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INFLUENCE OF "ACCESSION" TYPE AND CONSEQUENT "TOPPING" ON PRODUCTIVITY AND PROXIMATE COMPOSITION OF OKRA (*Abelmoschus esculentus* L. Moench) FRUIT IN A GHANAIAN OXISOL

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FACULTY OF AGRICULTURE, FOOD AND CONSUMER SCIENCES

DEPARTMENT OF HORTICULTURE

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BY

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THESIS SUBMITTED TO THE DEPARTMENT OF HORTICULTURE, FACULTY OF AGRICULTURE, FOOD AND CONSUMER SCIENCES, UNIVERSITY FOR DEVELOPMENT STUDIES, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN HORTICULTURE

NOVEMBER, 2025

DECLARATION

SUPERVISOR:

I hereby declare that the preparation and presentation of this thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies.

Professor Moomin Abu ….. ……27/01/2026…

(Supervisor) Signature Date

STUDENT:

I hereby declare that this thesis is the result of my original work and that no part of it has been presented for another degree in this University or elsewhere.

Mohammed Karimu ………… ……………. …27/01/2026…………

(Student) Signature Date

DEDICATION

This work is dedicated to my family and friends for their encouragement, love and support.

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ABSTRACT

Studies on the influence of “accession” type and consequent “topping” on productivity and proximate composition of okra was conducted at the orchard and Spanish Laboratory Complex, University for Development Studies (UDS), Faculty of Agriculture, Food and Consumer Sciences, Department of Horticulture, Tamale, Ghana. There is a significant knowledge gap regarding the impact of “topping” on the proximate composition of okra fruits. Lack of standardized “topping” practice among farmers, coupled with limited data on proximate composition hinders the optimization of okra productivity, hence the study. The study was a two-factor experiment in a Randomized Complete Block Design with five replications. The two factors considered were “accession” type {“Choochoo (C)”; “Jengbunjira” (J); “Maanpielli” (M); “Sheinmana” (S); and “Wuunmana” (W)} and “topping” stages {control, no “topping” (T0); “topping” at apical flower bud emergence (Ta); “topping” at one week after apical flower bud emergence (T1); and “topping” at two weeks after apical flower bud emergence (T2)}. These two factors were combined to make twenty treatment combinations {“Choochoo” not “topped” (CT0), “Choochoo” “topped” at apical flower bud emergence (CTa), “Choochoo” “topped” at one week after apical flower bud emergence (CT1), “Choochoo” “topped” at two weeks after apical flower bud emergence (CT2), “Jangbunjira” not “topped” (JT0), “Jangbunjira” “topped” at apical flower bud emergence (JTa), “Jangbunjira” “topped” at one week after apical flower bud emergence (JT1), “Jangbunjira” “topped” at two weeks after apical flower bud emergence (JT2), “Maanpielli” not “topped” (MT0), “Maanpielli” “topped” at apical flower bud emergence (MTa), “Maanpielli” “topped” at one week after apical flower bud emergence (MT1), “Maanpielli” “topped” at two weeks after apical flower bud emergence (MT2), “Sheinmana” not “topped” (ST0), “Sheinmana” “topped” at apical flower bud emergence (STa), “Sheinmana” “topped” at one week after apical flower bud emergence

(ST1), "Sheinmana" "topped" at two weeks after apical flower bud emergence (ST2), "Wuunmana" not "topped" (WT0), "Wuunmana" "topped" at apical flower bud emergence (WTa), "Wuunmana" "topped" at one week after apical flower bud emergence (WT1), "Wuunmana" "topped" at two weeks after apical flower bud emergence (WT2)}. Five healthy plants per treatment were randomly selected and tagged for the study. Choochoo" plants with "topping" at apical flower bud emergence (CTa) recorded a significantly higher number of flower buds and number of flowers. "Choochoo" "topped" at apical flower bud emergence (CTa) plants recorded the highest fresh fruit weight (414.7 g) produced per plant. Fresh fruit girth recorded significant interaction effects, where JTa plants recorded significantly higher fruit girth (36.47 mm). "Sheinmana" "topped" at apical flower bud emergence (STa) plants recorded the highest fruit length (9.12 cm) per plant. There were no interaction effects among the treatment combinations for the percentage moisture content of okra but "Choochoo" "topped" at apical flower bud emergence (CTa) plants recorded the highest (71.88 %) percentage moisture content, the highest percentage crude fat content (0.88 %), and the highest (70.6 %) percentage carbohydrate content. "Jangbunjira" not "topped" (JT0) plants recorded significantly higher percentage dry matter content (26.42 %). The highest (25.93 %) percentage crude protein was recorded by "Maanpielli" "topped" at apical flower bud emergence (MTa), and the highest (9.364 %) percentage crude ash content by "Wuunmana" "topped" at two weeks after apical flower bud emergence (WT2). "Choochoo" "topped" at apical flower bud emergence (CTa) was highly recommended for optimizing productivity with particular reference to the number of fruits and fruit weight critical to the fresh market. For processing goals, "Jangbunjira" "topped" at apical flower bud emergence (JTa) was recommended for optimum fruit girth, and "Sheinmana" "topped" at apical flower bud emergence (STa) for optimizing fruit length. For the determination of proximate composition, "Choochoo" "topped" at apical flower bud emergence (CTa) was prioritised for bulk consumption and enhanced digestion due to its high moisture, fat, and carbohydrate levels. "Jangbunjira" not topped, "Maanpielli" "topped" at apical flower bud emergence (MTa), "Choochoo" "topped" at two weeks after apical flower bud emergence (CT2), and "Wuunmana" "topped" at two weeks after apical flower bud emergence (WT2) enhanced: optimum dry matter content, protein content, and ash content respectively. The study found "topping" at apical flower bud emergence (Ta) a worthy technical agronomic practice for improved productivity and proximate composition in each case of the five "accessions" evaluated.

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LIST OF ACRONYMS

NAP: National Academies Press

AOAC: Association of Analytical Chemist

ASTM: American Society for Testing and Materials

LIST OF ABBREVIATIONS

NFE: Nitrogen-Free Extract

cm: Centimeter

DAS: Days After Planting

dS/m: Deci siemens per meter

EC: Electrical Conductivity

g: Gram

kcal: Kilocalorie

kJ: Kilojoule

mg: Milligram

mm: Millimeter

t/ha: Tons per hectare

WAP: Weeks After Planting

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Agriculture plays an important role in the economy of countries worldwide including serving as major source of food, income, and employment for most smallholder farmers in developing countries (Mozumdar, 2012; Byerlee *et al*., 2009). In Ghana, it is reported that agriculture contributes 20 % to the Gross Domestic Product (GDP) with export earnings of more than 30 % (Asare-Nuamah *et al*., 2023; Ayambila *et al*., 2023). This has led to the expansion of the export base of horticulture which is a major sector of agriculture in Ghana (Kuo *et al*., 2019; Thapa and Dhimal, 2017).

Fruit vegetables including okra, pepper, cucumber and garden eggs are rich sources of vitamins, minerals, and dietary fibre which help to protect the body against diseases, promote heart health, blood sugar management, boosts bone health, and better digestion (Rafflegeau *et al*., 2015; Weinberger and Lumpkin, 2007).

Okra is grown in the tropical and subtropical regions of the world (Singh *et al*., 2014). Its leaves, fruits, seeds and floral parts are consumed in soups, stews, and salads (Jena *et al*., 2018). Okra is a rich source of minerals and vitamins including vitamins A and C, calcium, potassium, folic acid, iron, and zinc (Godswill *et al*., 2020). The seeds contain oil which is rich in unsaturated fatty acids such as linoleic acid (Kostik *et al*., 2013).

In Ghana, okra designated as accessions under cultivation over the years in the various regions have been landraces (Obeng-Antwi *et al*., 2012). Okra is known by many local or native names worldwide. Some of these native names are “lady’s finger”, “gumbo”, and “bhindiin” in England, the United States of America, and India, respectively (Gemede, *et al*., 2016). In Ghana, these local names across the various ethnic groups include "mana", "nkruman", and "fetri" among the Dagomba, Akan, and Ewe, respectively.

According to Angadi *et al.* (2025), low productivity in okra is attributed to several challenges, including the choice of "accessions" and the "topping" technique adopted. These challenges could be reversed to significantly improve yields and nutritional qualities of the crop through the adoption of appropriate "accessions" and "topping" practices (Angadi *et al*., 2025). In addition, topping plays a crucial role in photosynthesis and plant health through the management of plant structure for improved light interception and reduced competition among leaves and other green parts of the plant (Wu *et al*., 2023).

1.2 Problem Statement

In regions where okra (*Abelmoschus esculentus*) serves as a significant dietary staple and economic crop, the optimization of productivity and nutritional value is a critical agricultural goal for achievement especially in the northern part of Ghana. This critical objective triggered the need for research on the influence of various okra "accession" types and "topping" stages on productivity and proximate composition of okra in the northern region.

Previous studies conducted in Northern Ghana revealed that 5% of okra growers are aware of the "topping" technique, albeit they never practiced it (Alhassan, 2019). This lack of scientific understanding and practice creates a significant knowledge gap for farmers. Without evidence-based guidance, they may adopt "topping" practices that are either inefficient or detrimental to both the quantity and nutritional quality of their yield. This finally leads to reduced productivity for farmers and a lower-quality food supply for consumers; and hindering efforts towards improving food security and public health in the region.

An examination of how different "accession" types of okra respond to "topping" in terms of reproductive parameters (number of flower buds produced/plant, number of flowers produced per plant), yield components (number of fruits produced per plant, fresh fruit weight per plant, fresh fruit girth per plant, and fresh fruit length per plant), and proximate composition (moisture content, dry matter content, fat, protein, carbohydrate, and ash contents) have not been sufficiently studied, particularly within the unique context of the highly weathered and poor-nutrient Ghanaian Oxisol. The outcome of this research could provide valuable insights into the selection of okra "accessions" that optimise both the productivity and nutritive quality, all things being equal, thereby supporting sustainable agricultural practices (Dhillon and Thakur, 2014). This is particularly relevant where agricultural efficiency and nutritional optimization significantly impact food security and the health of the masses (Mintesnot, 2016; Goddek *et al.*, 2015).

1.3 Justification

The "accessions" have been grown widely in northern Ghana but have not been subjected to the proposed agronomic practice ("topping") which has the potential to influence productivity and proximate composition positively. They are grown on poor soil such as the Oxisol without amendment and that could affect the productivity if an innovative practice such as the "topping" is not explored.

By identifying the most productive "accessions" and an effective "topping" technique, it goes a long way to increase the overall yield of okra, thereby improving its availability and affordability. It is anticipated that investigating this relationship can provide insights into effective management strategies for optimizing yield and proximate composition of okra.

The cultivation of okra is a major source of income for many smallholder farmers in Ghana (Osalusi et al., 2019). This study would provide evidence-based recommendations on which "accessions" perform best under local conditions and when combined with "topping" would be a viable technique for enhanced productivity and proximate composition. A higher yield per unit area directly translates to increased income for farmers, helping to alleviate poverty and improve their economic well-being. The findings will be directly applicable to local farming communities, empowering them with knowledge to make informed decisions in this regard. The Ghanaian Oxisols are characterized by low soil nutrient content and high acidity, which hinders crop growth and productivity (Dwomo and Dedzoe, 2010). This study's focus on such a soil type is critical because the findings will directly benefit okra growers in the study area for optimum productivity and possibly, enhanced proximate composition.

Although previous studies conducted on "topping" of okra, only a few, if any, have systematically investigated its effects on different "accessions" within the specific context of Ghanaian Oxisols. This research would fill the gap, by providing quantitative data on how these factors influence productivity and proximate composition of okra. It is also anticipated that this study will not only be practical but will also add new and valuable ideas to the fields of horticulture and crop science. It will also provide a foundation for further research on breeding and agronomic practices of okra.

1.4 RESEARCH OBJECTIVES

1.4.1 General Objective

To determine the influence of "accession" type and consequent "topping" stage on productivity and proximate composition of okra (*Abelmoschus esculentus* L. Moench) fruit in a Ghanaian oxisol.

1.4.2 Specific Objectives

i. To determine the influence of "accession" type and "topping" stage on the reproductive (number of flower buds and number of flowers) and yield (number of fruits per plant, fresh fruit weight per plant, fresh fruit girth per plant, and fresh fruit length per plant) parameters of okra fruit.

ii. To determine the influence of "accession" type and "topping" stage on proximate composition (percentage moisture content, percentage dry matter content, percentage crude fat content, percentage crude protein content, percentage carbohydrate content, and percentage ash content) of the okra fruit.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution of Okra

Okra originated from the Abyssinian centre, which includes Ethiopia, Eritrea and Anglo-Egyptian Sudan (Ahiakpa *et al*. 2017). The crop also spread to Egypt and Arabia through trade (Singh et al**.**, 2014). Okra is cultivated worldwide, especially in the United States, humid climates in Africa, and Sri Lanka in Asia.

2.2 Taxonomy of Okra

Okra, which was first classified in the genus *Hibiscus* and section *Abelmoschus,* belonged to the family *Malvaceae* (Matthew *et al*., 2018). Subsequently, the *Abelmoschus* was elevated to the genus rank (Onakpa, 2013). The *Abelmoschus* was widely accepted subsequently in contemporary literature and the taxonomic system of classification (Patil *et al*., 2015). In West and Central Africa, two cultivated species of okra, namely *Abelmoschus esculentus* and *Abelmoschus caillei,* were identified (Kumar *et al*., 2013).

2.3 Okra "Accessions"

The word "accession" has different meanings based on the area or place of usage. According to Breman *et al*. (2021), an "accession" is a group of related plant material from a single species which is collected at one time from a specific location. In other words, accessions encompass a wide variety of genetic materials, including landraces, cultivars and mutant varieties within a given gene bank (Marone *et al*., 2021). They play a vital role in crop improvement by providing genetic materials that can be used to develop new cultivars with desirable traits, such as disease resistance, climate change resilience and improved yield (Kumar *et al.*, 2024). There are over six million accessions that are conserved in gene banks, with okra accessions representing 2,283 worldwide (Kumar *et al*., 2021; Mohammed, 2020; Ahiakpa *et al*., 2017; Oppong-Sekyere *et al*., 2011). In West Africa, there are over 1,769 okra accessions compared to the rest of the world, with a high degree of morphological variations (Mkhabela *et al*., 2022; Falusi *et al*., 2012; Akinyele and Osekita, 2006). These collections are essential for maintaining genetic diversity and supporting sustainable agricultural practices globally (Pathirana and Carimi 2022). In Ghana, okra cultivation is carried out through the use of traditional varieties with designated native names in various ethnic languages (Oppong-Sekyere *et al*., 2011).

2.4 Morphology of Okra

Okra is a herbaceous annual plant that can grow up to 3 - 8 m tall (Olczyk *et al*., 2006). The plant has a deep taproot system (Vadar *et al*., 2019). It has an erect and robust stem, which is semi-woody and pigmented with a green or reddish tinge with varying branching (Gupta *et al*., 2021; Reddy *et al*., 2016). The leaves are alternate and palmately five-lobed with axillary and solitary flowers (Dehgan, 2023). Okra exhibits indeterminate growth and continuous flowering, which is affected by biotic and abiotic stresses (Zhong *et al*., 2024). The fruit is an elongated, conical or cylindrical capsule, comprising five cavities containing ovules and generally ribbed, developing in the leaf axil (Alamgir and Alamgir, 2017). The fruit is normally yellowish-green, green, purple or whitish-green. They grow rapidly into long (10 - 30 cm) and narrow (1 - 4 cm) pods with a tip that is either pointed like a beak or blunt (Reddy *et al*., 2016). In addition, the fruit contains numerous ovals, smooth, striated and dark green to dark brown seeds (Samim *et al*., 2018).

2.5 Heritability and Types of Genetic Variability of Okra

The goal of breeding programs is to integrate target traits into superior, high-yielding landraces of wild species that possess some undesirable characteristics (Kashyap *et al*., 2022). The Intrusion of particular traits may lead to a decline in yield as well as quality due to association (Suding *et al*., 2008). The fundamental technique for this development is to choose indigenously well-adapted germplasm which contains good genetic variability for high-yielding quality and drought resistance characters (Okigbo and Anyaegbu, 2021).

The viability of okra within the cultivated genotype for different characters has been reported by Ranga *et al*. (2021). The determination of heritability evaluations, using several methods (Barry *et al*., 2023), will provide information on the percentage of phenotypic modification that results from genetic factors for varying characters. However, heritability approximation alone is not enough to grasp the stages of possible genetic development that might emerge, even when individuals are carefully selected in breeding program that is most prominent.

The significance of heritability approximations is made better when combined with the selection differential or genetic advance (Ibrahim and Hussein, 2006). Information regarding the quantity and direction of the relationship among yield and yield-related traits is vital for speedy advancement in the selection and genetic enhancement of a crop (Khan *et al*., 2024). It is noted that consideration of this specifies the inter-relationship between two or more plant characteristics and yield. This will, in turn, give rise to appropriate measures for indirect selection for yield. Assessment of the kind and volume of genetic variability linked with the target character is very central. Determination of the type of genetic changeability may well help to formulate detailed and precise projections for breeding programmes concerning how further improvement on the target trait may yield higher results (Cooper *et al*., 2014).

Additive or non-additive types of genetic variability have been reported to be connected with many traits (Hivert *et al*., 2021). Genetic variability occurs through the increasing effect of minor alleles for additive types. Non-additive type of genetic variability is noted to be the result of dominance and epistasis (López-Fanjul *et al*., 2000). As a result of the intragenic interface, dominance comes about but epistasis is a result of intergenic interaction (Domingo *et al*., 2019). Moreover, these intergenic and intragenic interactions are also reported to be affected by the exterior inducements of the environment like drought, pests and diseases (Sharma and Verma, 2019).

2.6 Reproductive Growth and Development of Okra

2.6.1 Pollination and fertilization of okra

Pollination is important in the reproduction of flowering plant species. Pollination is known to involve the transfer of mature pollen grains from the anther of a flower to the stigma of flowers of the same species (Wan *et al*., 2024). This phenomenon results in sexual reproduction after fertilization. Sexual reproduction involves the recombination of genes which is absent in plants propagated through asexual means. Environmental factors including water and wind facilitate pollination. Insects such as bees play a role in the pollination of okra, resulting in cross pollination although it is self-pollinating (Salem and Ibrahim, 2025). Besides the genotype, temperature and humidity are a key climatic factor that influences the initiation of flower buds, flowering, anthesis, and stigma receptiveness (Mehmood *et al*., 2025). Anther dehiscence is crosswise and full dehiscence takes place between 5 - 10 minutes (Baldwin and Goldman, 2012). The duration is approximately an hour preceding and an hour later as the opening time of the flower is when maximum pollen fertilization can be achieved (Dahl *et al*., 2013).

Okra has perfect flowers and therefore will continue to flower and set fruits in the absence of pollinators. There are no clear distinctions in fruits developed from self-pollination or cross pollination, an indication that could lead to the conclusion that okra is potentially self-pollinating (Angbanyere, 2012). It is reported that cross pollination may occur between 4 - 19 % (Oyetunde and Ariyo, 2014) to as high as 42 %. The rate and degree of cross-pollination existing in a specified field are dependent on the variety, number of flowers, season and number of insects present (Sun *et al*., 2024).

2.6.2 Flower bud and floral formation of okra

Okra has 6 to 8 flower buds appearing at the axil of the leaves depending on the cultivar. The crown of the stem contains 3 - 4 underdeveloped flowers (Maurya *et al*., 2025). This continues until flowers appear profusely on the plant with the crown having up to 10 underdeveloped flowers. As the stem elongates flower buds open up as flowers. During flower development, single branches do not bear more than one flower within the two to three days duration for bud opening (Feng, *et al*., 2021). Each flower bud takes approximately four weeks from start to full blossom.

The style can bear anthers up to 100 (Åstrand *et al*., 2021). Pollen grains are deposited on the stigma either through an elongation of the stamen or by insect activities (Khan and Verma, 2024).

Although flowering in okra is continuous, it is mainly dependent on the biotic and abiotic factors (Hayamanesh, 2018). Okra takes up to 45 days after planting to reach maturity which is characterized by the development of pods depending on the cultivar (Maiti and Singh, 2021).

Depending on the cultivar, flowers are 1.5 - 3.5 inches in diameter, with five petals which are white to yellow, often with the base having a red or purple spot around the base of each of the petals (Vu, 2025). One distinct feature of flowers in the *Hibiscus* family is the way the stamens are joined one to another at the bottom of their filaments (Raghu *et al*., 2019). They usually create a cylindrical column around the pistil.

Plate 1: Okra flower (study area field survey 2019)

2.6.3 Fruit set, development, and maturity of okra

The fruit of okra are capsules which develops and grows quickly after flower appearance (Alenazi, 2011). Development and increase of the okra fruits are pronounced between the fourth and sixth day, as the diameter, height and length of the fruit increase rapidly (Al-Ubaydi, 2017). The best time to harvest fresh fruits to be consumed as vegetables is within the stage of fruit growth and elongation (Kyriacou and Rouphael, 2018). Preferably, immature fruits with high mucilage are harvested to prevent them from becoming fibrous on the stems of the plants. It is generally known among producers that fibre production could be noticed in the fruit five days after reaching the maturity stage (Maurya *et al*., 2013). The fibre content increases on the 9th day after fruit formation (Cachero and Belonias, 2021). Flowering and fruit development continue for an unspecified period in the life cycle, relative to the variety, environmental conditions and soil fertility (Baseer *et al*., 2024). In addition, regular harvesting ensures constant fruiting (Shivandu *et al*., 2024).

