

**UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL
DEVELOPMENT**



**GROWTH, YIELD AND STORABILITY RESPONSE OF TWO OKRO
VARIETIES TO INTEGRATED NUTRIENT MANAGEMENT**

DANIEL MAMUDU

(9201970001)

**A thesis submitted to the School of Graduate Studies, University of Skills Training
and Entrepreneurial Development in partial fulfillment of the requirements for the
award of a Doctor of Philosophy degree in Crop Science
(Agronomy/Crop Physiology)**

DECEMBER 2025

DECLARATION

Candidate's Declaration

I hereby declare that this thesis, with the exception of quotations and references contained in published works which have been duly acknowledged; is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Daniel Mamudu

Signature: **Date:**

Supervisors' Declaration

We hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Skills Training and Entrepreneurial Development.

Prof. Harrison Kwame Dapaah (Principal Supervisor)

Signature: **Date:**

Prof. (Mrs.) Margaret Esi Essilfie (Co-supervisor)

Signature: **Date:**

Prof. Stephen Larbi-Koranteng (Co-supervisor)

Signature: **Date:**

ACKNOWLEDGEMENTS

My most profound appreciation goes to Prof. Harrison Kwame Dapaah my principal supervisor, for his countless and endless support for the successful compilation of this thesis.

I thank him for his constructive criticism and guidance.

I would also like to extend my sincere gratitude to Prof. (Mrs.) Margaret Esi Essilfie and Prof. Larbi-Koranteng of the Crop and Soil Sciences Education Department, my Co-Supervisors, for their expert assistance, advice, guidance and encouragement from the beginning of the thesis to the end.

My next appreciation goes to my Principal Prof. Joseph Amikuzunu of St. John Bosco College of Education, Navrongo for his care and expert assistance which helped to bring this thesis to a successful completion.

Finally, I say thank you to Mr. Akolgo Listowel and Dr. Augustine Antwi-Bosiako for their support and advice.

DEDICATION

I dedicate this work to my beloved father Mr. John Bawie Bawah and my mother Madam Moro Fatima of blessed memory for their love and support throughout my education.

TABLE OF CONTENTS

CONTENTS	PAGE
DECLARATION	ii
ACKNOWLEDGEMENTS.....	iii
DEDICATION.....	iv
LIST OF TABLES.....	x
LIST OF FIGURES	xii
LIST OF PLATES	xiii
LIST OF ABBREVIATION.....	xiv
ABSTRACT	xv
CHAPTER ONE: INTRODUCTION.....	1
1.1 Background to the Study.....	1
1.2 Problem Statement and Justification.....	3
1.3 Hypothesis	4
1.4 Objectives of the Study	4
CHAPTER TWO: LITERATURE REVIEW.....	5
2.1 Origin and Distribution of Okro	5
2.2 Botany of Okro	5
2.2.1 Stem and leaves of okro.....	6
2.2.2 Flowers, fruits and seeds of okro.....	6
2.3 Classification of Okro Varieties	8
2.4 Nutritional Value and Economic Importance of Okro.....	11
2.5 Health Benefits of Okro	14
2.6 Global Production Values of Okro and Ghana's Contribution.....	15
2.7 Climatic and soil requirements	16
2.8 Land Preparation, Planting and Management Practices	18
2.8.1 Land preparation.....	18
2.8.2 Propagation of okro	19
2.8.3 Watering	20
2.8.4 Weed control.....	20
2.8.5 Fertilizer application.....	22

2.8.6	Inorganic fertilizers.....	23
2.8.7	Organic fertilizer.....	24
2.8.8	Effect of NPK fertilizer on growth and yield of okro.....	24
2.9	Storage Methods of Okro.....	29
2.9.1	Impact of storage methods on the nutrient components of okro	30
2.9.2	Impact of storage methods on the physical appearance of okro.....	31
2.9.3	Challenges of okro production in Ghana.....	32
CHAPTER THREE: MATERIALS AND METHODS		34
3.1	Description of Experimental Location/Site	34
3.2	Experimental Design and Treatments	35
3.3	Management Practices	35
3.3.1	Land preparation	35
3.3.2	Poultry manure preparation	36
3.3.3	Fertilizer and poultry manure application.....	36
3.3.4	Weed control and irrigation	36
3.3.5	Pest and disease control	37
3.4	Data Collected.....	37
3.4.1	Soil and poultry manure sampling and analysis	37
3.4.2	Plant phenology	40
3.4.3	Plant vegetative growth	40
3.4.4	Yield and yield components	42
3.5	Economic Analysis	42
3.6	Nutritional (Proximate) Analysis of Harvested Fresh Okro Fruits.....	43
3.7	Experimental Design and Treatments.....	45
3.8	Data Collected for Storage Experiment	47
3.9	Data Analysis	47
CHAPTER FOUR: RESULTS		48
4.1	Initial Soil and Poultry Manure Analysis	48
4.2	Soil Analysis after Harvest in 2021 and 2022 Cropping Seasons	50
4.3	Climatic Data of the Study Area.....	51
4.4	Phenology of Okro.....	52
4.4.1	Number of days to 50% emergence.....	52

4.4.2	Number of days to 50% flowering.....	53
4.4.3	Number of days to 50% fruiting.....	54
4.5	Vegetative Growth Parameters.....	55
4.5.1	Plant height.....	55
4.5.2	Number of leaves per plant.....	58
4.5.3	Stem diameter.....	61
4.5.4	Number of branches per plant.....	64
4.5.5	Plant canopy spread.....	67
4.5.6	Chlorophyll content of leaf.....	69
4.5.7	Dry matter accumulation.....	72
4.6	Yield and Yield Components.....	74
4.6.1	Number of fruits per plant.....	74
4.6.2	Fruit length.....	75
4.6.3	Fruit diameter.....	76
4.6.4	Total fruit yield.....	78
4.6.5	Partial budget analysis.....	79
4.7	Nutritional Analysis of Harvested Fresh Okro Fruits.....	86
4.7.1	Moisture content.....	86
4.7.2	Ash content.....	86
4.7.3	Crude protein content.....	88
4.7.4	Crude fat content.....	88
4.7.5	Crude fibre content.....	88
4.7.6	Carbohydrate content.....	89
4.7.7	Total sugars content.....	89
4.7.8	Total solids content.....	90
4.7.9	Total energy content.....	90
4.7.10	Nitrogen content.....	92
4.7.11	Vitamin C content.....	92
4.7.12	Potassium content.....	92
4.8	Nutritional Analysis of Okro Fruits after Storage.....	94
4.8.1	Moisture content.....	94
4.8.2	Total ash content.....	94
4.8.3	Crude protein content.....	97
4.8.4	Crude fat content.....	98

4.8.5	Crude fibre content	100
4.8.6	Carbohydrate content.....	101
4.8.7	Total sugars.....	104
4.8.8	Total solids.....	104
4.8.9	Total energy	107
4.8.10	Nitrogen content	108
4.8.11	Vitamin C content.....	111
4.8.12	Potassium content	112
CHAPTER FIVE: DISCUSSION		115
5.1	Soil and Poultry Manure Analyses	115
5.1.1	Initial physical and chemical composition of soil and poultry manure	115
5.1.2	Post-harvest Soil analysis in 2021 and 2022 cropping seasons.....	116
5.2	Plant Phenology	117
5.2.1	Days to 50% emergence	117
5.2.2	Number of days to 50% flowering.....	118
5.2.3	Number of days to 50% podding.....	119
5.3	Vegetative growth of okro	120
5.3.1	Plant height.....	120
5.3.2	Number of leaves per plant and stem diameter	121
5.3.3	Number of branches per plant.....	122
5.3.4	Plant canopy spread	123
5.3.5	Leaf chlorophyll content.....	124
5.3.6	Dry matter accumulation	124
5.4	Yield and Yield Components.....	125
5.4.1	Number of fruits per plant	125
5.4.2	Fruit length and fruit diameter	126
5.4.3	Total fruit yield.....	127
5.5	The partial budget analysis	127
5.6	Nutritional Quality of Fresh Harvested Okro Fruits	129
5.6.1	Moisture content and ash content of fresh okro.....	129
5.6.2	Crude protein, crude fat and crude fibre content of fresh okro	130
5.6.3	Carbohydrate, total sugar and total solids of fresh okro.....	131
5.6.4	Total energy of fresh okro	133

5.6.5	Nitrogen, vitamin C, and potassium content of fresh okro.....	133
5.7	Proximate Analysis of Fresh and Dried Okro after Storage	134
5.7.1	Moisture content, ash content, crude fat, and crude protein.....	134
5.7.2	Crude fibre content, carbohydrate, and total sugars	135
5.7.3	Total solids and total energy	137
5.7.4	Nitrogen, vitamin c and potassium	138
CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS		143
6.1	Conclusion	143
6.2	Recommendations for Adoption.....	145
6.3	Recommendations for Further/Future Studies	146
REFERENCES		147

LIST OF TABLES

Table 2. 1: Some classification of okro & their characteristics	10
Table 2. 2: Top ten okro-producing countries in the world.....	16
Table 3. 1: Proximate and selected nutrient analysis of fresh and dried okro.....	44
Table 4. 1: Initial soil characteristics of the experimental sites in 2021 and 2022 cropping seasons	49
Table 4. 2: Characteristics of poultry manure used in the experimental sites in 2021 and 2022 cropping seasons.....	49
Table 4. 3: Soil analysis after harvest in 2021 and 2022 cropping seasons.....	50
Table 4. 4: Climatic data of the study area in the 2021 and 2022 cropping seasons.....	51
Table 4. 5: Number of days to 50% emergence of okro as affected by variety and integrated nutrient management.....	52
Table 4. 6: Effect of integrated nutrient management on days to 50% flowering.....	53
Table 4. 7: Effect of integrated nutrient management on the number of days to 50% fruitng	54
Table 4. 8: Influence of integrated nutrient management on number of fruits per plant.	74
Table 4. 9: Effect of integrated nutrient management on fruit length of okro varieties	76
Table 4. 10: Effect of integrated nutrient management on fruit diameter of okro varieties in 2021 and 2022 cropping season.	77
Table 4. 11: Influence of integrated nutrient management on total fruit yield (t/ha) and number of fruits per plant.....	79
Table 4. 12: Partial budget analysis of Asontem during 2021 cropping season.....	81
Table 4. 13: Partial budget analysis of Clemson Spineless during 2021 cropping season	82
Table 4. 14: Partial budget analysis of Asontem during 2022 cropping seacon	84
Table 4. 15: Partial budget analysis of Clemson Spineles during 2022 cropping season	85

Table 4. 16: Effect of integrated nutrient management on nutritional analysis of fresh okro fruit for combined 2021 and 2022 cropping seasons.....	87
Table 4. 17: Effect of integrated nutrient management on nutritional analysis of fresh okro fruits for combined 2021 and 2022 cropping seasons.	91
Table 4. 18: Effect of integrated nutrient management on moisture and ash of fresh and dried okro after storage combined for 2021 and 2022 cropping seasons.....	96
Table 4. 19: Effect of integrated nutrient management on crude protein and crude fat content of okro combined for 2021 and 2022 cropping seasons.....	99
Table 4. 20: Effect of integrated nutrient management on crude fibre and carbohydrate content of okro combined for 2021 and 2022 cropping seasons.....	103
Table 4. 21: Effect of integrated nutrient management on total sugars, total solids of fresh and dried okro after storage combined for 2021 and 2022 cropping seasons.....	106
Table 4. 22: Effect of integrated nutrient management on total energy and nitrogen of fresh and dried okro after storage combined for 2021 and 2022 cropping seasons.....	110
Table 4. 23: Effect of integrated nutrient management on vitamin C and potassium content of fresh and dried okro after storage combined for 2021 and 2022 cropping seasons	114

LIST OF FIGURES

Figure 4. 1: Effect of integrated nutrient management on plant height of okro in 2021 cropping seasons.....	56
Figure 4. 2: Effect of integrated nutrient management on plant height of okro in 2022 cropping seasons.....	57
Figure 4. 3: Effect of integrated nutrient management on number of leaves per plant of okro in 2021 cropping seasons.....	59
Figure 4. 4: Effect of integrated nutrient management on number of leaves per plant of okro in 2022 cropping seasons.....	60
Figure 4. 5: Effect of integrated nutrient management on stem diameter per plant of okro in 2021 cropping seasons.....	62
Figure 4. 6: Effect of integrated nutrient management on stem diameter per plant of okro in 2022 cropping seasons.....	63
Figure 4. 7: Effect of integrated nutrient management on number of branches per plant of okro in 2021 cropping seasons.....	65
Figure 4. 8: Effect of integrated nutrient management on number of branches per plant of okro in 2022 cropping seasons.....	66
Figure 4. 9: Effect of integrated nutrient management on plant canopy spread in 2021 cropping seasons.....	67
Figure 4. 10: Effect of integrated nutrient management on plant canopy spread in 2022 cropping seasons.....	68
Figure 4. 11: Effect of integrated nutrient management on leaf chlorophyll content for 2021 cropping seasons.....	70
Figure 4. 12: Effect of integrated nutrient management on leaf chlorophyll content for 2022 cropping seasons.....	71
Figure 4. 13: Effect of integrated nutrient management on dry matter accumulation of okro 2021 and 2022.....	73

LIST OF PLATES

Plate 3. 1: Processed okro for storage.....	46
---	----

LIST OF ABBREVIATION

ANOVA	Analysis of Variance
BCR	Benefit-Cost Ratio
CDL	Critical Day Length
CRD	Completely Randomized Design
CSIR	Council for Scientific and Industrial Research
FAO	Food and Agriculture Organisation
FAOSTAT	Food and Agriculture Organisation's Statistical Database
IBP	India Biodiversity Portal
IWM	Integrated Weed Management
LSD	Least Significant Difference
MPhil.	Master of Philosophy
MRR	Marginal Rate of Return
NARP	National Agricultural Research Programme
NARS	National Agriculture Research Systems
NB	Net Benefits
PM	Poultry Manure
PTE	Potentially Toxic Elements
RCBD	Randomised Complete Block Design
TGB	Total Gross Benefits
TVC	Total Variable Cost
UNESCO	United Nation Education Scientific Cultural Organization
USTED	University of Skills Training and Entrepreneurial Development
WAP	Weeks After Planting
WIKI	Wikipedia

ABSTRACT

Field trials were conducted during the 2021 and 2022 cropping seasons at the University of Skills Training and Entrepreneurial Development (USTED) Research Farm. The objective of the study was to determine the growth and yield performance and post-harvest qualities of two okro varieties (a local and an exotic variety) in response to the integrated application of organic and inorganic fertilizers. The experiment contained six treatments: (i) 650 kg/ha NPK (full NPK), (ii) 20 t/ha Poultry Manure (full PM), (iii) 487.5 kg/ha NPK+5 t/ha PM ($\frac{3}{4}$ NPK + $\frac{1}{4}$ PM), (iv) 325 kg/ha NPK +10 t/ha PM ($\frac{1}{2}$ NPK + $\frac{1}{2}$ PM), (v) 162.5 kg/ha NPK + 15 t/ha PM ($\frac{1}{4}$ NPK + $\frac{3}{4}$ PM), and (vi) No Fertilizer (control). The experimental design used for the field experiment was laid out in a 2 x 6 factorial experiment arranged in a Randomized Complete Block Design (RCBD) with four (4) replications. The storability experimental design used was a 4 x 12 factorial arranged in a Completely Randomized Design (CRD) with 3 replications. On the average, Asontem, a local okro variety in the 2021 and 2022 cropping seasons, produced the tallest plant of 126.25 cm and 123 cm in plots where 487.5 kg/ha NPK+5 t/ha PM and 20 t/ha Poultry Manure were applied respectively, while Clemson, an exotic okro variety produced the maximum plant height of 125.65 cm and 122.98 cm where full PM was applied. Asontem okro variety produced the highest fruit yield of 10.03 t/ha and 4.73 t/ha in 2021 and 2022, respectively, under the 162.5 kg/ha NPK + 15 t/ha PM fertilizer combination. The control treatment recorded the least yield of 8.76 t/ha and 3.68 t/ha in both cropping seasons, respectively. Similarly, the Clemson okro variety produced, the highest fruit yield of 8.18 t/ha and 2.95 t/ha under the 325 kg/ha NPK +10 t/ha PM fertilizer treatment in both 2021 and 2022 cropping seasons. The control treatment had the lowest yields of 7.51 t/ha and 2.29 t/ha in both cropping seasons, respectively. The integrated management of poultry manure and NPK (15:15:15) fertilizer application significantly increased all growth and yield attributes of okro crops under rainfed conditions of the study

area. It is recommended that okro farmers should adopt integrated nutrient management strategies. For higher yields, Asontem with 162.5 kg/ha NPK + 15 t/ha PM and Clemson with 325 kg/ha NPK +10 t/ha PM could be considered for adoption. The nutritional analysis results indicated that both the sun-drying and freezing methods of okro after two months of storage period did not show any significant decrease in some nutrient content. The study showed that both sun-drying and freezing okro samples consistently yielded greater okro nutritional qualities during preservation over time. The freezing process on average preserved the nutrient content quality better when compared to the sun drying method. Hence sun drying and freezing methods could be adopted by okro farmers and value-chain actors in Ghana depending on the resources available to them.

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

Vegetables have great potential to improve nutrition and thereby consumers' health because most of them are good sources of vitamins, minerals, and proteins needed for the proper functioning and development of the human body (Wills *et al.*, 2016, Liu *et al.*, 2019). Synthetic fertilizers and pesticides in vegetable production have negatively impacted the soil, water quality, food security, and health of farmers and consumers (Muhammad *et al.*, 2020). Hence, sustainable, economically feasible, environmentally friendly soil fertility, pests, and disease management options are needed to improve vegetable production.

Okro (*Abelmoschus esculentus* L. Moench) is an important vegetable crop grown in the tropical and sub tropical parts of the world. It belongs to the Malvaceae family. Although about 50 species of *Abelmoschus* species have been described, 8-13 are the most widely accepted (Ogunbor, 2020; Hinsley 2022). It is a very good source of dietary fibre, Mg, Mn, K, vitamin K, and vitamin C. The okro seed oil is rich in unsaturated fatty acids and are essential for human nutrition. Moreover, it is beneficial for curing diabetes and some cancers. Also, Okro mucilage from the immature pods was found to be suitable for industrial and medicinal applications (Badrie, 2016). Okro is a multipurpose crop and serves as a source of nutrition, bio-medicine and functional ingredients for the food and pharmaceutical industry (Kpodo *et al.*, 2018).

Low soil fertility has been regarded as a crucial problem facing agricultural development and food security in sub-Saharan Africa (Davis, 2022b). To ensure high and sustainable okro yields, good soil fertility management is required to facilitate its production.

According to Kumar (2019), Okro responds very well to fertilizer application and effective fertilizer use is the key to its higher growth and yield. However, the sustainable use of inorganic fertilizers is constrained by their high cost and limited accessibility, particularly in developing regions, as well as challenges such as poor technical knowledge among farmers, soil acidification, and nutrient imbalance resulting from continuous application (Warke & Wakgari, 2024; Sande *et al.*, 2024).

Combining organic and inorganic fertilizers may be a sound soil fertility management strategy in many countries. Apart from enhancing crop yields, the practice has a greater beneficial residual effect that can be derived from the use of either organic or inorganic fertilizers applied alone. The nutrient use efficiency of crops is better with a combination of organic and inorganic fertilizer. Nutrient seemed more available to okro plants with mixes than organic or inorganic fertilizer when applied alone. Combined applications of organic fertilizer and inorganic fertilizers can be used to sustain and increase the yield of okro in the tropics (Musa *et al.*, 2020).

The demand for fresh okro has driven higher production, with annual output increasing, for example, from 66,539 tons in 2019 to 69,525 tons in 2023 Paulus *et al.*, (2021). Considering the increased in annual demand for fresh okro in Ghana, it is necessary to conduct further research into storage alternatives to maintain its quality, freshness as well as the shelf-life of the fresh fruits. Besides, information on how to enhance okro fruit quality after harvest and post-harvest storage time is inadequate. The form in which Okro is consumed sometimes gives room for processing.

1.2 Problem Statement and Justification

Synthetic fertilizer acquisition and its usage is a challenge for most smallholder farmers, especially for those who are engaged in vegetable crop production. Okro (*Abelmoschus esculentus* L.) is an important vegetable due to its health advantages and nutritional quality (Aderemi & Sangodoyin, 2019). Applying sufficient plant nutrients is required to sustain increased production in the face of depleting soil fertility status and continuous cropping. Inadequate information and insufficient knowledge on the use of different fertilizer sources and application rates are very common among vegetable farmers in Ghana. The integrated use of organic and inorganic amendments is more effective for reclamation and sustainable productivity of acidic or alkaline affected soils (Kaledhonkar *et al.*, 2019; Kumar *et al.*, 2022). Additionally, the cost of inorganic fertilizers has increased over the years, making them less affordable for most smallholder farmers, who are therefore unable to apply recommended rates to achieve maximum yields. Rising global input prices and market constraints have further limited farmers' access to fertilizers in Ghana (Adzawla *et al.*, 2025). Organic fertilizer sources such as animal manure are locally available and may constitute cheaper sources of maintaining soil fertility and offer alternatives to the use of inorganic fertilizers Miah *et al.* (2020). Integration of inorganic and organic fertilizers has the potential of increasing the yields of okro which could improve food security and the alleviation of malnutrition and poverty.

