plant spacing

Urea fertilizer applied at an increasing rate from N1 to N3 was observed to correlate to an increasing order in the stem growth of the okra plant (Figure 4.5). The highest rate of urea fertilizer applied (N3) performed better in influencing the thickest stem diameter (1.68 cm, 2.20 cm, and 2.69 cm) in the okra plant at 5 WAS, 6 WAS, and 7 WAS respectively than the other fertilizer rates applied. Okra plants that were subjected to N2 treatment were noted to have attained the intermediate stem diameter while the thinnest stem diameter (0.88 cm, 1.31 cm, and 1.57 cm) was achieved in plants subjected to N1 treatment.

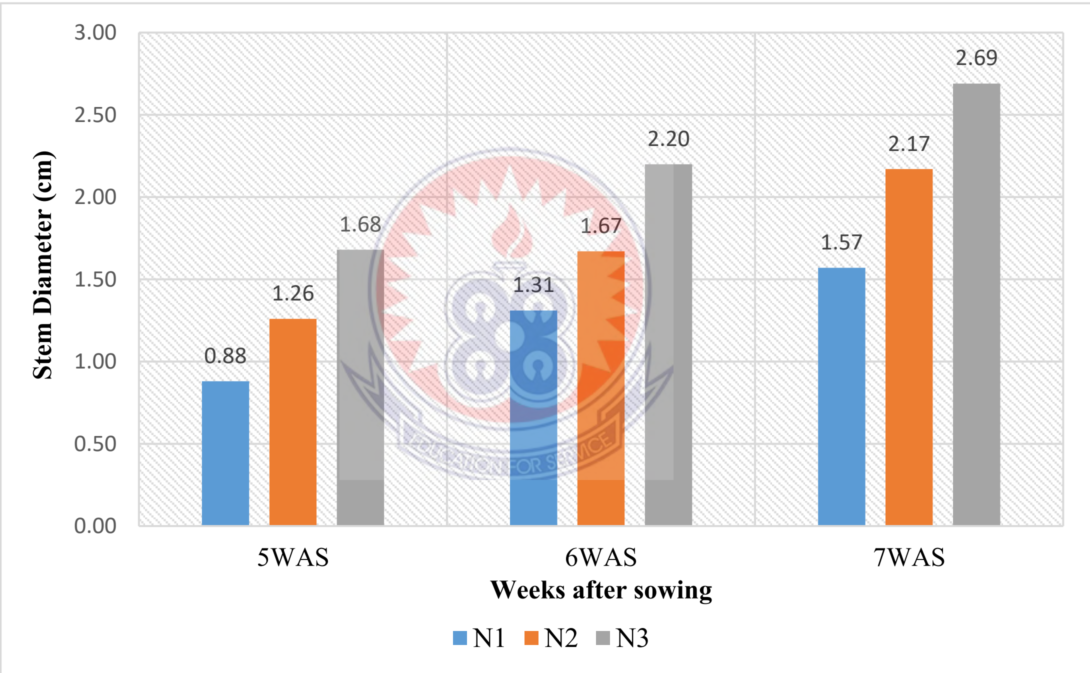

Figure 4.6: Stem diameter as influenced by different rates of urea fertilizer application

The influence on stem diameter by the treatment combinations is represented in Table 4.3. The result indicates that the various treatment combinations had a significant effect on the stem thickness of the okra variety *Asontem*. There was a statistical difference ($P<0.05$) in the stem diameter with increasing plant spacing with increasing rates of urea fertilizer application along the weeks. However, at 7 WAS stem diameter observed from plants subjected to the T8 treatment combination was not statistically different from plants that were under T8 and T1 treatment combination. In all, the thickest stem diameter (2.00 cm, 2.70 cm, and 3.23 cm) was achieved in the T9 treatment combination while the thinnest stem diameter of 0.80 cm, 1.07 cm, and 1.30 cm were from the T6 treatment combination.

Table 4.3: Stem diameter as influenced by treatment combinations

	Stem Diameter (cm)		
	5WAS	6WAS	7WAS
Spacing x Urea Fertilizer			
T1 (60 cm x 50 cm + 0 kg N ha^{-1})	0.93ab	1.33ab	1.57ab
T2 (60 cm x 60 cm + 46 kg N ha^{-1})	1.50d	2.17d	2.83d
T3 (60 cm x 40 cm + 69 kg N ha^{-1})	1.47d	1.80cd	2.07c
T4 (60 cm x 50 cm + 46 kg N ha^{-1})	1.17c	1.47d	2.00c
T5 (60 cm x 50 cm + 69 kg N ha^{-1})	1.57d	2.1abc	2.77d
T6 (60 cm x 40 cm + 0 kg N ha^{-1})	0.80a	1.07a	1.30a
T7 (60 cm x 40 cm + 46 kg N ha^{-1})	1.10bc	1.37ab	1.67b
T8 (60 cm x 60 cm + 0 kg N ha^{-1})	0.90ab	1.53bc	1.83bc
T9 (60 cm x 60 cm + 69 kg N ha^{-1})	2.00e	2.70e	3.23e
LSD (5%)	0.21	0.41	0.27
CV (%)	9.7	13.8	7.3

Means followed by or sharing the same letters within a column are not significantly different at a 5% level of significance; CV = coefficient of variation, LSD = least significant difference at 5%; WAS = Weeks after sowing, T = Treatment, S = Plant spacing

4.1.4 *Number of Branches per Plant*

The results on the number of branches per plant as influenced by plant spacing at 7 WAS, 8 WAS, and 9 WAS are presented in Table 4.4. Generally, an increase in plant spacing had a direct linear increase in the number of branches per plant over the recorded period. But significant difference ($P<0.01$) in the number of branches per plant was shown at the 8 and 9 weeks after sowing. Okra plants spaced closely to each other (S1) resulted in producing a lower number of branches per plant (2.33, 4.18, and 5.33); followed by the intermediate plant spacing (S2) which produced a greater number of branches per plant (2.58, 4.51, and 6.89) at 7 WAS, 8 WAS, and 9 WAS respectively. However, the maximum number of branches per plant (3.00, 5.29, and 7.80) were produced by plants in the widest spacing (S3) over the recorded period.

Table 4.4: Number of branches per plant as influenced by plant spacing and different rates of urea fertilizer application

	Number of branches per plant		
	7WAS	8WAS	9WAS
Plant Spacing			
S1 (60 cm x40 cm)	2.33a	4.18b	5.33c
S2 (60 cm x50 cm)	2.58a	4.51ab	6.89b
S3 (60 cm x60 cm)	3.00a	5.29a	7.80a
Urea Fertilizer			
N1 (0 kg N ha^{-1})	2.33a	3.91b	5.36c
N2 (46 kg N ha^{-1})	2.64a	4.64ab	6.78b
N3 (69 kg N ha^{-1})	2.93a	5.42a	7.89a
LSD (5%)	0.72	0.86	0.41
CV (%)	27.3	8.5	6.2

Means followed by or sharing the same letters within a column are not significantly different at a 5% level of significance; CV = coefficient of variation, LSD = least significant difference at 5%; WAS = Weeks after sowing, S = Plant spacing, N = Nitrogen

Table 4.4 shows the results on the number of branches per plant as influenced by urea fertilizer application at 7 weeks after sowing (WAS), 8 WAS, and 9 WAS. The number of branches produced per plant was significantly increased with an increase in the level of urea fertilizer applied. At 7 WAS, the number of branches per plant was not influenced by rates of urea fertilizer application. However, at 8 WAS and 9 WAS rates of urea fertilizer application had a significant influence on the number of branches per plant. Urea fertilizer applied at the highest rate (N3) resulted in producing the highest number of branches per plant of 2.93, 5.42, and 7.89 at 7 WAS, 8 WAS, and 9 WAS respectively. Plants that received no urea fertilizer application (N1) were seen to have produced the lowest number of branches per plant of 2.33, 3.91, and 5.36.