2.7 Propagation and Productivity of Okra

Okra is typically propagated by seed. To facilitate germination, the seeds can be soaked in water overnight before planting (Sharma *et al*., 2014). In home gardening, seeds are sown at a depth of 2.5 cm and soil reaches a temperature of 18 °C (Li *et al*., 2022). Seeds are planted in rows during commercial okra production at spacing of 65cm - 100 cm. Well-established crops are important for the utilization of agricultural inputs leading to an increase in productivity (Olczyk *et al*., 2006). The most popular method of okra planting is direct seeding. This is because it does not do well when transplanted. The seeds are sometimes mixed with wood ash before planting or soaked in water. The seeds are frequently planted in the ground directly (Staples and Bevacqua, 2006). In the tropical regions of Africa, farmers do not practice the transplanting of okra (Oluoch *et al*., 2009). However, in situations where they have to transplant okra, the seedlings are hardened and transplanted onto soils that are moist and well prepared. The seedlings are then subjected to outside lights and temperature within 5 - 7 days period after transplanting (Davis, 2022). If this method is to be used, then there is the need to ensure that the soil has enough moisture preferably at the time that the rains set-in. Seedlings are usually transplanted when they are 10 - 15 cm tall. Planting in rows is recommended (Gessesew *et al*., 2015).

2.8 "Topping" In Okra Production

Topping crop plants is a critical agricultural practice aimed at enhancing growth and yield quality (Shah *et al*., 2023). It involves the removal of the terminal portion of crop plants thereby enhancing leaf function, light interception, nutrient uptake and improvement of the source-sink relationship (Iqbal *et a*l., 2024). This technique is particularly significant in crops such as cotton, okra, tomato, corn and potatoes as it enhances productivity and management of plant health (Larkin *et al*., 2021).

There are various methods of "topping" which include manual, chemical and automated (Zhu *et al*., 2022). Previous works have reported the varying effects of topping on okra depending on the timing and management practices adopted (Akhi *et al*., 2022).

Growth, productivity and seed quality are increased with "topping" at the early stages compared to later stages of growth, providing sufficient time for regeneration of vegetative parts, enhancing the production of branches, resulting in increased photosynthetic activity, accumulation of more photosynthates, fruit formation and fruit production and ultimately increased seed size and yield (Lakshmi, 2015). The physiology behind this technique is to change the source-sink relationship by redirecting the vegetative growth.

"Topping" is receiving increasing global attention in vegetable crop production (Priyanka and Monalisha, 2017). "Topping" in okra may be done at the early or later stages of the plant's growth and development. During the later stage of growth and development, they tend to top out and produce a declining number of pods, resulting in a sharp decline in the output of the crop (Ounis *et al*., 2024). Thus, cutting back or "topping" allows the okra to reestablish itself. Cutting back okra allows the plant to rejuvenate and produce fruits at later stages in the life of the crop (Shah et al., 2023). Okra plants can be "topped" using pruning shears, leaving 6 to 12 inches of each plant above the ground. It can also be carried out by removing only the apical flower bud. Fertilization may be done to encourage the regrowth and development of side branches (Nada *et al*., 2024).

2.9 Cropping Systems

Okra, which is usually grown in the field, is found to have been contributing immensely to the quantity of harvested produce and the farmers' socio-economic needs (Olasantan, 2001). Exploitation of the mixed system is key to diversifying okra production in tropical Africa. In Nigeria, excluding intercropping technologies in mixed systems of production in vegetable crops by farmers is not accepted (Olasantan, 2001).

In Africa, okra production can be intercropped with other crops such as yam, legumes, cassava, as well as maize which are staple foods for millions of peoples, especially in the western and central parts of Africa (Nyamekye, 2021). Due to the increase in population growth, good arable land is scarce in Africa (Chamberlin *et al*., 2014). Cassava and Yam are long-duration crops that cover the land for 6 - 12 months. They are planted as early as the onset of the rains in wide-spaced ridges. They have a slow growth and shorter canopy spread and development (Kongsil *et al*., 2024), nonetheless, their systems of cultivation and growth and development habits offer a good chance for it to be intercropped with vegetables to improve production and productivity of the cropping system (Maitra *et al*., 2021).

Among the tropical African farmers, there is no known general consent as to how preparations for land are done for okra (Nyande *et al*., 2021). Farmers take into consideration factors such as crop types, season, mode of cropping, plant nutrition, fertility of the soil and the agro-ecological zone in land preparation (Ansong *et al*., 2018). Incorporation of organic fertilizer into the soil to break down completely during land preparation before planting is recommended. For good drainage, planting of okra is done on ridges generally on heavy clay soils rich in organic matter (Nkakini *et al*., 2008). Okra is sometimes planted along the furrows or raised mounds on any of the sides of the main crop which may be a staple food crop (Mallikarjunarao *et al*., 2015). It may also be planted on flat beds after clearing the land and burning the trash.

2.10 Requirements for Okra Production

2.10.1 Climatic Requirements

Okra performs well in well-drained soils that have high organic matter content with good aeration (Kumar *et al*., 2016). Medium loam to light sandy soils are preferred (Bagalea *et al*., 2024). Okra does well within 18 - 35 ^{o}C minimum and maximum mean range of temperatures, respectively (Gemechu, 2018). Okra does not perform well under temperatures below 15 ^{o}C because of its sensitivity to low temperatures (Hayamanesh, 2018). Heated greenhouse cultivation of the crop is commonly practised in Northern Europe (Budania and Dahiya, 2018). Storage of okra at temperatures of 45 - 50 ^{o}C and relative humidity of 90 - 95 % for 7 to 10 days maintains its freshness (Mwenya, 2024).

Flowering of most cultivars is stimulated by short day lengths in the tropical regions of Africa (Yao *et al*., 2025). A day length of less than 11 hours is essential for initial flowering. The flower buds tend to abort under long-day temperatures (Hayamanesh, 2018). Owing to the sensitivity of okra to ethylene, it is advisable that fruits such as apples and pears that release ethylene should not be stored with it (Dhall, 2013).

2.10.2 Soil Requirements

Okra grows in different types of soils with good drainage. Poorly drained and acidic soils are noted for their unsuitability for okra production (Makinde *et al*., 2022). The soil pH ideal for okra production ranges from 6.0 - 7.5. However, waterlogged soils are not good for the production of hokra (Temam, 2019). When planting okra in clay soil, it is recommended that transplants are used because seedling emergence in heavy soils is very difficult (Siddiqui *et al*., 2008). To achieve good results, the temperature of the soil must be 18.3 °C.

2.10.3 Fertilization

In tropical Africa, the fertility of the soil and the nutrition of the plant are important components in the production of vegetables (Rodelo-Torrente *et al.,* 2022). Organic and inorganic fertilizers are both beneficial to okra when used for side dressing. However, the use of inorganic fertilizer is affected by inadequate knowledge of application, scarcity and prohibitive cost. The use of fertilizer in the tropical regions of Africa is dependent on the agro-ecological zone, season as well as crop variety (Adzawla *et al*., 2021).

The use of fertilizer in most African countries has always reflected Government Policies (Jayne *et al*., 2013). In Ghana, the Government introduced a flagship program called Planting for Food and Jobs which has subsidized fertilizer and other farm inputs for farmers. The distribution and use of fertilizer in tropical Africa vary greatly. Therefore, it becomes difficult to determine the quantity of fertilizers used in the production of vegetables such as okra. Thus, making the forecasting of the need for fertilizers in the future for vegetable production such as okra more difficult (Wijesinghe *et al*., 2021). Although the use of fertilizer in the world has been in ascendency over the last 20 years, Africa is ranked the poorest in its fertilizer application rate for crop plants (Ciceri and Allanore, 2019). When too much nitrogen is applied to okra, it tends to grow vegetatively, resulting in poor yields (Baw *et al*., 2017). Shallow stirring of the soil near the plant reduces weed growth and competition with okra plants for nutrients.

2.10.4 Irrigation and water requirements

Okra does well in warm and moist soils for optimum growth and development (Adekiya *et al*., 2017). Nonetheless, okra plants have to be put under consistently moist soil conditions up to the end of the growing season. Okra is susceptible to saline conditions and therefore it is imperative to use good water during production (Saeed *et al*., 2014). Watering every week under dry conditions is good for okra as it leads to good yields. Sandy soils require regular watering compared to clay soils (Ismail and Ozawa, 2007). There have not been any accurate figures on the amount of water and how regularly it is required for okra, as this shows changes depending on where, time of the year, type of soil and irrigation type required (Home et al., 2002). However, under sprinkler irrigation, okra requires 7 MLha-1, 4-6 MLha-1 for drip irrigation, and 8-10 MLha-1 under furrow irrigation. When it comes to overhead-irrigated okra plants, water should not exceed 1.6 dSm^{-1} EC. For furrow and trickle irrigated okra, water up to 2 - 4 dsm^{-1} EC is required. In Tropical Africa, okra is mostly cultivated during the rainy season (Alimi, 2005). This is due to availability of water, thereby reducing irrigation costs. For example, in Southern Nigeria, the rainy season is bimodal, with long and plentiful rainfall for okra production. This, therefore, enables the farmers to grow okra two or three times within the year.

2.10.5 Weeding

Several weed species have been identified to infest okra in the field, depending on the location of the crop. These weeds include crabgrass, goose grass, bermuda grass, sickle pod, cocklebur, and nutsedge (Ounis *et al*., 2024). When the okra and weeds are not fully grown, tilling with a rolling cultivator will eliminate the smallest weeds. Use sweep cultivators or rolling cultivators, which are designed to bury the weeds that are less grown within the row later (Gatkal *et al*., 2025). Earthing up on the stem of the okra should be avoided because there is a tendency for stem rot. There have been limited registered herbicides for the control of weeds in okra fields. However, there is a need to follow application instructions well as the wrong usage will damage the crops (Daramola *et al*., 2020). The control of weeds in okra should be done throughout the full season since harvesting of okra takes a long time. Weeds can be controlled by using the appropriate weedicide. There is a need to employ Mechanical cultivation for the control of broadleaf weeds (Mohler *et al*., 2001). To avoid damaging the okra roots, cultivation must be done shallowly. Fields with known substantial infestations of broadleaf weeds may be avoided.

2.11 Diseases and Insect Pests of Okra

2.11.1 Diseases

2.11.1.1 Charcoal rot (*Macrophomina phaseolina)*

This disease is caused by fungi which attacks a wide range of crop including okra. It is mainly spread through microsclerotia in the soil (Lodha and Mawar, 2020). It has symptoms such as stem discoloration at the soil level (Ounis *et al., 2024*).

Stem cankers may spread upwards, thereby causing leaves to wilt and fall from the plant, with numerous small black sclerotia (fungal fruiting bodies) developing in the affected tissues. Management of the disease is by practicing crop rotation to non-host to decrease the build-up of inoculum in the soil (Latha *et al*., 2025). Additionally, water stress should be avoided, especially in areas where irrigation is practised.

2.11.1.2 Fusarium wilt (*Fusarium oxysporum)*

It is a fungal disease whose emergence is favored by warm temperatures. Infected seeds may be the source by which the disease is introduced into the soil or by human movement and contaminated equipment used to work on the farm (Gordon, 2017). It causes cotyledons and leaves of seedlings to wilt. It also makes the edges of the cotyledons chlorotic and necrotic (Okungbowa and Shittu, 2012). The older leaves also show chlorosis and wilting symptoms. The wilting is not usually pronounced but becomes pronounced when it rains heavily. The severe infection leads to stunted growth in plants and subsequently death (Gordon, 2017). The vascular system of infected plants becomes discoloured and visible when the stem is cut open. It can be controlled through the use of certified and disease-free seeds as well as plant varieties that are highly resistant to the *Fusarium* disease (Gupta and Kumar, 2020). In addition, soil fumigation is one of the management practices that may reduce the incidence of the disease.

2.11.1.3 Powdery mildew (*Oidium asterisk-pumice*)

It is a fungal disease producing powdery whitish substances on the leaves (Glawe, 2008). The patches of whitish substance may spread to cover the whole plant. Heavy infestation may lead to the leaves of the plant rolling upward and looking scorched (Kirichenko *et al.,* 2017). It can be controlled by flushing the fungus on the leaves through irrigation (Mao *et al.,* 2022). Crops should also be planted as early as possible. Fungicides may also be applied to the crop plants to control the incidence of the disease.

Plate 2: Powdery mildew disease of okra (https://plantvillage.psu.edu/topics/okra/infos)

2.11.1.4 Southern blight (*Sclerotium rolfsii*)

It is caused by fungi that can survive in the soil for a very long time (Liu *et al*., 2007). The disease is mainly found in tropical as well as subtropical parts of the world including the southern part of the United States (Kator *et al.,* 2015). Soils that are acidic and high in temperatures and humidity favour the emergence of the disease. The symptoms of the disease include browning of the stem (above and below the soil) with leaves suddenly becoming wilted, foliage becoming yellowish and the browning of branches and coverage of the stem by fan–like mycelial mat (Ekundayo *et al*., 2018). It can be controlled by (i) removing the infected plant parts (ii) avoiding overcrowding of plants (iii) ploughing crop debris deep into the soil and (iv) wrapping the lower part of the stem using aluminium foil above the soil.

2.11.1.5 White mold (*Sclerotinia sclerotium*)

It is a fungal disease that can survive in the soil for over five years. Its mode of dispersal is by wind or water from irrigation that has been contaminated as well as infected seeds (Kubota and Misawa, 2014). Signs such as cotton-like fungal growth on flowers which may be small, circular, dark green, water-soaked lesions on leaves, pods and branches become enlarged during periods of high humidity (Kalbande and Yadav, 2021). The end may be the death of branches or the whole plant. The disease can be controlled by (i) practicing crop rotation with crops that are of different families such as cereals and legumes (ii) practicing row planting parallel to the wind direction to prevent the spread of secondary infection of the disease nearby (iii) Avoiding excessive nitrogen fertilizer usage and (iv) widening the rows during planting

2.11.1.6 Okra Enation Leaf Curl Virus

It is a viral disease which is transmitted by the whitefly (Pasupathi *et al*., 2021). A small pin head enation is usually located around the lower surface area of the leaves of plants. In the later stages, the enation turns warty and rough in structure. The leaves reduce in size and the side branches of the stem and leaf petioles bend in shape along the enation. The leaves of the plants look thick as well as leathery but where the infection is high, the leaves appearing have bold enations and curling with some deformed fruits (Kumar and Vashisth, 2024). Control is by removing the infected plants and burning to curtail the continuous spread of the disease. In addition, the white flies can be checked by using yellow sticky traps it can also be controlled by spraying with the appropriate recommended insecticides.

Plate 3: Infected leaves with Enation (https://plantvillage.psu.edu/topics/okra/infos)

Plate 4: Twisted stem and leaf petiole caused by the okra enation leaf virus
(https://plantvillage.psu.edu/topics/okra/infos)

2.11.1.7 Yellow vein mosaic disease

This is a viral disease that is transmitted by the whitefly *Bemisia tabaci* (Swathi *et al*., 2023). This disease can cause huge loss when it starts at the early stages of plant growth and development. The plants that are infected show green and yellow alternate patches on the leaves. The veins of the leaves become chlorotic and clear (Jiang *et al*., 2025). Veins and veins-let thicken and become conspicuous as the disease progresses. The fruits of okra plants are smallish in size and yellowish-green in colour with distortion of the stems and leave seen in the advanced stage of the disease. The control measures include (i) planting resistant cultivars (ii) using certified or diseased-free seeds (iii) practicing crop rotation (iv) removing infected plants (v) ensuring good sanitation on the field and (vi) using appropriate recommended insecticide to control the vector.

Plate 5: Infected leaf (https://plantvillage.psu.edu/topics/okra/infos)

2.12.1 Insect Pests

2.12.1.1 Aphids (*Myzus persicae or Macrosiphum euphorbiae*)

These insects are usually green or yellow with small or soft bodies. They mostly hide at the back of leaves or beneath the stem of plants (Singh and Singh, 2021). They are made of different colors such as pink, brown, red or black depending on the plant species and type of host plant. The cornicles present (tubular structures) present project at the back of the body of aphids. They generally move very slowly when disturbed. Heavy aphid infestation may cause the leaves to become yellowish, distorted and necrotic, resulting in stunted growth (Singh and Singh, 2021). The aphids secrete a sugary substance called honeydew which causes the growth of sooty mold on crop plants (Konar *et al*., 2013). Pruning can be adopted as a control measure when aphids are concentrated on a few leaves or branches. In the case of transplants aphid infestation must be checked before planting. The use of tolerant or resistant varieties is preferred (Murovhi *et al*., 2020). Aphids can also be prevented by using mulches that are reflective such as silver-coloured plastics.

They can also be removed from the plant leaves by spraying with water that has high pressure. The use of appropriate insecticides is recommended where infestations are high (Konar *et al*., 2013).

2.12.2.2 Root-knot nematode (*Meloidogyne* spp).

It is characterized by the appearance of galls on the roots of okra (Ali *et al*., 2023). Sandy soils favour the survival rate of the nematodes and damages most likely to occur in gardens and fields. Galls growth on the roots may grow up to 3.3 cm which is usually not much, slows down the vigor of the plant, and brings about yellowing of plants and wilting during hot weather (Lilley *et al*., 2024). Control is by planting resistant varieties in soils with history of nematode infestation. In addition, soil sterilization can be done to reduce the population of the nematodes (Rubin *et al*., 2007).

2.12.2.3 Spider mites (*Tetranychus urticae)*

Spider mites grow well in dusty environments. Plants that are water-stressed are more susceptible to spider mites attack thereby rendering the leaves stippled yellow and covered with webs. They are usually not seen until noticeable indications on the plant are shown (Dhooria and Dhooria, 2016). For a home garden, control is done by spraying with intense water to decrease the build-up of spider mite populations. It is advisable to apply insecticidal soap to plants should the incidence of the mite become serious. Some chemical insecticides do not reduce the mite population because the biological enemies are killed thereby increasing the reproduction of the mite (Jakubowska *et al*., 2022).

2.13 Nutritional Composition of Okra

Okra can be referred to as diet food but not just a staple (National Research Council, 2006). Lipid components significantly play an important role in building up the nutritional as well as sensory quality of almost all categories of foods contained in okra (Gemede *et al.*, 2015). There are numerous amounts of fats by nature that vary in their chemical constitution as well as in their functional characteristics. Lipids in vegetable oils are categorised into four types, namely, triacylglycerols, diacylglycerols, polar lipids and free fatty acids (Asokapandian *et al.*, 2021). The natural attributes, stability, and nutritional quality of lipids are determined by the volume of fatty acid contained (Nagpal *et al.*, 2021). Triacylglycerols are the commonly found natural compounds in vegetable oils. They comprise saturated and unsaturated fatty acids having different lengths in their acyl chains. The number and the position of double bonds that are saturated, monoenoic, and polyunsaturated fatty acids, show their difference in the composition of the detailed fatty acids (Cronan, 2024). The repetition of methylene units is what structurally brings the distinction of monoenoic fatty acids from polyunsaturated fatty acids (Nwagbo and Bernstein, 2023). These fatty acids release an extremely flexible chain that rapidly reorients through conformational states and builds up an influential group of molecules for the promotion of health (Rizo *et al.*, 2024). Linoleic acid can be obtained from okra seed oil which is a polyunsaturated fatty acid and good nutrition for humans (Gemede *et al.*, 2015). The role of crude protein in human nutrition cannot be overemphasized. The biological value of protein is characterized by the amino acid contents, proportions and their assimilation by humans (Bonomini *et al.*, 2024). Okra has seed protein balance of tryptophan amino acids and lysine that are different from the proteins of pulses and cereals (Sanjeet *et al.*, 2010; Holser and Bost, 2004). Okra seeds contain important amino acids that correspond to other proteins of plant sources (Oyelade *et al.*, 2003). Consumption of immature pods of okra is considered as vital as fresh fruits, thus, it can be eaten in so many ways (Ndunguru and Rajabu, 2004). The composition of okra leaves per 100 g edible portion is 81.50 g water, 235.00 kJ (56.00 kcal) energy, 4.40 g crude protein, 0.60 g crude fat, 11.30 g carbohydrate content, 2.10 g crude fibre, 532.00 mg calcium, 70.00 mg phosorus, 0.70 mg iron, 59.00 mg ascorbic acid, 385.00 µg β-carotene, 0.25 mg thiamine, 2.80 mg riboflavin as well as 0.20 mg niacin (Varmudy, 2011; Gopalan *et al*., 2007). Carbohydrate's content is present in the mucilage form (Archana, 2013). The mucilage is highly soluble in water. Its solubility in water has an intrinsic 30 % viscosity value.

Dried okra sauce (powdered pods mixed with spices and regularly consumed in West Africa) does not have any beta carotene (vitamin A) or retinol (Dobe, 2024). The vital source of viscous fibre is the fresh okra pods, an important dietary constituent to lower cholesterol (Kendall and Jenkins, 2004). The greatest nutrient concentration is found in one-week fresh okra (Agbo *et al*., 2008).