In Ghana okro production and marketing is profitable for both farmers and stakeholders (Banson *et al.*, 2024), however, its production and availability all year round is hindered by several challenges. Key issues include postharvest losses, poor storage conditions leading to loss of nutritional value of okro. Besides, information on how to improve okro fruit quality after harvest and post-harvest storage time is inadequate hence, it is necessary

to conduct further research into storage alternatives to maintain its quality, freshness as well as the shelf-life of fresh fruits.

1.3 Hypothesis

1. Application of poultry manure, NPK (15:15:15) or their combinations is expected to increase the growth and yield performance of okro varieties.
2. The integrated use of poultry manure and NPK (15:15:15) will improve the post-harvest qualities of two okro varieties.
3. Different storage methods are expected to influence the nutritional qualities of okro varieties.

1.4 Objectives of the Study

The general objective of the study was to evaluate the yield performance and post-harvest qualities of local and exotic varieties of okro in response to the integrated application of organic and inorganic fertilizers.

The specific objectives of this study were to:

1. Assess the effect of integrated nutrient management on phenology and growth of okro varieties.
2. Determine the effects of integrated nutrient management on the yield and yield components of two okro varieties.
3. Assess the effect of integrated nutrient management on the nutritional quality of fresh fruits of a local and an exotic okro varieties.
4. Determine the effect of different storage methods on the nutritional quality of local and exotic okro fruits.
5. Assess the economic benefits or profitability of okro production as affected by integrated nutrient management.

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin and Distribution of Okro

Cultivated okro (*Abelmoschus esculentus* (L. Moench) is an important herbaceous annual fruit vegetable commonly grown in the tropics and warm temperate regions of the world (Thomas, 2022). It is also known as ladies' finger, bhindi, bamia, ochro, or gumbo (Khandaker *et al.*, 2017).

Okro originated from the Abyssinian center, an area that includes Ethiopia, a portion of Eritrea, and the eastern, higher part of the Anglo-Egyptian Sudan (Aprilliz, 2017; Bawa & Badrie, 2016). The crop was probably taken into Egypt by Muslims from the East who conquered Egypt in the seventh century. It was then taken from Ethiopia to Arabia across the narrow Red Sea or the narrower strait at its southern end. From Arabia, okro spread over North Africa, completely around the Mediterranean, and eastward. However, according to some other authors, *Abelmoschus esculentus* originated in India, Ethiopia, West Africa and Tropical Asia (Vidhi, 2023).

Okro is currently grown around the world, especially in the United States and in the humid climates in Africa as well as in Sri Lanka in Asia. In Africa, the crop is cultivated in Kenya, Nigeria, Sudan, Gabon, Cote d'Ivoire, Mali, Mauritania, Senegal, Cape Verde, Ghana, Egypt, Cameroon and Chad. It is also grown in the Southern Africa region such as in Angola, DR Congo, Malawi, Tanzania, and Zambia but often not on a very large scale (Anwar *et al.*, 2020).

2.2 Botany of Okro

Okro (*Abelmoschus esculentus* L. Moench.) is also called bhendi and ladies' finger is an important vegetable crop valued for its tender and green fruits in India. Bhendi fruits are

rich in calcium. Habit: robust, erect, and annual herb; Stem- Green or tinged red, erect, single or 2-3 branches, Leaves- Alternate stipules narrow, often tinged red Petioles, Lamina broadly Cordate, palmately 3-7 Lobed, Serrate pale green beneath. Roots are Tap root systems (Tihamiyu *et al.*, 2017).

2.2.1 Stem and leaves of okro

Okro stem is semi-woody and sometimes pigmented with a green or red tinge colour. It is erect, and variable in branching, with many short branches that are attached to thick semi-woody stems. The stem attains a height from 10 m in dwarf varieties to 23.1 m or 26.4 m (Aderemi *et al.*, 2022).

The woody stem bear leaves that are lobed and are generally hairy, some reaching up to 30.48 cm in length. Leaves are cordate (heart-shaped), simple, usually palmately -7 lobed and veined. Leaves are subtended by a pair of narrow stipules. The okro leaf is dark green and resembles a maple leaf.

2.2.2 Flowers, fruits and seeds of okro

The flowers are borne vertically only on the orthotropic axis every two or three days. The flower is axillary and solitary, borne on a peduncle 2.0-2.5 cm long. The flowers are large around 5.08 cm in diameter, with five white to yellow petals with a red or purple spot at the base of each petal. The flower lasts only for a day. Each blossom develops a small green pod. The flowers are almost always bisexual and actinomorphic. The perianth consists of 5 valvate, distinct or basally connate sepals and 5 distinct petals that are usually basally adnate to the androecium. The androecium consists of numerous monadelphous stamens with apically divergent filaments bearing 1-1-celled anthers. The gynoecium is a single compound pistil of two to many carpels, an equal number of styles or style branches, and

a superior ovary with two to many locules, each bearing one to numerous ovules. The calyx is completely fused to form a protective case for the floral bud and splits into lobes when the bud opens. The calyx, corolla and stamens are fused at the base and fall off as one piece after anthesis. The erect sexual parts consist of a five-to-nine-part style, each part with a capitate stigma, surrounded by the staminal tube bearing numerous filaments (Swamy *et al.*, 2023). The petals wilt in the afternoon and usually fall off the following day.

The fruit of okro could be elongated, conical or cylindrical. The fruit is a long pod and generally ribbed, developing in the leaf axil and spineless in cultivated kinds. The fruit is normally yellowish green to green but is sometimes purple or whitish green. The pods are edible portions, which are harvested while still tender and immature. 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.

Okro plant takes two to six hours to fertilize after pollination. Stigma is receptive at the opening of the flower. Hence, bud pollination is not effective in okro. Okro plant is propagated mainly by using seed and through other vegetative parts (transplanting) which are not used often in Africa (Fufa, 2019).

Okro plant is a self-pollinated (autogenous) crop but is considered as often cross-pollinated due to its showy corolla and the extent of cross-pollination is 4 - 19% depending on cultivar, competitive flora, insect population and the season. Hence, an isolation distance of 200 m between cultivars is recommended to produce pure seed (Fufa, 2019). Hybrid seed production of the heterosis is exploited in okro to produce other (particularly F1) hybrids

(Fufa, 2019). Okro fruit contains 20-50, oval, smooth, dark green to dark brown seeds (Vidhi, 2023).

2.3 Classification of Okro Varieties

Okro has been classified into two main varieties based on their photoperiodism. They include early okro varieties and late okro varieties (Hayamanesh, 2018; Iwuala *et al.*, 2021). The early varieties are adapted to several ecological zones. The early okro varieties have 12.50 hours of Critical Day Length (CDL). This property of these varieties makes the okro flower at any time of the year. These varieties are hence termed exotic okro cultivars which are found in several okro growing regions of the world. Among the early maturing okro varieties, includes the Clemson spineless variety. Clemson Spineless variety is better suited to a deep fertile sandy loam with good drainage and a soil pH of about 6.0 to 6.8 is optimum. It requires rainfall of 800-1000 mm and an average monthly temperature of 20°C to 30°C is considered optimum for growth, flowering, and fruiting. The Clemson spineless okro variety is an improved variety that, ranges from the popular lady finger that may be above 2 meters tall with fruits that are like a human finger, to dwarf, early maturing, and highly branching varieties with small to medium-sized fruits. The shape and colour of okro fruit varies with variety. Okro may be short, long, smoothed or ribbed and cylindrical; it may also be green, reddish-green, or pale green to yellow and its fibrous fruits or pods contain round, white seeds. The late okro varieties require more than 12.5 hours of Critical Day Length (CDL) of photoperiodism. These varieties are restricted in distribution to the most humid parts of West Africa. These varieties flower later in the year, around August-September, at the natural short-day length (Iwuala *et al.*, 2021).

Most of the local okro varieties in West Africa are late varieties. Among them include the Ankrah okro variety (6-7 months) and Atuogya-Asante (128 days) which are

predominantly found in Ghana. Okro can be produced anywhere in Ghana but as a warm-season crop, it does best in warm moist soils. Low-lying areas with evenly distributed annual rainfall of up to 1000 mm and temperatures between 25-35⁰C are most suitable. The crop can withstand extreme temperatures as occur in the dry season (Uwiringiyimana *et al.*, 2024).

Asontem okro variety is also an early maturing and one of the highest-yielding varieties of okro originating from Ghana (Table 2.1). It has also been found to have a significantly high yield of comparatively thicker mucilage (Aetiba & Osekre, 2016). He added that, even though this variety is known to be susceptible to insect pests and diseases, with good pest and disease management coupled with other yield enhancement techniques, it has the potential to improve the livelihood of its farmers.

Table 2. 1: Some classification of okro & their characteristics

Varieties of Okro	Characteristics
Emerald Variety	Emerald is a spineless variety of okro having a semi-cut leaf and a smooth round pod shape. It requires about 58 to 60 days to mature. Emerald variety is good for canning or processing (Nan, 2019).
Louisiana Green Velvet Variety	This okra species is known to retain seeds when sliced. Just like the Emerald species, this okro variety has a round pod shape, and it takes about 56 – 59 days to mature for harvest. (Nan, 2019).
Clemson Spineless	Clemson Spineless, as the name implies, is spineless and gives heavy yields. It has an angular-shaped pod and takes about 55 – 58 days to mature for harvest before it is supplied fresh to the market. This species is recommended for commercial okro farming because of its abundant yields. (Nan, 2019).
Dwarf Green Long Pod	The plant has several side branches with a star-shaped pod. If you're growing okro for profit, this is a good variety. It requires 52-55 days to reach maturity. (Nan, 2019).
Ewe okro	Ewe okro is small, averaging 7-10 centimetres in length, and has a short, angular, and compact shape with slight tapering toward the non-stem end. The semi-smooth, firm skin has many pronounced ribs running lengthwise and is dark green, coated in a light green velvety fuzz. Underneath the skin, the pale green to white flesh is mucilaginous, and tender, and contains many cream-coloured, oval seeds in a central cavity. Ewe okro has a crisp texture with a sweet, green flavor reminiscent of eggplant and asparagus. (Nan, 2019).
Asontem okro	Asontem okro is an early maturing and one of the highest-yielding varieties of okro originating from Ghana. It has also been found to have a significantly high yield of comparatively thicker mucilage (Aetiba & Osekre, 2016; Ahiakpa <i>et al.</i> , 2014). Even though this variety is known to be susceptible to insect pests and diseases, with good pest and disease management coupled with other yield enhancement techniques, it has the potential to improve the livelihood of its farmers.
Ankrah Local	Ankrah Local is a popular traditional okro variety cultivated in Ghana. It is known for its dark green pods and high productivity. The plants are vigorous, with good adaptability to diverse agro-climatic conditions. Ankrah Local is favored for its resilience to local pests and diseases, making it a reliable choice for many smallholder farmers (Adu-Dapaah <i>et al.</i> , 2019).
Apagbaa	Apagbaa is another well-known okro variety cultivated in Ghana. It is characterized by its long and slender green pods. The plants are generally robust, with good resistance to common pests and diseases. Apagbaa is favored by farmers for its consistent yield and market acceptance due to its attractive pod appearance (Oppong-Sekyere <i>et al.</i> , 2011).

Source Oppong-Sekyere *et al.* (2011)

2.4 Nutritional Value and Economic Importance of Okro

Okro is a highly important crop that contains high mineral content, and it enhances growth, and development serving as a catalysed metabolic process in the human body. The okro seed contained high ash content, which indicates that the seed would provide essential minerals needed for body development (Woumbo *et al.*, 2022). The leaves and pods are highly rich in protein. The fruits of okro contain calcium, water, carbohydrates, iron, protein, fat, vitamin ‘A’, thiamine, and ascorbic acid among others (Kumar *et al.*, 2017). Vitamins are required for good vision, bone growth, proper blood circulation, and aid digestion. A half cup of okro essentially contains about half the recommended level of vitamin B6, folic acid, and calcium (Woumbo *et al.*, 2022). This help to keep bones strong, lessen the chance of fractures, and help in women's reproductive health, especially in their menstrual cycle. Minerals are essential in human nutrition and vital for overall mental and physical well-being and are important constituents of bones, blood and nerve cells, teeth, tissues, and muscle function. Okro seeds and fruits contain high amounts of various minerals and phytochemicals helping in the maintenance of acid-base balance, the response of nerves to physiological stimulation and blood clotting.

Clemson spineless okro has high nutrient values in the leaves and fruits. The variety is found to be endowed with protein, carbohydrate, moisture, ash contents, crude fibre, and crude fat contents in varying compositions (Uwiringiyimana *et al.*, 2024). The fruits have higher carbohydrate and moisture content than they are in the leaves. The fruits of the Clemson okro variety have carbohydrate constituents higher than they are in the leaves (Ilodibia *et al.*, 2017). The leaves of the variety on the other hand have higher ash, protein, crude fat, and crude fibre content than they are in the fruits. Comparing the protein and ash content of Clemson okro with other varieties, Clemson spineless has a higher protein

component than other varieties. The crude fat and crude fibre are however lower in the Clemson spineless as compared with other okro varieties. In the comparison of the leaves and the fruits, studies revealed that the leaves of okro have higher nutrients than the fruits (Uwiringiyimana *et al.*, 2024).

It is a popular health food due to its high fibre, vitamin C, and folate content. Okro is also a good source of calcium and potassium. Okro is a rich source of iodine and other vital minerals and vitamins. Mucilage present in okro is polysaccharides i.e galacturonic and glucuronic acids (Singh & Ram, 2018).

Okro has many interesting uses and is known to be an economically important vegetable crop because its fresh leaves, buds, flowers, pods, stems and seeds all have value. It can be used in salads, stews, fresh or dried, and fried or boiled (Axe, 2021). Okro fruits are also dried or frozen for use especially during the off-season (Eagri, 2023). Dried okro fruit contains 13-22% edible oil and 20-24% protein and is used for refined edible oil. Dry fruit skin and fibres are used in the manufacture of paper, cardboard and fibres. Roots and stems are used for clearing cane juice for the preparation of jaggery (Eagri, 2023). Bast fibre from the stem of the plant has industrial uses such as the reinforcement of polymer composites. The mucilage produced by the okro plant can be used for the removal of turbidity from wastewater under its flocculant properties. Having a composition similar to a thick polysaccharide film, okro mucilage is under development as a biodegradable food packaging (Uwiringiyimana *et al.*, 2024). Nutrients in 1 cup of okro (Woumbo *et al.*, 2022) contain energy 33 calories, fiber 3.2 g, protein 1.9 g, carbohydrate 7.5 g, fat 0.2 g, magnesium 57 mg, calcium 82 mg, potassium 299 mg, sodium 7mg, vitamin C 23 mg,

vitamin K 31.3 mg, folate (vitamin B9) 60 µg, vitamin A 716 IU, thiamin (vitamin B1) 0.2 mg and vitamin B6 0.2 mg, according to Sachan *et al.* (2017).

In recent years, increasing attention has been paid to the role of diet in human health (Chowdhury *et al.*, 2019). In some countries, okro is also used in folk medicine as antiulcerogenic, gastroprotective, diuretic agents (Sultana *et al.*, 2019). However, little information on antioxidant capabilities of major phenolic compounds from okro seed is available.

Dried fruit contains 13-22% edible oil and 20-24% protein and is used for refined edible oil. Dry fruit skin and fibres are used in manufacture of paper, cardboard and fibres. Root and stem are used for clearing cane juice for preparation of jaggery (Eagri, 2023). The fruit pods are used for the extraction of oil. In the fishing industry, the stem fibres of okro are for making fish line traps. Vitamins are required for good vision, bone growth, and proper blood circulation, and aid digestion (Morris & Mohiuddin, 2021).

Mature fruits and stems containing crude fibre are used in the paper industry. Extracts from the seeds of the okro are an alternative source for edible oil while the greenish-yellow edible oil has a pleasant taste and odour and is high in unsaturated fats such as oleic acid and linoleic acid (Muhammad *et al.*, 2020). Okro is used in the mitigating of malnutrition and alleviation of food insecurity. Among all the vegetables, okro is one of the nutritious, affordable, and easy-to-cultivate crops that sufficiently contribute significantly to human health. Due to the high content of biopolymers, polysaccharides, and bioactive compounds such as beta-carotene, fruit extracts of okro have been used for various food and

pharmaceutical industry applications such as emulsifiers, drug tablet formulations or blood plasma replacement (Kpodo *et al.*, 2018).

2.5 Health Benefits of Okro

Okro is known to have health benefits including anti-diabetic, anti-cancer and anti-inflammatory properties. The phenolic compounds (quercetin derivatives, catechin oligomers and hydroxycinnamic derivatives) are known to have antioxidants, anti-inflammatory, and anti-cancer activities (Woumbo *et al.*, 2022). To expand the range of food and prevent diseases such as peptic ulcer and gastritis, the population of many countries prefers okro fruits, as they are rich in mucilaginous substances (Ogunkunle *et al.*, 2020). Okro, especially fresh pods, in addition to phenolic are rich in vitamin C (ascorbic acid) and vitamin A (Beta carotene) which are antioxidants, and protective of cancer (Woumbo *et al.*, 2022). The fibre diet is advisable for diabetes, high pressure and heart attack problems because of its ability to reduce the absorption of sugars preventing hyperglycemia and decreasing cholesterol levels. Moreover, its insoluble fibres and viscous fibres are able to reduce sugar and cholesterol levels in the blood (Dubey & Mishra, 2017).

Okro is a very good source of dietary fibre, magnesium, manganese, potassium, vitamin K and vitamin C. Okro seed oil is rich in unsaturated fatty acids which are essential for human nutrition. Moreover, it is beneficial for diabetes and some cancers. Okro is used to promote a healthy pregnancy. An incredibly essential B vitamin for creating and maintaining new cells, foliate is a vital substance for optimum pregnancy. Okro is used to improve heart health. The soluble fiber within okro helps you to reduce serum cholesterol and therefore decreases the chance of cardiovascular disease. Consuming okro is an efficient method to manage the body's cholesterol level. Okro is a rich source of iodine and other vital minerals

and vitamins. Mucilage present in okro is polysaccharides i.e galacturonic and glucuronic acids (Singh & Ram, 2018). Okro has many interesting uses and is known to be an economically important vegetable crop because its fresh leaves, buds, flowers, pods, stems and seeds all have value. It can be used to prepare, stew, fresh or dried, and fried or boiled (Axe, 2021). Fruit is useful against genitor-urinary disorders, spermetorrhoea and chronic dysentery. Fruits are also dried or frozen for use during the off-season (Eagri, 2023).

2.6 Global Production Values of Okro and Ghana's Contribution

In Ghana, okro is produced in almost all regions of the country. The major producers of okro in Ghana are in the Bono, Bono East, Ahafo, Northern, Volta, Ashanti, and the Greater Accra regions (Ahiakpa *et al*, 2014). According to FAO (2021), India is the top country for okro production in the world recording 6.47 million tonnes in 2021 accounting for 59.75% of the world's production.

The production of okro in West Africa, constitutes 30% of the global production annually and it is commonly referred to as “a perfect villager’s vegetable”. The production of okro in Ghana is also over 67,000 MT (FAOSTAT, 2022). Okro is mostly found in its fresh state in almost all markets in Ghana during the rainy season and in a dehydrated form during the dry season, particularly in Northern Ghana due to its strong commercial value for farmers and women/marketers (Agbenorhevi *et al.*, 2020). Okro is a robust crop under large-scale commercial production, yield losses are very high due to the incidence of several biotic and abiotic stresses (Abdulraheem *et al.*, 2022). Okro has a considerable area under cultivation in Africa and Asia with huge socio-economic potential.

Table 2. 2: Top ten okro-producing countries in the world

Country	Production (Tonnes/year)	Availability (kg/capita)	Area (ha)	Yield (kg /ha)
India	5,507,000	4.12	485,000	11,354.6
Nigeria	1,978,286	10.02	1,463,46	1,351.8
Sudan	287,300	7.04	26,754	10,738.6
Mali	241,033	12.61	21,488	11,217.1
Pakistan	117,961	0.58	15,584	7,569.5
Cote d'Ivoire	112,966	4.54	41,035	2,752.9
Cameroon	90,780	3.82	33,377	2,719.8
Ghana	66,360	2.24	3,160	21,000
Egypt	57,721	0.59	5,033	11,467.4
Malaysia	55,856	1.71	3,692	15,128.9

(Source: Atlas Big, 2021)

2.7 Climatic and Soil Requirements

Okro is a tropical, sub-tropical and temperate crop that requires warm and humid conditions for growth and development. It grows well under temperatures ranging between 25-30°C and thus it is susceptible to low temperatures. The height of the plant is seasonally dependent, growing taller during the rainy seasons than during the dry seasons. Okro seeds require soil temperatures ranging from 25-35°C for optimum growth with higher germination occurring at 35° C. Okro is sensitive to frost and extremely low temperatures (Xu *et al.*, 2021; Sun *et al.*, 2021). Under low temperatures of 17° C, okro germination fails while desiccation of flower buds occurs at temperatures above 42°C. Thus, there is a high loss of yield in okro at the germination at low temperatures and during flowering time when temperatures are high above 42°C.