The number of branches per plant as influenced by treatment combinations is presented in figure 4.6. The highest number of branches per plant (3.60, 6.40, and 9.33) was obtained in the T9 treatment combination while the lowest number of branches per plant (1.68, 3.33, and 4.33) was achieved in the T6 treatment combination. At 7 WAS, okra plants that were subjected to either the T5 or the T2 treatment combinations ended up producing the same number of branches (8). In all, the number of branches per plant varied significantly due to different plant spacing and different rates of urea fertilizer application.

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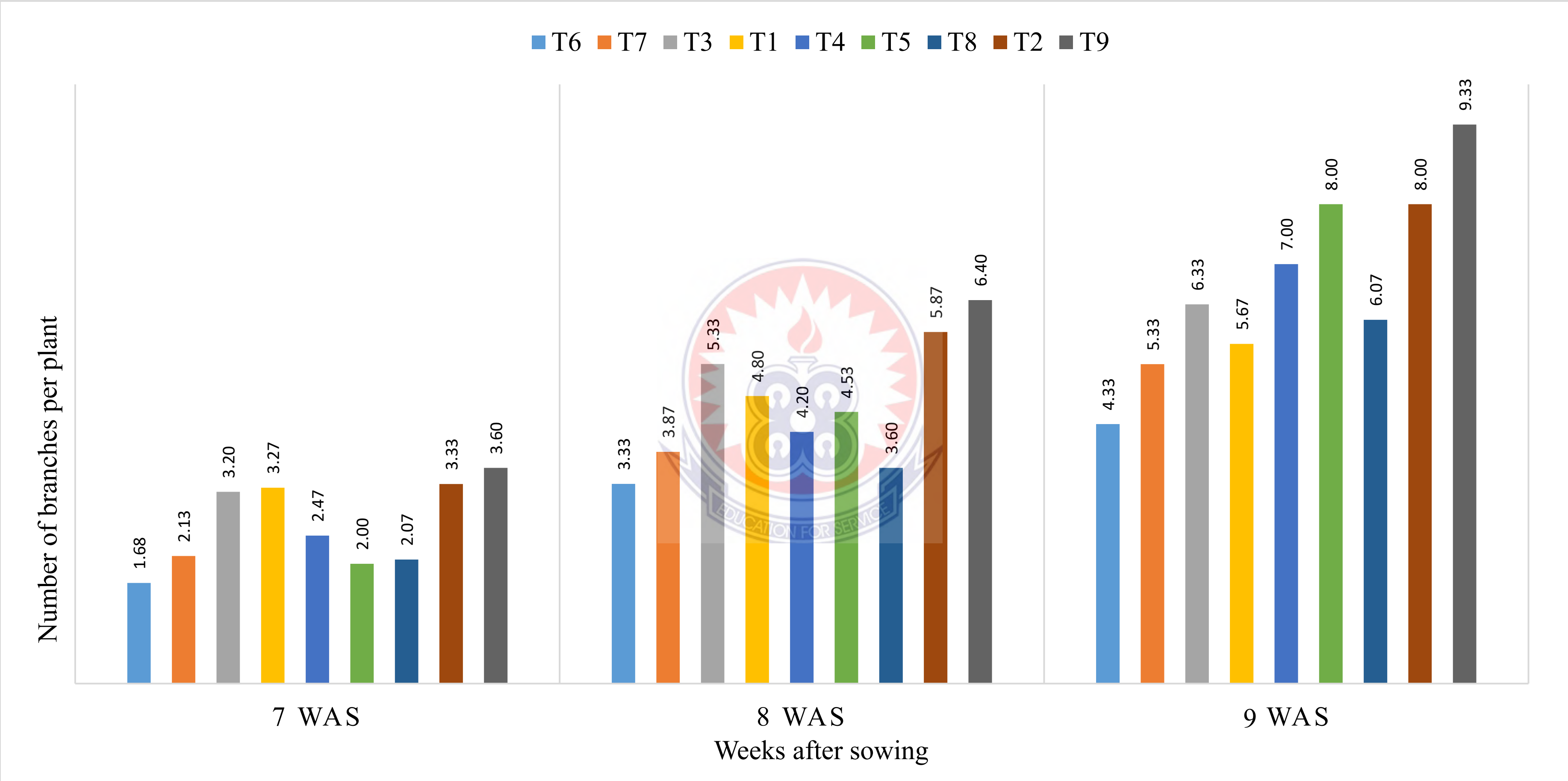

Figure 4.7: Number of branches per plant as influenced by treatment combinations

4.2 Yield and Yield Components of Okra

4.2.1 *Number of Pods per Plant*

The results on the number of pods per plant as influenced by plant spacing are shown in Table 4.5. An insight into the results indicates that various plant spacing affected the number of pods per plant significantly. The widest plant spacing (S3) had a significantly higher number of pods per plant (6) than the other treatments. The minimum number of pods per plant (4) was produced by the closest plant spacing (S1).

Urea fertilizer applied at the highest rate (N3) also produced a number of pods per plant (8) which was significantly higher than the other treatments. This was followed by N2 which recorded 6 pods per plant. The lowest number of pods per plant (3) was found in the control (N1). Again; there were significant differences observed between all the treatments for the number of pods per plant. All the amended plots showed significantly, increases in the number of pods produced per plant than in the control plots.

The number of pods per plant as influenced by treatment combinations is shown in Table 4.5. The results show that not only did an increase in plant spacing had a significant influence on the number of pods per plant but increasing the rates of urea fertilizer applied as well. Treatments combinations, T9, T5, and T3 resulted in producing a significantly higher number of pods per plant within their spacing treatment as compared to the other treatment combinations. However, in treatment combinations T8 and T1 the same number of pods per plant of 3 was seen irrespective of the difference in the treatment combinations.

In treatment combinations, T9 a significantly higher number of pods per plant (9) was found relative to the other treatment combinations. The minimum number of pods per plant of 2 was produced by the T6 treatment combination. In all, treatment combinations had a significant effect on the number of pods per plant.

4.2.2 *Fresh Pod Length (cm)*

The results on the fruit length (cm) as influenced by plant spacing, rates of urea fertilizer application, and their interaction are presented in Table 4.5.

The results indicate that all the plant spacing had an equal effect on fruit length. Yet, differences in the pod length were realized. The longest pod length of 6.98 cm was noted in pods plugged in the widest plant spacing (S3) while the shortest pod length of 6.44 cm was seen from pods harvested in the closest plant spacing (S1).

The different rates of urea fertilizer applied had a significant effect on the fresh pod length produced. The analysis of means showed that the differences existed when the control plots were compared with the treated plots but within the treated plots there were no significant differences in pod length measured. The longest fresh pod length of 7.62 cm was obtained from plots treated with the highest rates of urea fertilizer applied (N3) while the shortest fresh pod length of 5.55 cm was produced by plants in the control plots (N1).

The treatment combinations of different plant spacing and different rates of urea fertilizer applied had a significant effect on the fresh pod length measured. The longest fresh pod length of 7.90 cm was achieved in T9 and the shortest fresh pod length of 5.43 cm resulted from T6. Although treatment combinations influenced the fresh pod the length of *Asontem* okra, between T9 (7.90 cm) and T2 (7.80 cm), the fresh pod lengths were not significantly different from each other. A similar effect was noted between T5 (7.47 cm), T7 (7.20 cm), and T4 (7.17 cm) when their fresh pod length was compared.

4.2.3 *Fresh Pod Weight (g)*

The results on the fresh pod weight (g) as influenced by plant spacing, rates of urea fertilizer application, and their interaction are represented in Table 4.5.