2.14 Health Benefits of Okra

Okra seeds have high protein content with unsaturated fatty acids such as linoleic acid (Oyelade *et al*., 2003). Some countries use okra in the medicinal industry as an antiulcerogenic, gastroprotective, and diuretic agent (Elkhalifa *et al*., 2021). Okra among others is considered a health food because of its high vitamin C, folate and fibre content. It also serves as a potential source of Potassium and Calcium. The okra flower was found to contain a higher amount of total phenolics and flavonoids (Liao *et al*., 2012). According to Liao *et al*. (2012), okra is a good contributor to the antioxidant status and chemo-preventive agent. Okra is endowed with several minerals that provide almost all the health benefits that plants provide. A few of the advantages of okra are as follows;

Okra helps in stabilizing the sugar level of blood by regulating the rate at which the intestinal tract absorbs sugar as a result of the large amount of fibre it contains (Das *et al*., 2019). Okra helps to minimize the blood sugar levels within the body which goes a long way to assisting diabetic patients. Sugar assimilation is slowed down through the intestines which help to support blood sugar levels (Ngoc and Ngo, 2008). Kidney disease might be avoided by the frequent usage of okra. Okra is also useful for the health of the heart. The okra soluble fibre helps to reduce serum cholesterol. Okra is also useful in the health of the heart which in turn reduces the chance of cardiovascular diseases. Okra is furthermore loaded with pectin which is also a contributing factor in reducing high blood cholesterol. It is done by modifying the secretion and release of bile along the intestines (Ngoc and Ngo, 2008). The beta carotene and vitamin A contained in the okra fruit are both vital nourishment for sustaining good eyesight as well as healthy skin. Okra is well-eaten when combined with other healthy vegetables. Okra has so many advantages, as it is eaten simply in its natural form against other vegetables (Messing *et al*., 2014).

Okra is good for asthmatic patients (Sengkhamparn *et al*., 2009). Studies have reported that okra polysaccharide possesses anticomplementary and hypoglycaemic activity in normal mice (Zim, 2019). Also, okra polysaccharides tend to control cancerous ailments through the binding of bile acids (Kahlon *et al*., 2007; Lengsfeld *et al*.,2004). Additionally, Okra seed can normalize the glucose level of blood as well as lowering the lipid profile action in diabetic conditions (Sabitha *et al*., 2011).

2.15 Potential Use of Okra Mucilage

The slimy and thick substance in fresh and dried fruits of okra is termed mucilage. Mucilaginous substances are chemically acidic polysaccharides that have a link with proteins and minerals which are mostly found around the fruit walls (Zim, 2019). The okra mucilage is used in medicinal and industrial entities for the production of medicine. It is again used to replace plasma level or as an expander of blood volume (Das *et al*., 2019). Industrially, okra is usually used to finish certain papers as well as confectioneries among other functions (Farinde *et al*., 2007).

Though the makeup of polysaccharides varies greatly, neutral sugars rhamnose, galactose and galacturonic acid have often been reported (Hirose *et al*., 2004; Sengkhamparn *et al*., 2009). Extraction of mucilage as a viscous gum can be done through various procedures. The extraction procedures can result in changes in the chemical composition of the mucilage which can be attributed to the multiplicity of the extraction procedures (Hejna, 2021). Okra mucilage is of low-cost and naturally renewable and low-cost form of biodegradable material. High water solubility, plasticity, elasticity and viscosity are the physical and chemical properties of mucilage (Medina-Torres *et al*., 2000). Temperature, pH, sugar and salt contents, and storage time influence most physical and chemical properties (Ma *et al*., 2021; Junqueira *et al*., 2019).

2.16 Economic Value of Okra

Okra is one of the annual crops available in almost every vegetable market in Africa. It is a crop that requires warm conditions for growth (Schippers, 2000). The young leaves and immature fruits of okra are frequently eaten as green vegetables. It is therefore intentionally known for this purpose. Some use the leaves of okra as cattle feed though not the major use of the plant. Okra production worldwide as a fruit vegetable was purged at 6,000,000 metric tonnes per year (Jonah *et al*., 2017; Muhammad *et al*., 2020). The most important regions of production were localised in Ghana, Nigeria and Burkina Faso. More than 75 % of okra produced in Africa are in Central and

West Africa with a very low average productivity of 2.5 t/ha compared to East Africa (6.2 t/ha) and North Africa (8.8 t/ha) (Nkongho *et al*., 2022).

In Ghana, 28 % of the rural dwellers grow the three most important vegetables such as tomatoes, pepper and okra (Diao *et al.*, 2010). Oppong-Sekyere *et al.* (2011) reported that fresh okra is a vegetable commonly found in almost every vegetable market in Ghana during the rainy season. In the dry season, it is still found in the vegetable market especially in the Northern part of Ghana because the rural women consider it to be of strong commercial importance to them and as food in the diets of the populace in the villages and cities.

Growth, productivity, and seed quality are increased with pinching at early stages compared to later stages of growth (Sowmya *et al.,* 2017). This provides sufficient time for regeneration of vegetative parts, enhancing the production of branches, and also resulting in increased photosynthetic activity, accumulation of more photosynthates, and ultimately resulting in increased seed size and yield (Martiniello and Teixeira *et al*., 2011).

Okra bears flower in nodes and for that matter "topping" encourages the growth of productive branches by suppressing apical dominance thereby arresting the vertical growth. The physiology behind this technique is to change the source link relationship by redirecting the vegetative growth.

This increases the photosynthetic activities, accumulation of photosynthates, fruit formation fruit production and yield (Lakshmi *et al*., 2015). The potential of okra in enhancing livelihoods is huge for both rural and urban dwellers (NAP, 2006). The okra value chain offers a route to prosperity for traders as well as small and large– scale producers (Kumar *et al*., 2010).

2.17 Status of Okra in The Local and International Markets

Ghana's horticultural industry grows at a rate of 20 % annually (Afari-Sefa, 2010). Ghana is among the six top countries that supply horticultural commodities to the European Union markets. Figures from the Ghana Export Promotion Council suggest that the export of vegetables rose from 886 metric tonnes, which was valued at $439,000 in the year 1993 to 34,764 metric tonnes at a value of $7,700,000 in the year 2003 (Voisard and Jaeger, 2003). This included chili pepper, okra, aubergine, cluster beans, yard-long beans, sponge gourds and green pepper. The demand for fresh okra continues to increase both locally and internationally (Das *et al*., 2019; Moosavi *et al*., 2018). The yielding potential of okra in addition to its short duration when cultivated is making it attractive to many farmers economically thereby increasing its cultivation locally and internationally (Mohapatra *et al*., 2024). This increase in world okra production might be one of the factors driving the global market of okra seed (Nkongho *et al*., 2022). The potential of okra to increase the income of peasant farmers is on the ascendency. This is as a result of the popularity of ease of growth and appreciable retail prices of $7.07/kg average globally. Texas' research has revealed that the diversification of farm operations boosts the income and sustainability of farms (Barbieri and Mahoney, 2018). Thus, okra average retail market prices are hovering around $3.45 kg^{-1} in the frozen form to $7.07 kg^{-1} when sold fresh, this is considered to be high value (United States Department of Agriculture (USDA), 2016). Greater care must be taken when harvesting okra for the fresh market. The (USDA), 2016) stated that harvesting okra should be done carefully and neatly to maintain the good quality of appearance of the pods. To achieve uniform grading, harvesting of fruits should be done daily during periods of rapid growth (Tim-Coolong, 2014).

2.18 Harvesting of Okra

Usually, okra fruits must be harvested when flowers appear for five to six days as fruits are still tender at this stage. Most consumers prefer a pod length of 5 to 8cm (Shah *et al*., 2023). Knives may be used to cut the pods or may be snapped by hand during harvesting. When pods are too tough to bend with the fingers, and would not easily snap, they are discarded and would not be used as vegetables (Dubey and Mishra, 2017). Okra seeds can be stored and sown season after season and would not have issues with inbreeding depression since they are self-pollinating (Kumar *et al.*, 2016). To obtain seeds, pods are better left on the plant without harvesting to fully mature and dry (sometimes taken off when they show signs of drying). This technique has consequences on the production of fresh vegetables as the development of new pods may slow down, unlike when they are harvested (El-Ramady *et al*., 2015).

Okra seeds have very little preservation concern and can be kept in the pods or de-husked and stored in a cool, dry place until the next season. Harvested pods are dried, and cracked to remove seeds (Nkongho *et al*., 2022). Other materials like leaves and stems may be incorporated into the production of compost.

2.19 Yield Components of Okra

Fruit yield is a complex trait. It is the end product of several basic yield components (Medagam *et al*., 2012). Mal *et al*. (2013) observed fruit length, fruit girth, number of fruits, single fruit weight and plant biomass (fresh weight) in measuring the yield of okra. Production of varieties with higher yields is better fruit quality, and resistance to yellow vein mosaic virus is universally desired (Kumar 2015). Generally, an increase in planting density results in increased yield per unit area till a certain limit (Maurya *et al*., 2013; Firoz *et al*., 2007). Suitable plant spacing can lead to optimum seed yield, whereas too wide or too closed plant spacing could result in relatively low yield (Paththinige *et al*., 2008; Moniruzzaman *et al,* 2007). The plant spacing for okra production as suggested by different authors ranges from 20 to 40 cm between plants and 30 to 60 cm between rows (Gemechu 2018; Madisa *et al*., 2014). Ounis *et al.* (2024) stated that the yield potential of okra has been grossly affected by a lack of improved agronomic practices, poor soil as well as pests and diseases.

2.20 Postharvest Technology and Handling of Okra

For a desired shelf life, it is notable to highly consider the conditions under which fresh fruits, cut flowers and various vegetables are handled from the time of harvest to the final consumer (El-Ramady *et al*., 2015). These commodities demand excellent keeping conditions. From harvest, quality can only be maintained but not improved. Right after harvest, shelf life also begins (Ngure *et al*., 2009). Vegetables are highly perishable and so their shelf lives are moderately short. After harvest vegetables are living, and undergo respiration in the tissues which are also undergoing senescence and gradually dying (Kumar and Thakur, 2018). At harvest, vegetables are generally comprised of large amounts of water, with the majority containing about 90 - 95 % moisture (El-Ramady *et al*., 2015). An important factor that deteriorates harvested vegetables is water loss which affects the post-harvest quality condition of the commodity and largely affects its marketability (Kasso and Bekele, 2018). Upon harvesting, okra fruits speedily lose high levels of moisture, causing damage to pod quality. Recommendations are that harvesting of okra fruits should be conducted during times of the day, especially mornings and evenings when temperatures are cooler (Thompson, 2008). It is more advantageous that harvested okra fruits be stored in cooler places as possible. It is advisable to avoid exposing the harvested okra to direct sunlight for longer durations (Hassan, 2010). Making use of shaded storage areas will support the maintenance of good-quality pods. Okra must be stored in containers that are well-ventilated to reduce temperature build-up as a result of respiration. When kept in containers that have fewer or no vents, fruits face loss of colour as a result of bleaching, and the build-up of heat as a result of respiration (Kumar *et al*., 2024). When harvested, fruits should be handled carefully to avoid or reduce bruising. Pods turn black or brown when bruised for a short period. During harvesting and when handling okra, it is recommended to use cotton gloves. It is recommended that harvested okra be stored in well-aerated containers for conveying and storage purposes (Hassan, 2010). Fruits stored in poorly ventilated containers lose colour quickly, resulting from bleaching, and there could be an accumulation of heat since respiration of the okra continues (Yahia *et al*., 2011). When okra has been harvested, it is advisable to handle it carefully to avoid bruises, as these bruises cause the okra fruit to change colour to black or begin to brown within a few hours (Hassan, 2010). It is advisable to wear cotton gloves during the harvesting and handling of fruits since the plant and fruits have small spines.

Added to this precaution is the allergic reaction associated with contact with the spines on the pods and plant (Lovell *et al*., 2020). This reaction could be reduced when harvesters and pickers wear sleeve shirts and gloves to protect them from direct contact.

The fundamental prerequisite in picking, storage and conveying of horticultural commodities irrespective of the length they can essentially be preserved stands evidence guaranteeing the possibility of the commodity staying active while undergoing, respiration and transpiration (El-Ramady *et al*., 2015). The methods and techniques employed for harvesting, treatment, transporting and preserving the commodity to minimize fatalities, and maintain and as well retain their quality is termed postharvest technology; however, taking into consideration the whole chain, movement and procedures involved, it is termed as handling of post-harvest handling of crop produce (Verma and Joshi, 2000).

Food and postharvest losses of tremendously flexible degrees arise at various phases in postharvest systems. The postharvest system begins with harvesting, handling, storing, processing, and marketing, even to the last distribution or transfer to shoppers (Collins and Dent, 2022). The degree of loss is dependent on different variables such as perishability of the commodity, climate factors including temperature and humidity (Sebeko, 2015).

Okra can be preserved reasonably well for 7 - 10 days with a temperature range from 7 - 10 ºC and a corresponding relative humidity of 90 - 95 % (Stephen *et al*., 2023). Desiccation, strengthening, yellowing or staining and degeneration of okra at a rapid rate are some of the results of high temperatures (Rahman, 2020). With a relative humidity range of 90 - 95 %, it is essential to avert shrivelling. With lower temperature (below 7 ºC), chilling injury sets in, causing quality deterioration, demonstrated by surface staining, pitting and decay (Ahmad *et al*., 2015). Immature okra fruits are highly susceptible to a reduction in weight but may vary relatively with cultivars (Hasan *et al*., 2023).

2.20 Marketing of Okra

Okra production in the world market is estimated at 6 million t/year (Kumar *et al*., 2013). The world's okra production as of 2007 stood at a rate of 4.8 million metric tonnes, with India in the lead of production by 70 %, followed by Nigeria (15%), Pakistan (2%), Ghana (2%), Egypt (1.7%) and Iraq (1.7%) (Gulsen *et al*., 2007). For example, between 1991 - 1992, 0.22 million hectares was the total area of okra cultivation throughout the world, and the production stood at 1.88 million metric tonnes. The area cultivated and the production as of 2006 - 2007 stood at 0.396 million hectares and 4.07 million t. respectively, whilst in 2009 - 2010, the area cultivated increased to 0.43 million hectares, while the production also increased to 4.54 million metric tons (Mathiba, 2015).

2.21 Proximate Compositions of Okra

Proximate analysis involves the determination of the major components of food such as moisture, ash, crude fat, crude protein, crude fibre and carbohydrate contents (Jimoh and Abdullahi, 2017). Onwuka (2005) stated that food analysis is the resolution of the components of food into its proximate or ultimate parts. The proximate and mineral composition of okra pod accessions were determined by Gemede *et al*. (2016) using standard methods of the Association of Official Analytical Chemists (AOAC). The result of the study revealed that the proximate composition (g/100 g) in dry weight basis significantly varied and ranged: moisture/dry matter 9.69-13.33, crude protein 10.25-26.16, crude fat 0.56-2.49, crude fiber 11.97-29.93, crude ash 5.37-11.30, utilizable carbohydrate 36.66 - 50.97, and gross energy 197.26 - 245.55 kcal/100 g.

Moisture content, total ash, crude protein, crude fibre, and crude fat of the Okra pod accessions were determined according to (AOAC, 2019) using sub-components 923.03, 976.05, and 934.01, respectively. The utilizable carbohydrate content of okra pod accessions was calculated by weight difference (Gemede *et al*., 2016). The calculation, often referred to as Nitrogen-Free Extract (NFE), and is calculated as follows:

Percentage Crude Carbohydrate = 100 - (Percentage moisture + Percentage crude Protein + Percentage crude Fat + Percentage ash + Percentage crude fibre) (AOAC 934.01 for moisture, 976.05 for protein, 2019)

The gross energy content of okra pod accessions was determined by calculation from fat, carbohydrate, and protein contents using Atwater's conversion factors: 16.7 kJ/g (4 kcal/g) for protein, 37.4 kJ/g (9 kcal/g) for fat and 16.7 kJ/g (4 kcal/g) for carbohydrates and expressed in calories (Gemede *et al*., 2016).

CHAPTER THREE

3.0 MATERIALS AND METHODS

Field and laboratory studies on the influence of "accession" type and "topping" on productivity and proximate composition of fresh okra fruits were accomplished as follows:

3.1 Experimental Location

The experiment was conducted at the University for Development Studies (UDS) Nyankpala Campus. Nyankpala is located in the Savannah agro-ecological zone. The soils are predominantly sandy-loam free from concretions and derived from voltaian sandstone and classified as Nyankpala series (Kombiok *et al*., 2012). Due to continuous cropping over time, the soils are highly degraded, resulting in low amounts of organic matter (Appiah, 2020). The zone experiences unimodal rainfall ranging from 500 mm to 1,200 mm per annum. The rainfall starts in April-May and reaches its peak from July to September. The rainfall declines from October and eventually recedes in the later part of November to December (Lawson *et al*., 2013). The annual temperature ranges from 23.4 ^{o}C to 34. 5 ^{o}C and relative humidity ranging from 46.0 - 76.8 % (Kombiok *et al*., 2012).

3.2 Field Experimental Layout and Design

The experimental design was a Randomized Complete Block Design in a 5 × 4 factorial treatment structure with five blocks. "Choochoo" (C), "Jangbunjira" (J), "Maanpielli" (M), "Sheinmana" (S) and Wuunmana" (W) defined the "accession" factor and no "topping''(T0), "topping" at apical flower bud emergence (Ta), "topping" at one week after apical flower bud emergence (T1), and "topping" at two weeks after apical flower bud emergence (T2) defined the "topping" stage factor. Factor one was "accession" type at five levels and factor two was "topping" at four levels. These two factors were combined to form twenty (20) treatment combinations as follows:

1. "Choochoo" Not "Topped" (CT0)
2. "Choochoo" "Topped" at apical flower bud emergence (CTa)
3. "Choochoo" "Topped" at one week after apical flower bud emergence (CT1)
4. "Choochoo" "Topped" at two weeks after apical flower bud emergence (CT2)
5. "Jangbunjira" Not "Topped" (JT0)
6. "Jangbunjira" "Topped" at apical flower bud emergence (JTa)
7. "Jangbunjira" "Topped" at one week after apical flower bud emergence (JT1)
8. "Jangbunjira" "Topped" at two weeks after apical flower bud emergence (JT2)
9. "Maanpielli" Not "Topped" (MT0)
10. "Maanpielli" "Topped" at apical flower bud emergence (MTa)
11. "Maanpielli" "Topped" at one week after apical flower bud emergence (MT1)
12. "Maanpielli" "Topped" at two weeks after apical flower bud emergence (MT2)
13. "Sheinmana" Not "Topped" (ST0)
14. "Sheinmana" "Topped" at apical flower bud emergence (STa)
15. "Sheinmana" "Topped" at one week after apical flower bud emergence (ST1)
16. "Sheinmana" "Topped" at two weeks after apical flower bud emergence (ST2)
17. "Wuunmana" Not "Topped" (WT0)
18. "Wuunmana" "Topped" at apical flower bud emergence (WTa)
19. "Wuunmana" "Topped" at one week after apical flower bud emergence (WT1)
20. "Wuunmana" "Topped" at two weeks after apical flower bud emergence (WT2)

The field experimental layout was as follows:

Table 3.1: Field experimental layout

BLOCK I	BLOCK II	BLOCK III	BLOCK IV	BLOCK V
MT1	CT0	WT0	JT2	CTa
ST0	JTa	JTa	CT1	JTa
ST2	MT2	MT2	WT2	MTa
MT0	JT1	CT1	ST2	MT0
MTa	STa	CTa	MTa	WT2
JT2	CTa	STa	MT2	WT0
CT1	CT1	WTa	JTa	WTa
ST1	ST0	MTa	ST1	WT1
JT0	MT0	WT2	WT0	CT2
CT0	WT2	ST0	STa	CT0
MT2	WTa	MT1	MT1	ST2
CT2	JT2	JT0	CTa	JT0
WTa	ST1	WT1	CT2	ST0
JTa	ST2	CT2	CT0	JT1
WT2	JT0	JT2	WTa	ST1
STa	MT1	CT0	WT1	CT1
CTa	CT2	ST2	ST0	STa
JT1	MTa	MT0	JT1	MT2
WT0	WT0	JT1	MT0	MT1
WT1	WT1	ST1	JT0	JT2

3.3 Acquisition of Plant Materials / "Accessions"

Okra seeds of the "accessions" studied were procured from some selected communities in the Tolon District, Kumbungu District, and the Tamale Metropolis, (Table 3.2). The names of the okra accessions were written in the native Dagbani language (a predominantly spoken language in the study area). Seeds of the "accessions" were collected while in their pods to prevent mixed "accessions". Although the pods of the various "accessions" differed from one another, they played an important role in ensuring that the okra seeds are free from pests, diseases, and other environmental factors that could adversely affect the quality of the seed.

Table 3. 2: Okra "Accession" Type Label and Source

"Accession" Type Label	Source
"Choochoo"	Nagbilgu (Tolon District)
"Jangbunjira"	Kalaraga (Tamale Metropolitan)
"Maanpielli"	Cheyohi (Kumbungu District)
"Sheinmana"	Nyankpala (Tolon District)
"Wuunmana"	Tingoli (Tolon District)

The pictures of the different okra accessions (dried) are as follows:

Plate 6: "Choochoo"

Plate 7: "Jangbunjira"

Plate 8: “Maanpielli”

Plate 9: “Sheinmana”

Plate 10: “Wuunmana”

3.4 Sampling and Harvesting

Five sound plants from each plot were tagged for data collection on reproductive parameters, productivity parameters, and proximate composition experiments. Fruits were harvested from these tagged plants at an interval of three days. Fruits were harvested based on fresh market and consumer demand characteristics (tender stage). This is the stage at which the fruit is deemed appropriate for consumption, since it is the developmental stage where quality culinary properties of the fruit are evident. This stage was determined upon interaction with producers, sellers, and consumers on the recommended stage of harvest of okra fruits. Fruits were also examined by observing them in the field from flowering to harvesting to augment the expertise of these producers, sellers, and consumers. The key determinants of the stage of harvest were length, girth, colour, weight, and crispness of the distal end of the fruit (the paramount harvest index that goes with the other subsidiary harvest indices), specific to each "accession" type. A sample of five fruits per plot was used for fruit length and fruit girth determination using a digital caliper.

Fruits were also sampled for the determination of the proximate composition of okra fruit. Samples of each treatment were subjected to the proximate analysis according to the procedures outlined for the determination of a particular component at a time. These components were the moisture content, fat content, protein content, carbohydrate content, and ash content.