The normal growth and development of okro occur at temperatures between 24°C and 28°C with the first flower bud appearing at 24°C in the third leaf axil while at 28°C it may appear in the sixth leaf axil (Nzweundji *et al.*, 2020). This higher position is not necessarily accompanied by a delay in time because at higher temperatures the plants grow faster, and the higher position is reached earlier. All soils need to be pulverized, moistened, and enriched with organic matter before sowing.

Annual rainfall and mean temperatures of 900-1,000 mm and 18-35°C, respectively, support okro production (Uwiringiyimana *et al.*, 2024). Okro produces the greatest yields if supplemental irrigation is used to maintain soil moisture at optimum levels. Irrigation also may be needed to germinate seeds and for early plant establishment if rainfall is not adequate to meet the plant needs. Okro flowers and fruits during the hottest months of the summer and if adequate rainfall is not occurring, the addition of 3.81 cm of water every 10 days during the production season will provide for crop water needs. Although okro can tolerate both heat and drought, it will not maximise its potential for yield and profitability if stressed by drought.

A. esculentus is a crop that is adapted to wide varieties of soils, there are, however, some variations that occur among cultivars (Espeland & Kettenring, 2018). Okro plants require well-manured sandy to clay soils with sufficient organic matter and ample drainage system. Most okro cultivars yield well at a soil pH between 6.0 and 6.8. thus, supporting the uptake of nutrient from the soil. However, Pusa Sawani okro variety is adapted to higher pH ranges and is tolerant to high salinity. Continuous crop cultivation without proper fertilization is one of the major causes of soil degradation (Kopittke *et al.*, 2025). Soil fertility is a dynamic property which varies with crops, cropping intensity input and erosion. The fertility of the

soil has a declining trend throughout the country. This is due to low organic matter content of the soil, an intensive cropping system, improper cropping sequences, and inadequate fertilizer application and management. Crop production in Ghana will then be sustainable if we apply balanced nutrient elements and organic matter against crop removal and nutrient loss phenomena.

Most farmers rely mainly on the innate fertility of the soil and in addition considerable amount of money to achieve a reasonable yield of okro. Fertilizer is a very essential input in okro production. Optimum crop production of okro requires intensive management practices that conserve and manage soil and nutrients needed to maintain soil and water quality. Okro requires nutrients such as Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Sodium (Na) and Sulphur (S) for fertility maintenance and crop production.

2.8 Land Preparation, Planting and Management Practices

2.8.1 Land preparation

The start of every production process begins with the preparation of the soil. Therefore, proper land preparation is recommended to make land suitable for okro growth and development. Land preparation is done by ploughing 2-3 times at a depth of 20-25 cm and making the soil fine by removing debris, rocks, sticks, stubbles, and weeds, making the soil suitable for okro growth and development (Kumar, 2019).

Soil needs to be cultivated, and granular fertilizer worked into the soil before forming beds. Okro is susceptible to soil-borne pathogens such as *Verticillium* and *Fusarium* wilt (Abdulraheem *et al.*, 2022). An effective strategy to combat these diseases is through fumigation of the land in the fall of the year before planting, even though diseases may

surface during the later stages of the plant. Field levelling and division into small plots is the final stage in land preparation helps in crop management and eases crop maintenance (Kumar, 2019).

Generally, okro requires soils with specific properties including sandy or clay loam soils with medium drainage (Ali *et al.*, 2020). When grown in heavy clay soil, proper drainage must be applied to avoid too high soil moisture content. Depending on the yield target it is recommended to use neutral soil, not very acidic or alkaline.

2.8.2 Propagation of okro

Okro plant is propagated mainly by seed and through other vegetative parts (transplanting) which are not used often in Africa (Fufa, 2019). The seeds are obtained from the mother plants used as propagules for the next growing season. To enhance seeds viability, the matured seeds are allowed to remain in the dried pods on the plant till fully dried and turn hard and black. Then remove the pods, break open, and separate the seeds. Air-dry the seeds for few days before storage. Okro is commonly planted directly in the field. It requires five (5) kg of okro seeds to plant a hectare. To attain uniform germination, the seeds are soaked in water overnight before planting. Plant okro seeds in slightly moist soil at a rate of 2-3 seeds per hill at 30 cm and 2-5 cm deep. Replant missing hills three (3) days after emergence (DAE). Okro takes about 5-10 days to germinate. When the plants are about 10 cm tall, they are thinned to one plant per hole.

2.8.3 Watering

Studies by Ayanlade *et al.* (2018) emphasized the challenges posed by irregular rainfall, especially during the dry season, which can adversely impact okro production. In response to this, proper watering practices, are crucial for maintaining consistent moisture levels in the soil. Although okro is drought tolerant, it still requires considerable evenly distributed annual rainfall of up to 1000 mm for optimum growth and yield.

Various irrigation methods are employed in okro cultivation in Ghana. Drip irrigation, as investigated by Quansah & Darkwa (2016), has gained popularity for its efficiency in water use and precise delivery to the root zone, contributing to improved water management and increased yields. Additionally, studies like Agyin-Birikorang *et al.* (2022), have explored the effectiveness of sprinkler irrigation in okro cultivation, providing insights into its impact on water use efficiency and crop performance. In response to increasing water scarcity, studies like Otoo *et al.* (2020) have explored the adoption of water conservation practices in okro cultivation. Conservation strategies, such as rainwater harvesting and moisture-retaining mulches, aim to optimize water use efficiency and mitigate the impact of water scarcity on okro crops.

2.8.4 Weed control

Effective weed control is essential in okro (*Abelmoschus esculentus*) cultivation to ensure healthy plant growth and high yield. Weeds compete with okro plants for essential resources such as nutrients, water, light, and space, particularly during the early stages of growth. Uncontrolled weed growth can lead to stunted plants, reduced fruit size, and lower yields. Common weed management practices include manual weeding, hoeing, mulching, and the use of selective herbicides. Integrated weed management, which combines cultural, mechanical, and chemical methods, is often recommended for sustainable okro production

(Adekpe *et al.*, 2020). Maintaining a weed-free field during the first 4-6 weeks after planting is especially critical, as this period is when okro plants are most sensitive to competition (Olasantan & Bello, 2021).

Weed control is also important for reducing pest and disease incidence since some weeds serve as alternate hosts for harmful insects and pathogens. Additionally, clean fields improve harvesting efficiency and overall crop quality (Abubakar *et al.*, 2022). Weeds are the most easily observable factors limiting agricultural productivity. It is poor weed management, which has resulted in significant crop yield losses on smallholder farms in Ghana.

Weed control is essential in okro cultivation as weeds may harbour insects that transmit diseases to crops. Enhancement of okro yield is achieved with three weeding before harvest (Kugbe *et al.*, 2019). Okro yield loss of about 54.1 to 90.6% was reported due to weed competition. The most critical period of crop weed competition in okro is from 2-6 weeks after sowing. The use of herbicides for weed control is advocated for weed control due to their easy application and effectiveness in early control of weeds (Dash *et al.*, 2020). Crop rotation is another cultural practice that disrupts weed cycles and reduces the risk of weed persistence.

Chemical weed control which involves the use of herbicides in integrated weed management (IWM) is a common practice, but it requires careful consideration to minimize environmental impact and herbicide resistance. Research by Kaur *et al.* (2018) emphasizes the importance of selective herbicides in okro fields, targeting specific weed species while minimizing damage to the crop.

2.8.5 Fertilizer application

Ghana's diverse agroecological zones exhibit variations in soil fertility. A study by Mattila & Rajala (2022) emphasized the importance of soil testing to determine nutrient deficiencies. This underlines the need for tailored fertilizer recommendations based on specific soil conditions at a specific planting site in different regions of Ghana. Fertilizer application is critical for meeting the crop's nutrient demands during different growth stages. Osei *et al.* (2018) investigated the impact of split application of fertilizers on okro growth and yield. The study suggested that split application, providing nutrients at specific growth stages, could optimize nutrient uptake and enhance overall crop performance. Fertilizer applications should not only aim at maximizing yield but also consider economic sustainability for farmers. Studies like Adhikari & Gyawali (2024) evaluated the economic returns of different fertilizer regimes. The research highlighted the importance of balancing input costs with increased yields to ensure profitability for okro farmers in Ghana.

Research by Phares *et al.* (2020) investigated the effects of organic and inorganic fertilizers on okro yield and quality. The study found that a combination of organic and inorganic fertilizers significantly increased fruit yield, suggesting a synergistic effect. Organic fertilizers contribute to soil organic matter and microbial activity, enhancing nutrient availability for okro plants (Magar *et al.*, 2023). Fertilizers are broadly classified into organic and inorganic with respect to their origin. The inorganic is synthesized from inorganic materials while organic fertilizers are obtained from living organisms which are mainly plants and animals.

Nitrogen Fertilization: Nitrogen is a crucial nutrient influencing plant growth and yield. Studies such as Quansah *et al.* (2017) investigated the impact of nitrogen fertilizer on okro growth in Ghana. Proper nitrogen application positively correlated with increased plant height, leaf area, and yield. However, excessive nitrogen can lead to vegetative growth at the expense of fruiting, emphasizing the importance of balanced nutrient management.

Phosphorus and potassium management: Phosphorus and potassium are essential for flowering, fruiting, and overall plant development. A study by Assefa *et al.* (2020) explored the influence of phosphorus and potassium on okro growth. The research demonstrated that adequate levels of these nutrients positively influenced flower and fruit development, contributing to improved yield and quality.

2.8.6 Inorganic fertilizers

Inorganic fertilizers are also referred to as commercial or chemical fertilizers. As a result of their ability to supply essential nutrients much faster than organic fertilizers; inorganic fertilizers are widely used by farmers. The two categories of inorganic fertilizers are the straight or simple fertilizers and the compound or mixed fertilizers. Simple fertilizers contain only one nutrient element; an example is sulphate of ammonia and potash. Compound fertilizers on the contrary contain two or three of the primary nutrients of nitrogen, phosphorus and potassium, for example, NPK (15-15-15) compound fertilizer (Muhammad *et al.*, 2020).

2.8.7 Organic fertilizer

According to FAO (2022), one visible aspect of the efforts to make the agriculture sector more sustainable is the rise of organic agriculture, the main feature of which is its avoidance of synthetic fertilizer. In recent times, attention has been drawn to the use of organic fertilizers which used to be an ancient practice of maintaining soil fertility. The attention directed towards organic manure is because of the high cost of chemical fertilizers and their long-term negative effect on the chemical properties of the soil (Muhammad *et al.*, 2020). Organic fertilizers on the other hand can improve soil organic matter, soil structure, soil chemical properties and soil microbial activity. Soil organic matter again maintains the productivity of the soil (Magar *et al.*, 2023). In addition to the significant improvement of soil properties, poultry manure, which is one of the major sources of organic manure, is said to be readily available in large quantities in all sixteen (16) regions of Ghana. It should, however, be noted that the quality and quantity of poultry manure produced is dependent on the poultry feed, type and age of the bird.

2.8.8 Effect of NPK fertilizer on growth and yield of okro

Fertilizer is a very essential input in crop production. The application of fertilizer is necessary to enhance the soil nutrient status and increase crop yield. Okro requires nutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sodium (Na) and Sulphur (S) for fertility maintenance and crop production. These nutrients are specific in function and must be supplied to plants at the right time and in the right quantity. Naim and Abker (2016) reported that NPK are the most important macro-nutrients that okro requires for proper growth and yield. NPK fertilization among the various agronomic practices also influenced the growth and yield of okro. Okee (2021) reported an increase in okro yield

due to NPK fertilizer application even though the recommended rates of NPK fertilization vary greatly depending on the variety and the environment.

2.8.8.1 Effect of poultry manure on growth and yield of okro

The organic matter of the soil which can be replenished and maintained by the application of poultry manure has been reported by (Ibeh *et al.*, 2019) as the store house of plant nutrients. Nutrients contained in poultry manure and other organic sources are released more slowly and are stored for longer periods in the soil, thereby ensuring longer residual effects, improved root development and higher crop yield of okro. Naim and Abker (2016) reported that the production of okro with poultry manure could increase plant height and number of branches, thus indicating the importance of poultry manure on the vegetative growth of okro. This is also in conformity with the findings of Ibeh *et al.* (2019) who reported that poultry manure contains essential nutrients which are associated with high photosynthetic activities that promote root and vegetative growth.

Ibeh *et al.* (2019) made similar observations on okro in their separate studies. Poultry manure plays a vital role in the contribution of nutrients in okro production, it also acts as a storehouse for cation exchange capacity and as a buffering agent against undesirable pH fluctuation (Ibeh *et al.*, 2019).

Poultry manure provides a source of all necessary macro and micro-nutrients in available forms, thereby improving the physical and biological properties of the soil which could enhance the growth and development of okro plants (Naim & Abker, 2016). In support of this, Abbas *et al.* (2019) had reported that poultry manure increases soil pH, macronutrients, phosphorus and cation exchange capacity of the soil which improves okro

production. Poultry manure when efficiently and effectively used, ensures sustainable okro productivity by immobilizing nutrients that are susceptible to leaching (Abbas *et al.*, 2019).

Application of poultry manure helps in plant metabolic activity through the supply of some important micronutrients in the early vigorous stage of okro growth, which in turn increases yield at the later stage (Okee, 2021). The poultry industry worldwide has grown 31.5% between 2009 and 2019, according to FAOSTAT (2021). This intensification of the poultry industry has consequently increased the volume of poultry manure generated. Commonly, raw poultry manure is applied directly to agricultural soils as an organic amendment, to increase crop yields. However, poultry farms generally do not have enough agricultural land available to dispose in this way of all the poultry manure generated (Rizzo *et al.*, 2020).

Poultry manure is a mixture of organic and inorganic material and thus represents a potential source of nutrients that are important for agriculture, such as nitrogen (N) and phosphorus (P) (Rizzo *et al.*, 2020). Emerging contaminants are increasingly reported: microplastics and synthetic fibers have been detected in poultry litter and can act as vectors for chemicals and microbes, while steroid hormones and pesticide or insecticide residues add endocrine and toxic risks (Abd El-Hack *et al.*, 2024; Gržinić *et al.*, 2022). Together these hazards mean that beneficial nutrient recycling must be balanced with treatment, storage, and application controls (composting, regulated withdrawal periods, monitoring) to reduce pathogen survival, degrade organics, and limit contaminant accumulation in soils and crops (Ngogang *et al.*, 2021; Muhammad *et al.*, 2020; Mesfin, 2024).

2.8.8.2 Impact of integrated nutrient management on growth and yield of okro

Among several constraints of okro production in Ghana, nutrient management plays a key role in realizing sustainable yield from any given cultivation practice. Integrated nutrient management systems play a vital role in balancing soil fertility and plant nutrient supply to an optimum level through the judicious and efficient use of organic fertilizers leading to an eco-friendly approach and economically viable solution for this problem.

According to Seifu (2016), the application of organic manure had a significant effect on plant height, number of leaves, number of branches and number of pods of okro plant and there were significant differences in plant height, leaves, fruits, flowers, lengths and weight values obtained from the treatment of Integrated Nutrient Management during the growing period in the study. The increase in vegetative growth and yield of okro can be attributed to the joint application of chicken manure and NPK (15:15:15) fertilizers that might have acted complementary and supplementary to each other and resulted in an adequate slow but steady supply of nutrients (Kumar *et al.*, 2017b). Moreover, organic manures are also significant sources of major micronutrients much needed by plants as reported by Mishra *et al.* (2019). Nutrients seemed more available to okro plants with the mixture than the organic materials alone. Similar results by Kumar *et al.* (2017b) found that the combined use of inorganic, organic and bio-fertilizers (Integrated Nutrient Management practices) not only improved the quality of fruit and soil health, but it can also produce better vegetative growth and yield of okro.

Several researchers reported that the combinations of organic and inorganic fertilizers perform better on crop yield than when each of them is solely used (Mishra *et al.*, 2019). This indicates that the Integrated Nutrient Management strategy is certainly a good substitute for enhancing soil fertility and crop productivity.

2.8.8.3 Diseases and insect pest control

A number of pests and diseases affect okro plant. The most important pests of okro are cotton stainers and stink bugs. The most serious fungal diseases are Cercospora blight, powdery mildew, fruit rot and root-knot nematode. The degree of occurrence of pests could be reduced if not eliminated by practising field sanitation, use of resistant varieties, and crop rotation.

In West Africa, the plant is attacked by two flea beetle species, *P. uniformis* and *P. sjostedti* which are responsible for heavy defoliation. Flea beetles infest seedlings and can cause economic damage by feeding on the leaves. If more than 2-3 individuals appear per seedling, then chemical control measures should be initiated (Uwiringiyimana *et al.*, 2024).

According to FAOSTAT (2020), Whiteflies (*B. tabaci*), Jassids (*E. lubica*), and Aphids (*A. gossypii*) attack okro. These pests infest leaves, stems, branches, and pods, especially during the dry season. Pods and flowers are primary targets of spiny bollworm (*Earias insulanaa*), while the caterpillar of the American bollworm (*Heliothis armigera* Hubner) prefers the reproductive parts of the plant, including buds, flowers, and fruits. Control measures against this pest are only recommended in intensive production areas.

Diseases are most severe in cloudy, damp weather, and other unfavourable climatic conditions in okro fruit. Excessive heat and very limited water (rainfall) also promote diseases such as the mosaic virus diseases (Kumar *et al.*, 2017b).

2.8.8.4 Harvesting

Harvesting practices and post-harvest handling significantly impact the physical characteristics of okro. Proper timing of harvest, careful handling to avoid mechanical damage, and appropriate sorting and washing are crucial steps in maintaining the initial quality of okro fruit (Mohammed *et al.*, 2020; Pua *et al.*, 2017). Okro needs to be harvested regularly, as pods quickly become overgrown and therefore unmarketable. Ideally, okro should be harvested every two days. To harvest okro, cut the stem just above the cap with a knife; if the stem is too hard to cut, the pod is probably too old and should be discarded. The harvester wears glove and long sleeves when cutting the okro because most varieties are covered with tiny spines that will irritate your skin. This will not be the case when it is a spineless variety. After the first harvest, remove (pruning) the lower leaves to help speed up production. Okro seed is easily saved for next season by leaving some of the last pods on the plant until they get very large. They should be removed and dried. The seeds may be separated easily from the pods.

2.9 Storage Methods of Okro

To preserve okro, it is dried, canned, powdered, pickled, or frozen. For instance, okro leaves are mature capsules that are dried and stored in parts of Africa for local use in the high-temperature season for the preparation of soups and stews (Dantas *et al.*, 2021). Because of the mucilaginous properties of the plant, the fruits are also used.

The fruit pods of okro should be handled with care to avoid bruising. Okro should be stored in small quantities in a properly ventilated area. The storage and shelf life of okro ranges from 7-10 days. The immature fruits are also preserved at lower temperatures for later consumption when there is a shortage of fresh produce. Recently, okro is mostly stored in fresh and frozen form by supermarkets and other commercial ventures (Adu-Dapaah *et al.*, 2019; Mahajan *et al.*, 2018). The stored dried pod with the seeds is then stored in cool dry places to be used in cultivation and propagation. For consumption purposes, the dried pods are powdered and stored in dry and cool places. The leaves are also dried and stored for use in the future to prepare soup in the northern parts of Ghana (Dantas *et al.*, 2021). Small-scale farmers in most cases slice the immature pods, dry them under the sun, and pack them in sacks for later sale. The preservation of colour, texture, or weight is with storage conditions of 7-10°C temperature and 90-95% relative humidity for 7-10 days (Vikash *et al.*, 2019). In Africa, most of the indigenes dry the pods and leaves and store them.

2.9.1 Impact of storage methods on the nutrient components of okro

Okro being a very important vegetable crop valued for its edible “slime” producing pods is a natural health-enhancing food crop fortified with retinol, retinal, and retinoic acid. It also has several provitamin A carotenoid, iron, calcium, carbohydrate, protein, fat, thiamine, riboflavin, ascorbic acid, niacin, and β -carotene. High crude fibre, foliate, antioxidants and potassium are also reported in okro (Prakash & Baskaran, 2018; Swamy *et al.*, 2019; Wenli *et al.*, 2021). These nutrient compositions recorded in this study could be influenced by the storage and preservation methods.

The physical and chemical properties of the mucilaginous substances found in crops are influenced by the treatment methods (Etaware & Etaware, 2019a). It is stated that the proximate, physicochemical, and biochemical properties of mucilage-producing crops such as okro are greatly improved when they are dried by oven. Other okro varieties' nutrient composition was also best improved and preserved by sun drying. This indicated that the optimization of the nutrient components of okro depends solely on the drying techniques used.