Fresh pod weight was significantly influenced by plant spacing. Okra plants spaced widely at 60 cm x 60 cm resulted in a fresh pod weight of 25.82 g and was significantly heavier than the pod weight measured in the other treatments. The lightest in weight (20.96 g) was measured from pods harvested in the closest plant spacing (S1).

Significantly, a higher fresh pod weight of 27.50 g was recorded in urea fertilizer applied at a higher rate of 69 kg N ha^{-1}. Plots where no urea fertilizer was applied (N1) measured the lowest fresh pod weight of 18.46 g. The results from the analysis of treatment means revealed that an increasing quantity of urea fertilizer applied to okra correlated to the heavier fresh pods of okra.

Fresh pod weight was again influenced by the treatment combinations of plant spacing and urea fertilizer application. The results show a significant increase in fresh pod weight of okra when plant spacing and urea fertilizer were increased. In treatment combinations, T9 the heaviest fresh pod weight of 30.78 g was achieved, followed by T5 with a fresh pod weight of 27.36 g and 26.61 g in T2. The lowest fresh pod weight value measured in the control plots, T6 (16.65 g), T1 (18.66 g), and T8 (20.07 g). Even among the control plots, increasing plant spacing resulted in increasing weight in the fresh pods harvested. On the other hand, the fresh pod weight of 24.13 g and 24.35 g produced by okra plants treated with T4 and T3 treatment combination respectively were seen not to be different from each other statistically.

4.2.4 *Fresh Pods Diameter (cm)*

The results on the fresh pod diameter as influenced by plant spacing, different rates of urea fertilizer application, and their interactions are presented in Table 4.5.

Plant spacing had a significant effect on the fresh pod diameter that was measured. The results indicated that fresh pod diameter was seen to be increasing with increasing plant spacing. Therefore, the thickest fresh pod (2.47 cm) was noted in pods plugged from plants with the widest plant spacing (S3) while the thinnest fresh pod diameter (1.94 cm) was obtained from pods harvested from okra plants in the closest plant spacing (S1).

A perusal of the results indicates that fresh pod diameter was significantly affected due to different rates of urea fertilizer applied. Among the treatments, the maximum fresh fruit diameter (2.73 cm) was found from pods harvested from plots treated with the highest rate of urea fertilizer applied (N3). The minimum fresh fruit diameter of 1.74 cm was produced by pods harvested from control plots (N1).

Consequently, the interaction of plant spacing and different rates of urea fertilizer applied had a significant influence on the fresh pod diameter measured. The thickest fresh pod produced from plant spacing was treated with higher rates of urea fertilizer. In treatment combinations, T9 recorded the thickest fresh pod of 3.08 cm followed by 2.71 cm in T5 and 2.38 cm in T3. The smallest fresh pod diameter of 1.49 cm was obtained from pods harvested in the control plot, T6. Even though treatment combinations affected fresh pod diameter in general, between T4 and T2, treatment combinations had an equal influence on the fresh pod diameter of pods obtained from these plots. Similarly, between T8 and T7, the treatment combinations did not have an effect on the fresh pod diameter obtained.

4.2.5 *Fresh Pod Yield (t/ha)*

The results on the fresh pod yield as influenced by plant spacing, different rates of urea fertilizer application, and their interactions are presented in Table 4.5.

The fresh pod yield per hectare was influenced significantly by the various plant spacing. The yield was seen to have increased significantly from the minimum of 0.51 t ha^{-1} with the widest plant spacing (S3) to a yield of 0.96 t ha^{-1} from 60 cm x 50 cm plant spacing. The maximum yield of 1.72 t ha^{-1} was achieved in plots with the highest population (S1).

The use of different rates of urea fertilizer on the other hand also had a significant effect on the fresh pod yield per hectare. It was observed that fresh pod yield per hectare increased with an increasing rate of urea fertilizer application. Urea fertilizer applied at the highest rate (N3) resulted in influencing the okra plant to produce the maximum fresh pod yield of 1.66 t ha^{-1}. This was followed by a fresh pod yield of 1.04 t ha^{-1} obtained from plots treated with urea fertilizer applied at a rate of 46 kg N ha^{-1}. The lowest fresh pod yield of 0.51 t ha^{-1} was achieved in plots that were not treated with urea at all (N1).

A significant effect was noted for the interaction of plant spacing and different rates of urea fertilizer application on fresh pod yield per hectare basis. The maximum fresh pod yield of 2.55 t ha^{-1} was obtained from plots subjected to the T3 treatment combination followed by the fresh yield of 1.79 t ha^{-1} produced from plots subjected to the T7 treatment combination. The minimum fresh pod yield of 0.27 t ha^{-1} was obtained from plots subjected to the T8 treatment combination. Notably, the results from the analysis of treatment means showed that the lowest fresh pod yield obtained from plots treated with the T8 treatment combination was not significantly different from those recorded in T1 (0.43 t ha^{-1}), T4 (0.79 t ha^{-1}), T8 (0.27 t ha^{-1}), T2 (0.54 t ha^{-1}) and T9 (0.72 t ha^{-1}). Again, the fresh pod yield of 1.71 t ha^{-1} produced by plots treated with the T7 treatment combination was also at par with the yield obtained from plots treated with the T5 treatment combination.

Table 4.5: Yield and yield factors as influenced by different plant spacing, different rates of urea fertilizer application, and their interactions

	NPP	FPW (g)	FPD (cm)	FPL (cm)	Pod Yield (t ha^{-1})
Plant Spacing					
S1 (60 cm x 40 cm)	4.41a	20.96a	1.94a	6.44a	1.72c
S2 (60 cm x 50 cm)	5.56b	23.39b	2.19ab	6.89a	0.96b
S3 (60 cm x 60 cm)	6.44c	25.82c	2.47b	6.98a	0.51a
LSD (5%)	0.59	1.61	0.31	0.54	0.34
Urea Fertilizer					
N1 (0 kg N ha^{-1})	2.74a	18.46a	1.741a	5.55a	0.51a
N2 (46 kg N ha^{-1})	5.67b	24.20b	2.138b	7.13b	1.66c
N3 (69 kg N ha^{-1})	8.00c	27.50c	2.73c	7.62b	1.04b
LSD (5%)	0.59	1.61	0.31	0.54	0.34
Plant Spacing x Urea Fertilizer					
T1 (60 cm x 50 cm + 0 kg N ha^{-1})	2.67ab	18.66ab	1.65ab	5.58a	0.43a
T2 (60 cm x 60 cm + 46 kg N ha^{-1})	6.67d	26.61ef	2.26cd	7.80c	0.72a
T3 60 cm x 40 cm + 69 kg N ha^{-1})	6.67d	24.35de	2.38cd	6.73b	1.79b
T4 60 cm x 50 cm + 46 kg N ha^{-1})	6.00d	24.13de	2.22cd	7.20bc	1.71b
T5 (60 cm x 50 cm + 69 kg N ha^{-1})	8.00e	27.36f	2.71de	7.47bc	0.79a
T6 (60 cm x 40 cm + 0 kg N ha^{-1})	2.22a	16.65a	1.49a	5.43a	0.82a
T7 (60 cm x 40 cm + 46 kg N ha^{-1})	4.33c	21.87cd	1.94abc	7.17bc	2.77c
T8 (60 cm x 60 cm + 0 kg N ha^{-1})	3.33bc	20.07bc	2.08bc	5.64a	0.27a
T9 (60 cm x 60 cm + 69 kg N ha^{-1})	9.33f	30.78g	3.08e	7.90c	0.54a
LSD (5%)	1.02	2.79	0.54	0.94	0.58
CV (%)	10.8	6.9	14.2	8.0	31.6

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; CV=coefficient of variation, LSD=least significant difference at 5%; NPP = Number of pods per plant, FPW = Fresh pod weight, FPD = Fresh pod diameter, FPL = Fresh pod length, T = Treatment, N = Nitrogen, S = Plant spacing

CHAPTER FIVE

5.0 DISCUSSION

5.1 Vegetative Growth of Okra

5.1.1 *Plant Height*

5.1.1.1 Effects of different plant spacing on plant height

The maximum plant height achieved by closer plant spacing (S1) could be due to a higher rate of competition for light and other growth resources among the crops thereby resulting in the development of long stems that spurred growth in plant height.