3.5 DATA COLLECTION PROCEDURES AND PARAMETERS MEASURED

3.5.1 Determination of Reproductive Parameters

3.5.1.1 Number of flower buds produced per plant

The number of flower buds per plant was determined beginning from the date of appearance of the buds through regular experimental field visits, checks, and observations. The number of flower bud count per plant was recorded, added together, and averaged for the mean number of flower buds produced per plant.

3.5.1.2 Number of flowers produced per plant

The number of flowers produced per plant was determined by numerically counting the flowers upon blooming/at flower bud opening on the sampled plants. Daily field visits were conducted to ensure that all new flowers were captured. The number of flower counts per plant was recorded, added together, and averaged for the mean number of flowers produced per plant.

3.5.2 Determination of Productivity Parameters

3.5.2.1 Number of fruits per plant

The number of fruits per plant was determined by manually counting sound fruits harvested from the five sampled plants, averaged and recorded as the mean number of fruits per plant.

3.5.2.2 Fresh fruit weight (g) per plant

Fresh fruit weight was determined gravimetrically using a digital scale (Sartorius BSA 124 S) with a Liquid crystal Display (LCD) screen immediately after harvest. The fruit weight of each tagged plant was calculated cumulatively after the final harvest. The totals of the fresh fruit weights of the five (5) sampled plants for each treatment were summed up and averaged for the fresh fruit weight per plant.

3.5.2.3 Fresh fruit girth (mm) per plant

A single defined point that is at a third of the length of the fruit from the proximal end was the reference for this determination. This point of the fruit was carefully held using a digital caliper and the measurement was read and recorded in millimetres (mm). The fruit girth of each tagged plant was calculated cumulatively after the final harvest. The totals of the fresh fruit girths of the five (5) sampled plants for each treatment were summed up and averaged for the fresh fruit girth per plant.

3.5.2.4 Fresh fruit length (cm) per plant

The length of freshly harvested okra fruits from each treatment was determined using a vernier caliper. The proximal end of the okra fruit samples was positioned on one jaw of the vernier caliper. The vernier caliper was closed gently to touch the distal end of the fruit. The measurement was recorded from the display on the caliper. The fruit length of each tagged plant was calculated cumulatively after the final harvest. The totals of the fresh fruit lengths of the five (5) sampled plants for each treatment was summed up and averaged for the fresh fruit length per plant.

3.5.3 Determination of Proximate Composition

3.5.3.1 Percentage Moisture Content

The moisture content of the okra fruit was determined using the oven-dehydration method, following the guidelines of the AOAC 934.01 (2016). Fresh okra fruits were harvested and cleaned by washing with distilled water to remove any dirt or debris, and then cut into small, uniform pieces to facilitate efficient and even dehydration.

Empty aluminium moisture dishes were cleaned and dried in a hot air oven at 105 °C for 30 minutes, then transferred to a desiccator to cool to room temperature (25 °C). This step ensureds the dishes are free of any residual moisture. The weight of each cooled dish was accurately measured and recorded.

Approximately five grams (5 g) of the prepared fresh okra sample were weighed into each pre-weighed dish. The weight of the dish and the fresh sample combined was recorded as the initial weight. The dishes containing the samples were then placed in a hot air oven set at 105 °C and dehydrated until a constant weight was achieved. The samples were periodically removed from the oven, placed in a desiccator to cool, and then reweighed to check for a constant weight.

After achieving a constant weight, the final weight of the dish and the dehydrated sample was recorded as the final weight.

The percentage moisture content was calculated on a wet basis using the difference between the initial (fresh) and final (dehydrated) weights (ISO, 2020).

That is:

$$\text{Percentage Moisture content} = \frac{\text{fresh sample weight} - \text{dehydrated sample weight}}{\text{fresh sample weight}} \times 100$$

3.5.3.2 Percentage Dry Matter Content

Fruits from five (5) sampled okra plants were first cleaned by washing with distilled water to remove any dirt or foreign material. The cleaned fruits were then cut into small, uniform pieces to facilitate even and thorough dehydration.

A clean, dry, and pre-weighed aluminium dish was used to contain the sample. The empty dish was dried in an oven and cooled in a desiccator to ensure it's free of any moisture before its initial weight was recorded. A fresh sample of 20g of prepared fresh okra fruits was then placed into this dish, and the combined weight was recorded. The weight of the fresh okra sample (fresh weight) was calculated by subtracting the weight of the empty dish.

The dish with the fresh okra was then placed in a drying oven set at 105°C. It remains in the oven until a constant weight is reached. After dehydration, the dish and its contents were carefully transferred to a desiccator to cool. This step is vital to prevent the dehydrated sample from reabsorbing moisture from the air, which would affect the results.

After cooling, the dish with the dehydrated okra was weighed again. The weight of the dehydrated okra sample (dehydrated weight) was determined by subtracting the weight of the empty dish from the weight of the sample (ASTM D2974, 2020). The percentage dry matter content of okra was determined according to the procedure outlined.

That is:

$$\text{Percentage dry matter content} = \frac{\text{Dehydrated sample weight}}{\text{Fresh sample weight}} \times 100$$

3.5.3.3 Percentage Crude Fat Content

The percentage of crude fat content was determined using the Soxhlet extraction method (AOAC, 2012). Two grams (2 g) of the dehydrated, ground okra sample were accurately weighed and placed into a pre-weighed porous cellulose thimble. The thimble was then positioned inside the central chamber of the Soxhlet extractor. The empty, clean, and dry aluminium fat extraction cups (round-bottom flasks) were weighed to the nearest 0.001 g, and the weight was recorded.

Approximately 50 ml of petroleum ether (a flammable and volatile solvent) was added to the pre-weighed fat extraction cup. The cup was then placed on the heating mantle component of the Soxhlet apparatus. The assembled Soxhlet extractor, with the thimble and sample inside, was carefully mounted onto the cup. A condenser was then placed on top of the extractor. The entire setup was secured and positioned in a fume cupboard to minimise the risk of inhaling solvent fumes.

The heating mantle was switched on, causing the petroleum ether to boil and vaporise. The solvent vapour travelled up a side arm, condensed at the top, and dripped down into the thimble, immersing the sample. The solvent's level within the thimble gradually rose until it reached the top of the siphon tube. At this point, the solvent, now containing the extracted fat, was siphoned back into the heating cup. This cyclical process of extraction and siphoning was allowed to continue for 6 hours to ensure complete extraction of all lipids.

The percentage crude fat content was calculated on a dry weight basis using the following formula (AOAC, 2012).

That is:

Percentage fat content = $\frac{Weight\ of\ extract\ (W2-W1)}{Weight\ of\ sample} \times 100$

3.5.3.4 Percentage Crude Protein Content

A precisely weighed, dehydrated, and powdered fruit sample of two grams (2.0 g) of freshly harvested fruits from five (5) sampled okra plants was placed into a Kjeldahl flask using the using the Kjeldahl method (AOAC 976.05, 2019). Concentrated sulfuric acid (H_2SO_4) was added to the flask. This mixture was then heated in a digester for six hours. The acid acted as a powerful oxidising agent, breaking down the organic matter in the sample. This process converts the nitrogen present in the sample into ammonium sulfate (NH_42SO_4). After digestion, the flask was cooled, and distilled water was carefully added to dilute the solution.

The digested sample solution was made alkaline by the addition of sodium hydroxide (NaOH). This converted the ammonium sulfate into ammonia gas (NH_3). The flask was then connected to a distillation apparatus. The mixture was heated to produce steam, which carried the ammonia gas into a receiving flask containing a solution of boric acid (H_3BO_3) and an indicator. The ammonia gas was trapped by the boric acid, forming ammonium borate, which changed the indicator's colour.

The ammonium borate solution in the receiving flask was then titrated with a standardised 0.1 N hydrochloric acid (HCl) solution. The acid neutralises the ammonium borate. The titration continued until a colour change indicated the endpoint, indicating that all the trapped ammonia had been neutralised. The volume of HCl used was recorded. A blank test, performed without a sample, was also conducted to account for any nitrogen present in the reagents (AOAC 976.05, 2019).

That is:

Percentage total nitrogen = $\frac{1.4007 \times (V2-V1) \times N}{1000 \times 0.1} \times 100$

Where:

V_1 = Volume of hydrochloric acid solution required for the blank test.

V_2 = Volume of hydrochloric acid solution required for the test portion

N = Normality of the hydrochloric acid

Therefore, Percentage crude protein (P) = Percentage N x 6.25

3.5.3.5 Percentage Carbohydrate Content

Carbohydrate content was estimated by weight difference. The calculation, often referred to as Nitrogen-Free Extract (NFE), is calculated as follows:

Percentage Crude Carbohydrate = 100 - (Percentage moisture + Percentage crude Protein + Percentage crude Fat + Percentage ash + Percentage crude fibre) (AOAC 934.01 for moisture, 976.05 for protein, 2019)

3.5.3.6 Percentage Ash Content

This was determined by weighing two grams (2 g) of dehydrated powdered okra fruit sample in crucibles using an electronic device. The initial weight of the crucible and sample was recorded.

The crucible containing the sample was then placed inside a muffle furnace. The sample was heated in the furnace to a very high temperature (530 °C) for three hours. This high temperature incinerated all the organic components (carbohydrates, proteins, and fats), leaving behind only the non-combustible minerals as a grayish-white residue.

After incineration, the crucible was carefully removed from the furnace and immediately transferred to a desiccator. The crucible was then allowed to cool to room temperature in the desiccator. Once cooled, the crucible with the ash was weighed again. The weight of the ash was determined by subtracting the weight of the empty crucible from this final weight (AOAC 923.03, 2019).

That is:

$$\text{Ash content (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

3.6 Data Analysis

Data collected were subjected to Analysis of Variance using the GenStat Statistical Package (version 12.5). Treatment means were compared using the Duncan Multiple Range (DMR) Test at 5 % probability level.

CHAPTER FOUR

4.0 RESULTS

The results of the study were presented as Tables 4.1 to 4.11 and in Figure 4.1, and interpreted accordingly.

4.1 INFLUENCE OF "ACCESSION" TYPE AND "TOPPING" STAGE ON REPRODUCTIVE PARAMETERS OF OKRA

4.1.1 Influence of "Accession" Type and "Topping" Stage on Number of Flower Buds Produced Per Plant.

"Choochoo" plants with "topping" at apical flower bud emergence (CT_a) recorded the highest (42) number of flower buds compared to the rest of the treatments. This was followed by "Jangbunjira" "topped" at apical flower bud emergence (JTa) (40.2), "Sheinmana" "topped" at apical flower bud emergence (STa) (40.2), and "Wuunmana" "topped" at apical flower bud emergence (WTa) (40.2); and "Maanpielli" "topped" at apical flower bud emergence (MTa) (40). "Sheinmana" "topped" at two weeks after apical flower bud emergence (ST_2) recorded the least (36.6) number of flower buds per plant which is significantly lower than "Choochoo" "toppec" at apical flower bud emergence (42). "Topping" at apical flower bud emergence consistently produced the highest number of flower buds with significant difference to only "Sheinmana" "topped" at two weeks after apical flower bud emergence (ST2). The number of flower buds produced by most of the "accessions" at no "topping" (T0), "topping" at one week after apical flower bud emergence (T1), and "topping" at two weeks after apical flower bud emergence (T2) were not significantly different from each other.

Table 4.1: Influence of "Accession" Type and "Topping" Stage on Number of Flower Buds Produced Per Plant

"Accession" Type	"Topping" Stage			
	T_0	T_a	T_1	T_2
"Choochoo"	40[abc]	42[a]	37.4[bcd]	37.8[bcd]
"Jangbunjira"	37[abc]	40.2[ab]	38[bcd]	37.6[bcd]
"Maanpielli"	37.8[bcd]	40[abc]	38.4[bcd]	37.8[bcd]
"Sheinmana"	37.2[bcd]	40.2[ab]	37.6[bcd]	36.6[d]
"Wuunmana"	37.4[bcd]	40.2[ab]	38.4[bcd]	37.6[bcd]
Grand mean	38.46			
CV (%)	5.2			

Values assigned with the same letter(s) along rows or columns are not significantly different according to Duncan Multiple Range (DMR).

4.1.2 Influence of "Accession" Type and "Topping" Stage on Number of Flowers Produced Per Plant

"Choochoo" plants with "topping" at apical flower bud emergence (CTa) recorded the highest number of flowers (36.6) compared to the other treatments. This was followed by "Wuunmana" "topped" at apical flower bud emergence (WTa) (35.6) and "Sheinmana" topped at apical flower bud emergence (STa) (35). "Sheinmana" topped at two weeks after apical flower emergence (ST2) recorded the least number of flowers per plant (30.2) and was significantly lower than "Choochoo" plants "topped" at apical flower bud emergence (36.6). All the five "accessions" under "topping" at apical flower bud emergence recorded a higher number of flowers ranging from 34 to 36.6.

Table 4.2 Influence of "Accession" Type and "Topping" Stage on Number of Flowers Produced Per Plant

Accession Type	"Topping" Stage T_0	T_a	T_1	T_2
"Choochoo"	33.4^{abcd}	36.6^{a}	31.2^{cd}	31.2^{cd}
"Jangbunjira"	30.8^{cd}	34^{abc}	31.2^{cd}	31^{cd}
"Maanpielli"	31.4^{cd}	34.8^{ab}	32.2^{bcd}	31.2^{cd}
"Sheinmana"	30.6^{cd}	35^{ab}	31.2^{cd}	30.2^{cd}
"Wuunmana"	31^{cd}	35.6^{a}	31.8^{bcd}	31.2^{cd}
Grand mean	32.28			
CV (%)	7.1			

Values assigned with the same letter(s) along rows or columns are not significantly different according to Duncan Multiple Range (DMR).

4.2 INFLUENCE OF "ACCESSION" TYPE AND "TOPPING" STAGE ON PRODUCTIVITY PARAMETERS OF OKRA

4.2.1 Influence of "Accession" Type and "Topping" Stage on Number of Fruits Produced Per Plant

"Choochoo" "topped" at apical flower bud emergence (CTa) recorded the highest number of fruits (41.4) produced per plant followed by "Sheinmana" "topped" at apical flower bud emergence (40.8) (STa,). These two treatments (CTa and STa) were statistically similar but, in each case, significantly higher than the other treatments except "Maanpielli" "topped" at apical flower bud emergence (38.6). "Wuunmana" not "topped" (WT0) recorded the lowest number of fruits per plant of okra (Table 4.3).

Table 4.3: Influence of "Accession" Type and "Topping" Stage on Number of Fruits Produced Per Plant

"Accession" Type	"Topping" Stage T_0	T_a	T_1	T_2
"Choochoo"	30.6[bcd]	41.4[a]	29.8[cde]	28.4[cde]
"Jangbunjira"	27.4[cdef]	34.0[b]	26.6[cdefg]	25.4[efgh]
"Maanpielli"	31.2[bc]	38.6[a]	29.0[cde]	29.6[bcde]
"Sheinmana"	29.2[cde]	40.8[a]	30.0[bcde]	28.6[cde]
"Wuunmana"	22.0[h]	26.2[defgh]	22.2[gh]	23.8[fgh]
Grand mean	29.74			
CV (%)	10.7			

Values assigned with the same letter(s) along rows or columns are not significantly different according to Duncan Multiple Range (DMR).

4.2.2 Influence of "Accession" Type and "Topping" Stage on Fresh Fruit Weight (g) Per Plant

"Choochoo" "topped" at apical flower bud emergence (CTa) plants recorded the highest fresh fruit weight (414.7 g), followed by "Sheinmana" "topped" at apical flower bud emergence (STa) (408.8 g), "Jangbunjira" "topped" at apical flower bud emergence (JTa) (401.5 g), and "Maanpielli" "topped" at apical flower bud emergence MTa (386.6 g). These four treatments were also statistically similar to each other. The lowest fresh fruit weight was recorded by "Wuunmana" not "topped" (WT0) (245.8 g) and "Wuunmana" "topped" at two weeks after apical flower bud emergence (WT2) (245.5 g). These two treatments were statistically similar and were significantly lower than the high performing treatments.

Table 4.4: Influence of "Accession" Type and "Topping" Stage on Fresh Fruit Weight (g) Per Plant

"Accession" Type	"Topping" Stage T_0	T_a	T_1	T_2
"Choochoo"	310.5^{bc}	414.7^{a}	284.5^{bcd}	298.2^{bc}
"Jangbunjira"	330.9^{b}	401.5^{a}	302.9^{bc}	321.8^{b}
"Maanpielli"	312^{bc}	386.6^{a}	296.1^{bc}	290.4^{bcd}
"Sheinmana"	291.7^{bcd}	408.8^{a}	286.1^{bcd}	300.3^{bc}
"Wuunmana"	245.8^{d}	287.4^{bcd}	263.6^{cd}	245.5^{d}
Grand mean	314.0			
CV (%)	10.8			

Values assigned with the same letter(s) along rows or columns are not significantly different according to Duncan Multiple Range (DMR).

4.2.3 Influence of "Accession" Type and "Topping" Stage on Fresh Fruit Girth (mm) Per Plant

Fruit girth was significantly (P≤0.05) affected by the interaction between accession" type and "topping". The result revealed that "Jangbunjira" "topped" at apical flower bud emergence (JTa) recorded the highest fruit girth (36.74 mm), which is an indication that this combination of "accession" type and "topping" was most effective in increasing fruit girth. This was followed by WT0 (33.13 mm), showing slightly lower, but with some substantial effect. The CT1 plots recorded the least fruit girth per plant, indicating that this treatment was less effective for fruit girth (Figure 4.1).

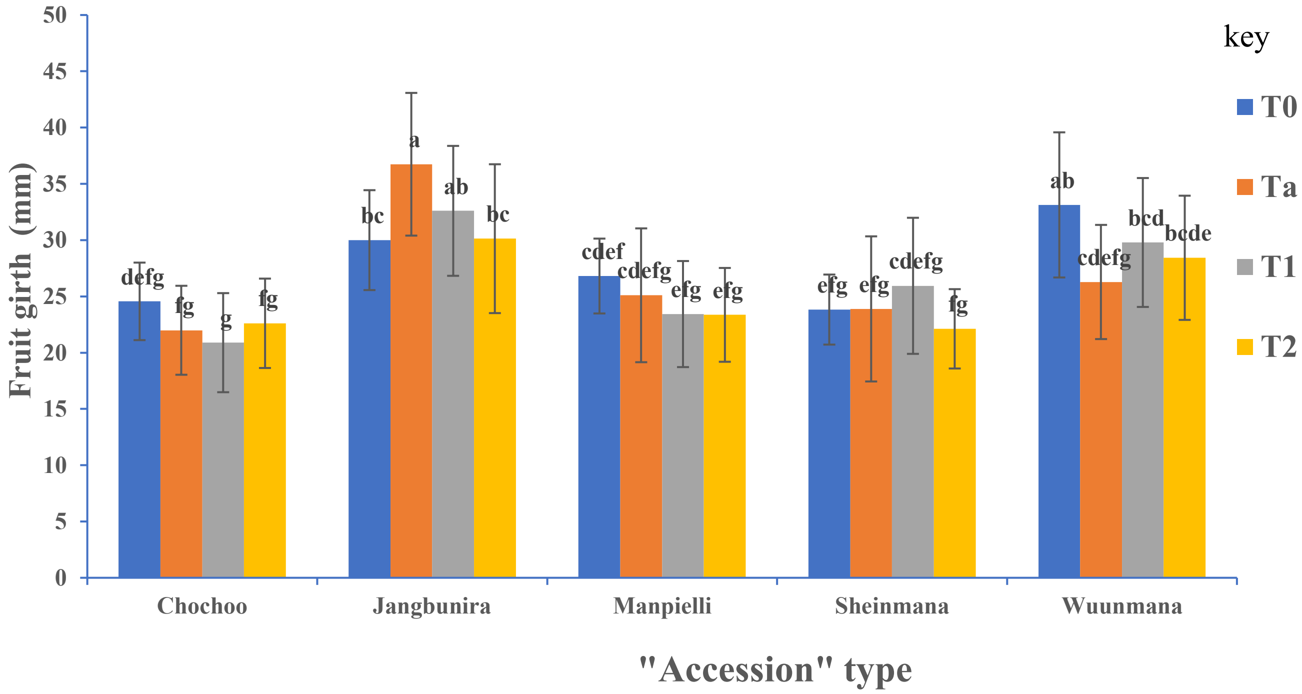

Figure 4.1: Influence of "Accession" Type and "Topping" Stage on Fresh Fruit Girth (mm) Per Plant.

4.2.4 Influence of "Accession" Type and "Topping" Stage on Fresh Fruit Length (cm) Per Plant

"Sheinmana" "topped" at apical flower bud emergence (STa) plants recorded the highest fresh fruit length (9.12 cm) per plant of okra which was significantly higher than those of all the other treatments. It was followed by "Wuunmana" "topped" at apical flower bud emergence (WTa) (7.93 cm) plants, and "Jangbunjira" "topped" at two weeks after apical flower bud emergence (JT2) (5.02 cm) plants recorded the shortest fruit length per plant (Table 4.5).

Table 4.5: Influence of "Accession" Type and "Topping" Stage on Fresh Fruit Length (cm) Per Plant

"Accession" Type	"Topping" Stage T_0	T_a	T_1	T_2
"Choochoo"	5.84^{de}	6.74^{bcde}	5.94^{de}	6.19^{cde}
"Jangbunjira"	5.58^{de}	6.02^{de}	5.47^{de}	5.02^{e}
"Maanpielli"	5.59^{de}	6.8^{bcd}	5.83^{de}	6.23^{cde}
"Sheinmana"	6.62^{bcde}	9.12^{a}	7^{bcd}	7.67^{abc}
"Wuunmana"	6.02^{de}	7.93^{ab}	5.81^{de}	5.94^{de}
Grand mean	6.37			
CV (%)	69.6			

Values assigned with the same letter(s) along rows or columns are not significantly different according to Duncan Multiple Range (DMR).