2.9.2 Impact of storage methods on the physical appearance of okro

Okro's physical attributes, including colour, size, and shape are influenced by genetic factors, environmental conditions during growth, and post-harvest handling practices (Adu-Dapaah *et al.*, 2019; Mahajan *et al.*, 2018). Hence, these factors significantly impact okro's appearance (Mohammed *et al.*, 2020; Pua *et al.*, 2017; Selvaraj *et al.*, 2016), which subsequently affect its marketability. Refrigeration has been shown to retard physiological processes, maintaining okro colour and reducing deterioration. Research suggests that controlled atmosphere storage can slow ageing processes, influencing the visual quality of okro (Li *et al.*, 2019).

Drying food materials is an effective method of extending the longevity of preserved products (Etaware & Etaware, 2019b). The problems of loss in quality, mucilage rheological properties and limited shelf life are major setbacks in the marketing of fresh okro in Nigeria (Etaware & Etaware, 2019a) due to its high respiratory rate and increased perishable ability index.

2.9.3 Challenges of okro production in Ghana

Okro is susceptible to various pests and diseases, including aphids, whiteflies, nematodes, and fungal infections (Adu-Dapaah *et al.*, 2018). These challenges lead to yield losses and increased production costs.

Unpredictable Weather Patterns: Climate variability, including irregular rainfall and temperature fluctuations, poses a significant challenge to okro production. Inconsistent weather patterns can affect crop growth, flowering, and fruit development, leading to reduced yields (Haokip *et al.*, 2020).

Poor Soil Fertility and Land Degradation: Many okro-growing regions in Ghana face challenges related to poor soil fertility and land degradation. Continuous cultivation without proper soil management practices leads to nutrient depletion and decreased soil quality, affecting okro yield and quality (Kartini *et al.*, 2024).

Lack of Access to Quality Seeds: Farmers often face challenges in accessing high-quality okro seeds, resulting in lower germination rates and overall crop performance. The limited availability of improved varieties adapted to local conditions further hinders productivity (Ghislain *et al.*, 2015).

Post-Harvest Losses and Market Access: Inadequate post-harvest infrastructure, storage facilities, and transportation systems contribute to significant post-harvest losses in the okro supply chain. Additionally, limited market access and value-addition opportunities affect the income of okro farmers (Rafee *et al.*, 2024). Addressing these challenges requires a holistic approach that includes integrated pest management, climate-smart agricultural

practices, soil fertility improvement strategies, improved seed systems, and investments in post-harvest infrastructure. By addressing these challenges, Ghana can enhance the resilience and sustainability of its okro production industry. Some of the popular and suitable varieties of okro cultivated in Ghana includes Asontem, Clemson Spineless, Labadi Dwarf, Indiana, Saloni (F1), and Torkor(Afrane, 2018).

CHAPTER THREE: MATERIALS AND METHODS

Experiment 1: Field Experiment

3.1 Description of Experimental Location/Site

The study was carried out at the Multipurpose Crop Nursery research field of University of Skills Training and Entrepreneurial Development (USTED), Mampong campus. The study was conducted from August to November 2021 during the minor rainy season, and from March to June 2022 in the major rainy season.

Mampong-Ashanti (07°8¹N, 01°24¹¹W) has an altitude of 475.5 m above sea level and is located within the transitional agro-ecological zone of Ghana, lying between the semi deciduous forest to the south and the Guinea savannah region to the north. The rainfall pattern of the area is bimodal. The major rainy season starts in March and ends in July, with a peak rainfall in June, while the minor season rain occurs between September and November with a peak rainfall in October. The mean annual rainfall and temperature figures are 1094.2 mm and 30.8⁰C, respectively. The mean daily temperature ranges from 25°C to 37°C.

The soils of the Bediase series, classified as Chromic Luvisols under the FAO/UNESCO (1988) system, are typical of the Savannah Ochrosol class derived from Voltaian sandstone formations of the Afram Plains. These soils are generally deep, well-drained, and possess a sandy loam texture, providing good aeration and satisfactory moisture-holding capacity that supports crop growth (Awoonor *et al.*, 2025). Their slightly acidic pH range of 5.5-6.5 is suitable for most arable crops, though liming may be beneficial for optimizing nutrient availability (Bationo *et al.*, 2020).

3.2 Experimental Design and Treatments

The experimental design used for the field experiment was a 2 x 6 factorial experiment arranged in a randomized complete block design (RCBD) with four (4) replications. The treatments were made up of two factors: Factor (A): Two okro varieties [(i) Asontem (Local) and (ii) Clemson Spineless (Exotic)] and Factor (B): Soil Amendments (i) 650 kg/ha NPK (full NPK), (ii) 20 t/ha Poultry Manure (full PM), (iii) 487.5 kg/ha NPK+5 t/ha PM ($\frac{3}{4}$ NPK + $\frac{1}{4}$ PM), (iv) 325 kg/ha NPK +10 t/ha PM ($\frac{1}{2}$ NPK + $\frac{1}{2}$ PM), (v) 162.5 kg/ha NPK + 15 t/ha PM ($\frac{1}{4}$ NPK + $\frac{3}{4}$ PM), and (vi) No Fertilizer (control). Each plot size measured 3.6 m wide (consisted of 6 rows per plot) x 5 m long. The planting distances were 60 cm between rows and 50 cm within rows, with an expected plant population of 2880 plants/ha in both 2021 and 2022 cropping seasons.

The seeds of both the local and exotic (Clemson spineless) varieties of okro were obtained from Agri-seed Company Ltd, Kumasi Ghana. Clemson spineless is an early maturing variety. The crop starts bearing fruits at 6-8 weeks after planting and harvesting continues for 8-10 weeks. Asontem matures between 75-85 days after planting.

3.3 Management Practices

3.3.1 Land preparation

The land was prepared by ploughing with a disc plough followed by harrowing to obtain the desired tilth for proper seed germination and establishment of the crop. Besides, The well decomposed poultry manure and the NPK fertilizer were applied two weeks before and two weeks after planting, respectively.

3.3.2 Poultry manure preparation

The fresh poultry manure without litter (at least two weeks old) was collected from USTED's poultry production farm at Mampong-Ashanti using empty sacks and transported to the experimental site. The manure was kept under a tree covered with a black polythene bag for three weeks to enable further decomposition before application.

3.3.3 Fertilizer and poultry manure application

Inorganic fertilizer NPK (15:15:15) was applied two weeks after seedling emergence for the speedy establishment of the okro plants. The fertilizer was side-placed 10 cm away from the plants at a depth of 2-3 cm.

The decomposed farm poultry manure was incorporated into the prepared land for plots that received poultry manure and worked into the soil at a depth of 15 cm, two (2) weeks before sowing okro seeds. Sowing was done with a cutlass to a depth of about 3-5 cm. Three seeds of okro per stand were sown and thinned to one seedling per stand two weeks after planting (DAP). The planting distances were 60 cm between rows and 50 cm within rows. The plot size was 3.6 m wide and 5 m long. Each plot was made up of 6 rows per plot. The plant population was 3,168 plants/ha.

3.3.4 Weed control and irrigation

Weed Control: Two handweeding with a hoe were done at three (3) and six weeks after sowing to keep the field free of weeds.

Watering: Watering was done using water hose two times a day in the morning before 9:00 am and in the evening after 4:00 pm especially during the minor raining season in 2021.

3.3.5 Pest and disease control

The okro plants were sprayed using Golan 200 SL at the rate of 12 mls per 15 litres knapsack full of water. Golan SL is a broad-spectrum insecticide with stomach action and strong systemic and translaminar activity, for soft and foliar application. It has systemic and contact action. The spraying was done during plant growth, at five days intervals. Spraying started 3 weeks after seedling emergence until the plant started fruiting. Active ingredient of Golan was Acetamiprid at a concentration of 200 SL. I used Golan 200 SL only because it was highly effective in controlling aphids, jassids, whiteflies and flea beetles.

3.4 Data Collected

3.4.1 Soil and poultry manure sampling and analysis

Soil samples were randomly taken from the experimental site before the sowing of okro for physical and chemical analysis. Composite sampling was done along a Z plan across the four blocks using a soil core sampler. The composite samples taken from the top layer 0-30 cm depth were bulked together, air-dried, and sieved using a 2-mm mesh.

Representative samples of the well decomposed poultry manure used for both the 2021 minor and 2022 major cropping seasons were taken and analyzed for their chemical properties also at the Department of Renewable Natural Resources' Soil Laboratory at Kwame Nkrumah University of Science and Technology (KNUST) Kumasi. The poultry manure was analyzed for the following parameters: pH, percentage (%) Organic Carbon (Total C), percentage (%) total N, percentage (%) Available Phosphorus (P), percentage (%) Ca, percentage (%) Mg, Na, Fe, Cu, Zn, and Arsenic. Percent Total Nitrogen (N) percentage (%) total potassium (K), percentage (%) organic matter (O.M), percentage (%) Moisture content.

The soil chemical properties analysed were pH, Organic Matter, Organic Carbon (%), available N (kg/ha), available P (kg/ha), available K (kg/ha), Na (mmol/kg), Ca (Cmol/kg), Mg (Cmol/kg), Al (Cmol/kg) and H (Cmol/kg). The methodology used to analyze the soil and poultry manure chemical and physical properties were as follows:

Determination of pH by the use of a pH meter (1:2.5 soil-water) Method: Measured using a pH meter in a 1:2.5 (w/v) soil or manure-to-water suspension (McLean,1982).

Determination of Organic Carbon (OC) by the use of a Walkley and Black dichromate oxidation method: oxidation of organic carbon by potassium dichromate and sulfuric acid, followed by titration (Walkley & Black, 1934).

Determination of Total Nitrogen (N) by the use of a Kjeldahl digestion method: organic nitrogen is converted to ammonium sulfate, distilled, and titrated to determine total nitrogen content (Bremner, 1996).

Determination of Available Phosphorus (P) by the use of the Bray or Olsen method

1. For acidic soils: Bray No. 1 method (HCl + NH₄F extractant).
2. For neutral to alkaline soils: Olsen method (NaHCO₃ extractant) (Olsen and Sommers, 1982).

Determination of Exchangeable Potassium (K), Calcium (Ca), and Magnesium (Mg) by the use of a NH₄OAc extraction + AAS/Flame photometer Method: Extraction using 1 N ammonium acetate (NH₄OAc) at pH 7.0, followed by determination with Flame

Photometer (for K) or Atomic Absorption Spectrophotometer (for Ca and Mg). (Thomas, 1982).

Determination of Total Phosphorus, Potassium, Calcium, and Magnesium in Manure by the use of a Wet acid digestion Method: ($\text{H}_2\text{SO}_4\text{--H}_2\text{O}_2$ or $\text{HNO}_3\text{--HClO}_4$), followed by analysis using a spectrophotometer (for P) or flame photometer/AAS (for K, Ca, Mg) (AOAC, 2005).

Determination of Moisture Content by the use of an Oven drying at 105°C method: Weigh a known sample, dry at 105°C for 24 hours, and reweigh. The weight loss represents moisture content (AOAC, 2005).

Determination of Ash Content by the use of a Muffle furnace at 550°C : Method: Ignition of a dried sample at 550°C for 4 hours in a muffle furnace; the residue is the ash (AOAC, 2005).

Determination of Cation Exchange Capacity (CEC) by the use of a NH_4OAc extraction method: Extraction with 1 N ammonium acetate, followed by replacement of NH_4^+ with Na^+ or K^+ and measurement of exchanged NH_4^+ (Rhoades, 1982).

Besides, the physical properties of the soil such as the soil texture (Sand %, Clay %, and Silt %) was also determined. The analysis of the soil samples was also carried out at the Department of Renewable Natural Resources' Soil Laboratory at Kwame Nkrumah University of Science and Technology (KNUST) Kumasi.

3.4.2 Plant Phenology

3.4.2.1 Days to 50% emergence

The number of days to 50% emergence was estimated from the day of planting to when 50% of the plants in the two harvestable rows in the middle had emerged.

3.4.2.2 Number of days to 50% flowering

The number of days to 50% flowering was taken from the day of planting to when 50% of the plants in the two middle/central harvestable rows produced a flower each.

3.4.2.3 Number of days to 50% podding

Five plants were randomly selected and tagged within the harvestable plot area. To calculate 50% Podding, I continue daily monitoring and recording the number of plants that have developed pods. The number of days to 50% podding is the total number of days from the date of sowing to the day when half of the tagged plants have formed pods.

3.4.3 Plant Vegetative Growth

3.4.3.1 Plant height

Plant height was measured from five (5) randomly sampled plants with the help of measuring tape from the base of the plant at soil level to the tip of the last leaf at 4, 6, 8, 10, and 12 weeks after planting (WAP). The average plant height was then computed and recorded.

3.4.3.2 Stem diameter

The stem girth or diameter was determined using a venier caliper on each of the five (5) tagged plants at 4, 6, 8, 10, and 12 weeks after planting (WAP). The mean values were then computed and recorded.

3.4.3.3 Number of branches per plant

This was determined by counting all the developed primary lateral branches on each of the five (5) tagged plants and the mean value was recorded for each of the treatments.

3.4.3.4 Number of leaves per plant

The number of leaves per plant was counted after 4, 6, 8, 10, and 12 weeks after planting (WAP) by counting all leaves of the five randomly tagged plants. The mean number of leaves per plant for each treatment was recorded.

3.4.3.5 Canopy spread

The maximum spread of the plant in north-south and east-west directions on the five (5) randomly sampled plants was measured with measuring rule and the mean values computed.

3.4.3.6 Chlorophyll content of leaf

Leaf chlorophyll content was determined using the chlorophyll meter at 6 WAP and 10 WAP. Three leaves located at the middle of the growing plant were measured and the mean value computed.

3.4.3.7 Dry matter accumulation

Two plants were randomly sampled from each plot and cut into smaller pieces. After that, the fresh weight was taken using the electronic balance at 4, 6, 8, 10, and 12 weeks after planting WAP. The samples were then oven-dried at 70⁰C for 48 hours. Samples were then weighed using an electronic balance and the dry matter yield of plants per treatment was subsequently estimated.

3.4.4 Yield and Yield Components

3.4.4.1 Number of fruits per plant

The number of fresh fruits per plant was obtained by harvesting all fruits from the five (5) randomly selected (tagged) plants which reached physiological maturity. The number of fruits in each one of the tagged plants was counted and then computed to obtain the mean number of fruits per plant for all treatments.

3.4.4.2 Fruit length

The length of five randomly selected fruits was measured in centimetres from the base level of the fruit to the apex using a meter rule at 1st, 2nd, 3rd, 4th, and 5th picks and mean values were calculated and recorded.

3.4.4.3 Fruit diameter

The fruit diameter was measured by taking the mid-part of the fruit using a vernier callipers at 1st to 5 harvest and the mean values were computed and expressed in cm.

3.4.4.4 Total fruit yield

The fruit yield per hectare was determined at harvest from the harvested fruits from the two middle/ harvestable rows. The total weight per plot was expressed in kilogram per hectare and the mean recorded.

3.5 Economic Analysis

Economic analysis was carried out to determine the profitability and economic viability of okro production under the different treatment combinations. The analysis involved the computation of Total Gross Benefits (TGB), Total Variable Cost (TVC), Net Benefits (NB), Benefit-Cost Ratio (BCR) and Marginal Rate of Return (MRR).

The Total Gross Benefit (TGB) was obtained by multiplying the total yield (kg/ha) by the prevailing market price of okro (Gh¢/kg). The Total Variable Cost (TVC) included all expenses that varied with production, such as the cost of seed, fertilizers, manure, labor, and other field operations. The Net Benefit (NB) was calculated as:

$$NB = TGB - TVC$$

The Benefit-Cost Ratio (BCR) was determined as the ratio of Net Benefit to Total Variable Cost, which indicates the profitability of each treatment. A BCR greater than one implies that the enterprise is profitable.

$$BCR = \frac{NB}{TVC}$$

The Marginal Rate of Return (MRR) was determined as:

$$MRR = \frac{\Delta NB}{\Delta TVC} \times 100$$

3.6 Nutritional (Proximate) analysis of harvested fresh okro fruits

Proximate analysis of fresh okro fruits from the field experiment was conducted at the Department of Food Science and Biochemistry Laboratory at KNUST to determine the percentage moisture content, percentage ash content, percentage fat/lipid, percentage protein, percentage fiber, percentage carbohydrate content, percentage total energy, percentage total potassium (K), and vitamin C content. Details of the nutrient/proximate analysis are presented in Table 3.1.

Table 3. 1: Proximate and selected nutrient analysis of fresh and dried okro

Nutrient / Parameter	Analytical Method	Principle of the Method	Reference (APA)
Moisture Content (%)	Oven-drying method	The sample was dried at 105°C until it reaches a constant weight; the weight loss represents the moisture content.	AOAC (2019)
Ash Content (%)	Muffle furnace incineration	Organic matter was burned off at 550°C; the residue represents the total mineral content.	AOAC (2019)
Crude Protein (%)	Kjeldahl method	Nitrogen was digested, distilled, and titrated; total N × 6.25 gives protein.	AOAC (2019)
Crude Fat (%)	Soxhlet extraction	Fats are extracted from the dried sample using a nonpolar solvent (petroleum ether).	AOAC (2019)
Crude Fiber (%)	Acid and alkali digestion	Sample digested in dilute acid and alkali; residue dried and ashed to determine indigestible fiber.	AOAC (2019)
Carbohydrate (%)	By difference	100 (Protein + Fat + Fiber + Ash + Moisture).	AOAC (2019)
Total Solids (%)	Oven-Drying Method (AOAC 934.01)	Based on the gravimetric principle: water is evaporated from the sample by heating at 105°C until constant weight. The remaining mass represents total solids.	AOAC International (2021)
Total Sugars (%)	Phenol–sulphuric acid method	Sugars react with phenol and concentrated H ₂ SO ₄ to produce a colored complex measured at 490 nm.	Dubois <i>et al.</i> (1956)
Total Energy (kcal/g)	Bomb Calorimetry (AOAC 968.04)	Based on complete combustion of sample in an oxygen-rich environment. Heat released raises water temperature in calorimeter; proportional to sample's energy.	Abdelhamid & Soliman (2022)
Nitrogen (N, %)	Kjeldahl Method (AOAC 979.09)	Based on conversion of organic nitrogen to ammonium sulfate via acid digestion, followed by release of ammonia upon alkalization. The ammonia is distilled and titrated to quantify nitrogen.	Zhang <i>et al.</i> (2021)
Vitamin C (Ascorbic Acid, mg/100 g)	2,6-Dichlorophenol indophenol (DCPIP) titration	Ascorbic acid reduces blue dye (DCPIP) to a colorless form; the amount of dye reduced equals the vitamin C content.	AOAC (2019)
Potassium (K, %)	Flame photometry	Potassium ions emit light at characteristic wavelengths when excited in a flame.	AOAC (2019)

AOAC. (2019) and Dubois *et al.* (1956).

Experiment 2: Storage Experiment

3.7 Experimental Design and Treatments

The storage experiment for the 2021 and 2022 cropping seasons were carried out at the St. John Bosco's COE Science Laboratory, Navrongo.

The storability experimental design used was a 4 x 12 factorial experiment arranged in a completely randomized design (CRD) with 3 replications. The treatments consisted of (A) four storage methods [(i) Whole fruit sun dried (ii) Cut/chopped fruit sundried (iii) Ground/powdered sundried fruit and (iv) Fresh fruit refrigeration], and (B) two (2) varieties by six (6) fertilizer combinations.

Fresh okro samples for the storage experiment of this study were obtained from the experimental field at the USTED Multipurpose Crop Nursery, Mampong Campus at the physiological maturity stage (Plate 3.1). Five (5) fresh matured okro fruits harvested from the field were bulked together and twenty (20) were sampled for drying. Storage methods used for this experiment included sun drying and refrigeration. The fresh okro fruits were dried as whole fruit and some chopped/cut into 5 mm thickness using sharp sterilized knife before sun drying. The sun drying lasted for ten (10) days between the hours of 9:00 am to 3:00 pm each day. Some of the dried okro was then ground or powdered and put in zip polythene bags and stored at room temperature at the St. John Bosco's College of Education Science Laboratory. Date of storage was 5th July to 5th September 2021 in the 2021 cropping season and from 2nd June to 2nd August 2022 in the 2022 cropping season.



Asontem fresh okro



Clemson spineless fresh okro



Asontem cut dried okro



Clemson spineless cut dried okro



Asontem whole/cut powdered



Clemson spineless whole/cut powdered



Processed okro powder for storage

Plate 3. 1: Processed okro for storage

3.8 Data Collected for Storage Experiment

The fresh and dried okro samples from the storage experiment were analyzed for their proximate analysis at the Department of Food Science and Biochemistry Laboratory at Kwame Nkrumah University of Science and Technology (KNUST), Kumasi. The proximate analysis determined were same as indicated in Table 3.1.

3.9 Data Analysis

The data collected for both the field and storage experiments were analyzed using analysis of variance (ANOVA) with SAS-Statistical Package (SAS 9.4, 2013). Means which differed significantly were separated using the Fisher's Protected Least Significance Difference (LSD) at 5% level of significance ($P= 0.05$).