Pedersen (2008) reported similar observations in their experiments that when plants are spaced too closely, they grow tall to reach for the light, developing long, scrawny branches that tend to be weak; ultimately, plants do not produce as many leaves, flowers, fruits or seeds as compared to plants that have optimum light. A similar result was achieved by Haile *et al.* (2016) who reported that plant height showed an increase with a decrease in both inter-and intra-row spacing. Maurya *et al.* (2013) also obtained the highest (147.20 cm) plant height for 'Clemson Spineless' sown at the closest (30 cm x 45 cm) plant spacing while the lowest (111.70 cm) plant height was recorded in the widest (60 cm x 45 cm) spacing. Agba *et al.* (2018) reported that close intra-row spacing of 60 cm x15 cm had the tallest okra plants (57.58 cm in 2015 and 59.34 cm in 2016). Gemechu, (2018) attained significantly highest height at 30 cm inter-row spacing both flowering and end of crop harvest at Assosa, Western Ethiopia. And further reported that the height of plants tends to be reduced as inter-row spacing increases.

5.1.1.2 Effects of different rates of urea fertilizer application on plant height

The increase in plant height (figure 4.1) in response to increased application of urea fertilizer (N3), could be attributed to an enhanced synthesis of protein in the plant, which is a fundamental building material of cells elongation and a constituent of all enzymes.

This is consistent with the findings of Firoz, (2009) who suggested that plant height in okra was enhanced by N fertilizer up to 120 kg N/ha and reported that the higher dose of N might have enhanced cell division and formation of more tissues resulting in luxuriant vegetative growth and thereby increased plant height. Attarde *et al.* (2012) stated that maximum plant height in okra was found to increase with an increase in nitrogen fertilizer rate up to 92 kg ha^{-1} whereas, the lowest plant height was recorded amongst untreated plots. Similarly, Suryati *et al.* (2015) reported nitrogen to have a significant role in stimulating the vegetative growth of plants as a whole, especially the growth of stems that can spur growth in plant height. Rahman *et al.* (2020) stated in their report that the highest plant height (22.95, 71.75, and 123.20 cm at 20, 40, and 60 DAT, respectively) was attained in the treatment N3 (180 kg N ha^{-1}) whereas the lowest plant height (21.23, 66.5 and 115.10 cm at 20, 40 and 60 DAT, respectively) was achieved by the control treatment N0 (0 kg N ha^{-1}). They further revealed that with the increase in nitrogen fertilizer application, plant height was increased up to a certain level.

5.1.1.3 Effect of treatments combinations on plant height

The favorable effect of plant spacing and nitrogen in promoting the growth of the plant in terms of the height of the plant in T3 (Table 4.2) might be because the closer plant spacing had higher plant density which created competition among the population for light and resulted in increased in plant height. Amongst the plant nutrients, nitrogen has the property to enhance the vegetative growth and capacity of plants to utilize the greater amount of nitrogen with increasing doses. This might be due to the higher utilization of nitrogen but in the closer spacing, there is no scope for horizontal spread so it might have increased plant height (Brar and Singh, 2016).

The result is in accordance with Brar and Singh, (2016) who reported that a maximum height of the plant (94.3 cm) was recorded with the combination of N100 and with the closest plant spacing, S10 in okra. The minimum height of the plant (82.3 cm) was recorded with the treatment combinations N75 with spacing S20. Agba *et al.* (2018) also reported similar results at all periods of measurements either at 4 WAP or 50% flowering, the interaction between 60 cm x 60 cm intra-row spacing combined with 250 kg/ha of NPK 20:15:15 always gave the highest plant height.

5.1.2 *Number of Leaves per Plant*

5.1.2.1 Effect of different plant spacing on number of leaves per plant

The significant differences in the number of leaves per plant attained in the wider plant spacing (S3) could be that, at that plant spacing, there were favorable growth conditions that enhanced vegetative growth such as the increase in the number of branches which ultimately resulted in the increased number of leaves per plant.

A similar result was reported by Bin-Ishaq (2009), that the number of leaves per plant significantly increased as the plant density decreased and the number of leaves decreased as plant density increased. Maurya *et al.* (2013) also obtained a similar result of the maximum number of leaves per plant of 15.25 when okra plants were sown at the widest plant spacing of 60 cm x 45 cm whereas the minimum leaves per plant (10.57) was produced with plants in the closest plant spacing of 30 cm x 45 cm.

Furthermore, the average leaves per plant (22.8) were found to be maximum in the widest spacing S_{20}. However, average minimum leaves per plant (20.6) were recorded in the closest spacing S_{10} reported by Brar and Singh, (2016). In 2017, Amanga and others also reported having recorded the maximum number of leaves per plant (15.65 and 15.95) respectively these wider plant spacing of 60 cm × 40 cm and 60 cm × 30 cm, when okra was sown in Gambella region, Western Ethiopia.

5.1.2.2 Effect of different rates of urea fertilizer application on the number of leaves per plant

The maximum number of leaves per plant achieved with the higher rates of urea fertilizer application could be attributed to the fact that the increase in N doses might have enhanced the cell division and formation of more tissue resulting in excessive vegetative growth and thereby increasing the number of leaves per plants.

This result is consistent with the findings of Ghoneim, (2016) which suggest that the application of 60 kg N ha^{-1} to okra plants increased leaves per plant. The number of leaves was found maximum in the treatment of nitrogen with 120 kg ha^{-1} in all stages and at final harvesting was reported by Khanal *et al.* (2020). Similarly, Rahman *et al.* (2020) also reported the highest number of leaves per plant (10.40, 56.80, and 62.07 at 20, 40, and 60 DAT, respectively) was found from the highest level of treatment N2 (150 kg N ha^{-1}) whereas the lowest number of leaves per plant (9.40, 47.60 and54.60 at 20, 40 and 60 DAT, respectively) was recorded from the control treatment N0 (0 kg N ha^{-1}).

5.1.2.3 Effect of treatment combinations on the number of leaves per plant

The maximum number of leaves per plant recorded in T9 could be that there were favorable growth conditions at the wider spacing that enhanced vegetative growth such as the increase in the number of branches which ultimately resulted in the increased number of leaves per plant. Again, the increase in N doses might have also enhanced the cell division and formation of more tissue resulting in excessive vegetative growth and thereby increasing the number of leaves per plants

A similar result was reported by Agba *et al.* (2018) that the interaction between the widest 60 cm x 60 cm intra-row spacing combined with 250 kg/ha NPK 20:15:15 fertilizer gave the highest number of leaves.

5.1.3 *Stem Diameter*

5.1.3.1 Effect of different plant spacing on stem diameter

The biggest stem diameter values attained by plants spaced at 60 cm x 60 cm might be that, there was less competition for plants' nutrients at that wider plant spacing, that were in sufficient quantities to have been absorbed by the plants to have significantly influenced the diameter of the stems of okra plants to be thicker.

These findings are echoed more in a report made by Maurya *et al.* (2013) that the thickest stem diameter of 2.50 cm was achieved in the widest plant spacing of 60 cm x 45 cm. Shiyam (2016) also reported a similar result that suggested that okra plants spaced closely at 30 cm x 45 cm resulted in producing the thinnest stem diameter of 1.74 cm. The results of this experiment are quite different from the findings made by Falodun and Ogedegbe, (2016) that stem collar diameter decreased as planting spacing increased and therefore recorded the thickest diameter (0.60 cm) for a closer plant spacing S1 (40 cm x 30 cm) while the wider plant spacing S4 (70 cm x 30 cm) produced plants with the thinnest diameter (0.36 cm).