4.3 INFLUENCE OF "ACCESSION" TYPE AND "TOPPING" STAGE ON PROXIMATE COMPOSITION OF OKRA FRUIT

4.3.1 Influence of "Accession" Type and "Topping" Stage on Percentage Moisture Content of Freshly Harvested and Oven-Dried Okra Fruits

"Choochoo" "topped" at apical flower bud emergence (CTa) recorded the highest moisture content (71.88 %) and was statistically similar to "Jangbunjira" not "topped (JT0) (71.45 %) and "Maanpielli" "topped" at two weeks after apical flower bud emergence (MT2) (71.4 %). "Wuunmana" "topped" at two weeks after apical flower bud emergence (WT2) plants recorded the least moisture content (66.63 %).

Table 4.6: Influence of "Accession" Type and "Topping" Stage on Percentage Moisture Content of Freshly Harvested and Oven-Dried Okra Fruits

"Accession" Type	"Topping" Stage			
	T_0	T_a	T_1	T_2
"Choochoo"	70.92[a]	71.88[a]	71.09[a]	70.75[ab]
"Jangbunjira"	71.45[a]	71.2[a]	68.98[ab]	71.14[a]
"Maanpielli"	70.03[ab]	69.67[ab]	70.28[ab]	71.4[a]
"Sheinmana"	71.35[a]	70.68[ab]	70.6[ab]	70.47[ab]
"Wuunmana"	70.51[ab]	71.11[a]	71.04[a]	66.63[b]
Grand mean	70.56			
CV (%)	4.00			

Values assigned with the same letter(s) along rows or columns are not significantly different according to Duncan Multiple Range (DMR).

4.3.2 Influence of "Accession" Type and "Topping" Stage on Percentage Dry Matter Content of Freshly Harvested and Oven-Dried Okra Fruits

The highest percentage dry matter content (26.42 %) was recorded by "Jangbunjira" not "topped" (26.42 %) plants, and it is significantly different from all the other treatments (Table 4.7). The lowest (9.62 %) mean dry matter content was recorded by "Sheinmana" not "topped. However, this was not significantly different from the majority of the other treatments.

Table 4.7: Influence of "Accession" Type and "Topping" Stage on Percentage Dry Matter Content of Freshly Harvested and Oven-Dried Okra Fruits

"Accession" Type	"Topping" Stage			
	T_0	T_a	T_1	T_2
"Choochoo"	11.1[b]	10.43[b]	10.41[b]	10.71[b]
"Jangbunjira"	26.42[a]	10.54[b]	12.64[b]	10.33[b]
"Maanpielli"	11.71[b]	12.67[b]	11.51[b]	10.47[b]
"Sheinmana"	9.62[b]	9.97[b]	10.98[b]	10.87[b]
"Wuunmana"	10.69[b]	10.53[b]	10.66[b]	10.04[b]
Grand mean	11.61			
CV (%)	69.50			

Values assigned with the same letter(s) along rows or columns are not significantly different according to Duncan Multiple Range (DMR).

4.3.3 Influence of "Accession" type and "Topping" Stage on Percentage Crude Fat Content of Freshly Harvested and Oven-Dried Okra Fruits

Table 4.8 showed that "Choochoo" "topped" at apical flower bud emergence (CTa) plants recorded the highest percentage fat content (0.88 %), which was significantly different from those of "Choochoo" not "topped" (CT0) and "Jangbunjira" not "topped" (JT0) plants. "Choochoo" not "topped" (0.316 %) and "Jangbunjira" not "topped" (0.27 %) both recorded low percentage fat content and were significantly lower than that of "Choochoo" "topped" at apical flower bud emergence plants.

Table 4.8: Influence of "Accession" Type and "Topping" Stage on Percentage Crude Fat Content of Freshly Harvested and Oven-Dried Okra Fruits

"Accession"	"Topping" Stage			
Type	T_0	T_a	T_1	T_2
"Choochoo"	0.316^{b}	0.88^{a}	0.594^{ab}	0.448^{ab}
"Jangbunjira"	0.27^{b}	0.454^{ab}	0.584^{ab}	0.354^{ab}
"Maanpielli"	0.396^{ab}	0.39^{ab}	0.71^{ab}	0.408^{ab}
"Sheinmana"	0.388^{ab}	0.348^{ab}	0.486^{ab}	0.568^{ab}
"Wuunmana"	0.618^{ab}	0.528^{ab}	0.394^{ab}	0.646^{ab}
Grand mean	0.489			
CV (%)	70.80			

Values assigned with the same letter(s) along rows or columns are not significantly different according to Duncan Multiple Range (DMR).

4.3.4 Influence of Accession Type and "Topping" Stage on Percentage Protein Content of Freshly Harvested and Oven-Dried Okra Fruits

There were no significant interaction effects among the treatment combinations for protein content per plant (Table 4.9). Among the treatments, "Maanpielli" "topped" at apical flower bud emergence (MTa) plants recorded the highest (25.93 %) crude protein, followed by "Jangbunjira" "topped" at apical flower bud emergence (JTa) and were significantly greater than the rest of the treatments including "Choochoo" "topped" at one week after apical flower bud emergence (CT1) plants which recorded the lowest (6.67 %) crude protein content (Table 4.9).

Table 4.9: Influence of "Accession" Type and "Topping" Stage on Percentage Crude Protein Content of Freshly Harvested and Oven-Dried Okra Fruits

"Accession" Type	"Topping" Stage			
	T_0	T_a	T_1	T_2
"Choochoo"	14.46^{abcd}	15.91^{abcd}	6.67^{d}	14.22^{abcd}
"Jangbunjira"	9.36^{cd}	25.05^{ab}	23.53^{ab}	18.05^{abcd}
"Maanpielli"	22.97^{ab}	25.93^{a}	11.49^{bcd}	17.95^{abcd}
"Sheinmana"	18.91^{abcd}	22.31^{abc}	18.1^{abcd}	14.03^{abcd}
"Wuunmana"	24.09^{ab}	19.22^{abcd}	19.15^{abcd}	16.85^{abcd}
Grand mean	17.91			
CV (%)	49.30			

Values assigned with the same letter(s) along rows or columns are not significantly different according to Duncan Multiple Range (DMR).

4.3.5 Influence of "Accession" Type and "Topping" Stage on Percentage Carbohydrate Content of Freshly Harvested and Oven-Dried Okra Fruits

The interaction effects among the treatment combinations for carbohydrate content per plant did not show any significant difference (Table 4.10). Even though there were no significant interaction effects among the treatment combinations for carbohydrates, "Choochoo" "topped" at apical flower bud emergence (CTa) plants had significantly higher (70.6 %) carbohydrate content and was similar to that of "Wuunmana" "topped" at apical flower bud emergence (WT) (69.6 %). The lowest (64.2 %) percentage carbohydrate content was recorded by "Sheinmana" "topped" at two weeks after apical flower emergence (ST2).

Table 4.10: Influence of "Accession" Type and "Topping" Stage on Percentage Carbohydrate Content of Freshly Harvested and Oven-Dried Okra Fruits

"Accession" Type	"Topping" Stage			
	T_0	T_a	T_1	T_2
"Choochoo"	67.4^{abcd}	70.6^{a}	65.2^{cd}	65.2^{cd}
"Jangbunjira"	64.8^{cd}	68^{abc}	65.2^{cd}	65.2^{cd}
"Maanpielli"	65.4^{cd}	68.8^{ab}	66.2^{bcd}	65.2^{cd}
"Sheinmana"	64.6^{cd}	69^{ab}	65.2^{cd}	64.2^{d}
"Wuunmana"	65^{cd}	69.6^{a}	65.8^{bcd}	65.2^{cd}
Grand mean	66.28			
CV (%)	3.5			

Values assigned with the same letter(s) along rows or columns are not significantly different according to Duncan Multiple Range (DMR).

4.3.6 Influence of "Accession" Type and "Topping" Stage on Percentage Ash Content of Freshly Harvested and Oven-Dried Okra Fruits

The results in Table 4.11 showed that "Choochoo" "topped" at two weeks after apical flower bud emergence (CT2) plants, and the "Wuunmana" "topped" at two weeks after apical flower bud emergence (WT2) plants recorded similar and significantly higher ash content of 9.358 % and 9.364 %, respectively, per plant compared to the other treatment combinations. "Sheinmana" "topped" at one week after apical flower bud emergence (ST1) plants was the next highest (9.204 %) and was statistically similar to those of "Wuunmana" "topped" at two weeks after apical flower bud emergence (WT2) plants and "Choochoo" "topped" at two weeks after apical flower bud emergence plants. "Jangbunjira" not "topped" (JT0) plants recorded the lowest (6.976 %) percentage ash content which was significantly lower than that of the highest performing treatments (CT2 and WT2).

Table 4.11: Influence of "Accession" Type and "Topping" Stage on Ash Content of Freshly Harvested and Oven-Dried Okra Fruits

"Accession" Type	"Topping" Stage			
	T_0	T_a	T_1	T_2
"Choochoo"	8.826^{abc}	9.062^{abc}	8.468^{abcd}	9.358^{a}
"Jangbunjira"	6.976^{e}	7.942^{bcde}	7.816^{abcde}	8.256^{abcde}
"Maanpielli"	7.734^{cde}	7.73^{cde}	7.214^{de}	7.172^{de}
"Sheinmana"	8.918^{abc}	8.682^{abc}	9.204^{ab}	8.602^{abc}
"Wuunmana"	8.612^{abc}	8.406^{abcd}	8.65^{abc}	9.364^{a}
Grand mean	8.35			
CV (%)	11.00			

Values assigned with the same letter(s) along rows or columns are not significantly different according to Duncan Multiple Range (DMR).

CHAPTER FIVE

5.0 DISCUSSION

The findings of this study are discussed in sections 5.1, 5.2, and 5.3.

5.1 Influence of "Accession" type and "Topping" Stage on the Reproductive parameters (Number of flower buds and flowers) of Okra

"Choochoo" plants with "topping" at apical flower bud emergence (CT_a) recorded a significant influence on the number of flower buds and number of flowers, resulting in the highest production of more flower buds and subsequent flowers compared to the other treatments. The other treatments, "Choochoo" "topped" at one week after apical flower bud emergence (CT1), "Choochoo" "topped" at two weeks after apical flower bud emergence (CT2), and "Maanpielli" "topped" at two weeks after apical flower bud emergence (MT2), were seen to have closely competitive performance. This could suggest that "topping" done at the immediate initiation of the apical bud in the life of the plant could help to regenerate more branches comparatively faster and vigorously and subsequently translate to more flower buds and flowers. This finding is in tandem with the findings reported by Muraro *et al*. (2016) that "topping" for yield also causes the redirection of auxins biosynthesised at apical points to other parts of the plant to supplement lateral branching and a possible high number of flower buds, flowers, and fruits. The implication is that "topping" stimulated the redirection of auxins biosynthesised at the apical shoots to other parts of the plant, supplementing lateral branching and resulting in improved budding, flowering, and subsequent fruit set and fruiting. Similarly, "topping" increases the potential of flower budding points on the plant, thereby increasing the number of flower buds and flowers produced on the plant. Patel *et al*. (2017) and Sowmya *et al.* (2017) stated that "topping" as an agronomic practice has proven to enhance reproduction or growth and development in vegetable crop production.

5.2 Influence of "Accession" Type and "Topping" Stage on the Fruit Productivity of Okra

Okra "accession" types that were "topped" at apical flower bud emergence favoured comparatively more fruit formation in "Choochoo" "topped" at apical flower bud emergence (CTa) (41.4) and "Sheinmana" "topped" at apical flower bud emergence (STa) (40.8) plants than the other treatments. This might be as a result of okra plants that were "topped" at the apical flower bud emergence, causing more lateral branches to emerge and subsequently producing comparatively more flower buds, flowers, and thereby enhancing fruiting. This confirms the findings of Kallsen (2004) that, after "topping", plant auxins, which are responsible for growth at apical points, are redirected to lateral areas of the plant to support lateral branching and possible flowering and fruiting. This also agrees with the report by Janardhan (2021), who worked on "pinching" 4WAP and 6WAP, and the results tallied with this work's "topping" at apical flower bud emergence and "topping" one week after apical flower bud emergence, respectively.

Kattel *et al*. (2023) studied the effects of "pinching" also known as "topping" at 20 and 30 days after sowing (DAS) on the seed yield of okra (cv. Arka Anamika) at Bagalkot, Karnataka, India and concluded that apical "pinching" at 20 DAS was most suitable for enhancing the yield and of seeds in okra production. The 20 DAS simulates with "topping" at the apical flower bud emergence, established for enhancing okra fruit yield. Aikins *et al*. (2017) stated that adequate translocation of photosynthates from source to sink indicated beneficial effects on reproductive growth and yield of okra affirms this work.

The interaction between "accessions" type and "topping" stage was not significant for fruit weight. This observation is consistent with Akhi *et al.* (2022), who reported that apical pinching, also known as "topping" in this work, did not significantly impact the "Asontem" okra pod weight. Even though the interaction of "accessions" and "topping" was not significant, the "accessions" that were treated with Ta ("topping" at apical flower bud emergence) distinguished themselves by recording enhanced fruit weight than the rest of their counter-part treatments as "Choochoo" "topped" at apical flower bud emergence (CTa) was seen to record the highest fruit weight. The early "topping" may have resulted in more branching, leading to more leaves and green parts, resulting in increased photosynthetic activity and the transport of photosynthates from 'source' tissues to 'sink' tissues. This results in substantial fruits, thereby increasing the overall fruit weight of okra.

The combination of "accession" type and "topping" stage increased fruit girth. "Jangbunjira" "topped" at apical flower bud emergence (JTa) plants recorded the highest fruit girth, which could have been attributed to both the gene constitution of the "accession" and "topping" at the apical flower bud emergence, resulting in enhanced girth size. "Wuunmana" not "topped" (WT0) also recorded high girth size and that might have been as a result of the gene constitution too. The findings of this study agree with Ali *et al*. (2021) who stated that "pinching" significantly ($P < 0.001$) affected the pod diameter of okra fruits. The authors stated that pinching at the 3rd node stage of the okra plant, which was the earliest stage, recorded a higher fruit diameter than pinching at the later stages.

It was observed that "Sheinmana" "topped" at apical flower bud emergence (STa) plants recorded the highest fruit length, which might be due to the combined influence of the gene constitution of the "accessions" and "topping" at apical flower bud emergence. According to Shah *et al.* (2023), the beneficial effects of pinching on pod length might be related to the production and translocation of nutrients from source to sink, characteristic of the genetic makeup or gene constitution. Similarly, translocation of carbohydrates in sufficient amounts to the sink could enhance the length of okra fruits (Kauser *et al*., 2016).

5.3 Influence of "Accession" Type and "Topping" Stage on Proximate Composition of Okra Fruits

"Choochoo" plants "topped" at apical flower bud emergence (CTa) had the highest percentage moisture content of 71.88. "Wuunmana" "topped" at two weeks after apical flower bud emergence (WT2) showed significantly low moisture content (66.63) in comparison to the others. The comparatively low moisture content at "topping" at two weeks after apical flower bud emergence (T2) was specific to the "Wuunmana" "accession". This suggests that "Wuunmana" is more sensitive to the T2 "topping" stage in terms of its fruit's moisture maintenance compared to the other four "accessions". Moisture plays a crucial role in the marketability and storability of fresh okra. The moisture content of a food product indicates its water activity and a measure of its liability to microbial contamination (Uyoh *et al*., 2013). The result in the present study could be a combined effect of "accession" type and "topping" stage.

There were statistical similarities among all treatments for percentage dry matter content except "Jangbunjira" not "topped" (JT0). "Jangbunjira" not "topped" recorded a significantly higher percentage of dry matter content (26.42) than the other treatments. This may have been as a result of a genotypic characteristic when left "untopped". This finding is, however, contrary to the report by Akhi *et al*. (2022), who observed that the dry matter content of okra was not positively impacted in okra plants that were not "topped". The percentage dry matter content values in almost all the treatments in this study, ranging from 9.62 to 12.67, align with the dry matter content range for fresh okra, i.e., 10% to 12% reported by Aamir and Boonupthip (2017).

Among the different "accessions" and the respective "topping" stages, CTa recorded the highest crude fat content (0.88). "Jangbunjira" not "topped" (JT0) recorded the least (0.27) fat content. The highest fat content (0.88) obtained in this study was higher than the value (0.18g/100g) reported by Emmanuel *et. al*. (2014) but lower than 9.22 to 10.57 g/100g reported by Adetuya *et al*. (2011), both of whom did similar studies. This increase suggests that "topping" at apical flower bud emergence (Ta) which occurs earlier compared to "topping" at one week after apical flower bud emergence (T1) and "topping" at two weeks after apical flower bud emergence (T2) may have triggered the redirection of photosynthates away from stem growth and into the developing fruit, specifically favouring the synthesis of lipids. According to Xu *et al*. (2019), lipids are energy-dense compounds, and a slight increase in their concentration may reflect a physiological response to a change in the plant's sink-source relationship. Haufe *et al*. (2011) reported that a dietary fat intake, which provides only 1% to 2% of total caloric energy, as reflected by the low-fat content observed in this study, is highly recommended for human consumption. The authors further suggested that foods naturally low in fat can significantly contribute to a reduced risk of cardiovascular disease, such as atherosclerosis, cancer, and early ageing.

It was found that MTa plants recorded the highest (25.93) percentage crude protein content, followed by JTa plants (25.05). The other treatments recorded significant variations in protein content. This significant variations in protein content may have been a result of inherent genetic factors specific to any of the "accession" types. Protein content values recorded for different "accessions" in this study are significantly higher than the value (4.81g/100g) reported by Emmanuel *et al*. (2014).

In terms of carbohydrate content, it was observed that "topping" at apical flower bud emergence (Ta) interaction with all the "accessions" recorded the highest as compared to not "topped" (T0), "topping" at one week after apical flower bud emergence (T1), and "topping" at two weeks after apical flower bud emergence (T2) interactions with the same "accessions". "Choochoo" "topped" at apical flower bud emergence (CTa) had the highest (70.6) percentage carbohydrate content, followed by "Wuunmana" "topped" at apical flower bud emergence (WTa) (69.6), "Sheinmana" "topped" at apical flower bud emergence (STa) (69), "Maanpielli" "topped" at apical flower bud emergence (MTa) (68.8), and "Jangbunjira" "topped" at apical flower bud emergence (JTa) (68) which may be as a result of the early stages of "topping" employed. The other treatments with later stages of "topping" recorded percentage carbohydrate content values ranging from as low as 64.2 to 67.4. This supports the findings of Ammaiyappan *et al*. (2023), who reported that "apical" nipping during early growth stages can enhance lateral growth, potentially influencing enhanced sucrose translocation and overall yield. Babar et al. (2023) also stated that late removal (5-7 weeks) of the apical bud results in reduced yield and carbohydrate content.

"Topping" at apical flower bud emergence (Ta) performed almost at par with not "topped" (T0), "Topping" at one week after apical flower bud emergence (T1), and "Topping" at two weeks after apical flower bud emergence (T2) as far as percentage ash content is concerned, in almost all the "accessions". The highest percentage ash content was recorded at "Choochoo" "topped" at two weeks after apical flower bud emergence (CT2) (9.35) and "Wuunmana" "topped" at two weeks after apical flower bud emergence (WT2) (9.364). These findings are not far from the report by Adetuya *et al*. (2011), who reported 7.19 g/100 to 9.63 g/100 ash content in related studies. The content of ash in a food sample is an indicator of the mineral components (Nnamani *et al*., 2009; Omotoso, 2006). High ash content in vegetables indicates a high quantity of minerals in the samples (Naz *et al*., 2018).

There was high ash content in all the "accessions" in this study, regardless of "topping" or the stage of "topping". This may have been as a result of the inherent characteristics or gene constitution of the okra "accessions" under study. In this regard, "topping" may not have played a major role in the enhanced ash content reported by the various "accessions" in this study.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the findings of the study, the following conclusions were made:

"Choochoo" "topped" at apical flower bud emergence (CTa) produced the highest number of flower buds and flowers. "Jangbunjira" "topped" at apical flower bud emergence (JTa) and "Sheinmana" "topped" at apical flower bud emergence (STa) recorded moderate number of flower buds and was statistically similar to "Choochoo" not "topped" (CT0) and "Maanpielli" "topped" at apical flower bud emergence (MTa). "Wuunmana" "topped" at apical flower bud emergence (WTa) had moderate performance in both number of flower buds and number of flowers whilst "Sheinmana" "topped" at two weeks after apical flower bud emergence (ST2) recorded the least.

The highest number of fruits was recorded by "Choochoo" "topped" at apical flower bud emergence (CTa) followed by "Sheinmana" "topped" at apical flower bud emergence (STa) and the least number of fruits was recorded by "Wuunmana" not "topped" (WT0).

The highest fruit weight was recorded by "Choochoo" "topped" at apical flower bud emergence (CTa) whilst the second highest was "Sheinmana" "topped" at apical flower bud emergence (STa) and "Wuunmana" "topped" at two weeks after apical flower bud emergence (WT2) recorded the least.

"Jangbunjira" "topped" at apical flower bud emergence (JTa) recorded a significantly higher fruit girth followed by "Wuunmana" not "topped" (WT0) and "Choochoo" "topped" at one week after apical flower bud emergence (CT1) being the least.