CHAPTER FOUR: RESULTS

4.1 Initial Soil and Poultry Manure Analysis

Tables 4.1 shows result of the chemical and physical properties of the soil at experimental sites for the 2021 and 2022 cropping seasons. The results showed that the soil was moderately acidic in both seasons. Total nitrogen (N) was medium, but varied between seasons, being low in 2021 and moderately high in 2022. Available phosphorus (P) and total potassium (K) were lower in 2021 than in 2022, with P below the critical level (10%) and K slightly above the critical level (0.15%) in both experiments (Table 4.1). Calcium (Ca) was higher in 2022 exceeding the critical level of 2.0 Cmol/kg, while magnesium (Mg) was very low in 2021, but high in 2022. Organic matter content remained below the critical level (3.0%) in both seasons, but was higher in 2022. Cation exchange capacity (CEC) was adequate in both years. The physical analysis showed that the soil was sandy loam in both seasons (Table 4.1).

Results showing the characteristics of the poultry manure used for the 2021 and 2022 cropping seasons are indicated in Table 4.2. The pH of the poultry manure used for both seasons was slightly alkaline, with the pH slightly higher in the 2022 cropping season (7.7) than in 2021 (7.22). The manure contained high concentrations of N, P, K, Ca, Mg, and micronutrients such as manganese (Mn), Chlorine (Cl), Boron (B) and Iron (Fe). While nitrogen content was high in both seasons, it was higher in 2021 than in 2022. Organic matter content was lower in 2021 (31.64%) compared to 2022 (36.5%). Available phosphorus (P) was significantly higher in 2022 (1.42%) than in 2021 (0.09%), while potassium (K) was very high in both years. Magnesium (Mg) was higher in 2021 but moderate in 2022. Sodium (Na) levels were very high in both seasons, and organic carbon was found to be adequate. Calcium (Ca) was high in 2021 and very high in 2022. Moisture content was slightly higher in 2021 (15.8%) than in 2022 (14.2%).

Table 4. 1: Initial soil characteristics of the experimental sites in 2021 and 2022 cropping seasons

Soil Characteristics	2021 cropping season	2022 cropping season
Soil Chemical Properties		
Soil pH	5.50	5.50
Organic carbon (%)	0.20	1.10
Organic.Matter (%)	0.34	1.90
Available N (kg/ha)	0.14	0.20
Available P (Kg/ha)	0.50	0.70
Available K (kg/ha)	0.16	0.20
Na (mmol/kg)	0.05	0.10
Ca (Cmol/Kg)	1.00	3.70
Mg (Cmol/Kg)	0.20	1.00
Al (Cmol/Kg)	1.00	0.90
H (Cmol/Kg)	0.17	1.60
Physical Properties		
Sand (%)	87.44	86.4
Clay (%)	9.36	8.5
Silt (%)	3.2	5.0
Soil texture:	Sandy Loam	Sandy Loam

Table 4. 2: Characteristics of poultry manure used in the experimental sites in 2021 and 2022 cropping seasons

Poultry Manure Characteristics	2021 cropping Season	2022 cropping Season
pH	7.22	7.70
N (%)	2.66	2.40
P (%)	0.09	1.42
K (%)	15.67	12.3
Na (%)	8.33	8.10
O.C (%)	18.34	21.20
O.M (%)	31.64	36.50
Ca (%)	1.16	3.20
Mg (%)	1.08	0.40
Moisture (%)	15.80	14.20

4.2 Soil Analysis after Harvest in 2021 and 2022 Cropping Seasons

Soil analyses conducted after harvesting in the study area indicated that in the 2021 and 2022 cropping seasons, there was an improved soil fertility and nutrient retention capacity, which can enhance productivity in subsequent cropping seasons. Soil pH values recorded as shown in Table 4.3 ranged from 5.8 to 6.4 indicating moderate acidity. Nitrogen content observed in both 2021 and 2022 seasons was 1.42% and 0.27%, respectively. Organic matter content was lower in 2021 (1.84%) compared to 2022 (2.76%). Available phosphorus (P) was significantly higher in 2022 (5.75%) than in 2021 (1.5%), while potassium (K) was very high in both seasons. Magnesium (Mg) was moderately higher in both 2021 and 2022 cropping seasons. Sodium (Na) and organic carbon levels recorded as shown in Table 4.3 were high in both seasons. Calcium (Ca), Al and H were high in both 2021 and 2022 seasons. Results of the physical properties of the soil after harvesting indicated in Table 4.3 shown that the soil was loamy soil.

Table 4. 3: Soil analysis after harvest in 2021 and 2022 cropping seasons

Soil parameter	2021 cropping season	2022 cropping season
Chemical properties		
pH	5.80	6.40
N (%)	1.42	0.27
P (mg/Kg)	1.50	5.75
K (Cmol/Kg)	1.52	1.53
Na (Cmol/Kg)	0.65	0.68
O.C (%)	0.87	2.50
O.M (%)	1.84	2.76
Ca (Cmol/Kg)	1.76	4.50
Mg (Cmol/Kg)	0.69	2.30
Al (Cmol/Kg)	1.72	1.80
H (Cmol/Kg)	0.97	2.47
Physical properties		
Sand (%)	85.74	82.30
Clay (%)	8.56	7.62
Silt (%)	3.85	4.84
Soil texture	Loamy Soil	

4.3 Climatic Data of the Study Area

As shown in Table 4.4. the average minimum temperature was about 22.3 °C and the maximum average temperature was 35.0 °C in the months of October and February, respectively in the 2021 cropping season. The minimum and maximum average temperature recorded in the 2022 cropping season was 21.5 °C and 35.2 °C in January and February. The average humidity was about 77.0 percent in the 2021 cropping season. The average humidity was about 82% in the 2022 cropping season. The minimum rainfall and maximum rainfall recorded was 34.4 mm in January and 225.1 mm in September in the 2022 cropping season.

Table 4. 4: Climatic data of the study area in the 2021 and 2022 cropping seasons

Month	2021 cropping season				2022 cropping season			
	Total rainfall (mm)	Temp Max (°C)	Temp Min (°C)	Relative humidity (%)	Total rainfall (mm)	Temp Max (°C)	Temp Min (°C)	Relative humidity (%)
JAN.	34.4	33.3	23.2	66	0.0	34.8	21.5	46
FEB.	63.1	35	24.3	62	72.5	35.2	24.4	60
MAR.	62.8	33.5	23.2	68	109.2	34	23.9	67
APR.	48.9	33.8	24.2	67	79.6	33.1	23.5	66
MAY	176.0	33.4	24.2	68	147.8	32.7	23.8	71
JUN	101.7	31.5	23.1	73	149.0	31	23.3	74
JUL	144.2	30.1	22.9	75	203.6	30	22.7	74
AUG	169.5	29.7	22.7	77	100.8	29.7	22	78
SEPT	225.1	30.3	23.2	77	190.1	29.1	21.9	82
OCT	208.7	32.1	22.3	72	108.4	31.9	22.5	74
NOV	73.4	33.1	23.4	68	0	0	0	0
DEC	0.0	34.3	23.7	58	0	0	0	0

Source: Ghana Meteorological Agency 2022 Mampong-Ashanti.

Experiment 1: Field Experiment

4.4 Phenology of Okro

4.4.1 Number of days to 50% emergence

Table 4.5 shows result of days to 50% emergence as influenced by variety and integrated nutrient management in the 2021 and 2022 cropping seasons. Days to 50% emergence were generally similar between 2021 and 2022, ranging between 6–9 days. There were however, significant differences between the varieties and among the fertilizer rates in both seasons. On the average, Asontem took slightly longer days to emerge (7–9 days) than Clemson spineless (6–8 days) (Table 4.5). The application of 20 t/ha poultry manure (full PM) and NPK + PM combinations emerged slightly earlier than the control (no fertilizer) and 650 kg/ha NPK (full NPK). None of the interactions between year, variety and fertilizer was significant for days to 50% emergence.

Table 4. 5: Number of days to 50% emergence of okro as affected by variety and integrated nutrient management

Fertilizer combination	Days to 50% emergence					
	2021 cropping season			2022 cropping season		
	Ason-tem	Clem-son	Mean	Ason-tem	Clem-son	Mean
650 kg /ha NPK	9	7	8	8	8	8
20 t/ha Poultry Manure	7	6	7	8	7	8
487.5 kg /ha NPK + 5t/ ha PM	7	6	7	7	7	7
325 kg/ ha NPK + 10 t/ha PM	7	6	7	7	7	7
162.5 kg/ ha NPK + 15t/ha PM	7	7	7	7	7	7
Control	8	8	8	8	8	8
Mean	8	7		8	7	
CV (%)		7.08			7.08	
Year (LSD=0.05)		NS			NS	
Variety (LSD=0.05)		0.21**			0.21**	
Fertilizer (LSD=0.05)		0.32**			0.32**	
Interaction						
Year x Variety (LSD=0.05)		NS			NS	
Year x Fertilizer (LSD=0.05)		NS			NS	
Variety x Fert. (LSD=0.05)		NS			NS	
Year x Var. x Fert. (LSD=0.05)		NS			NS	

* = p< 0.05; NS= Not significant; **= p<0.01

4.4.2 Number of days to 50% flowering

The effects of integrated nutrient management on the number of days to 50% flowering of okro varieties, are shown in Table 4.6. Significant differences ($P < 0.05$) were observed in both the varieties and fertilizer treatment in both seasons. The Ason tem variety in 2021 and 2022 cropping seasons used on the average 75-77 days to 50% flowering, while Clemson used 56-58 days to 50% flowering (Table 4.6). On the average, the 650 kg/ha NPK and 162.5 kg/ha NPK + 15t/ha PM fertilizer application flowered slightly earlier (66 days) than the other fertilizer treatments (67-68 days) 487.5 kg/ha NPK+5 t/ha PM, 325 kg/ha NPK +10 t/ha PM, 20 t/ha PM and no fertilizer application (control). Similar to days to 50% emergence, there were no significant ($P > 0.05$) interaction effects between the variety x fertilizer, year x variety, year x fertilizer or variety x fertilizer x year.

Table 4. 6: Effect of integrated nutrient management on days to 50% flowering.

Fertilizer combination	Number of days to 50% flowering					
	2021 cropping season			2022 cropping season		
	Ason-tem	Clem-son	Mean	Ason-tem	Clem-son	Mean
650 kg /ha NPK	76	56	66	75	56	66
20 t/ha Poultry Manure	77	57	67	76	58	67
487.5 kg /ha NPK + 5t/ ha PM	77	58	68	77	57	67
325 kg/ ha NPK + 10 t/ha PM	77	57	67	77	57	67
162.5 kg/ ha NPK + 15t/ha PM	75	56	66	77	56	67
Control	77.	58	68	76	58	67
Mean	77	57		76	57	
CV (%)		2.49			2.49	
Year (LSD=0.05)		NS			NS	
Variety (LSD=0.05)		0.67**			0.67**	
Fertilizer (LSD=0.05)		1.17**			1.17**	
Interaction						
Year x Variety (LSD=0.05)		NS			NS	
Year x Fertilizer (LSD=0.05)		NS			NS	
Variety x Fert. (LSD=0.05)		NS			NS	
Year x Var. x Fert. (LSD=0.05)		NS			NS	

* = $p < 0.05$; NS= Not significant; **= $p < 0.01$

4.4.3 Number of days to 50% fruiting

There were significant differences between varieties and among the fertilizer treatments for days to 50% fruiting (Table 4.7). However, none of the interaction effects were significant. On the average, Asontem fruited within 78-79 days, while Clemson fruited 58–60 days across both seasons. The 650 kg/ha NPK (full NPK), 162.5 kg/ ha NPK + 15t/ha PM and 487.5 kg /ha NPK + 5t/ ha PM fruited in 67-70 days. While, 20 t/ha PM (full PM) and 325 kg/ha NPK +10 t/ha PM, on the average, fruited in 69 days. The no fertilizer application (control) took an average of 70 days to bear fruits (Table 4.7). There were no significant interaction effects of year, variety and fertilizer treatments.

Table 4. 7: Effect of integrated nutrient management on the number of days to 50% fruiting

Fertilizer combination	Number of days to 50% fruiting					
	2021 cropping season			2022 cropping season		
	Ason-tem	Clem-son	Mean	Ason-tem	Clem-son	Mean
650 kg /ha NPK	77	57	67	78	58	68
20 t/ha Poultry Manure	79	58	69	78	59	69
487.5 kg /ha NPK + 5t/ ha PM	78	58	68	79	60	70
325 kg/ ha NPK + 10 t/ha PM	79	59	69	78	60	69
162.5 kg/ ha NPK + 15t/ha PM	76	58	67	78	59	69
Control	80	60	70	79	61	70
Mean	78	58		79	60	
CV (%)		2.26			2.26	
Year (LSD=0.05)		NS			NS	
Variety (LSD=0.05)		0.54**			0.54**	
Fertilizer (LSD=0.05)		1.27*			1.27*	
Interaction						
Year x Variety (LSD=0.05)		NS			NS	
Year x Fertilizer (LSD=0.05)		NS			NS	
Variety x Fert. (LSD=0.05)		NS			NS	
Year x Var. x Fert. (LSD=0.05)		NS			NS	

* = p< 0.05; NS= Not significant; **= p<0.01

4.5 Vegetative Growth Parameters

4.5.1 Plant height

Figures 4.1 and 4.2 show the effects of different fertilizer combinations on plant height of two okro varieties (Asontem and Clemson) during the 2021 and 2022 cropping seasons.

In both years, fertilizer application significantly ($P < 0.05$) increased plant height of both varieties at the 10 and 12 weeks after planting (WAP). And the other sampling days, treatment differences were not significant at 4, 6. And 8 WAP.

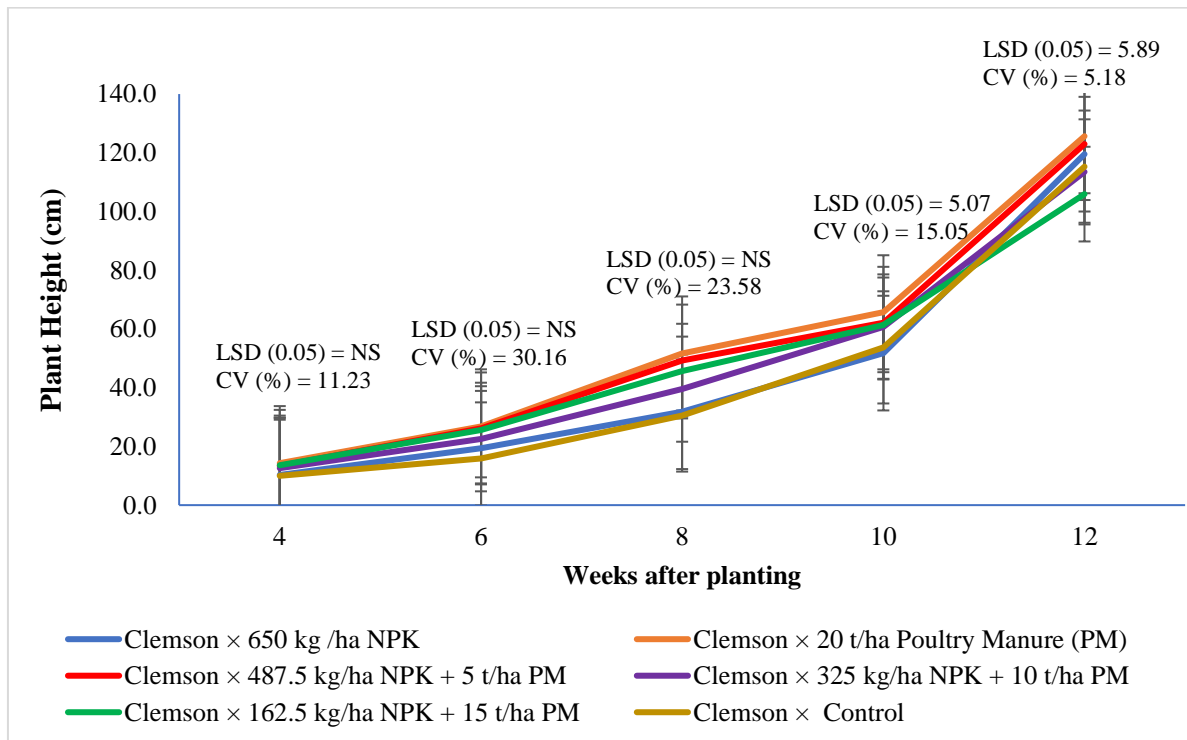
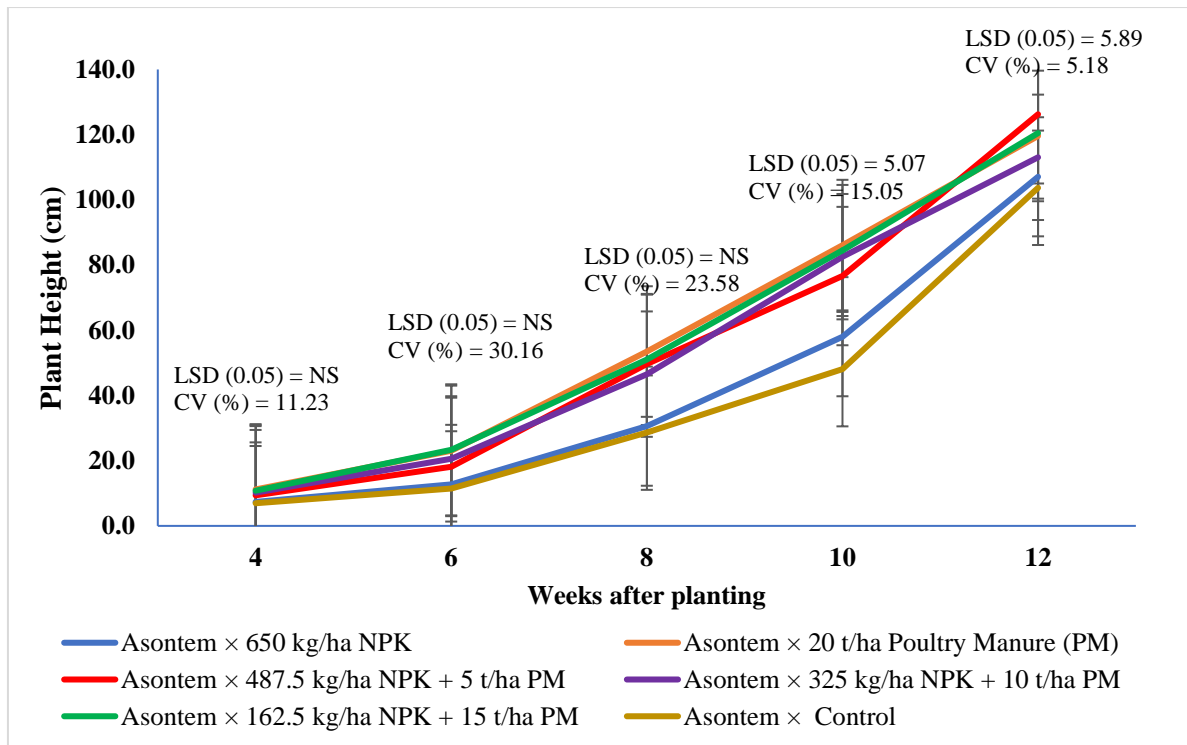


Figure 4. 1: Effect of integrated nutrient management on plant height of okro in 2021 cropping seasons.