5.1.3.2 Effect of different rates of urea fertilizer application on stem diameter

The increase in stem diameter under higher levels of nitrogen might be attributed to the increased availability of nitrogen for the structural components of protein molecules which might have increased the synthesis of protein and carbohydrates in favour of increasing cell division and elongation to might have hastened this vegetative growth.

This is in line with the findings made by Firoz (2009) that proposed that a higher dose of nitrogen fertilizer in the okra plant enhances cell division and the formation of more tissues resulting in luxuriant vegetative growth. Dhankhar and Singh, (2013) also achieved a maximum stem diameter in the okra plant with a higher application of 100 kg N ha^{-1}. Raditiya (2017) further reported that an increase in stem diameter was caused by nutrients needed by the plants in higher quantities to be absorbed by plants so that it significantly affects the diameter of the stems of okra plants. These findings are echoed more recently by Rahman *et al.* (2020) in their findings that suggested that the highest stem base diameters (0.78, 0.91, and 3.25 at 20, 40, and 60 DAT, respectively) were found in the higher nitrogen treatment N3 (180 kg N ha^{-1}) whereas the lowest stem base diameters (0.68, 0.86, and 2.88 at 20, 40 and 60 DAT, respectively) were recorded from the control treatment N0 (0 kg N ha^{-1}).

5.1.3.3 Effect of treatments combinations on stem diameter

The thickest stem diameter by treatment combinations, T9 could be that at the wider plant spacing there were favourable growth conditions that enhance vegetative growth such as the increase in cell division which ultimately resulted in increased stem diameter. Again, the increase in N doses might have enhanced the formation of more tissue resulting in excessive vegetative growth and thereby increasing the stem diameter.

This result is in accordance with the report made by Brar and Singh (2016) that, okra sown at the widest plant-to-plant spacing of 20 cm treated with the highest nitrogen rate of 125 kg ha^{-1} resulted in the thickest stem diameter (1.95 cm). Similar results were reported by Khanal *et al.* (2020) when okra plants were spaced widely at 60 cm x 30 cm plant spacing and a nitrogen fertilizer rate of 120 kg ha^{-1}.

5.1.4 *Number of Branches per Plant*

5.1.4.1 Effect of different plant spacing on number of branches per plant

The production of more branches at the wider inter-row spacing might be due to the plants grown in wider spacing having less competition for moisture and light as compared to plants grown in closer spacing. This could favor more photosynthesis and allocation of assimilates for all growth points as compared to the closest inter-row spacing. Thus, the lateral growth of the plant has been favoured and tends to produce plants with more lateral branches at wider spacing (Gemechu, 2018).

Ekwu and Nwokwu (2012) reported similar observations in their experiments that suggest that the maximum number of branches per plant was obtained from wider plant spacing, whereas minimum numbers of branches per plant were recorded from closer plant spacing. The maximum (1.72) branches per plant were recorded in the widest (60 cm x 45 cm) plant spacing and the minimum (1.24) branches per plant in the closest (30 cm x 45 cm) plant spacing was reported by Maurya *et al.* (2013). Haile *et al.* (2016) reported that the maximum number of branches per plant (2.16) was obtained from the widest plant spacing combination (70 cm x 30 cm), whereas minimum numbers of branches per plant (0.28) were recorded from the narrow spacing combinations of 30 cm x 15 cm. A report from Agba *et al.* (2018) indicated that okra sown at closer intra-row spacing gave taller plants with fewer numbers of branches and leaves per plant than wide intra-row spacing. Khanal *et al.* (2020) also reported the maximum number of branches (3) produced per plant was obtained from the lower plant population (60 cm × 30 cm plant spacing).

5.1.4.2 Effect of different rates of urea fertilizer application on the number of branches per plant

The influence of nitrogen on the number of branches per plant can be attributed to the fact that nitrogen is the fundamental part of the chlorophyll molecule and essential in the formation of amino acids, which are the building blocks of all proteins including enzymes, which control virtually all biological processes.

The result obtained conforms with the report made by Khandaker *et al.* (2017) that the highest number of branches (7) per plant was recorded from the highest rate of NPK fertilizer rates. Soni *et al.* (2006) reported that the number of branches increased with increasing rates of N up to 125 kg ha^{-1}. Consistent with the results of this study, Ekwu *et al.* (2010) reported that the application of nitrogen at the rate of 140 kg ha^{-1} produced the highest number of branches as compared to 0 kg N ha^{-1}. Khan *et al.* (2016) also reported that the highest number of fruits per plant and number of branches per plant of sweet pepper in response to increased application of nitrogen fertilizer up to 150 kg N ha^{-1}. This is in contrast to the results of Bin-Ishaq, (2009) who reported that increasing the N application rate up to 45 kg N ha^{-1} was associated with significant progressive increases in number of branches per plant. And that application of more nitrogen beyond 46 kg ha^{-1} did not favour the production of a greater number of branches.

5.1.4.3 Effect of treatments combinations on the number of branches per plant

The significant differences recorded by the wider plant spacing and the higher rate of urea could be that, at the wider spacing, there were favourable growth conditions that enhance vegetative growth such as the increase in the number of branches. And at the higher rates of urea fertilizer application increased the N doses in the leaves which might have enhanced the cell division and formation of more tissue resulting in excessive vegetative growth and thereby increasing the number of branches per plant.

This is consistent with the findings of Gemechu, (2018) who observed that the number of branches per plant increased due to the interaction effect (inter-row and nitrogen) of the main factors. The maximum number of branches per plant was counted at the widest inter-row spacing of 60 cm in combination with a higher rate of nitrogen applied at 92 kg ha^{-1}. Khanal *et al.* (2020) also observed the maximum number of branches (3) under the application of 120 N kg ha^{-1} at wider plant spacing of 60 cm x 30 cm. This is in contrast to the report by Amanga *et al.* (2017) that indicated the maximum number of branches (2.93) was recorded from the interaction of plant populations grown at the plant spacing of 60 cm x 30 cm and application of 46 kg N ha^{-1}, whereas the minimum number of branch per plant (1.9) was obtained under row spaced and nitrogen interaction of 60 cm x 20 cm and 0 kg N ha^{-1} respectively.

5.2 Yield and Yield Components of Okra

5.2.1 *Number of Pods per Plant*

5.2.1.1 Effect of different plant spacing on number of pods per plant

The maximization of fresh pods in response to lowering plant population could be that plants grown under low population density have good growth performance since competition for available resources is limited as compared to plants grown under high plant population density.

This result can be supported by Ekwu and Nwokwu (2012) report that suggested that the number of the fruit of okra significantly increased with a decrease in population density. Brar and Singh, (2016) reported wider spacing S_{20} expressed a significantly greater number of fruits per plant (31.5) than closer spacing S_{10} (28.8). Khanal *et al.* (2020) reported the widest plant spacing of 60 cm × 30 cm to have given the maximum number of pods per plant (31).

5.2.1.2 Effect of different rates of urea fertilizer application on the number of pods per plant

The higher number of pods per plant under an increased level of nitrogen may be higher vigor of the plant and utilization of proteinous metabolites for the build-up of new tissues.

The result is consistent with the work by Brar and Singh, (2016) reported that the highest number of fruits per plant (36.7) with the application of the highest level of nitrogen, 125 kg N ha^{-1}. With the application of a higher rate of nitrogen at a rate of 120 kg ha^{-1} Khanal *et al.* (2020) reported having observed the maximum number of pods per plant of 33.