"Sheinmana" "topped" at apical flower bud emergence (STa) had a significantly longer fresh fruit length. The moderately short fruit length was recorded by "Wuunmana" "topped" at apical flower bud emergence (WTa) and "Jangbunjira" "topped" at two weeks after apical flower bud emergence (JT2) recorded the least.

"Choochoo" "topped" at apical flower bud emergence (CTa) recorded the highest percentage moisture, crude fat, and carbohydrate contents of okra. The second highest moisture content and the lowest moisture content was recorded by "Jangbunjira" not "topped" (JT0) and "Wuunmana" "topped" at two weeks after apical flower bud emergence (WT2), respectively.

"Maanpielli" "topped" at one week after apical flower bud emergence (MT1) recorded moderately low-fat content and "Choochoo" not "topped" (CT0), the least.

The highest carbohydrate content was recorded by "Choochoo" "topped" at apical flower bud emergence (CTa) and "Wuunmana", "topped" at apical flower bud emergence (WTa) recorded a moderately low carbohydrate content, with "Sheinmana" "topped" at two weeks after apical flower bud emergence (ST2) being the least.

"Maanpielli" "topped" at apical flower bud emergence (MTa) recorded significantly higher crude protein content, followed by "Wuunmana" "topped" at apical flower bud emergence (WTa) and "Sheinmana" "topped" at two weeks after apical flower bud emergence (ST2) as the least.

"Wuunmana" "topped" at two weeks after apical flower bud emergence (WT2) had the highest percentage ash content of okra and were closely followed by "Choochoo" "topped" at two weeks after apical flower bud emergence (CT2). The lowest percentage ash content was recorded by "Jangbunjira" not "topped" (JT0).

In general, "topping" at apical flower bud emergence improved productivity and enhanced proximate composition of the okra fruit than the other treatments comparatively.

6.2 Recommendations

For more number of flower buds and flowers, "Choochoo" "topped" at apical flower bud emergence (CTa) is recommended.

For more number of fruits, "Choochoo" "topped" at apical flower bud emergence (CTa) should be considered, where the fresh market is the focus. "Choochoo" "topped" at apical flower bud emergence (CTa) should be prioritised where fruit weight was the objective whilst "Jangbunjira" "topped" at apical flower bud emergence (JTa) and "Sheinmana" "topped" at apical flower bud emergence (STa) be recommended where fruit girth and fruit length, respectively, were the objectives particularly for processing.

For purposes of bulk consumption to enhance digestion, "Choochoo" "topped" at apical flower bud emergence (CTa) produce which has high levels of moisture, fat, and carbohydrates should be prioritized; whilst "Jangbunjira" not "topped" (JT0) for dry matter content, "Maanpielli" "topped" at apical flower bud emergence (MTa) for protein content, and "Choochoo" "topped" at two weeks after apical flower bud emergence (CT2) and "Wuunmana" "topped" at two weeks after apical flower bud emergence (WT2) for ash content, be recommended to be part of the main dish/meal for consumption as vegetables.

Thus, "topping" as an agronomic practice in okra production should always be done at the apical flower bud emergence stage to enhance reproductive components, productivity, and proximate composition of okra fruit.

It is recommended that other related works be done to provide descriptors for the "accessions".

It is also recommended that the work is continued to the breeder level to achieve varietal status for the "accessions".

Okra farmers should be sensitised on this work through the Ministry of Food and Agriculture extension agents.

REFERENCES

Aamir, M., and Boonsupthip, W. (2017). Effect of microwave drying on quality kinetics of okra. *Journal of Food Science and Technology*. 54(5): 1239-1247.

Adekiya, A. O., Agbede, T. M., Aboyeji, C. M., and Dunsin, O. (2017). *Response of okra (Abelmoschus esculentus (L.) Moench) and soil properties to different mulch materials in different cropping seasons. Scientia Horticulturae*. *217*: 209-216.

Adzawla, W., Atakora, W. K., Kissiedu, I. N., Martey, E., Etwire, P. M., Gouzaye, A., and Bindraban, P. S. (2021). Characterization of farmers and the effect of fertilization on maize yields in the Guinea Savannah, Sudan Savannah, and Transitional agroecological zones of Ghana. *EFB Bioeconomy Journal*, *1*, 100019. Africa. *Science of the Total Environment*. *648*: 669-680.

Afari-Sefa, V. (2010). Horticultural exports and livelihood linkages of rural dwellers in southern Ghana: An agricultural household modeling application. *The Journal of Developing Areas*. *44*(1): 1-23.

Agbo, A. E., Gnakri, D., Beugre, G. M., Fondio, L., and Kouamé, C. (2008). Maturity degree of four okra fruit varieties and their nutrients composition. *Electronic Journal of Food Plant Chemistry*. *5*: 1 - 4.

Ahiakpa, J. K., Magdy, M., Werner, O., Amoatey, H. M., Yeboah, M. A., Appiah, A. S., ... and Ros, R. M. (2017). Intra-specific variation in West African and Asian germplasm of okra (Abelmoschus spp L.). *Annals of Agricultural Sciences*. 62(2): 131-138.

Ahmad, M. S., Siddiqui, M. W., Ahmad, M. S., and Siddiqui, M. W. (2015). Factors affecting postharvest quality of fresh fruits. *Postharvest quality assurance of fruits: practical approaches for developing countries*. 7-32.

Aikins, A. K., Najombu T., and Msibi, S. T. (2017). Effect of apical pinching on the performance of (Asontem) okra. *World Journal of Agriculture Science.* 13 (2): 68 - 74.

Akhi, M. Z., Islam, M. S., Debnath, B., Ferdousi, J., and Nath, D. D. (2022). Effect of Genotypes and De-Topping on Growth and Yield of Okra. *American Journal of Agricultural Science, Engineering, and Technology*. *6*(3): 113-117.

Akinyele, B. O. and Osekita, O. S. (2006). *Correlation and path coefficient analyses of seed yield attributes in okra* (*Abelmoschus esculentus* (L.) Moench). *African Journal of Biotechnology*. *5*(14): 59-69.

Alamgir, A. N. M., and Alamgir, A. N. M. (2017). Pharmacognostical Botany: Classification of medicinal and aromatic plants (MAPs), botanical taxonomy, morphology, and anatomy of drug plants. Therapeutic use of medicinal plants and their extracts: *Pharmacognosy*. 177-293.

Alenazi, M. M. (2011). *Improvement of okra (Abelmoschus esculentus) growth, yield and qualtiy by using plant growth regulators* in vivo *and* in vitro *conditions*. Doctoral Dissertation, University of Malaya. 2-20

Alhassan, M. D. (2019). *Exploratory research on "topping" in okra production in the northern region of Ghana*. Thesis (BSc.) not published. Department of Horticulture, Faculty of Agriculture, Food and Consumer Sciences, University for Development Studies, Nyankpala, Ghana. 1-4.

Ali, A., Nabi, G., Khan, M. I. M. N., Israr, M., Ali, S., Rehman, J., and Ali, W. (2021). Pinching effects on growth and yield of okra. *Pure and Applied Biology (PAB).* 11(1): 135-145.

Ali, W. M., Abdel-Mageed, M. A., Hegazy, M. G. A., Abou-Shlell, M. K., Sultan, S. M., Salama, E. A., and Yousef, A. F. (2023). Biocontrol agent of root-knot nematode Meloidogyne javanica and root-rot fungi, Fusarium solani in okra morphological, anatomical characteristics and productivity under greenhouse conditions. *Scientific Reports*. 13(1): 11103.

Alimi, T. (2005). Economics of monocropping okra under tropical conditions during the rainy and dry seasons. *Journal of Vegetable Science*. 11(2): 19-34.

Al-Ubaydi, R. M., Al-Shakry, E. F., Al-Samara, M. A., and Al-Mohmadawy, S. M. (2017). *Effect of irrigation intervals on growth, flowering and fruits quality of okra Abelmoschus esculentus (L.) Monech. African Journal of Agricultural Research*. 12(23): 2036-2040.

Ammaiyappan, A., Geethalakshmi, V., Bhuvaneswari, K., Kalarani, M. K., Thavaprakaash, N., & Prahadeeswaran, M. (2023). Long-term response of rainfed sorghum to diverse growing environments and optimal sowing window at Coimbatore. *Journal of Agrometeorology*. 25(4): 532-538.

Angadi, S. P., Hegde, G., Tikoo, S. K., and Kumar, A. (2025). Variety Improvement in Vegetables: Perspective of the Seed Industry. In Indian Seed Sector: *Evolution, Technology, Trade and Impact*. Springer Nature Singapore. 115-164

Angbanyere, M. A. I. (2012). *The effect of pollinators and pollination on fruit set and fruit yields of okra (Abelmoschus esculentus* (L) Moench*) in the forest region of Ghana.* (Doctoral dissertation, Kwame Nkrumah University of Science and Technology, Kumasi). 56 – 63.

Ansong Omari, R., Bellingrath-Kimura, S. D., Sarkodee Addo, E., Oikawa, Y., and Fujii, Y. (2018). Exploring farmers' indigenous knowledge of soil quality and fertility management practices in selected farming communities of the guinea savannah agroecological zone of Ghana. *Sustainability*. 10(4): 1034.

AOAC (2012). *Fat (crude) or ether extract in meat. Official Methods of Analysis* (19th ed.). Gaithersburg, MD: AOAC International.

AOAC (2016). *Official methods of analysis of AOAC International* (20th ed.). Rockville, MD: AOAC 934.01 International.

AOAC (2019). *Official methods of analysis of AOAC International* (21st ed.). Rockville, MD: AOAC International 976.05.

AOAC (2019). *Official methods of analysis of AOAC International* (21st ed.). Gaithersburg, MD: AOAC International 934.01 for moisture, 976.05 for protein.

AOAC (2019). *Official methods of analysis of AOAC International* (21st ed.). Gaithersburg, MD: AOAC International 923.03.

Appiah, E. A. (2020). *Calibration of soil test results for phosphorus and nitrogen fertilization for maize (zea mays l.) production in northern Ghana* (Doctoral dissertation). 23-45.

Archana, G., Sabina, K., Babuskin, S., Radhakrishnan, K., Fayidh, M. A., Babu, P. A. S., ... and Sukumar, M. (2013). Preparation and characterization of mucilage polysaccharide for biomedical applications. *Carbohydrate Polymers*. 98(1): 89-94.

Asare-Nuamah, P., Amoah, A., and Asongu, S. A. (2023). Achieving food security in Ghana: Does governance matter? *Politics and Policy*. *51*(4): 614 - 635.

Asokapandian, S., Sreelakshmi, S., and Rajamanickam, G. (2021). Lipids and oils: an overview. *Food biopolymers:* Structural, functional and nutraceutical properties. 389-411.

ASTM (2020). *Standard test methods for determining the water (moisture) content, ash content, and organic material of peat and other organic soils* (ASTM D2974-20e1). West Conshohocken, PA: ASTM International. https://www.astm.org/d2974-20.html.

Åstrand, J., Knight, C., Robson, J., Talle, B., and Wilson, Z. A. (2021). Evolution and diversity of the angiosperm anther: trends in function and development. *Plant Reproduction*. 34(4): 307-319.

Ayambila, S. N., Adam, U., and Tetteh Anang, B. (2023). The determinants of nontraditional agricultural exports' growth in Ghana. *Cogent Economics and Finance*. 11(1): 2197322.

Babar, M. A., Bangulzai, B. A., Lehri, S. M., Kashif, M., Ahmed, S., Arif, M., ... and Asif, M. (2023). *Effect of terminal and axillary bud pruning on growth and yield attributes* *of okra (Abelmoschus esculentus L.) under the climatic conditions of Quetta. Pure and Applied Biology* (PAB). 13(1): 75-81.

Bagalea, P., Shresthab, A. K., Girib, H. N., Regmia, P., and Subedic, D. (2024). *Performance of Broccoli (Brassica oleracea Var. Italica L.) Varieties on Postharvest Quality at Rampur, Chitwan. Reviews in Food and Agriculture (RFNA).* 5(1): 1-5.

Baldwin, B. G., and Goldman, D. H. (Eds.). (2012). *The Jepson manual: vascular plants of Bangladesh Agricultural University, Mymensingh*. 2-3.

Barbieri, C., and Mahoney, E. (2018). Why is diversification an attractive farm adjustment strategy? Insights from Texas farmers and ranchers. *Journal of Rural Studies*. 25(1): 58-66.

Barry, C. J. S., Walker, V. M., Cheesman, R., Davey Smith, G., Morris, T. T., and Davies, N. M. (2023). How to estimate heritability: a guide for genetic epidemiologists. *International Journal of Epidemiology*. 52(2): 624-632.

Baseer, A. Q., Niazi, P., Monib, A. W., Hassand, M. H., Hejran, A. B., Sarwari, A., ... and Fahmawi, S. M. S. (2024). Lifecycle transitions in plant development: ripening, senescence, and cell death. *Journal of Pharma Insights and Research.* 2(2): 169-179.

Baw, A. O., Gedamu, F., and Dechassa, N. (2017). *Effect of plant population and nitrogen rates on growth and yield of okra* [*Abelmoscus esculentus (L). Moench*] *in Gambella Region, Western Ethiopia. African Journal of Agricultural Research*. 12(16): 1395-1403

Bonomini, M. G., Prandi, B., and Caligiani, A. (2024). *Black soldier fly* (*Hermetia illucens L.*) *whole and fractionated larvae: In vitro protein digestibility and effect of lipid and chitin removal*. *Food Research International*. 196: 115102.

Breman, E., Ballesteros, D., Castillo-Lorenzo, E., Cockel, C., Dickie, J., Faruk, A., ... and Ulian, T. (2021). Plant diversity conservation challenges and prospects-the perspective of botanic gardens and the Millennium Seed Bank. *Plants.* 10(11): 2371.

Budania, Y. K., and Dahiya, H. S. (2018). Impact of microclimate modification on okra cultivation: A global review. *International Journal of Current Microbiology and Applied Sciences.* 7(10): 426-438.

Byerlee, D., De Janvry, A., and Sadoulet, E. (2009). Agriculture for development: Toward a new paradigm. *Annual Review of Resource Economics.* 1(1): 15-31.

Cachero, T. E., and Belonias, B. S. (2021). Changes in the nutritional composition of okra fruit and seed during early development. *Annals of Tropical Research*. 43(1): 67-79.

Chamberlin, J., Jayne, T. S., and Headey, D. (2014). Scarcity amidst abundance? Reassessing the potential for cropland expansion in Africa. *Food Policy*. *48*: 51-65.

Ciceri, D., and Allanore, A. (2019). Local fertilizers to achieve food self-sufficiency in Africa. *Science of the Total Environment*. *648*: 669-680.

Collins, R., and Dent, B. (2022). Value chain management and postharvest handling. Conference on Machine Learning. *Proceedings of Machine Learning Research* (PMLR). 20166-20270.

Cooper, M., Messina, C. D., Podlich, D., Totir, L. R., Baumgarten, A., Hausmann, N. J., ... and Graham, G. (2014). Predicting the future of plant breeding: complementing empirical evaluation with genetic prediction. *Crop and Pasture Science*. 65(4): 311-336.

Cronan, J. E. (2024). Unsaturated fatty acid synthesis in bacteria: mechanisms and regulation of canonical and remarkably noncanonical pathways. *Biochimie*. 218: 137-151.

Dahl, Å., Galán, C., Hajkova, L., Pauling, A., Sikoparija, B., Smith, M., and Vokou, D. (2013). The onset, course and intensity of the pollen season. *Allergenic pollen: A review of the production, release, distribution and health impacts*. 29-70.

Daramola, O. S., Adigun, A. J., and Adeyemi, R. O. (2020). *Efficacy and economics of integrated weed management in okra (Abelmoschus esculentus (L.) Moench). Agricultura Tropica Et Subtropica*. 53(4): 199-206.

Das, S., Nandi, G., and Ghosh, L. K. (2019). Okra and its various applications in drug delivery, food technology, health care and pharmacological aspects-a review. *Journal of Pharmaceutical Sciences and Research.* 11(6): 2139-2147.

Davis, T. W. (2022). Grower's guide: a review for sustainable production of okra (Abelmoschus Esculentus) in West Africa and other regions. *International Journal of Research and Applied Science Engineering Technology.* 10 (10): 128 - 138.

Dehgan, B. (2023). Angiosperms: flowering plants. In Garden Plants Taxonomy. Ferns, Cham: Springer International Publishing.*Gymnosperms, and Angiosperms (Monocots).* 173-603.

Dhall, R. K. (2013). Ethylene in post-harvest quality management of horticultural crops: A review. *Research and Reviews: A Journal of Crop Science and Technology*. *2*(2): 9-24.

Dhillon, W. S., and Thakur, A. (2014). Canopy management and effects of pruning on flowering tendencies in fruit trees. In *National Seminar-cum-Workshop on physiology of flowering in perennial fruit crops. Lucknow, India.* 182 - 201.

Dhooria, M. S., and Dhooria, M. S. (2016). Mite Pests of Horticultural Crops. *Fundamentals of Applied Acarology*. 219-274.

Diao, X., Hazell, P., and Thurlow, J. (2010). The role of Agriculture in African development. *World Development*. 38(10): 1375-1383.

Dobe, M. (2024). Nutrition, Diet, and Health: role of macronutrients, micronutrients, and Nutraceuticals. *In Micronutrients and Macronutrients as Nutraceuticals*. 321-357.

Domingo, J., Baeza-Centurion, P., and Lehner, B. (2019). The causes and consequences of genetic interactions (epistasis). *Annual review of genomics and human genetics.* 20(1): 433-460.

Dubey, P. and Mishra, S. (2017). A review on: Diabetes and okra (*Abelmoschus esculentus*). *Journal of Medicinal Plants Studies*. 5(3): 23-26.

Dwomo, O., and Dedzoe, C. (2010). Oxisol (Ferralsol) Development In Two Agro-Ecological Zones of Ghana: A Preliminary Evaluation of Some Profiles. *Journal of Science and Technology (Ghana).* 30(2): 82-93.

Ekundayo, E. A., Ekundayo, F. O., Osibote, I. A., Boboye, B. E., and Adetuyi, F. C. (2018). *Growth responses of okra (Abelmoschus esculentus) to inoculation with Trichoderma viride, mancozeb and Sclerotium rolfsii in sterile and non-sterile soils*. 45.

Elkhalifa, A. E. O., Alshammari, E., Adnan, M., Alcantara, J. C., Awadelkareem, A. M., Eltoum, N. E., ... and Ashraf, S. A. (2021). *Okra (Abelmoschus esculentus) as a potential dietary medicine with nutraceutical importance for sustainable health applications. Molecules.* 26(3): 696.

El-Ramady, H. R., Domokos-Szabolcsy, É., Abdalla, N. A., Taha, H. S., and Fári, M. (2015). Postharvest management of fruits and vegetables storage. *Sustainable Agriculture Reviews:* 15: 65-152.

Emmanuel, C. N., Nulit R., Rusea, G. O. (2014) Nutritional and biochemical properties of Malaysian okra variety. *Advancement in Medicinal Plant Research.* 2: 16-19.

Falusi, O. A., Dangana, M. C., Daudu, O. A. Y., and Teixeira da Silva, J. A. (2012). *Studies on morphological and yield parameters of three varieties of Nigerian okra [Abelmoschus esculentus (L.) Moench].* 31.

Farinde, A. J., Owolarafe, O. K., and Ogungbemi, O. I. (2007). An overview of production, processing, marketing and utilisation of okra in egbedore local government area of Osun State, Nigeria. *Agricultural Engineering International.* 1: 23-48.

Feng, J. Q., Xia, Q., Zhang, F. P., Wang, J. H., and Zhang, S. B. (2021). Is seasonal flowering time of Paphiopedilum species caused by differences in initial time of floral bud differentiation. *Annals of Botany Plants*. 13(5): 053.

Firoz, Z. A., Islam, M. A., Mohiuddin, M., and Rahman, M. M. (2007). Yield and yield attributes of okra as influenced by planting time and plant spacing in hill slope condition. *Progressive Agriculture*. 18(2): 67-73.

Gatkal, N. R., Nalawade, S. M., Shelke, M. S., Sahni, R. K., Walunj, A. A., Kadam, P. B., and Ali, M. (2025). Review of cutting-edge weed management strategy in agricultural systems. *International Journal of Agricultural and Biological Engineering*. 18(1): 25-42.

Gemechu, E. M. (2018). *Effect of inter-row spacing and nitrogen rates on growth, yield components, and yield of okra [Abelmoschus esculentus (L.) Moench] at Assosa. Western Ethiopia. Life Science Journal*. 15: 1-16.

Gemede, H. F., Haki, G. D., Beyene, F., Woldegiorgis, A. Z., and Rakshit, S. K. (2016). Proximate, mineral, and antinutrient compositions of indigenous Okra (*Abelmoschus esculentus*) pod accessions: implications for mineral bioavailability. *Food Sscience and Nutrition*. 4 (2): 223 - 233.

Gemede, H. F., Ratta, N., Haki, G. D., Woldegiorgis, A. Z., and Beyene, F. (2015). Nutritional quality and health benefits of okra (Abelmoschus esculentus): A review. *Journal of Food Process Technol*. *6*(458): 2.

Gessesew, W. S., Woldetsadik, K., and Mohammed, W. (2015). *Growth parameters of onion (Allium cepa L. var. Cepa) as affected by nitrogen fertilizer rates and intra-row spacing under irrigation in Gode, South-Eastern Ethiopia. Agriculture, Forestry and Fisheries*. 4(6): 239-245.

Glawe, D. A. (2008). The powdery mildews: a review of the world's most familiar (yet poorly known) plant pathogens. *Annual Review. Phytopathology*. 46(1): 27-51.