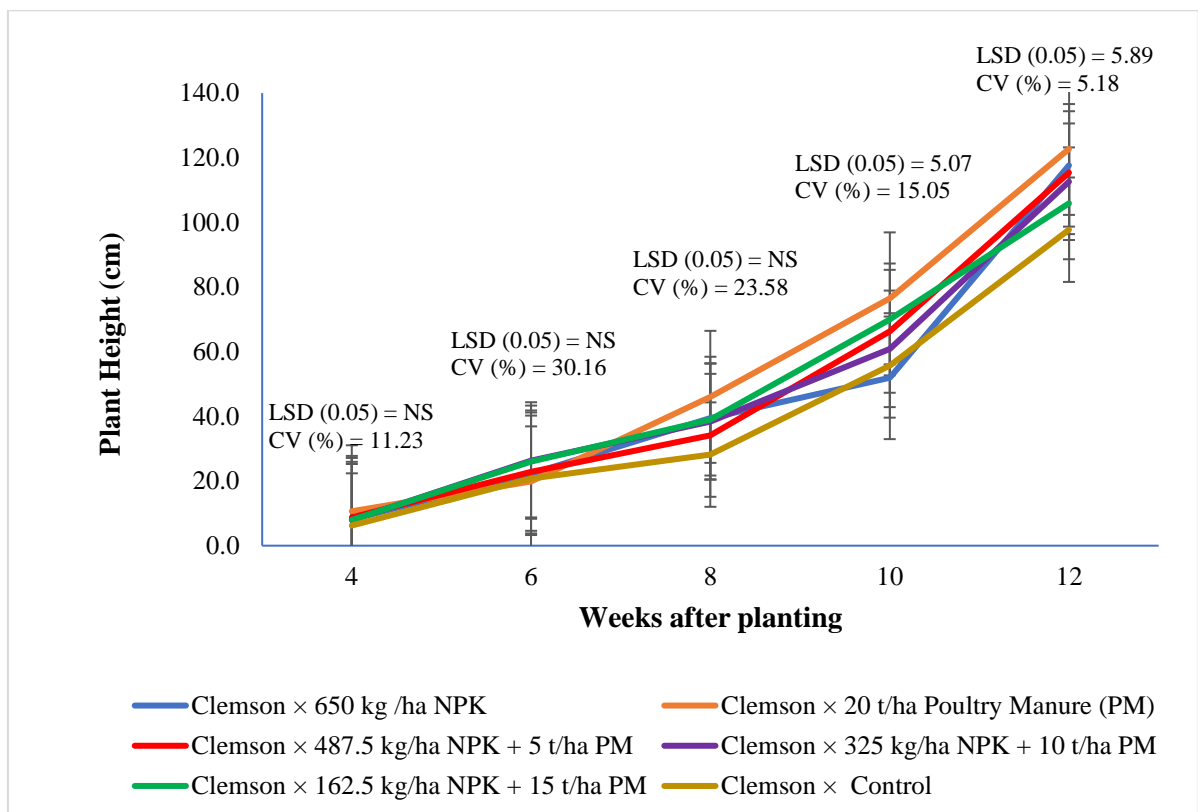
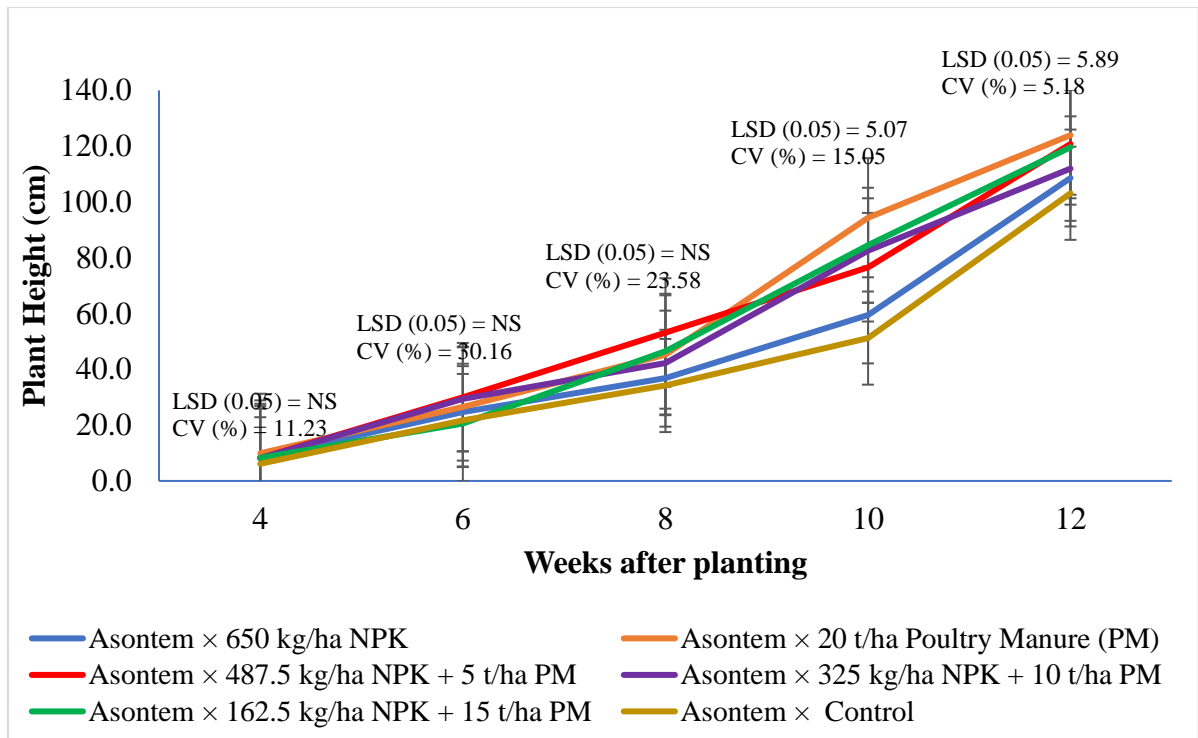


Figure 4. 2: Effect of integrated nutrient management on plant height of okro in 2022 cropping seasons.

4.5.2 Number of leaves per plant

Figures 4.3 and 4.4 shows the effect of poultry manure (PM) and NPK fertilizer treatments on the number of leaves per okro plant during the 2021 and 2022 cropping seasons. In 2021 cropping season, the number of leaves per plant for Asontem were generally higher for 162.5 NPK + 15 t/ha PM and 487.5 kg/ha NPK + 5 t/ha PM, intermediate for 650 kg/ha 325 kg/ha NPK + 10 t/ha PM and least for no fertilizer (control) and 20 t/ha PM over the sampling periods (Figure 4.3). For Clemson, 20 t/ha PM and 650 kg/ha NPK had the highest number of leaves per plant, with no fertilizer (control) producing the lowest number of leaves per plant at the 12 WAP. The 325 kg/ha NPK + 10 t/ha PM, 487.5 kg/ha NPK + 5 t/ha PM and 162.5 NPK + 15 t/ha PM had intermediate number of leaves per plant (Figure 4.3).

In 2022 cropping season, at 12 WAP for both Asontem and Clemson spinless, 20 t/ha PM and 162.5 NPK + 15 t/ha PM generally produced the highest number of leaves per plant, followed by 650 kg/ha NPK, 325 kg/ha NPK + 10 t/ha PM and 487.5 kg/ha NPK + 5 t/ha PM, while the no fertilizer (control) had the least number of leaves per plant over the sampling periods (Figure 4.4).

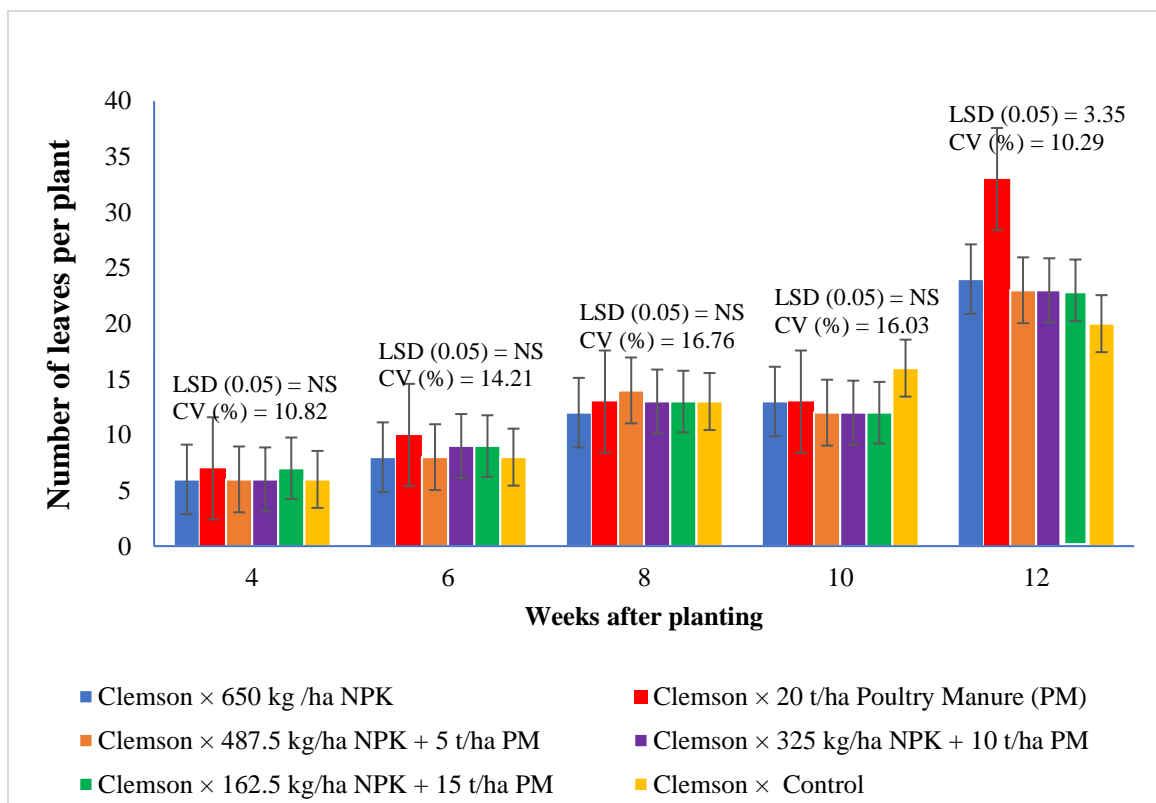
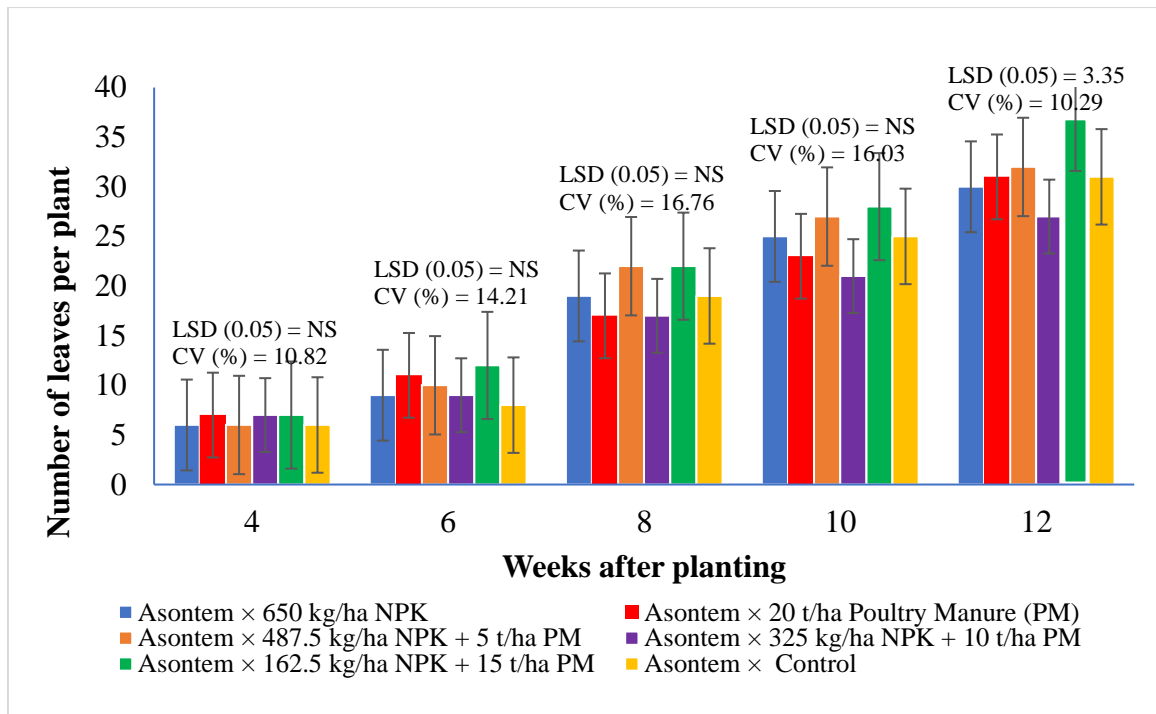


Figure 4. 3: Effect of integrated nutrient management on number of leaves per plant of okro in 2021 cropping seasons

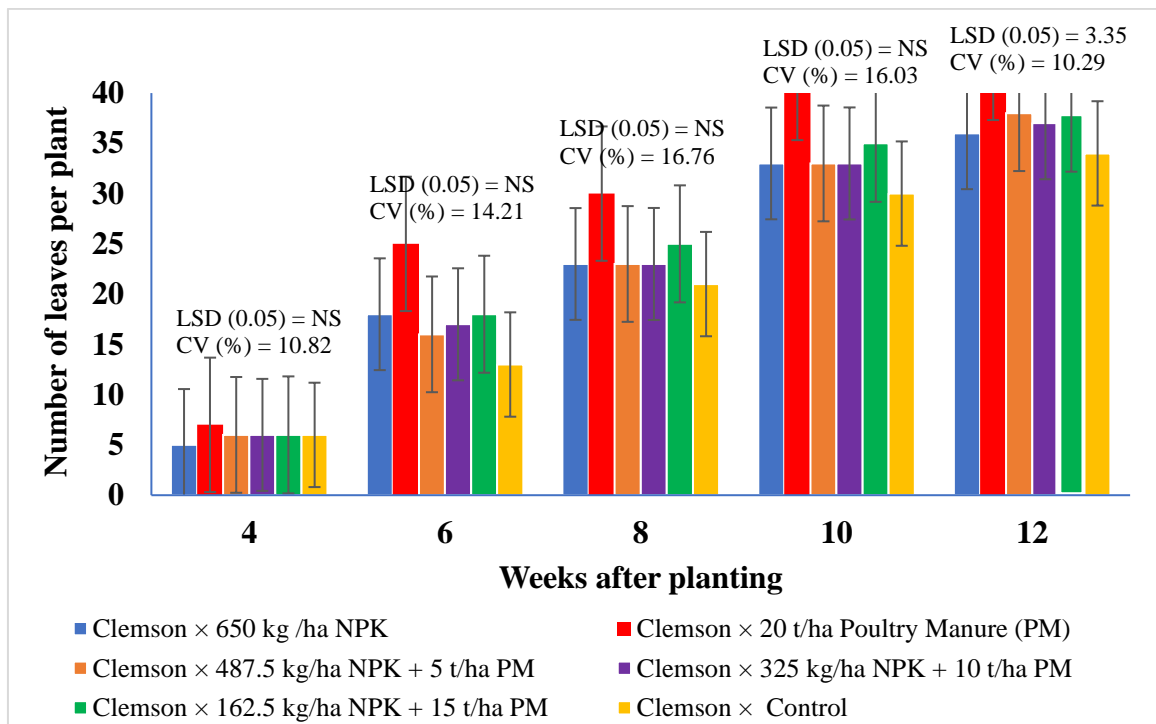
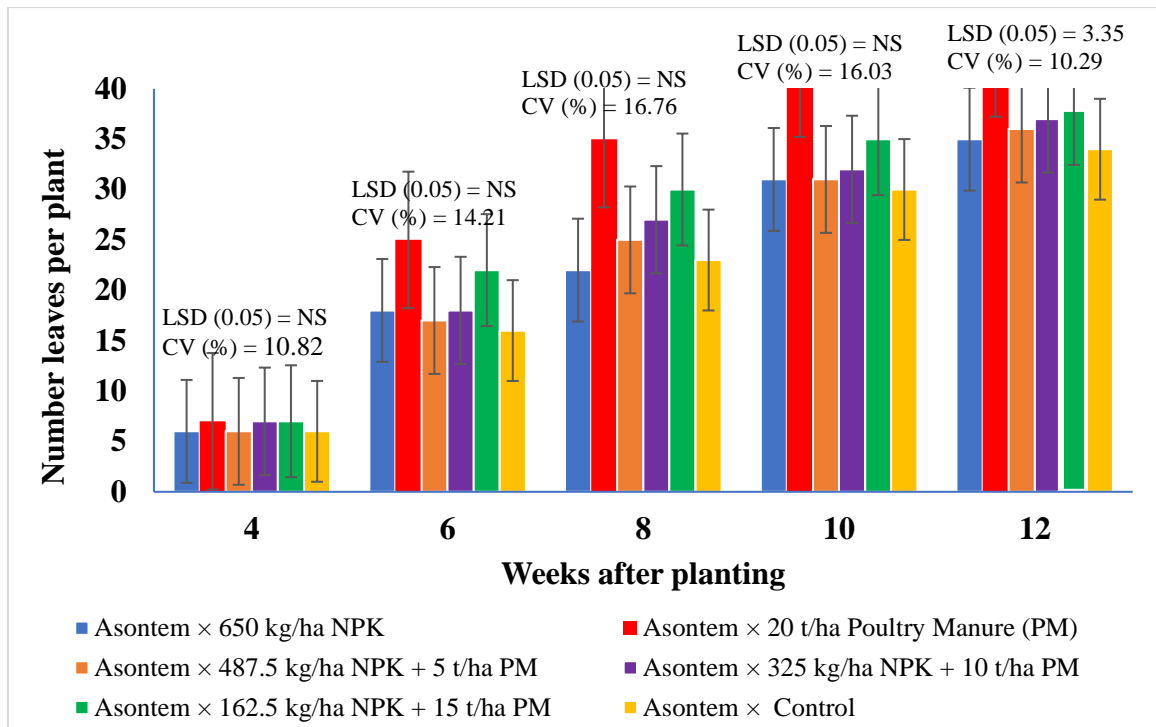


Figure 4. 4: Effect of integrated nutrient management on number of leaves per plant of okro in 2022 cropping seasons

4.5.3 Stem diameter

The results in Figures 4.5 and 4.6 show the effect of integrated nutrient management on the stem diameter of Asontem and Clemson spineless okro varieties during the 2021 and 2022 cropping seasons. The stem diameter did not differ significantly over the sampling period in 2021 cropping season. Generally, there were no significant differences in the stem diameter per plant among the fertilizer treatments for both Asontem and Clemson spineless varieties for both cropping seasons (Figures 4.5 and 4.6). The integrated nutrient combinations of NPK and PM had similar stem diameter per plant as the sole NPK, sole PM and the control.

Similarly, in 2022 cropping season, the stem diameter did not differ significantly over the sampling periods for both Asontem and Clemson spineless.

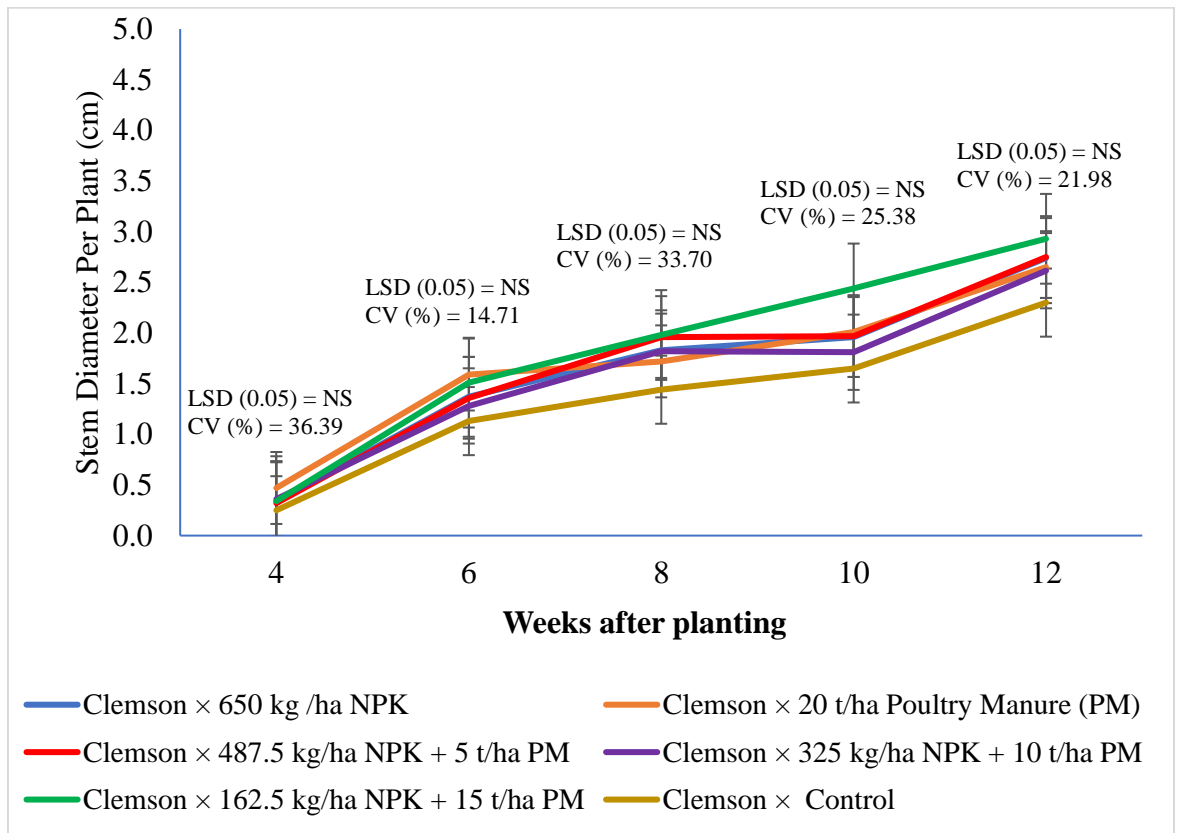
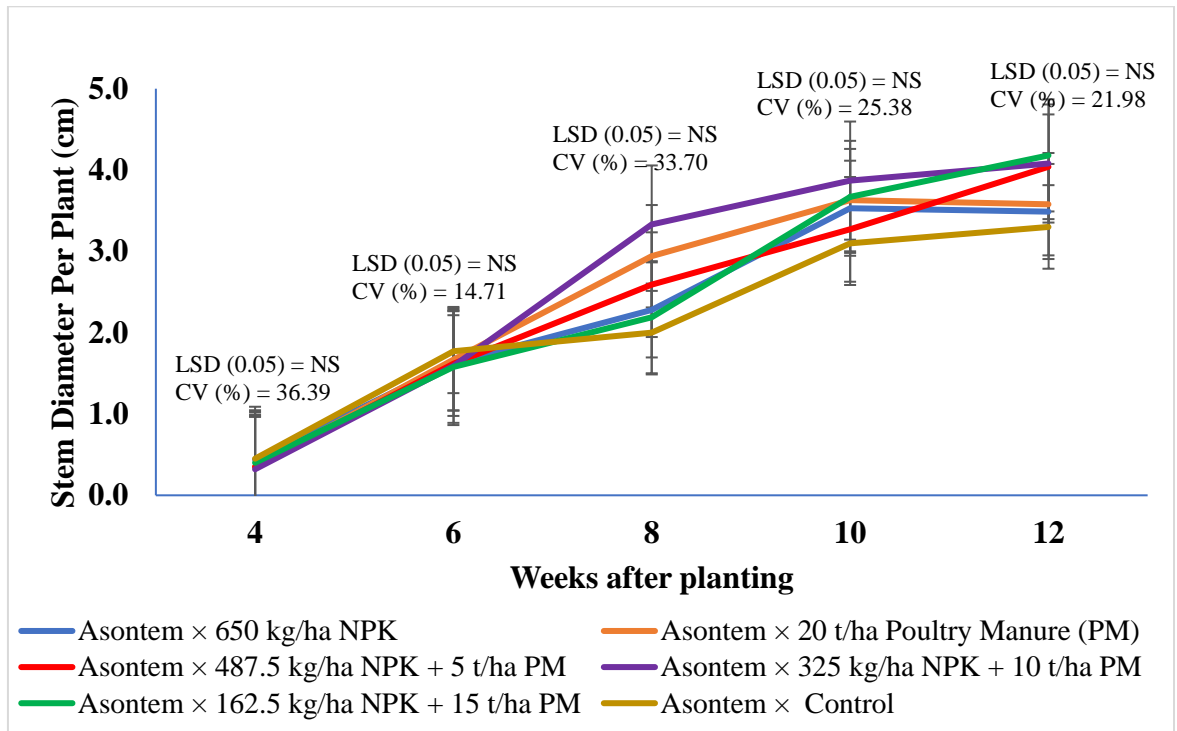


Figure 4. 5: Effect of integrated nutrient management on stem diameter per plant of okro in 2021 cropping seasons.