Rahman *et al.* (2020) reported that the highest number of fruits per plant (24.10) was found from the treatment N2 (150 kg N ha^{-1}) whereas the lowest number of fruits plant-1 (16.30) was recorded from the control treatment N0 (0 kg N ha^{-1})

5.2.1.3 Effect of treatments combinations on the number of pods per plant

The increase in the interaction of inter-row spacing and nitrogen fertilizer from nil to 69 kg ha^{-1} could be that at wider spacing and high nitrogen fertilizer rate, the number of branches and weight of a single fruit increase due to the availability of sufficient resources (Gemechu, 2018).

This is consistent with the findings of Brar and Singh (2016) who reported that the highest number of pods per plant (40.2) was obtained with the combination of higher nitrogen level, N_{125}, and wider plant spacing, S_{20}. Similar results were also reported by Navdeep and Daljeet (2016) that the highest number of pods per plant (40.2) was obtained with the combination of spacing of 20 cm and nitrogen125 kg ha^{-1}. Amanga *et al.* (2017) findings also revealed that under the interaction of low plant population (60 cm × 40 cm) and nitrogen application rate of 46 kg N ha^{-1}, they observed the maximum length of green pods. Rahman *et al.* (2020) obtained the highest number of fruits per plant (24.10) to be found from the treatment N2 (150 kg N ha^{-1}) whereas the lowest number of fruits plant^{-1} (16.30) was recorded from the control treatment N0 (0 kg N ha^{-1}).

5.2.2 *Fresh Pod Length (cm)*

5.2.2.1 Effect of different plant spacing on fresh pod length

Although plant spacing had no significant effect on fresh pod length, the longest pod being recorded in the widest spacing could be that better performances were attained from less competition for plant resources. This favored cell elongation in the pods which resulted in them being longer than the other pods.

The non-significance of the length of tender fruits was reported also by Ijoyah *et al.* (2010) and Gemechu (2018). However, the results contradicted the finding of Moniruzzaman *et al.* (2007) reported pod length and pod diameter to be significantly influenced due to plant spacing.

5.2.2.2 Effect of different rates of urea fertilizer application on fresh pod length

An increase in the length of fresh pods could be because the low plant population responded well to the applied nitrogen rate which favored metabolic changes that resulted in cell elongation in the pod thereby the fruits being long.

This result is in agreement with the finding made by Brar and Singh, (2016) that the application of higher levels of nitrogen at N100 (1.50 cm) and N125 (1.86 cm) proved more effective in respect of diameter when compared with N75 (1.05 cm). Khan *et al.* (2016) obtained the longest (13.987 cm) and the shortest (11.250 cm) green pod lengths from nitrogen rates of 160 kg and 0 kg ha^{-1} respectively, and reported that green pod length gradually increased with the increase in nitrogen levels. Rahman *et al.* (2020) reported the highest fruit length (18.11, 16.00, and 13.20 cm at 20, 40, and 60 DAT, respectively) was found from the treatment N2 (150 kg N ha^{-1}) whereas the lowest fruit length (14.12, 12.99 and 10.73 cm at 20, 40 and 60 DAT, respectively) was recorded from the control treatment N0 (0 kg N ha^{-1}). Ngegba *et al.* (2020) also reported the longest (30.9 cm) pod length to have been recorded for the application of 120 NPK 15:15:15 kg ha^{-1}.

5.2.2.3 Effect of treatments combinations on fresh pod length

An increase in the length of fresh pods concerning the interaction of the two factors could be because a low plant population responded well to the applied nitrogen rate which favored metabolic changes in plants resulting in the production of lengthy pods. It is obvious that wider spacing results in better growth performances of the plant as a result of low competition for resources which can significantly result in increased pod length per plant.

Uddin *et al.* (2014) reported that the longest fruit was found from 120 N kg ha^{-1} (16.8 cm) whereas the minimum was recorded from the control, 0 N kg ha^{-1} (13.8 cm). However, the current results contradict the finds of Gemechu (2018) who reported a maximum length (29.01 cm) of green pods low plant population (60 cm × 40 cm) and nitrogen application rate of 46 kg N ha^{-1}.

5.2.3 *Fresh Pod Diameter (cm)*

5.2.3.1 Effect of different plant spacing on fresh pod diameter

Wider plant spacing results in better growth performances of the plant as a result of low competition for resources which can significantly result in increased assimilation production and greater partitioning of metabolites and nutrients towards the reproductive organs.

This result is in agreement with the findings of Maurya *et al.* (2013) that the widest (2.05 cm) fruit diameter was produced by plant spaced at the widest (60 cm x 45 cm) plant spacing while the lowest (1.59 cm) fruit diameter was recorded in the closest (30 cm x 45 cm) plant spacing. Khanal *et al.* (2020) showed that minimum pod diameter (3.07 cm) was recorded from the plots higher plant population of 30 cm x 30 cm. Moniruzzaman *et al.* (2007) reported that pod diameter is significantly influenced due to plant spacing.

5.2.3.2 Effect of different rates of urea fertilizer application on fresh pod diameter

The enhancing effect of N on fresh pod diameter may be attributed to the beneficial effect of N on stimulating meristemic activity and producing more tissues and organs.

This is in line with Marschner, 1986 who reported that nitrogen plays a major role in protein and nucleic acids synthesis and protoplasm formation. The thickest diameter of a green pod (1.59cm) was obtained from the highest dose of nitrogen 160 kg/ha whereas the smallest diameter of a green pod (1.36cm) was recorded from the control treatment (Khan *et al.*, 2016).

5.2.3.3 Effect of treatments combinations on fresh pod diameter

An increase in fresh pod diameter concerning the interaction of the plant spacing and different rates of urea fertilizer application could be because the low plant population responded well to the applied nitrogen rate which favored cell division in the plant resulting in the production of thicker pods. It is also obvious that wider spacing results in better growth performances of the plant as a result of low competition for resources which can significantly result in increased pod diameter. This improved their vegetative growth, synthesis, and translocation of assimilates from the source to the sink, thus resulting in a significant increase in the size of fruits.

This is following the report made by Khanal *et al.* (2020) that okra pod diameter was significantly maximum in treatment of higher nitrogen level of 90 kg ha^{-1} (3.40 cm) and a wider plant spacing of 60 cm × 30 cm (3.24 cm). The results contradict the findings of Amanga *et al.* (2017) that suggested that a higher pod diameter (3.07 cm) from the low plant population spaced at 60 cm x 30 cm and from the nitrogen application rate of 46 kg N ha^{-1}.

5.2.4 *Fresh Pod Weight (g)*

5.2.4.1 Effect of different plant spacing on fresh pod weight

The maximum weight under the widest spacing may be due to the increase in assimilates production and greater partitioning of metabolites and nutrients towards the reproductive organs. This has eventually happened as a result of reduced competition between widely spaced plants for space, light, nutrients, and moisture (Khanal *et al.*, 2020).

El-Waraky (2014) reported similar results that the weight of pods was highest at the widest plant spacing (50 cm × 25 cm). Mauryal *et al.* (2013) also reported that heavier fresh weight per fruit (23.17 g) was obtained in the widest (60 cm x 45 cm) plant spacing while the lighter (16.60 g) fresh weight per fruit was recorded in the closest (30 cm x 45 cm) plant spacing. Kumar *et al.* (2016) observed maximum weight per fruit (7.46 g) for wider spacing of 60 cm x 30 cm and superior to 45 cm x 30 cm (7.41 g) and 30 × 30 cm (7.13 g) respectively. Khanal *et al.* (2020) also recorded the heaviest pods of 18.33g to have been produced by the plants at the wider spacing (60 cm × 30 cm), while the minimum green fruit weight (17.20 g) from the closest spacing (30 cm x 30 cm).

5.2.4.2 Effect of different rates of urea fertilizer application on fresh pod weight

An increase in fruit weight may be due to the adequate supply of nitrogen to the plants. This improved their vegetative growth, synthesis, and translocation of photosynthesis from the source to the sink, thus resulting in a significant increase in the weight and size of fruits.