Goddek, S., Delaide, B., Mankasingh, U., Ragnarsdottir, K. V., Jijakli, H., and Thorarinsdottir, R. (2015). Challenges of sustainable and commercial aquaponics. *Sustainability*. 7(4): 4199-4224.

Godswill, A. G., Somtochukwu, I. V., Ikechukwu, A. O., and Kate, E. C. (2020). Health benefits of micronutrients (vitamins and minerals) and their associated deficiency diseases: A systematic review. *International Journal of Food Sciences*. 3(1): 1-32.

Gopalan, C., Sastri, S. B. V., and Balasubramanian, and S. (2007). Nutritive value of Indian foods. National Institute of Nutrition (NIN), India. 23-26.

Gordon, T. R. (2017). Fusarium oxysporum and the Fusarium wilt syndrome. Annual Review of Phytopathology. 55(1): 23-39.

Gulsen, O., Karagul, S. and Abak, K. (2007). Diversity and relationships among Turkish okra germplasm by sequence-related amplified polymorphism (SRAP) and phenotypic marker polymorphism. *Biologia*. 62 (1): 41-45.

Gupta, A., and Kumar, R. (2020). Management of seed-borne diseases: an integrated approach. Seed-borne diseases of agricultural crops: detection, diagnosis and management. 717-745.

Gupta, P. K., Patra, S., and Samanta, K. K. (2021). Potential of okra for application in textiles: A review. *Journal of Natural Fibers*. 18(11): 1788-1800.

Hasan, M. U., Singh, Z., Shah, H. M. S., Kaur, J., Woodward, A., Afrifa-Yamoah, E., and Malik, A. U. (2023). Oxalic acid: A blooming organic acid for postharvest quality preservation of fresh fruit and vegetables. *Postharvest Biology and Technology.* 112-574.

Hassan, K. (2010). Postharvest handling of fruits and vegetables. *Department of Horticulture, Bangladesh Agricultural University, Mymensingh*. 2-3.

Haufe, S., Engeli, S., Kast, P., Böhnke, J., Utz, W., Haas, V., ... and Jordan, J. (2011). Randomized comparison of reduced fat and reduced carbohydrate hypocaloric diets on intrahepatic fat in overweight and obese human subjects. *Hepatology*. 53(5): 1504-1514.

Hayamanesh, S. (2018). *The effect of high temperature on physiological and metabolic parameters and reproductive tissues of okra (Abelmoschus esculentus (L.) Moench)* (Doctoral dissertation). 18-21

Hejna, A. (2021). Potential applications of by-products from the coffee industry in polymer technology–Current state and perspectives. *Waste Management*. 121: 296-330.

Hirose, K., Endo, K., and Hasegawa, K. (2004). A convenient synthesis of lepidimoide from okra mucilage and its growth-promoting activity in hypocotyls. *Carbohydrate* Research. 339(1): 9-19.

Hivert, V., Sidorenko, J., Rohart, F., Goddard, M. E., Yang, J., Wray, N. R., ... and Visscher, P. M. (2021). Estimation of non-additive genetic variance in human complex traits from a large sample of unrelated individuals. *The American Journal of Human Genetics*. 108(5): 786-798.

Holser, R. A. and Bost, G. (2004). Hybrid Hibiscus seed oil compositions. *Journal of the American Oil Chemists' Society*. 81(8): 795-797. https://doi.org/10.31018/jans.v7i1.645.

Home, P. G., Panda, R. K., and Kar, S. (2002). *Effect of method and scheduling of irrigation on water and nitrogen use efficiencies of Okra (Abelmoschus esculentus). Agricultural Water Management.* 55(2): 159-170.

Ibrahim, M. M. and Hussein, R. M. (2006). Variability, heritability and genetic advance in some genotypes of roselle (*Hibiscus sabdariffa L.*). *World Journal of Agricultural Science.* 2(3): 340-345.

International Organization for Standardisation (ISO). (2020). *Oilseeds — Determination of moisture and volatile matter content* (ISO Standard No. 665:2020). https://www.iso.org/standard/77995.html.

Iqbal, M., Iqbal, S., Jahangeer, A., Arshad, M., Akhtar, N., Hussain, A., and Abbas, Q. (2024). Optimizing Seed Cotton Yield: Exploring the Synergistic Effects of De-topping Stage and Plant Spacing. *Sarhad Journal of Agriculture*. *40*(4): 1277-1287.

Ismail, S. M., and Ozawa, K. (2007). Improvement of crop yield, soil moisture distribution and water use efficiency in sandy soils by clay application. *Applied Clay Science*. 37(1-2): 81-89.

Jakubowska, M., Dobosz, R., Zawada, D., and Kowalska, J. (2022). A review of crop protection methods against the two spotted spider mite-Tetranychus urticae Koch (Acari: Tetranychidae)-with special reference to alternative methods. *Agriculture.* 12(7): 898.

Janardhan, M. B. V. (2021). Effect of plant spacing and apical pinching on growth and yield of okra (Abelmoschus esculentus L.) cv. Phule Vimukta (Doctoral dissertation, Mahatma Phule Krishi Vidyapeeth). 27-30.

Jayne, T. S., Mather, D., Mason, N., and Ricker-Gilbert, J. (2013). How do fertilizer subsidy programs affect total fertilizer use in Sub-Saharan Africa? Crowding out, diversion, and benefit/cost assessments. *Agricultural Economics*. 44(6): 687-703.

Jena, A. K., Deuri, R., Sharma, P., and Singh, S. P. (2018). Underutilized vegetable crops and their importance. *Journal of Pharmacognosy and Phytochemistry*. 7(5): 402 - 407.

Jiang, T., Chen, J., Xu, K., Sharon, B., Li, L., Guo, J., ... and Lu, L. (2025). Citrus yellow vein clearing virus infection triggers phloem remobilization of iron-and zinc-nicotianamine in citrus. *Plant Physiology*. 197(2): 528.

Jimoh, W. L. O., and Abdullahi, M. S. (2017). Proximate analysis of selected sorghum cultivars. *Bayero Journal of Pure and Applied Sciences*. 10(1): 285-288.

Jonah, P. M., Timon, F., Bongi, A. D., Mibzar, R., and Mshelmbula, B. P. (2017). Growth And Yield Traits of Okra (Abelmoschus Esculentus L.) Moench, As Influenced by NPK 15: 15: 15 and Poultry Manure in Mubi, Adamawa State. *International Journal of Innovative Research. Advanced Studies*. 4(7): 399-404.

Junqueira, L. A., Amaral, T. N., Félix, P. C., Botrel, D. A., Prado, M. E. T., and de Resende, J. V. (2019). Effects of change in PH and addition of sucrose and NaCl on the emulsifying properties of mucilage obtained from Pereskia aculeata Miller. *Food and Bioprocess Technology*. 12: 486-498.

Kahlon, T. S., Chapman, M. H., and Smith, G. E. (2007). In vitro binding of bile acids by okra, beets, asparagus, eggplant, turnips, green beans, carrots, and cauliflower. *Food Chemistry*. 103(2): 676-680.

Kalbande, B. B., and Yadav, A. M. (Eds.). (2021). Plant Pathology and Disease Management. *Journal of Sericulture*. 37(1): 17-20.

Kallsen, C. E. (2004). Topping and Pruning Effects on Yield and Fruit Size of Navel Orange. *Horticultural Science*. 39(4): 885-886.

Kashyap, A., Garg, P., Tanwar, K., Sharma, J., Gupta, N. C., Ha, P. T. T., ... and Rao, M. (2022). Strategies for utilization of crop wild relatives in plant breeding programs. *Theoretical and Applied Genetics*. 135(12): 4151-4167.

Kasso, M., and Bekele, A. (2018). Post-harvest loss and quality deterioration of horticultural crops in Dire Dawa Region, Ethiopia. *Journal of the Saudi Society of Agricultural Sciences*. 17(1): 88-96.

Kator, L., Hosea, Z. Y., and Oche, O. D. (2015). Sclerotium rolfsii: Causative organism of southern blight, stem rot, white mold and sclerotia rot disease. *Annals of Biological Research*. 6(11): 78-89.

Kattel, D., Gajurel, K., Thapa, S., Panthi, B., Subedi, S., and Khanal, B. (2023). Investigating the effect of pinching on plant growth, yield and quality of different varieties of okra (*Abelmoschus esculentus, L.*). *Asian Journal of Research and Review in Agriculture.* 5(1): 24-33.

Kauser, H., Bhoomika, R. H., and Ibaad H. M. (2016). Effect of sowing dates and stage pinching on growth, seed yield and quality of fenugreek (Trigonella foenum-graecum L.). *Research Environmental Life Science* 9(9): 1076-1078.

Kendall, C. W., and Jenkins, D. J. (2004). A dietary portfolio: maximal reduction of lowdensity lipoprotein cholesterol with diet. *Current Atherosclerosis Reports*. *6* (6): 492-498.

Khan, A. A., Iqbal, B., Jalal, A., Khan, K. A., Al-Andal, A., Khan, I., ... and Elboughdiri, N. (2024). Advanced Molecular approaches for improving crop yield and quality: a review. *Journal of Plant Growth Regulation*. 43(7): 2091-2103.

Khan, S., and Verma, S. (2024). Extra-stigmatic pollen germination and pistil elongation: a novel strategy towards reproductive assurance in Dodonaea viscosa subsp. angustifolia. *Australian Journal of Botany.* 72(2): 20-35.

Kirichenko, N., Augustin, S., Barham, E., Cech, T., Drenkhan, R., Morales-Rodriguez, C., ... and Witzell, J. (2017). Damage to leaves of broadleaf woody plants. In Field guide for the identification of damage on woody sentinel plants. Wallingford. 37-69

Kombiok, J. M., Buah, S. S. J., Dzomeku, L. K. and Abdulai, H. (2012). Sources of pod yield losses in groundnut in the Northern Savanna zone of Ghana. *West African Journal of Applied Ecology*. 20 (2): 53 - 63.

Konar, A., More, K. A., and Ray, S. D. (2013). Population dynamics and efficacy of some insecticides against aphid on okra. *Journal of Crop and Weed*. 9(2): 168-171.

Kongsil, P., Ceballos, H., Siriwan, W., Vuttipongchaikij, S., Kittipadakul, P., Phumichai, C., ... and Rojanaridpiched, C. (2024). Cassava breeding and cultivation challenges in thailand: past, present, and future perspectives. *Plants*. 13(14): 1899.

Kostik, V., Memeti, S., and Bauer, B. (2013). Fatty acid composition of edible oils and fats. *Journal of Hygienic Engineering and Design*. 4: 112-116.

Kubota, M., and Misawa, T. (2014). Gray mold and sclerotinia rot of okra plants. *Annual Report of the Kanto-Tosan Plant Protection Society*. 61: 43-46.

Kumar, A., Kumar, P., and Nadendla, R. (2013). A review on: Abelmoschus esculentus (Okra). *International Research Journal of Pharmaceutical and Applied Sciences*. 3(4): 129-132.

Kumar, Mohit, Uttam Kumar Mandal, and Syed, M. (2024). "Dermatological formulations." In *Dosage Forms, Formulation Developments and Regulations*. Academic Press. 613-642.

Kumar, P. L., Cuervo, M., Kreuze, J. F., Muller, G., Kulkarni, G., Kumari, S. G., …and Negawo, A. T. (2021). Phytosanitary interventions for safe global germplasm exchange and the prevention of transboundary pest spread: the role of CGIAR germplasm health units. *Plants*. 10(2): 328.

Kumar, R., Das, S. P., Choudhury, B. U., Kumar, A., Prakash, N. R., Verma, R., Chakraborti, M., Devi, A. G., Bhattacharjee, B., Das, R., Das, B., Devi, H. L., Das, B., Rawat, S., and Mishra, V. K. (2024). Advances in genomic tools for plant breeding: Harnessing DNA molecular markers, genomic selection, and genome editing. *Biological Research*. *57*(1): 80.

Kumar, S. (2015). Morphological characterization and agronomic evaluation of yellow vein mosaic virus resistant single cross hybrids for yield and quality traits in okra (Abelmoschus esculentus L. Moench). *Open Access Library Journal*. 2(7): 1.

Kumar, S., and Thakur, K. S. (2018). Physiology of Fruit and Vegetable Development. *Advances in Horticultural Crop Management and Value Addition*. 199-213.

Kumar, S., Dagnoko, S., Haougui, A., Ratnadass, A., Pasternak, N., and Kouame, C. (2010). Okra (Abelmoschus spp.) in West and Central Africa: Potential and progress on its improvement. 15.

Kumar, Y., and Vashisth, L. (2024). Chapter-11 Study on Yellow Vein Mosaic Virus of Okra and Management. *Viral Diseases of Vegetable and Fruit Crops*. 33: 151.

Kuo, C. G., Ramasamy, S., Nair, R. M., and CS, M. (2019). Horticultural Research and Development in South Asian Association for Regional Cooperation (SAARC). 14-19

Kyriacou, M. C., and Rouphael, Y. (2018). Towards a new definition of quality for fresh fruits and vegetables. *Scientia Horticulturae*. 234: pp. 463-469.

Lakshmi, J., Gowda R., Parashivamurthy, Narayanaswamy S., and Shivanandam V.N. (2015). Influence of pre-flowering pinching and Maleic hydrazide spray on plant growth, seed yield and quality attributes in fenugreek *Legume Research-An International Journal*. 38(3): 353-357.

Larkin, R. P., Honeycutt, C. W., Griffin, T. S., Olanya, O. M., and He, Z. (2021). Potato growth and yield characteristics under different cropping system management strategies in northeastern US. *Agronomy*. 11(1): 165.

Latha, P., Karthikeyan, M., and Johnson, I. (2025). Disease Management in Organic Vegetable Production. *In Organic Production of Vegetable Crops*. Apple Academic Press. 605-630.

Lawson, I. Y. D., Issahaku, A., Acheampong, S. K., Adams, B., and Tuffour, V. (2013). Time of planting and weed suppression abilities of some legumes intercropped with maize in the Guinea savanna zone of Ghana. *Agriculture and Biology Journal of North America*. 4(4): 358-363.

Lengsfeld, C., Titgemeyer, F., Faller, G. and Hensel, A. (2004). Glycosylated compounds from okra inhibit adhesion of Helicobacter pylori to human gastric mucosa. *Journal of Agricultural and Food Chemistry*. 52 (6): 1495-1503.

Li, X., Welbaum, G. E., Rideout, S. L., Singer, W., Zhang, B., Li, X., and Zhang, B. (2022). Vegetable Soybean and Its Seedling Emergence in the United States. *Legumes Research; Jimenez-Lopez, JC, Clemente, A., Eds*. 1-25.

Liao, H., Liu, H., and Yuan, K. (2012). A new flavonol glycoside from the Abelmoschus esculentus Linn. *Pharmacognosy Magazine*. 8 (29): 12.

Lilley, C. J., de Souza, V. H. M., and Eves-van den Akker, S. (2024). Plant diseases caused by nematodes. *In Agrios' Plant Pathology*. Academic Press. 607-649.

Liu, B., Tu, C., Hu, S., Gumpertz, M., and Ristaino, J. B. (2007). Effect of organic, sustainable, and conventional management strategies in grower fields on soil physical, chemical, and biological factors and the incidence of Southern blight. *Applied Soil Ecology*. 37(3): 202-214.

Lodha, S., and Mawar, R. (2020). Population dynamics of Macrophomina phaseolina in relation to disease management: A review. *Journal of Phytopathology*. 168(1): 1-17.

López-Fanjul, C., Fernández, A., and Toro, M. A. (2000). Epistasis and the conversion of non-additive to additive genetic variance at population bottlenecks. Theoretical Population Biology. 58(1): 49-59.

Lovell, C., Paulsen, E., and Lepoittevin, J. P. (2020). Adverse skin reactions to plants and plant products. *Contact Dermatitis*. 1-49.

Ma, F., Li, X., Ren, Z., Särkkä-Tirkkonen, M., Zhang, Y., Zhao, D., and Liu, X. (2021). Effects of concentrations, temperature, pH and co-solutes on the rheological properties of mucilage from Dioscorea opposita Thunb. and its antioxidant activity. *Food Chemistry*. 360: 130022.

Madisa, M. E., Mathowa, T., Mpofu, C., and Oganne, T. A. (2014). *Effects of plant spacing on the growth, yield and yield components of okra (Abelmoschus esculentus L.) in Botswana*. *American Journal of Experimental Agriculture*. 6(1): 7-14.

Maiti, R. K., and Singh, V. P. (2021). A review on recent research in okra (*Abelmoschus esculentus L.*). *Farming and Management*. 6(2): 77-107.

Maitra, S., Hossain, A., Brestic, M., Skalicky, M., Ondrisik, P., Gitari, H., and Sairam, M. (2021). Intercropping-A low input agricultural strategy for food and environmental security. *Agronomy*. 11(2): 343.

Makinde, A. I., Oyekale, K. O., and Daramola, D. S. (2022). *Growth and yield of okra (Abelmoschus esculentus L. Moench) as influenced by fertilizer application under different cropping systems. Agricultural Socio-Economics Journal*. 22(1): 29-36.

Mal, B., Mahapatra, P., Mohanty, S., and Mishra, H. N. (2013). Growth and yield parameters of okra (Abelmoschus esculentus) influenced by Diazotrophs and chemical fertilizers. *Journal of Crop and Weed*. 9(2): 109-112.

Mallikarjunarao, K., Pradhan, R., and Das, R. K. (2015). Dry land techniques for vegetable production in India-A review. *Agricultural Reviews*. 36(3): 227-234.

Mao, H., Wang, Y., Yang, N., Liu, Y., and Zhang, X. (2022). Effects of nutrient solution irrigation quantity and powdery mildew infection on the growth and physiological parameters of greenhouse cucumbers. *International Journal of Agricultural and Biological Engineering*. 15(2): 68-74.

Marone, D., Russo, M. A., Mores, A., Ficco, D. B., Laidò, G., Mastrangelo, A. M., and Borrelli, G. M. (2021). Importance of landraces in cereal breeding for stress tolerance. *Plants*. 10(7): 1267.

Martiniello, P., and Teixeira da Silva, J. A. (2011). Physiological and bioagronomical aspects involved in growth and yield components of cultivated forage species in Mediterranean environments: A review. *The European Journal of Plant Science and Biotechnology*. 5(2): 64-98.

Mathiba, M. T. (2015). *Influence of heat, aluminium toxicity and exposure to Bacillus subtilis on the germination of Abelmoschus esculentus* (Doctoral dissertation, MSc thesis, University of South Africa, South Africa). 24-97.

Matthew, O., Ohwo, U. O., and Osawaru, M. E. (2018). Morphological characterisation of okra (Abelmoschus (Medik) accessions. *Makara Journal of Science*. 22(2): 67-76.

Maurya, B. K., Karmakar, P., Singh, D. P., Singh, H., Singh, S., Pal, S., ... and Rai, N. (2025). Mechanism of Hybrid Development and Quality Seed Production in Okra. *In Hybrid Seed Production for Boosting Crop Yields: Applications, Challenges and Opportunities.* Singapore: Springer Nature Singapore. 503-533.

Maurya, R. P., Bailey, J. A., and Chandler, J. S. A. (2013). *Impact of plant spacing and picking interval on the growth, fruit quality and yield of okra (Abelmoschus esculentus (L.) Moench)*. *American Journal of Agriculture and Forestry*. 1(4): 48-54.

Medagam, T. R., Kadiyala, H., Mutyala, G., and Hameedunnisa, B. (2012). Heterosis for yield and yield components in okra (*Abelmoschus esculentus (L.*) Moench). *Chilean Journal of Agricultural Research*. 72(3): 316.

Medina-Torres, L., Brito-De La Fuente, E., Torrestiana-Sanchez, B., and Katthain, R. (2000). Rheological properties of the mucilage gum (Opuntia ficus indica). *Food hydrocolloids.* 14(5): 417-424.

Mehmood, M., Tanveer, N. A., Joyia, F. A., Ullah, I., and Mohamed, H. I. (2025). Effect of high temperature on pollen grains and yield in economically important crops: a review. *Planta*. 261(6): 1-23.

Messing, J., Thöle, C., Niehues, M., Shevtsova, A., Glocker, E., Borén, T., and Hensel, A. (2014). Antiadhesive properties of Abelmoschus esculentus (Okra) immature fruit extract against Helicobacter pylori adhesion. *PLoS One*. 9 (1): 84836.

Mintesnot, H. D. A. (2016). Review on contribution of fruits and vegetables on food security in Ethiopia. *Journal of Biology, Agriculture and Healthcare*. 6(11): 49-58.

Mkhabela, S. S., Shimelis, H., Gerrano, A. S., and Mashilo, J. (2022). *Phenotypic and genotypic divergence in okra [Abelmoschus esculentus (L.) Moench] and implications for drought tolerance breeding*: A review. *South African journal of botany*. 145: 54-56

Mohammed A., J. (2020). *Phenotypic Diversity, Genetic Variation and Association of Morpho-Agronomic and Biochemical Traits in Okra [Abelmoschus esculentus (L.) Moench] Genotypes in Ethiopia* (Doctoral dissertation, Haramaya university). 25.

Mohapatra, S., Padhi, J., and Singh, S. (2024). Enhancing yield and economic benefits through sustainable pest management in Okra cultivation. Scientific Reports. 14(1): 22220.

Mohler, C. L., Liebman, M., and Staver, C. P. (2001). Mechanical management of weeds. *Ecological management of agricultural weeds*. Cambridge University Press. New York. 139-209.

Moniruzzaman, M., Uddin, M. Z., and Choudhury, A. K. (2007). Response of okra seed crop to sowing time and plant spacing in south eastern hilly region of Bangladesh. *Bangladesh Journal of Agricultural Research*. 32(3): 393-402.