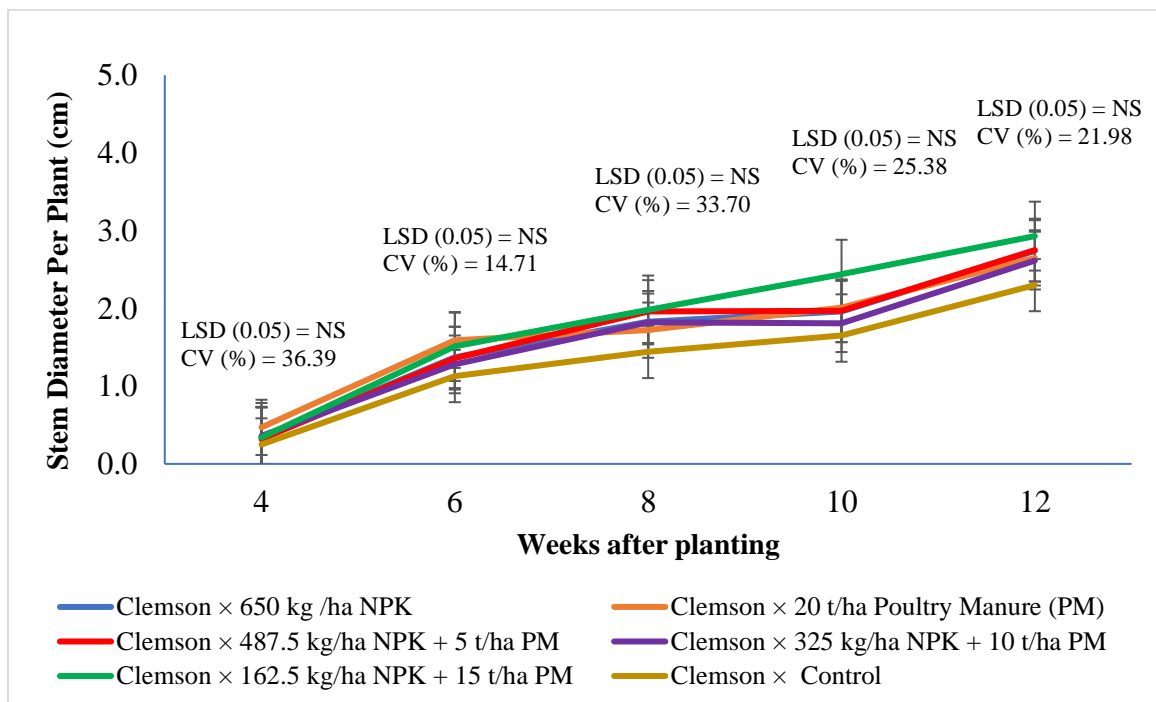
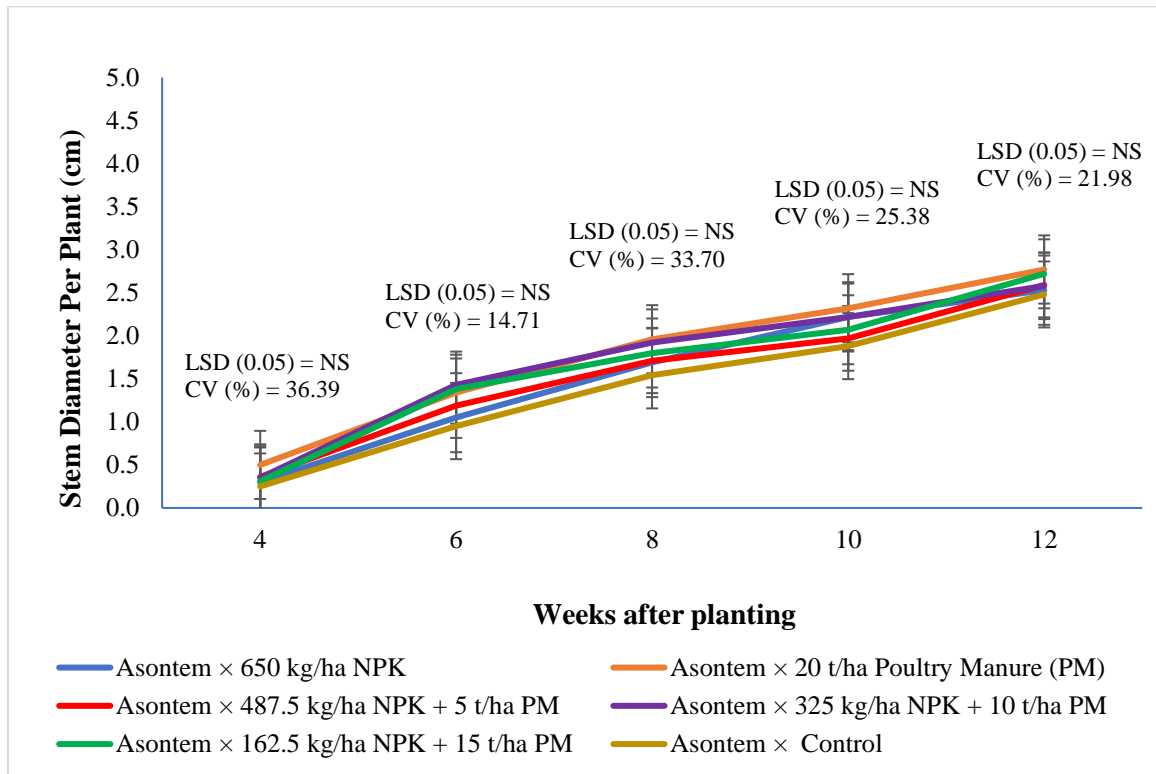


Figure 4. 6: Effect of integrated nutrient management on stem diameter per plant of okro in 2022 cropping seasons.

4.5.4 Number of branches per plant

Results in Figures 4.7 and 4.8 show the number of branches per okro plant as influenced by integrated nutrient management. Generally, there were no significant differences in the number of branches produced per plant among the fertilizer treatments for both Asontem and Clemson spineless varieties for both cropping seasons (Figures 4.7 and 4.8). The integrated nutrient combinations of NPK and PM had similar number of branches per plant as the sole NPK, sole PM and the control.

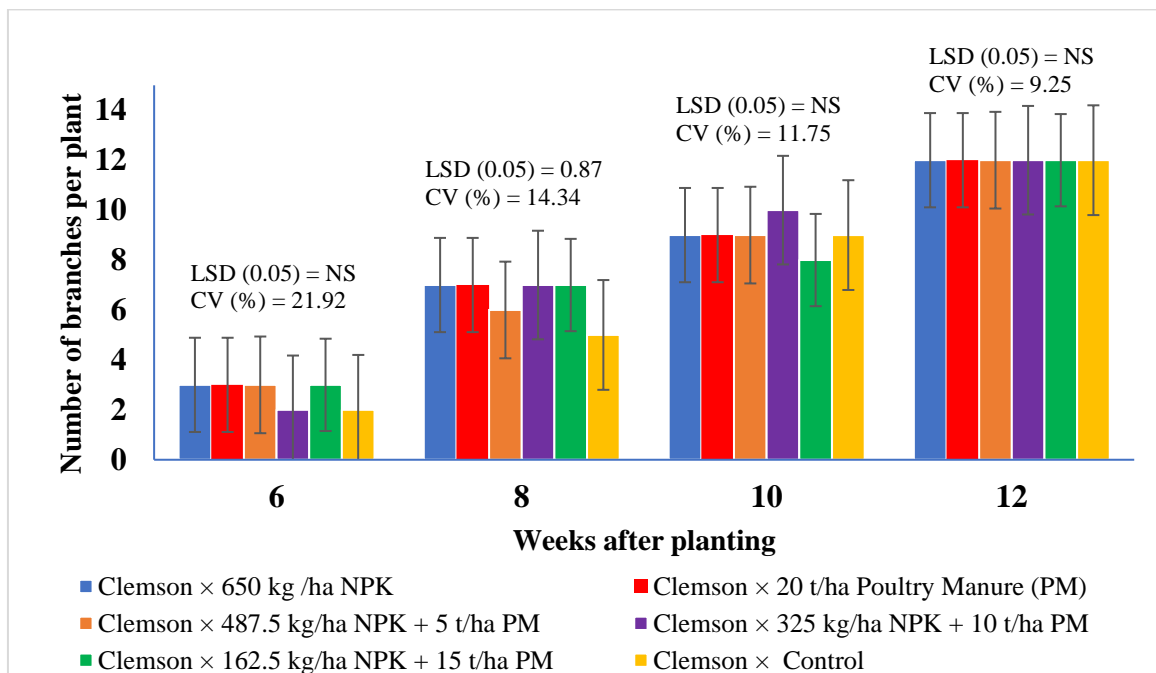
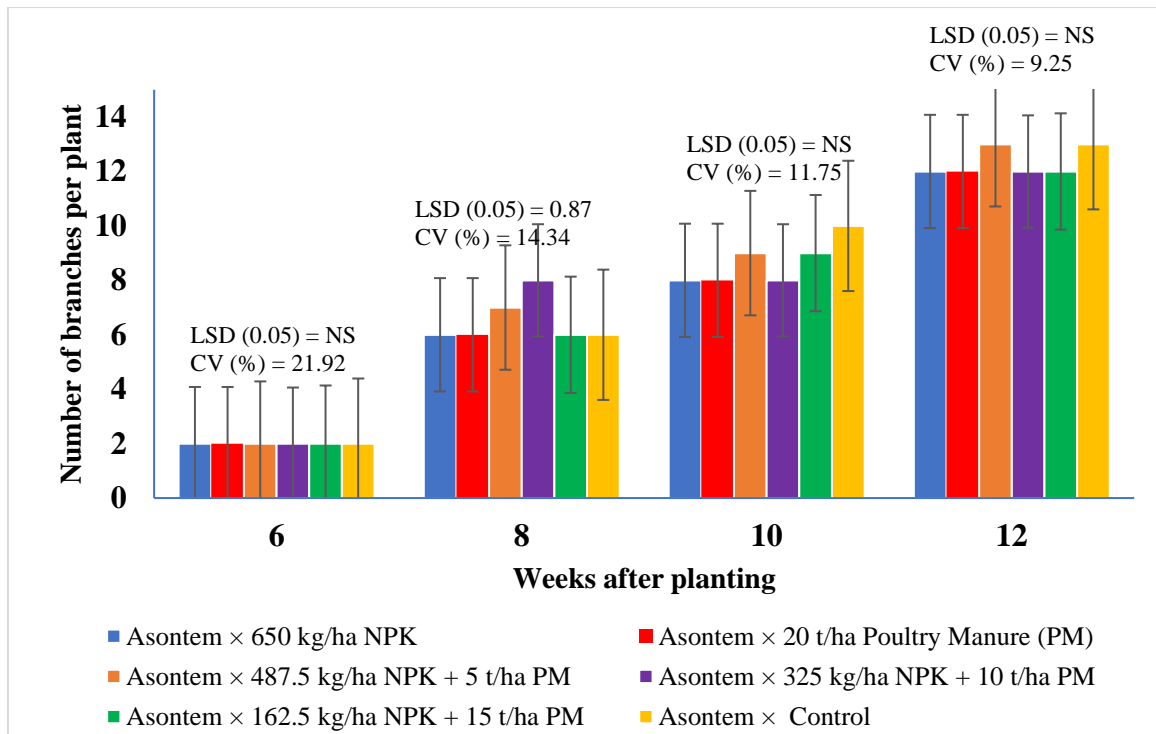


Figure 4. 7: Effect of integrated nutrient management on number of branches per plant of okro in 2021 cropping seasons.

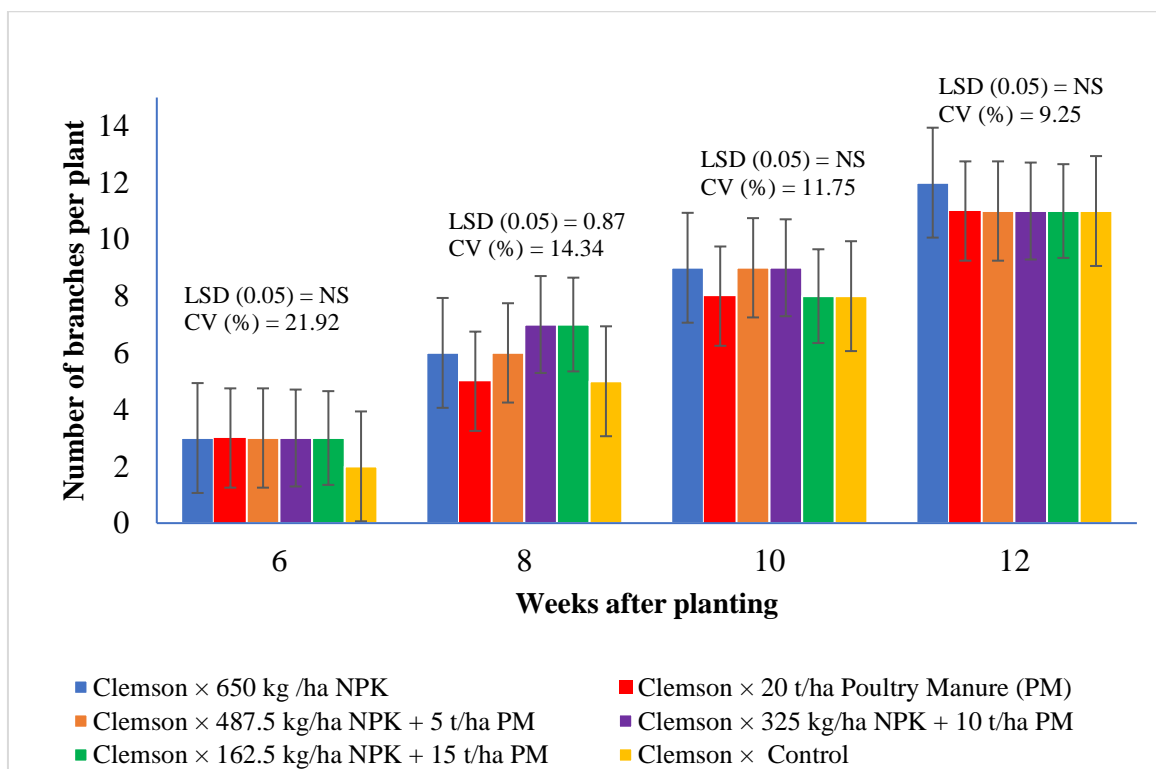
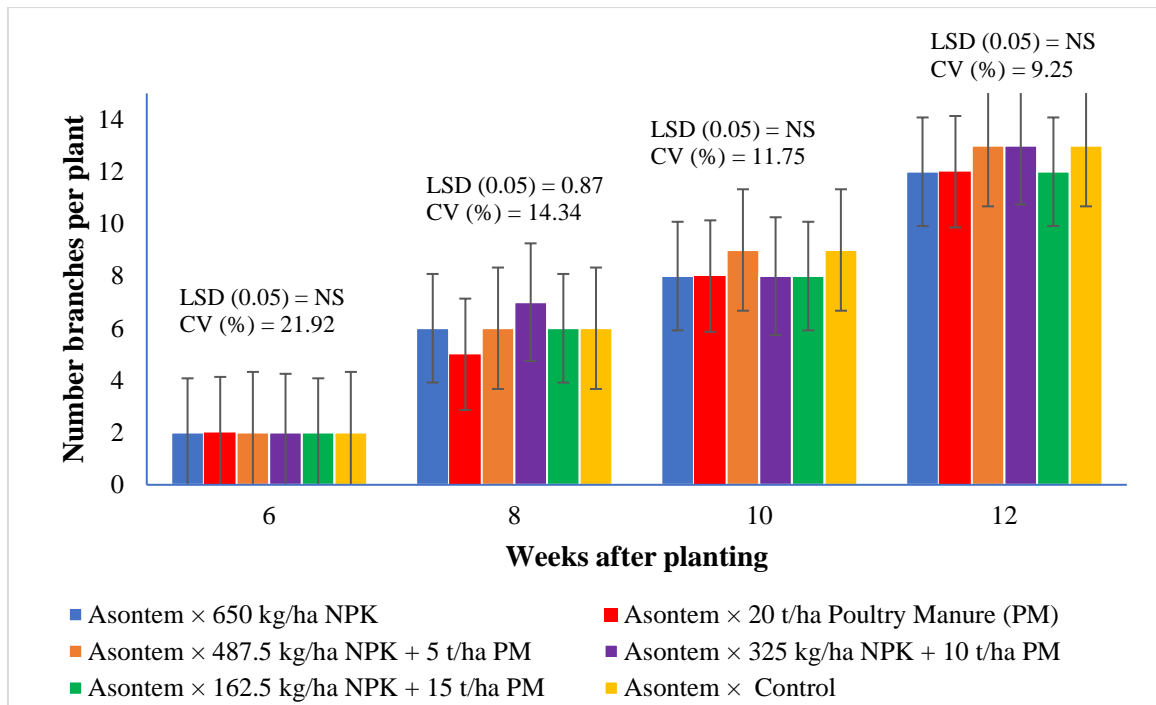


Figure 4. 8: Effect of integrated nutrient management on number of branches per plant of okro in 2022 cropping seasons.

4.5.5 Plant canopy spread

Plant canopy results are shown in Figures 4.9 and 4.10. Varietal and fertilizer treatment differences were not significant ($P>0.05$) on all sampling days in the 2021 and 2022 cropping seasons.