The result is consistent with the findings of Narayanamma *et al.* (2006) that suggested that higher doses of N application lead to an increase in size and weight. Similarly, studies by Kumar *et al.* (2016) reported that decreasing the nitrogen rate application reduced the fruit weight of okra when they had a maximum weight per fruit of 8.82 g when 85 kg N/ha was applied to okra followed by 60 kg N/ha (7.32 g) and 35 kg N/ha (5.92 g) respectively. Rahman *et al.* (2020) Results revealed that the highest single fruit weight (16.59 g) was found from the treatment N2 (150 kg N ha^{-1}) whereas the lowest single fruit weight (15.14 g) was recorded from the control treatment N0 (0 kg N ha^{-1}). Maduagwuna *et al.* (2021) reported weight per pod was increased by 26% when 60 kg N/ha was applied or 44% when 100 kg N/ha was applied than when no N was applied.

5.2.4.3 Effect of treatments combinations on fresh pod weight

An increase in fresh pod weight at the widest plant spacing level and higher nitrogen rate could have resulted from efficient utilization of resources leading to improved vegetative growth, synthesis, and translocation of assimilates from the source to sink, thus resulting in a significant increase in weight of fruits.

Navdeep and Daljeet (2016) reported that the highest pod weight of 10.2 g obtained was due to interaction with N100 and S15, while the lowest 6.2 g pod weight was due to the combined effect of nitrogen fertilizer rate of 75 kg N ha^{-1} and Spacing 10cm. Gemechu (2018) reported the maximum weight of tender fruit (25.67 g) to have been recorded from inter-row spaced at 60 cm in combination with the application of a higher nitrogen fertilizer rate at 92 kg N ha^{-1}, whereas; the minimum weight of tender fruit (22.09 g) was obtained from the combination of inter-row spaced at 30 cm and 0 kg N ha^{-1}. The interaction of 90 N kg ha^{-1} and 45 cm × 30 cm had a significantly maximum pod weight (20.96 g) was reported by Khanal *et al.* (2020).

5.2.5 *Fresh pod yield (t ha^{-1})*

5.2.5.1 Effect of plant spacing on fresh pod yield (t ha^{-1})

The total yield mainly depends upon the yield per plant and plant population (Khanal *et al.*, 2020). Therefore the highest fresh pod yield of okra per hectare in closed spacing may be attributed to the plant-to-plant distance being decreased, the number of plants per unit area increases, ultimately resulting in a higher number of plants per unit area and enhanced utilization of accessible natural growth resources than wider spacing (Amjad et al., 2001; Zibelo *et al.*, 2016).

The result is following Firoz (2009) who reported that the highest yield of okra was recorded from close spacing, which was statistically different from the other two spacing and the widest spacing produced the lowest yield. Maurya *et al.* (2013) reported the highest (18.96 ton) yield per hectare to be in the closest (30 cm x 45 cm) plant spacing. A similar result was reported by Norman *et al.* (2019) that, the highest pod yield per hectare (6.34 and 7.35) were from plots treated with closer plant spacing (50 cm x 40 cm) and was significantly different from all other plant spacing treatments while the lowest pod yield per hectare (2.34 and 2.71) was recorded in the wider plant spacing (70 cm x 40 cm) in both 2017 and 2018 cropping seasons. Khanal *et al.* (2020) reported having obtained a significantly higher yield (24.62 t ha^{-1}) with closer spacing of 45 cm × 30 cm.

5.2.5.2 Effect of rates of urea fertilizer application on fresh pod yield (t ha^{-1})

The increase in fresh pod yield as influenced by the higher rate of urea fertilizer application could be that rate might have induced plant to high leaf area index for a high plant population which resulted in improved light interception to have led to higher biomass production and yield than under a low plant population.

Akanbi et al., (2010) reported that the application of N led to a significant influence on the fresh fruit yield of okra. Similar results were also observed by De Souza Medeiros *et al.* (2018) who found okra yield (16.4 t/ha) from higher nitrogen application at 120 kg ha^{-1}. Okra yield was found to be significantly maximum with the treatment of 90 kg ha^{-1} nitrogen (23.22 t ha^{-1}), the highest rate of nitrogen application was reported by Khanal *et al.* (2020). Rahman *et al.* (2020), also reported the highest yield (13.89 t ha^{-1}) from the highest rate of nitrogen treatment, N2 (150 kg N ha^{-1}) which was significantly different from other treatments whereas the lowest yield (9.21 t ha^{-1}) was recorded from the control treatment N0 (0 kg N ha^{-1}). Jana *et al.* (2010) reported that 150 kg N ha^{-1} produced the highest fruit yield (12.2 t ha^{-1}).

5.2.5.3 Effect of treatments combinations on fresh pod yield (t ha^{-1})

The combined effect of the treatment resulting in a significantly maximum fresh pod per hectare could be attributed to the fact that at higher planting density, individual plant performance is decreased but the higher number of plants per unit area and a higher rate of urea fertilizer application compensated for lower individual performance, consequently, yielding fruits than the other treatments combinations.

This result corresponds with the findings reported by Aniekwe *et al.* (2017) that significantly higher growth and yield performance of okra were achieved with the interaction of plant density and fertilizer. Agba *et al.* (2018) reported treatments combinations of closer plant spacing of 60 cm x 15 cm and a higher rate of 200 kg/ha NPK 20: 10: 10 fertilizer gave the highest pod yield (8.26 t/ha in 2015) and (8.03 t/ha in 2016).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Crop growth and development and their subsequent maximum yield by crop have been reported to be influenced by the application of a sufficient level of fertilizers to a suitable plant spacing. This study, therefore, evaluated the effect of different plant spacing and rates of urea fertilizer application on the growth, yield, and yield components of okra variety, *Asontem*.

Accordingly, three different plant spacing and three different rates of urea fertilizer application were combined in a field experiment at the experimental field at the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Asante Mampong campus. The experiment was arranged in a 3 x 3 factorial using a randomized complete block design with three replications on a plot size of 4.8 m x 3.0 m per treatment unit.

Data were collected from ten randomly selected plants from the central rows and their averages were analyzed. The results showed that vegetative growth parameters of okra plants were affected by the plant spacing, application of different urea rates of fertilizer, and their treatment combinations when the results were taken over the recorded periods. The widest plant spacing, S3 (60 cm x 60 cm), the highest urea fertilizer application, N3 (69 kg N ha^{-1}), and their interactions produced the maximum number of leaves per plant, the stem girth value, and the number of branches per plant. However, the closest plant spacing, S1 (60 cm x 40 cm) treated with urea fertilizer applied at 69 kg N ha^{-1} resulted in the highest mean plant height of the other treatments and their respective combinations.

Yield components of the okra plant were also influenced by plant spacing, the application of urea fertilizer, and their interactions. The widest plant spacing, S3 (60 cm x 60 cm), the highest rate of urea fertilizer N3 (69 kg N ha^{-1}), and their treatment combination T9 (60 cm x 60 cm + 69 kg N ha^{-1}) respectively recorded the higher number of fruits per plant (6.44, 8.00 and 9.33); fresh pod weight (25.82 g, 27.50 g, and 30.78 g); fresh pod diameter (2.47 cm, 2.73 cm, and 3.08 cm) and the fresh pod length (6.98 cm, 7.62 cm, and 7.90 cm). The maximum fresh pod yield of 1.72 t ha^{-1}, 1.66 t $ha^{-1,}$ and 2.55 t ha^{-1} was recorded in the closest plant spacing, S1 (60 cm x 40 cm) treated with urea fertilizer at the highest rate of 69 kg N ha^{-1} and their treatments combinations respectively.