Moosavi, S.A., Aghaalikhani, M., Ghobadian, B., Fayyazi, E. (2018). Okra: A potential future bioenergy crop in Iran. *Renewable Sustainable Energy Review*. 93: 517-524.

Mozumdar, L. (2012). Agricultural productivity and food security in the developing world. *Bangladesh Journal of Agricultural Economics*. 35: 53-69.

Muhammad, M., Kutawa, A. B., Tadda, S. A., Muhammad, A., and Adamu, M. (2020). *Productivity of okra (Abelmoschus esculentus L. Moench) as Influence by NPK Fertilizer and poultry manure in Northern Sudan Savanna Region of Nigeria*. *International Journal of Forest, Animal and Fisheries Research*. 4(6): 52.

Muraro, D., Larrieu, A., Lucas, M., Chopard, J., Byrne, H., Godin, C., and King, J. (2016). A multi-scale model of the interplay between cell signalling and hormone transport in specifying the root meristem of Arabidopsis thaliana. *Journal of Theoretical Biology*. (404): 182-205.

Murovhi, J., Phophi, M. M., and Mafongoya, P. (2020). *Efficacy of plant materials in controlling aphids on Okra (Abelmoschus esculentus L. Moench) in Limpopo Province of South Africa*. *Agronomy*. 10(12): 1968.

Mwenya, J., Saengrayap, R., Arwatchananukul, S., Aunsri, N., Kamyod, C., Jakkaew, P., ... and Chaiwong, S. (2024). Efficient temperature control in okra transportation using phase change materials inside packaging box. *Food Packaging and Shelf Life*. 46: 101383.

Nada, R. S., Soliman, M. N., Zarad, M. M., Sheta, M. H., Ullah, S., Abdel-Gawad, A. I., ... and Elateeq, A. A. (2024). Effect of Organic Fertilizer and Plant Growth-Promoting Microbes on Growth, Flowering, and Oleanolic Acid Content in Calendula officinalis under Greenhouse Conditions. *Egyptian Journal of Soil Science*. 64(3): 815-831.

Nagpal, T., Sahu, J. K., Khare, S. K., Bashir, K., and Jan, K. (2021). Trans fatty acids in food: A review on dietary intake, health impact, regulations and alternatives. *Journal of Food Science.* 86(12): 5159-5174.

National Research Council. (2006). *Lost Crops of Africa: Vegetables*. The National Academies Press. 2: https://doi.org/10.17226/11763

Naz, S., Anjum, M. A., Naqvi, S. A. H., Siddique, B., and Zulfiqar, M. A. (2018). Assessment of proximate, nutritional and mineral contents in some traditional vegetables consumed in Multan. *Pakistan. Pakistan Journal of Agricultural Research*. 31(4): 45-48.

Ndunguru, J. and Rajabu, A. C. (2004). Effect of okra mosaic virus disease on the aboveground morphological yield components of okra in Tanzania. *Scientia Horticulturae*: *99* (3-4): pp. 225 - 235.

Ngoc, T. and Ngo, N. (2008). *Hypolipidemic effect of extracts from Abelmoschus esculentus L. (Malvaceae) on Tyloxapol-induced hyperlipidemia in mice. Warasan Phesatchasat*. 35: 42-46.

Ngure, J. W., Aguyoh, J. N., and Gaoquiong, L. (2009). Interactive effects of packaging and storage temperatures on the shelf-life of okra. 46.

Nkakini, S. O., Akor, A. J., Fila, I. J., and Chukwumati, J. (2008). Investigation of soil physical property and okra emergence rate potential in sandy loam soil for three tillage practices. *Journal of Agricultural Engineering and Technology (JAET)*. 16(2): 34-43

Nkongho, R. N., Efouba-Mbong, J. T., Ndam, L. M., Ketchem, G. A., Etchu-Takang, E. G., and Agbor, D. T. (2022). Seed production system and adaptability of okra (*Abelmoschus esculentus* L.) cultivars in Buea, Cameroon. *Plos one*. 17(12): 36.

Nnamani C. V., Oselebe H. O., and Agbautu A. (2009) Assessment of nutritional values of three underutilized indigenous leafy vegetables of Ebonyi state, Nigeria. *Africa Journal of Biotechnology*. 8: 2321-2324.

Nwagbo, U., and Bernstein, P. S. (2023). Understanding the roles of very-long-chain polyunsaturated fatty acids (VLC-PUFAs) in eye health. *Nutrients*. 15(14): 3096.

Nyamekye, C. A. (2021). *Health issues related to the production and consumption of cassava as a staple food* (Master's thesis, Norwegian University of Life Sciences, As). 23.

Nyande, A., George, M. S., Kassoh, F. A., and Bah, A. M. (2021). *Growth and yield response of okra (Abelmoschus esculentus) to varying rates of different sources of organic soil amendments at Njala, Moyamba District, Southern Sierra Leone. African Journal of Agricultural Research*. 17(8): 1144-1154.

Obeng-Antwi, K., Craufurd, P. Q., Menkir, A., Ellis, R. H., and Sallah, P. Y. K. (2012). Phenotypic diversity in maize landraces in Ghana. *International Journal of Science and Advanced Technology.* 5: 39-70.

Okigbo, R. N., and Anyaegbu, C. G. (2021). *Breeding strategies for improving drought tolerance and yield in indigenous vegetable crops*. *International Journal of Agriculture and Rural Development*. 24(1): 123-132.

Okungbowa, F. I., and Shittu, H. O. (2012). Fusarium wilts: An overview. Environ. *Research journal.* 6(2): 83-102.

Olasantan, F. O. (2001). Optimum plant populations for okra (*Abelmoschus esculentus*) in a mixture with cassava (*Manihot esculenta*) and its relevance to rainy season-based cropping systems in South-Western Nigeria. *The Journal of Agricultural Science*. 136 (2): 207-214.

Olczyk, T., Cushman, K., and Klassen, W. (2006). Okra in-row spacing alters plant growth and yield in southern Florida. *HortScience*. 41(3): 507-508.

Oluoch, M. O., Pichop, G. N., Silué, D., Abukutsa-Onyango, M. O., Diouf, M., and Shackleton, C. M. (2009). Production and harvesting systems for African indigenous vegetables. *African Indigenous Vegetables in Urban Agriculture*. 1: 145-176.

Omotoso, O. T. (2006) Nutritional quality, functional properties and anti-nutrient compositions of the larva of Cirina forda (Westwood) (Lepidoptera: Saturniidae). *Journal of Zhejiang University of Science. 7*: 51-55.

Onakpa, M. M. (2013). Ethnomedicinal, phytochemical and pharmacological profile of genus Abelmoschus. Phytopharmacology. 4(3): 648-663.

Onwuka, G. I. (2005). Food analysis and instrumentation, proximate composition of food minerals. 1st edition. Nigeria theory and practice. Naplithali Prints, Nigerian. 64(81): 140-146.

Oppong-Sekyere, D., Akromah, R., Nyamah, E. Y., Brenya, E., and Yeboah, S. (2011). Characterization of okra (*Abelmoschus spp. L.*) germplasm based on morphological characters in Ghana. *Journal of Plant Breeding and Crop Science*. 3(13): 367-379.

Osalusi, C. S., Akanni-John, R., Okeke, E. N., and Ogunsola, J. O. (2019). Analysis of the profitability of okra production among small holder okra farmers in Akinyele local Government Area, Oyo State, Nigeria. *International Journal of Environment, Agriculture and Biotechnology*. *4*(50): 1377-1381.

Ounis, S., Turóczi, G., and Kiss, J. (2024). Arthropod pests, nematodes, and microbial pathogens of okra (Abelmoschus esculentus) and their management—A review. Agronomy. 14(12): 2841.

Oyelade, O. J., Ade-Omowaye, B. I. O., and Adeomi, V. F. (2003). Influence of variety on protein, fat contents and some physical characteristics of okra seeds. *Journal of Food Engineering*. 57(2): 111-114.

Oyetunde, O. A., and Ariyo, O. J. (2014). Genetics of seed yield and related traits in biparental crosses of okra, *Abelmoschus esculentus (L.) Moench*. *Nigerian Journal of Genetics*, *28*(2): 8-14.

Pasupathi, E., Murugan, M., Chinniah, C., Ramalingam, J., Karthikeyan, G., and Harish, S. (2021). Effect of okra plant resistance on transmission rate of okra enation leaf curl virus by its vector whitefly, *Bemisia tabaci*. *Journal of Applied and Natural Science*. 13: 63.

Patel, A. N., Parmar K. V., Nayak R. S., and Patel M. N. (2017). Influence of pinching and plant growth regulators on morphological and sex expression of bottle gourd (*Lagenaria siceraria L.*). *International Journal of chemical studies*. *5*(4): 2035-2038.

Pathirana, R., and Carimi, F. (2022). Management and utilization of plant genetic resources for a sustainable agriculture. *Plants*. 11(15): 2038.

Paththinige, S. S., Ranaweera Banda, R. M., and Fonseka, R. M. (2008). Effect of plant spacing on yield and fruit characteristics of okra (*Abelmoschus esculentus*). P. 25.

Patil, B. C., Patil, R. H., Salimath, P. M., and Kajjidoni, S. T. (2015). Genetic resources of okra (*Abelmoschus spp*.) and their utilisation in crop improvement-A review. *Journal of Applied and Natural Science.* 7(1): 522-538**.**

Priyanka, S., and Monalisha, B. (2017). Effect of pinching treatments on growth flowering and yield of okra cv. Pusa A4. *Trends in Biosciences*. 10 (17): 3089-3092.

Rafflegeau, S., Bruno L., Benoit D., Philippe B., Pierre C., Thierry L., Alexia P., and Jérôme S. - B. (2015). "Contributing to production and to international markets." *Family farming and the worlds to come*. (3): 129-144.

Raghu, K., Naidoo, Y., and Dewir, Y. H. (2019). Secretory structures in the leaves of Hibiscus sabdariffa L. *South African Journal of Botany*. *121*: 16-25.

Rahman, K. Z. (2020). *Screening, Characterization and Improvement of Nutrient Rich Okra Variety for Resistance to Yellow Vein Mosaic Virus* (Doctoral dissertation, University of Rajshahi). Pp. 31.

Ranga, A. D., Kumar, S., and Darvhankar, M. S. (2021). Variability among different yield and yield contributing traits of Okra (*Abelmoschus esculentus L. Moench*) genotypes. *Electronic Journal of Plant Breeding*. 12(1): 74-81.

Reddy, M. T., Pandravada, S. R., Sivaraj, N. A. T. A. R. A. J. A. N., and Sunil, N. E. E. L. A. M. (2016). Characterization of Indian landrace germplasm and morphological traits desirable for designing a customer-driven variety in okra (*Abelmoschus esculentus L. Moench*). *Journal of Global Agriculture and Ecology*. 6(1): 7-34.

Rizo, J., Sari, L., Jaczynska, K., Rosenmund, C., and Lin, M. M. (2024). Molecular mechanism underlying SNARE-mediated membrane fusion enlightened by all-atom molecular dynamics simulations. *Proceedings of the National Academy of Sciences*. 121(16): 2321447121.

Rodelo-Torrente, S., Torregroza-Espinosa, A. C., Pallares, M. M., Osorio, D. P., Paternina, A. C., and Echeverría-González, A. (2022). Soil fertility in agricultural production units of tropical areas. *Global Journal of Environmental Science and Management.* 8(3): 403-418.

Rubin, B., Cohen, O., and Gamliel, A. (2007). Soil solarisation: an environmentallyfriendly alternative. In the *Technical Workshop on non-chemical alternatives to replace methyl bromide as a soil fumigant, Budapest, Hungary*. p. 26-28.

Sabitha, V., Ramachandran, S., Naveen, K. R. and Panneerselvam, K. (2011). Antidiabetic and antihyperlipidemic potential of *Abelmoschus esculentus (L.) Moench*. in streptozotocin-induced diabetic rats. *Journal of Pharmacy and Bioallied Sciences*. 3(3): 397.

Saeed, R., Mirza, S. and Ahmad, R. (2014). Electrolyte leakage and relative water content as affected by organic mulch in okra plant (*Abelmoschus esculentus (L.) Moench*) grown under salinity. *Federal Urdu University of Arts, Science and Technology Journal of Biology*. 4(2): 221-227.

Salem, K. F., and Ibrahim, A. A. (2025). Development of Vegetable Crop Hybrids Using the Male Sterility System. In *Male Sterility Systems in Vegetable Crop Improvement*. Singapore: Springer Nature Singapore. 125-171.

Samim, S., Sood, S., Singh, A., Verma, A., and Kaur, A. (2018). Morphological characterisation of okra (*Abelmoschus esculentus (L.) Moench*). *International Journal of Current Microbiology and Applied Sciences*. 7(10): 2011-19.

Sanjeet, K., Dagnoko, S., Haougui, A., Ratnadass, A., Pasternak, D., and Kouame, C. (2010). Okra (*Abelmoschus spp.*) in West and Central Africa: potential and progress on its improvement. *African Journal of Agricultural Research*. 5(25): 3590-3598.

Schippers, R. R. (2000). *African indigenous vegetables: an overview of the cultivated species*. Pp. 221.

Sebeko, T. (2015). Assessment of Postharvest loss for perishable products from Wholesalers to consumers. *Seeds*. *6*(2-3): 195-209.

Sengkhamparn, N., Verhoef, R., Schols, H. A., Sajjaanantakul, T. and Voragen, A. G. (2009). Characterisation of cell wall polysaccharides from okra (*Abelmoschus esculentus (L.) Moench*). *Carbohydrate Research*. 344(14): 1824-1832.

Shah, S. M. M., Asif, F., and Fatima, H. (2023). Pinching Effect on Plant Growth, Yield, and Quality of Different Varieties of Okra. *EPH-International Journal of Agriculture and Environmental Research*. 9(2): 28-33.

Sharma, A. D., Rathore, S. V. S., Srinivasan, K., and Tyagi, R. K. (2014). Comparison of various seed priming methods for seed germination, seedling vigour and fruit yield in okra (*Abelmoschus esculentus L. Moench*). *Scientia Horticulturae*. 165: 75-81.

Sharma, R., and Verma, S. (2019). Environment-pathogen interaction in plant diseases. *Agricultural Reviews*. 40(3): 192-199.

Shivandu, S. K., Dhiman, A., Dhiman, N., Sharma, I., Chawla, R., Rana, G., and Arya, N. (2024). Recent trends in crop regulation as a base of round year fruit production for profitable market returns to grower: *A review. Plant Archives.* 24(2): 34-45

Siddiqui, Y., Meon, S., Ismail, R., Rahmani, M., and Ali, A. (2008). Bio-efficiency of compost extracts on the wet rot incidence, morphological and physiological growth of okra (*Abelmoschus esculentus [(L.) Moench*). *Scientia Horticulturae*. *117*(1): 9.

Singh, P., Chauhan, V., Tiwari, B. K., Chauhan, S. S., Simon, S., Bilal, S., and Abidi, A. B. (2014). An overview on okra (*Abelmoschus esculentus*) and its importance as a nutritive vegetable in the world. *International Journal of Pharmacy and Biological Sciences.* 4(2): 227-233.

Singh, R., and Singh, G. (2021). Aphids. In Polyphagous pests of crops. Springer Singapore. 105-182.

Sowmya P. T., Naruka I. S., Shktawat R. P. S. and Kushwah SS. (2017). Effect of sowing dates and stage of pinching on growth, yield and quality of fenugreek (*Trigonella foenum-graecum* L). *International Journal of Biol-Resource and Stress Management.* 8 (1): 91-95.

Staples, G. W., and Bevacqua, R. F. (2006). Areca catechu (betel nut palm). *Species Profiles for Pacific Island Agroforestry*. 1(13): 1-9.

Stephen, B. O., Miracle, I., Tosin, P., and Nkiru, E. (2023). Comparative study of different storage conditions on the physical properties of okra. *Journal of Agricultural Engineering and Technology.* 28(2): 12-24.

Suding, K. N., Lavorel, S., Chapin Iii, F. S., Cornelissen, J. H., DIAz, S., Garnier, E., ... and Navas, M. L. (2008). Scaling environmental change through the community-level:

A trait-based response-and-effect framework for plants. *Global Change Biology*. 14(5): 1125-1140.

Sun, S. F., Li, Y. B., Leng, J., Zhang, D. H., Zhang, W. L., and Zhang, B. (2024). Multiple insect pollination contributes to differential phenotypic selection on floral traits in Stellera chamaejasme. *BMC Plant Biology*. 24(1): 1141.

Swathi, M., Gaur, N., and Singh, K. (2023). Virus vector relationship of yellow mosaic virus and whitefly, *Bemisia tabaci* (Gennadius) in soybean. *Legume Research-An International Journal.* 46(7): 946-950.

Temam, N. (2019). *Agromorphological Characterization and Evaluation of okra (Abelmoschus esculentus L. Moench) Genotypes at Melkassa, Centeral Ethiopia* (Doctoral dissertation, Haramaya university). p. 28.

Thapa, M. B., and Dhimal, S. (2017). Horticulture development in Nepal: Prospects, challenges and strategies. *Universal Journal of Agricultural Research*. 5(3):177-189.

Thompson, A. K. (2008). *Fruit and vegetables: harvesting, handling and storage*. John Wiley and Sons. p. 14.

Tim C. Paul C., Darbie G., and Charles V. (2014). Time of planting and weed suppression abilities of some legumes intercropped with maize in the Guinea Savanna Zone of Ghana. *Agricultural Biology Journal of North America*. 4: 358 - 363.

United States Department of Agriculture. (2016). Food Data Central. U.S. Department of Agriculture. https://fdc.nal.usda.gov.

Uyoh, E. A., Ita, E. E., and Nwofia, G. E. (2013). Evaluation of the chemical composition of tetrapleura tetraptera (schum and thonn.) taub. accessions from cross river state, Nigeria. *International Journal of Medicinal and Aromatic Plants*. 3(3): 386-394.

Vadar, H. R., Pandya, P. A., and Patel, R. J. (2019). Effect of subsurface drip irrigation depth scheduling in summer Okra. Emergent Life Sciences Research. 5: 52-61.

Varmudy, V. (2011). Need to boost okra exports. *Facts For You*. *Vegetable Farmers' Decisions*. Hector Kobbekaduwa Agrarian Research and Training Institute. p. 19.

Verma, L. R., and Joshi, V. K. (2000). Post-harvest technology of fruits and vegetables. *Postharvest Technology of Fruits and Vegetables*. *1*: 1-76.

Voisard, J.-M., and Jaeger, P. (2003). *Ghana Horticultural Sector Development Study*. World Bank; Ghana Export Promotion Council. pp. 8-11.

Vu, H. Q. (2025). Genetic Landscape of Zephyranthes: Insights into Breeding and Propagation. In Breeding of Ornamental Crops: *Bulbous Flowers*. Cham: Springer Nature Switzerland. pp. 757-782.

Wan, X., Sun, D., and Gao, C. (2024). Flower opening dynamics, pollen-ovule ratio, stigma receptivity and stigmatic pollen germination (in-vivo) in Chaenomeles speciosa (Sweet) Nakai. Scientific Reports. 14(1): 7127.

Weinberger, K., and Lumpkin, T. A. (2007). Diversification into horticulture and poverty reduction: a research agenda. *World Development*. 35(8):1464-1480.

Wijesinghe, P., Wickramasinghe, W. R., and Kuruppu, V. (2021). Factors influencing the use of agrochemicals in vegetable farming: A case study from Sri Lanka. *Journal of the National Science Foundation of Sri Lanka*. 49(1): 53-63.

Wu, Y., Tang, J., Tian, J.,Du, M., Gou, L., Zhang, Y., and Zhang, W. (2023). Different concentrations of chemical topping agents affect cotton yield and quality by regulating plant architecture. *Agronomy. 13*(7): 1741.

Xu, X., Vanhercke, T., Shrestha, P., Luo, J., Akbar, S., Konik-Rose, C., ... and Liu, Q. (2019). Upregulated lipid biosynthesis at the expense of starch production in potato (Solanum tuberosum) vegetative tissues via simultaneous downregulation of ADP-glucose pyrophosphorylase and sugar-dependent expressions. *Frontiers in Plant Science*. 10: 1444.

Yahia, E. M., Ornelas-Paz, J. D. J., and Elansari, A. (2011). Postharvest technologies to maintain the quality of tropical and subtropical fruits. In *Postharvest biology and technology of tropical and subtropical fruits.* Woodhead Publishing. pp. 142-195.

Yao, Y. H., Degni, B. F., Dupuis, P., Canale, L., Fanny, A. K., Haba, C. T., and Zissis, G. (2025). Growth and Floral Induction in Okra (*Abelmoschus esculentus L.*) Under Blue and Red LED Light and Their Alternation. Horticulturae. 11(5): 548.

Zhong, W., Wu, L., Li, Y., Li, X., Wang, J., Pan, J., ... and Chen, W. (2024). GhSBI1, a Cup-Shaped Cotyledon 2 homologue, modulates branch internode elongation in cotton. *Plant Biotechnology Journal*. 22(11): 3175-3193.

Zhu, L. X., Lian-Tao L., Hong-Chun, S., Yong-Jiang, Z., Ke, Z., Zhi-Ying, B., An-Chang, L., He-Zhong, D., and Cun-Dong, L. (2022). "Effects of chemical topping on cotton development, yield and quality in the Yellow River Valley of China." *Journal of Integrative Agriculture.* 21(1): 78-90.

Zim, A. F. M. (2019). *Effect of okra (Abelmoschus esculentus) Mucilage on Glucose Level and Lipid Profile of Alloxan-Induced Diabetic Mice* (Doctoral dissertation, Chattogram Veterinary and Animal Sciences University). p. 28.