In general, the use of different plant spacing, the application of different rates of urea fertilizer, and their interactions showed a significant effect on the plant in all the vegetative growth parameters taken, yield, and yield components of okra variety *Asontem*.

6.2 Recommendations

1. It is recommended that the okra variety *Asontem* should be sown at 60 cm x 40 cm plant spacing with urea fertilizer application rate of 69 kg N ha^{-1} for optimum yield per hectare.
2. It is also recommended that further research should be carried out on the plant spacing and the different rates of urea fertilizer applied on okra variety *Asontem* at different locations.

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APPENDICES

APPENDIX A:

ANOVA Table for Vegetative Growth Parameters of Okra

Randomized Complete Block AOV Table for Plant Height

At 5 weeks after sowing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	33.201	16.600	2.15	
Rep.*Units* stratum					
Spacing	2	40.254	20.127	2.61	0.104
Fertilizer	2	1297.443	648.721	84.15	<.001
Spacing.Fertilizer	4	45.864	11.466	1.49	0.253
Residual	16	123.346	7.709		
Total	26	1540.107			

At 6 weeks after sowing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	21.254	10.627	3.27	
Rep.*Units* stratum					
Spacing	2	89.436	44.718	13.77	<.001
Fertilizer	2	1550.712	775.356	238.79	<.001
Spacing.Fertilizer	4	58.728	14.682	4.52	0.012
Residual	16	51.953	3.247		
Total	26	1772.083			

At 7 weeks after sowing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.316	0.158	0.03	
Rep.*Units* stratum					
Spacing	2	180.210	90.105	19.77	<.001
Fertilizer	2	1125.601	562.800	123.49	<.001
Spacing.Fertilizer	4	63.959	15.990	3.51	0.031
Residual	16	72.917	4.557		
Total	26	1443.003			

ANOVA Table for Vegetative Growth Parameters of Okra

Randomized Complete Block AOV Table for Number of Leaves per Plant

At 5 weeks after sowing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	14.234	7.117	2.89	
Rep.*Units* stratum					
Spacing	2	40.261	20.130	8.17	0.004
Fertilizer	2	602.545	301.273	122.20	<.001
Spacing.Fertilizer	4	28.566	7.141	2.90	0.056
Residual	16	39.446	2.465		
Total	26	725.052			

At 6 weeks after sowing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	18.421	9.210	2.35	
Rep.*Units* stratum					
Spacing	2	117.630	58.815	15.03	<.001
Fertilizer	2	1395.354	697.677	178.34	<.001
Spacing.Fertilizer	4	20.797	5.199	1.33	0.302
Residual	16	62.593	3.912		
Total	26	1614.794			

At 6 weeks after sowing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	18.421	9.210	2.35	
Rep.*Units* stratum					
Spacing	2	117.630	58.815	15.03	<.001
Fertilizer	2	1395.354	697.677	178.34	<.001
Spacing.Fertilizer	4	20.797	5.199	1.33	0.302
Residual	16	62.593	3.912		
Total	26	1614.794			

At 7 weeks after sowing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	48.296	24.148	2.89	
Rep.*Units* stratum					
Spacing	2	251.630	125.815	15.06	<.001
Fertilizer	2	1908.074	954.037	114.17	<.001

Spacing.Fertilizer	4	98.370	24.593	2.94	0.053
Residual	16	133.704	8.356		
Total	26	2440.074			

Randomized Complete Block AOV Table for Stem Diameter

At 5 weeks after sowing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.22296	0.11148	7.32	
Rep.*Units* stratum					
Spacing	2	0.56519	0.28259	18.55	<.001
Fertilizer	2	2.88296	1.44148	94.64	<.001
Spacing.Fertilizer	4	0.22148	0.05537	3.64	0.027
Residual	16	0.24370	0.01523		
Total	26	4.13630			

At 6 weeks after sowing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.68963	0.34481	6.06	
Rep.*Units* stratum					
Spacing	2	2.46296	1.23148	21.64	<.001
Fertilizer	2	3.60296	1.80148	31.66	<.001
Spacing.Fertilizer	4	0.26593	0.06648	1.17	0.361
Residual	16	0.91037	0.05690		
Total	26	7.93185			

At 7 weeks after sowing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.57407	0.28704	11.70	
Rep.*Units* stratum					
Spacing	2	4.12074	2.06037	83.97	<.001
Fertilizer	2	5.67630	2.83815	115.67	<.001
Spacing.Fertilizer	4	0.54148	0.13537	5.52	0.005
Residual	16	0.39259	0.02454		
Total	26	11.30519			

Randomized Complete Block AOV Table for Number of Branches per Plant

At 7 Weeks after sowing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2.6163	1.3081	2.53	
Rep.*Units* stratum					
Spacing	2	2.0474	1.0237	1.98	0.170
Fertilizer	2	1.6207	0.8104	1.57	0.239
Spacing.Fertilizer	4	8.5748	2.1437	4.15	0.017
Residual	16	8.2637	0.5165		
Total	26	23.1230			

At 8 weeks after sowing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2.8474	1.4237	1.94	
Rep.*Units* stratum					
Spacing	2	5.8519	2.9259	3.98	0.040
Fertilizer	2	10.2785	5.1393	6.99	0.007
Spacing.Fertilizer	4	9.9615	2.4904	3.39	0.035
Residual	16	11.7659	0.7354		
Total	26	40.7052			

At 9 weeks after sowing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	8.0207	4.0104	23.77	
Rep.*Units* stratum					
Spacing	2	28.0030	14.0015	82.99	<.001
Fertilizer	2	29.0252	14.5126	86.02	<.001
Spacing.Fertilizer	4	1.3837	0.3459	2.05	0.135
Residual	16	2.6993	0.1687		
Total	26	69.1319			

APPENDIX B:

ANOVA Table for Yield and Yield Components of Okra

Randomized Complete Block AOV Table for Number of Fresh Pods per Plant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	5.0453	2.5226	6.82	
Rep.*Units* stratum					
Spacing	2	20.9712	10.4856	28.35	<.001
Fertilizer	2	130.5267	65.2634	176.46	<.001
Spacing.Fertilizer	4	2.6831	0.6708	1.81	0.176
Residual	16	5.9177	0.3699		
Total	26	165.1440			

Randomized Complete Block AOV Table for Fresh Pod Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	13.837	6.919	2.66	
Rep.*Units* stratum					
Spacing	2	106.269	53.134	20.43	<.001
Fertilizer	2	376.263	188.132	72.35	<.001
Spacing.Fertilizer	4	7.106	1.776	0.68	0.614
Residual	16	41.607	2.600		
Total	26	545.081			

Randomized Complete Block AOV Table for Fresh Pod Length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	1.1813	0.5906	2.01	
Rep.*Units* stratum					
Spacing	2	1.4733	0.7366	2.51	0.113
Fertilizer	2	21.1056	10.5528	35.97	<.001
Spacing.Fertilizer	4	0.3714	0.0929	0.32	0.863
Residual	16	4.6934	0.2933		
Total	26	28.8249			

Randomized Complete Block AOV Table for Fresh Pod Diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.24861	0.12431	1.27	
Rep.*Units* stratum					
Spacing	2	1.28642	0.64321	6.55	0.008
Fertilizer	2	4.41695	2.20848	22.48	<.001
Spacing.Fertilizer	4	0.18812	0.04703	0.48	0.751
Residual	16	1.57154	0.09822		
Total	26	7.71165			

Randomized Complete Block AOV Table for Fresh Pod Yield per hectare

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.4820	0.2410	2.11	
Rep.*Units* stratum					
Spacing	2	6.7357	3.3679	29.52	<.001
Fertilizer	2	5.9851	2.9926	26.23	<.001
Spacing.Fertilizer	4	1.4496	0.3624	3.18	0.042
Residual	16	1.8255	0.1141		
Total	26	16.4780			