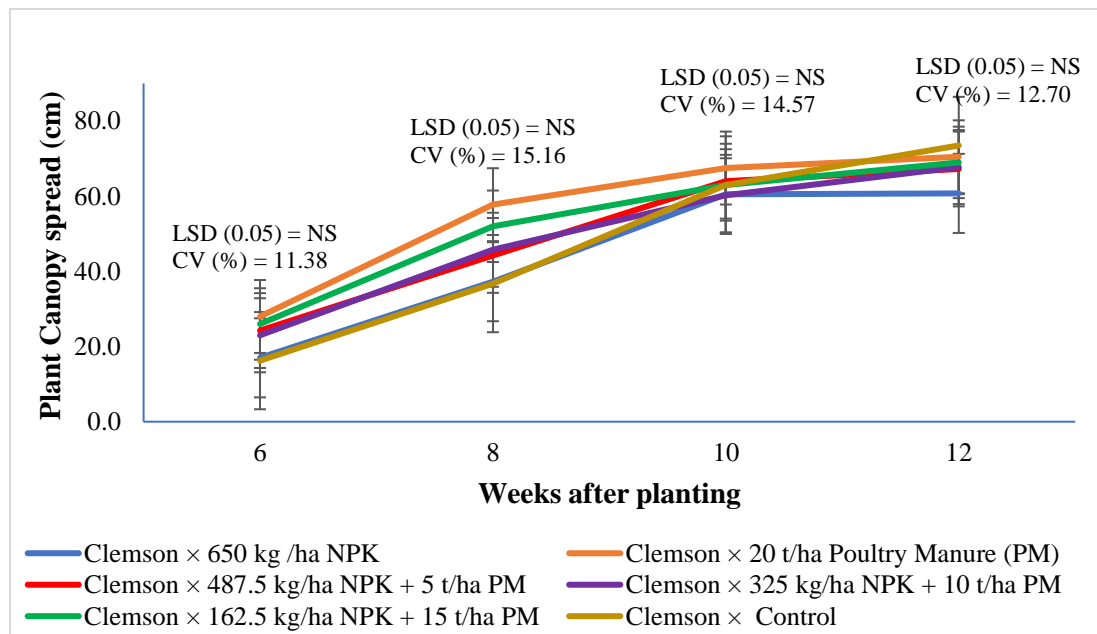
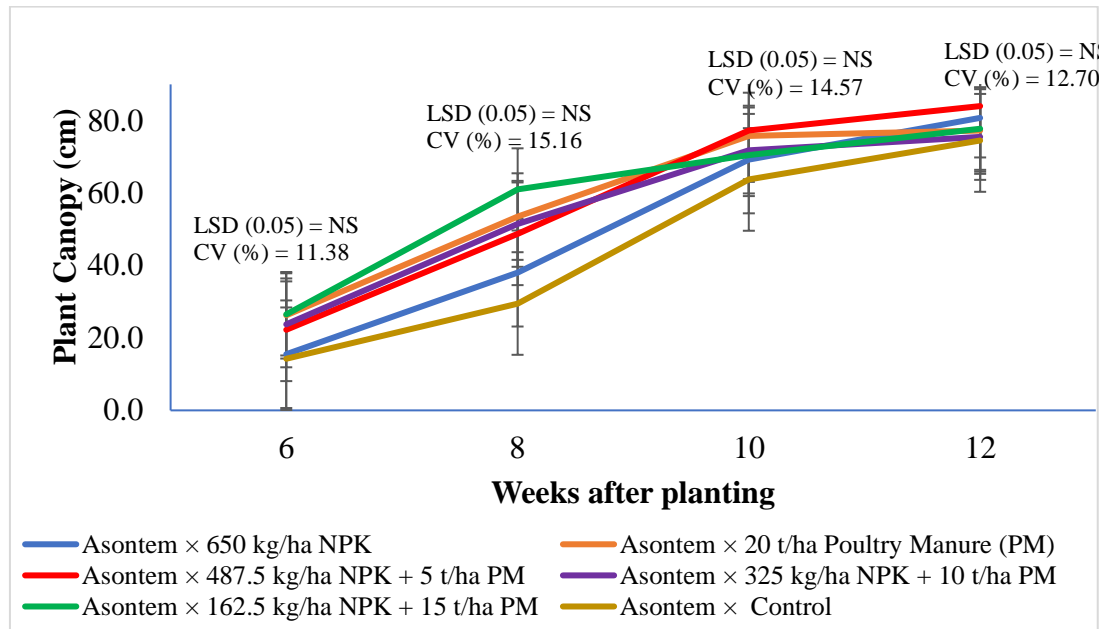


Figure 4. 9: Effect of integrated nutrient management on plant canopy spread in 2021 cropping seasons.

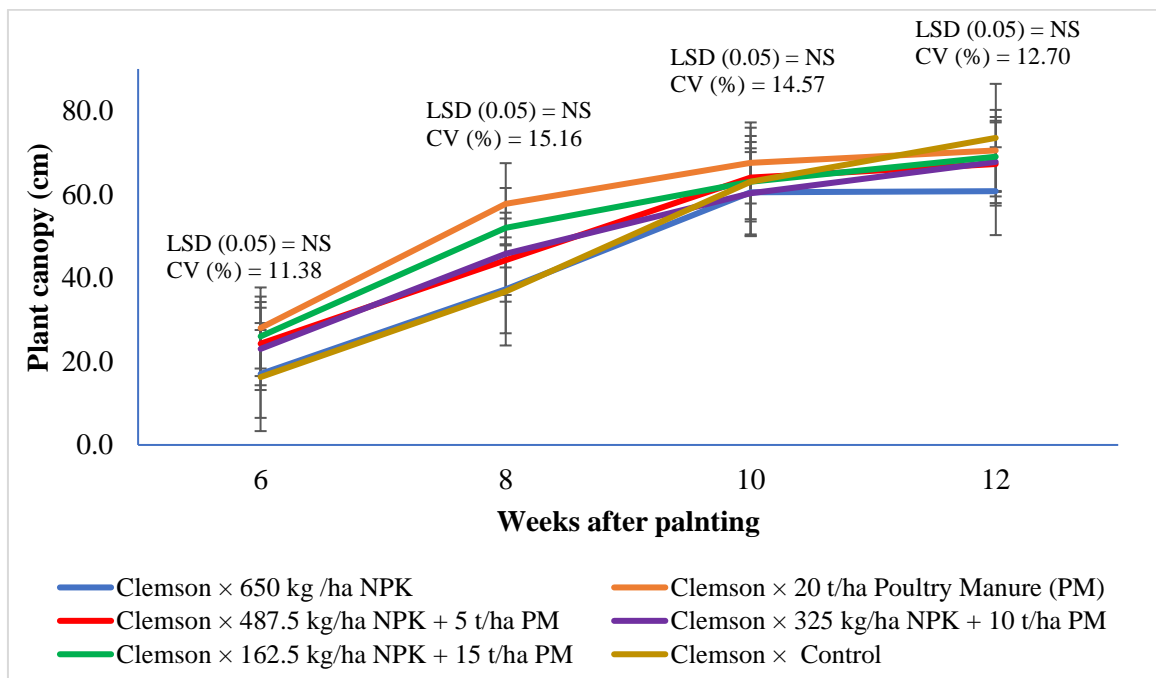
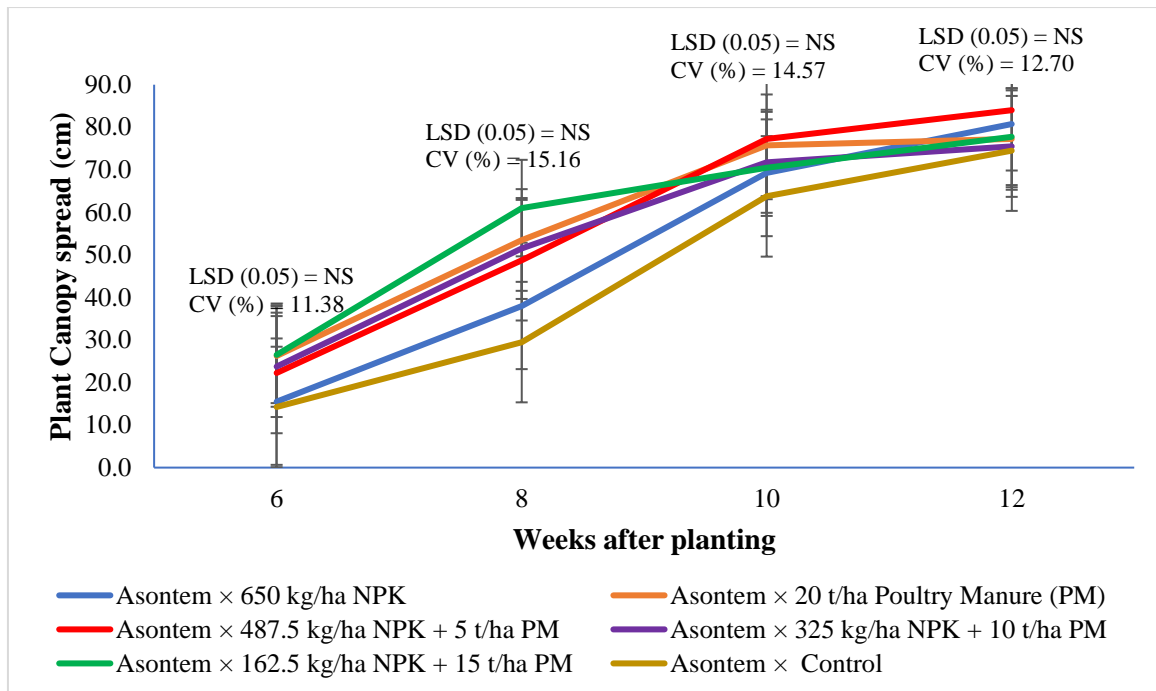


Figure 4. 10: Effect of integrated nutrient management on plant canopy spread in 2022 cropping seasons.

4.5.6 Chlorophyll content of leaf

Figures 4.11 and 4.12 show the results of chlorophyll content of leaf as influenced by the combined effect of poultry manure (PM) and NPK (15:15:15) fertilizer in both 2021 and 2022 cropping season. Generally, the chlorophyll content did not differ significantly at each sampling period for both cropping seasons.

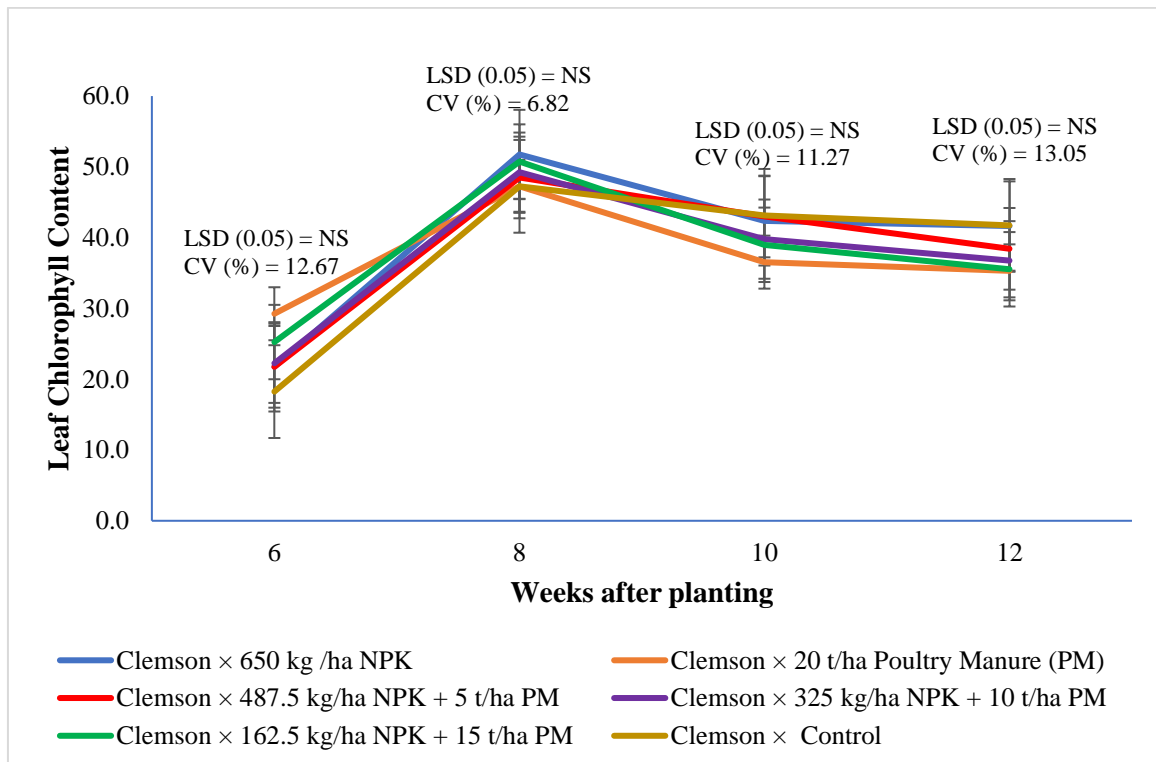
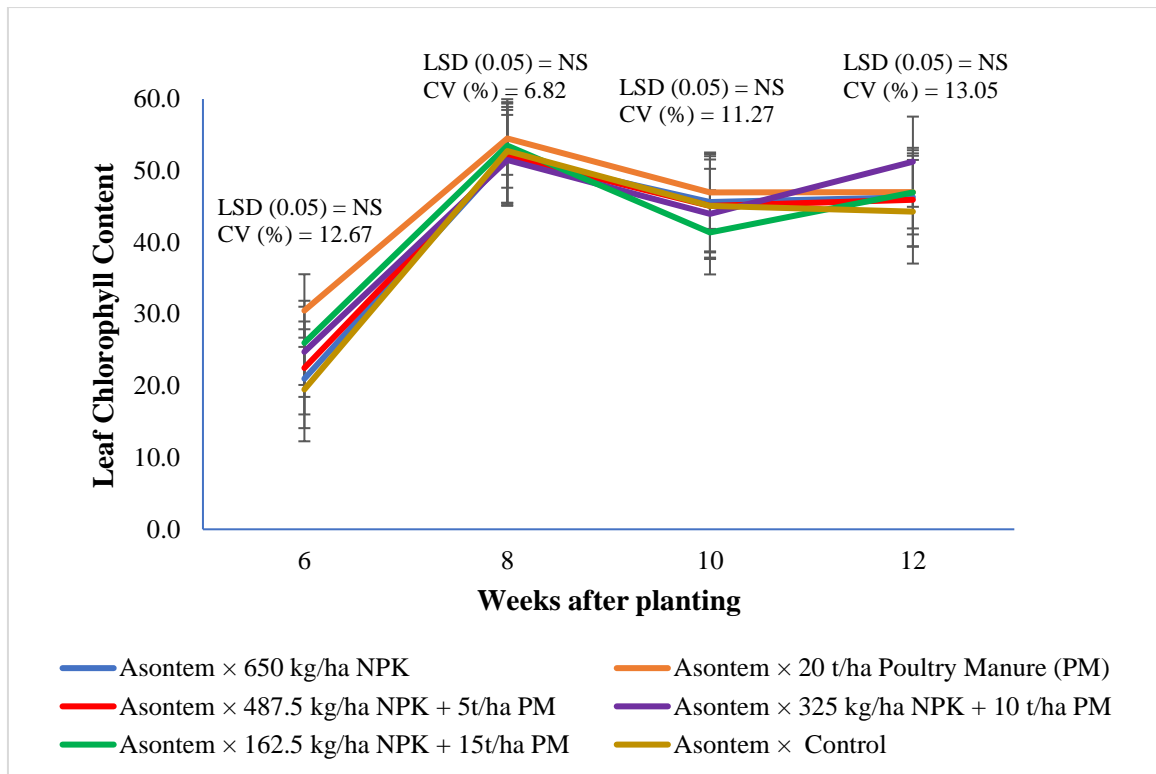


Figure 4. 11: Effect of integrated nutrient management on leaf chlorophyll content for 2021 cropping seasons.

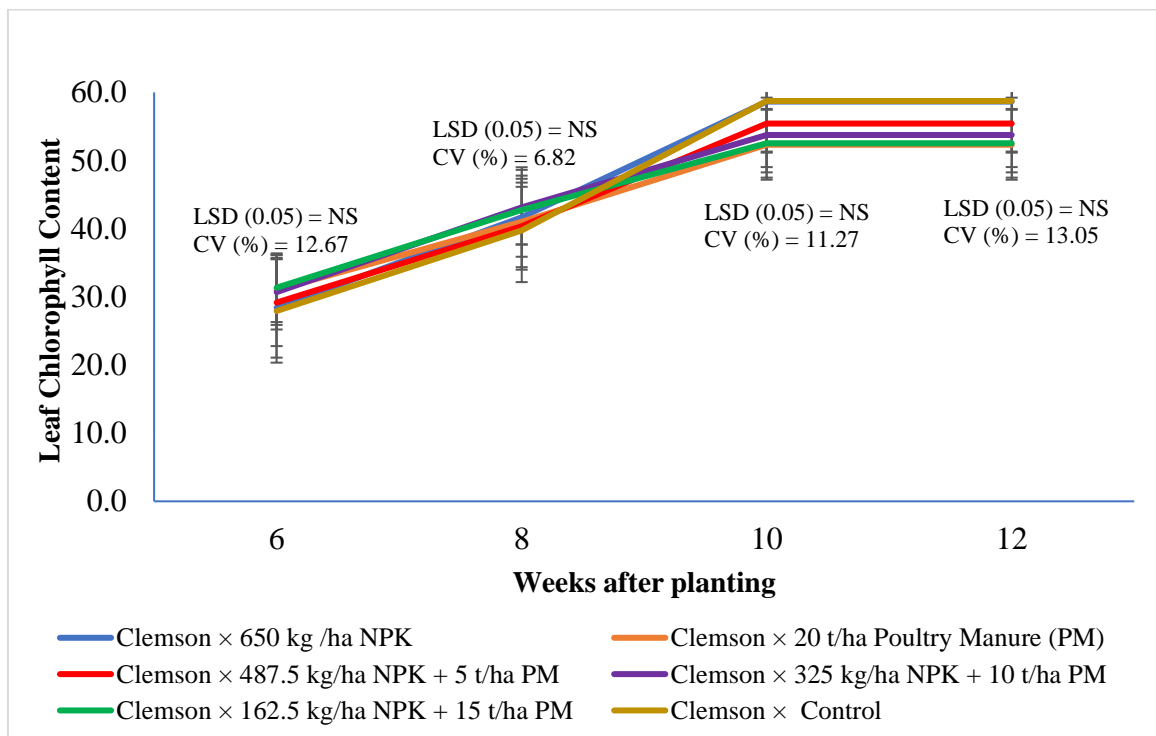
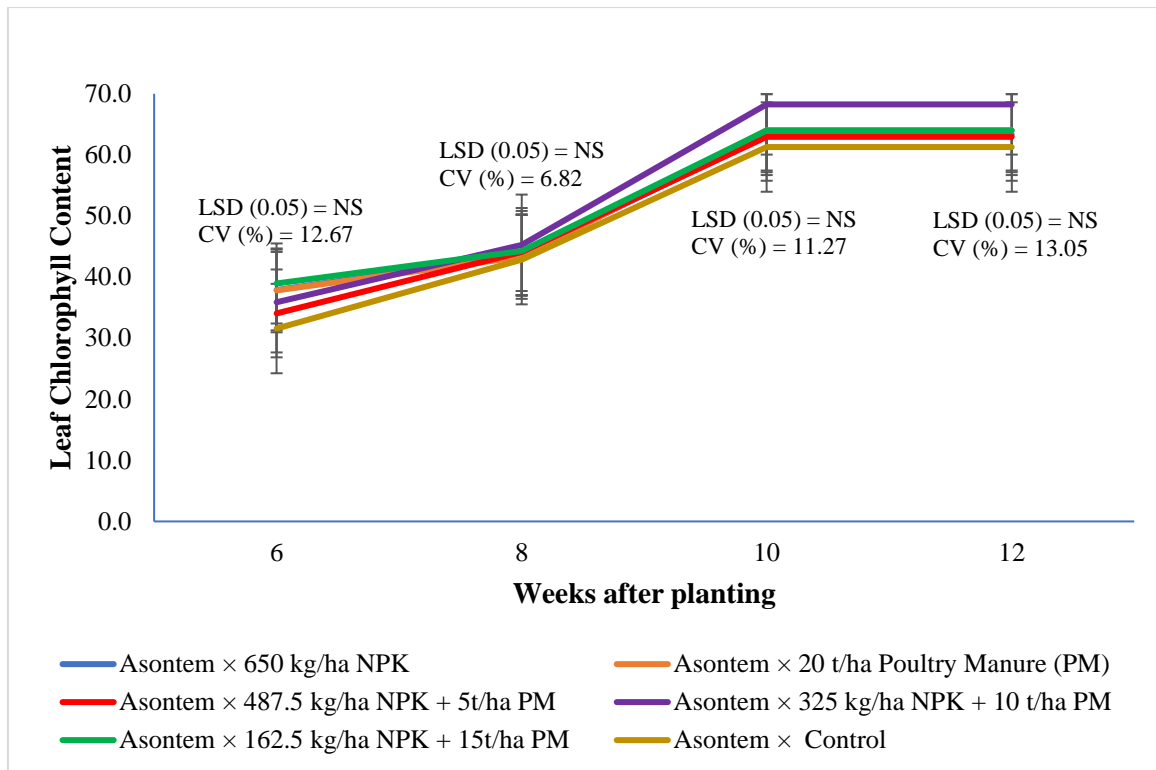


Figure 4. 12: Effect of integrated nutrient management on leaf chlorophyll content for 2022 cropping seasons

4.5.7 Dry matter accumulation

Figure 4.13 shows the results of dry matter yield accumulation of Asontem and Clemson spineless varieties as affected by integrated nutrient management for the 2021 and 2022 cropping seasons combined. The trends in dry matter accumulation were similar for both varieties. Generally, the combination of 325 kg/ha NPK + 10 t/ha PM and 20 t/ha PM applied to both varieties had the highest dry matter accumulation over the sampling periods (Table 4.13). The combination of 162.5 kg/ha NPK + 15 t/ha PM and 487.5 kg/ha NPK + 5 t/ha PM produced intermediate dry accumulation over the sampling periods, while the 650 kg/ha NPK and no fertilizer (Control), on the average, had the least dry matter accumulation over the sampling periods (Table 4.13).

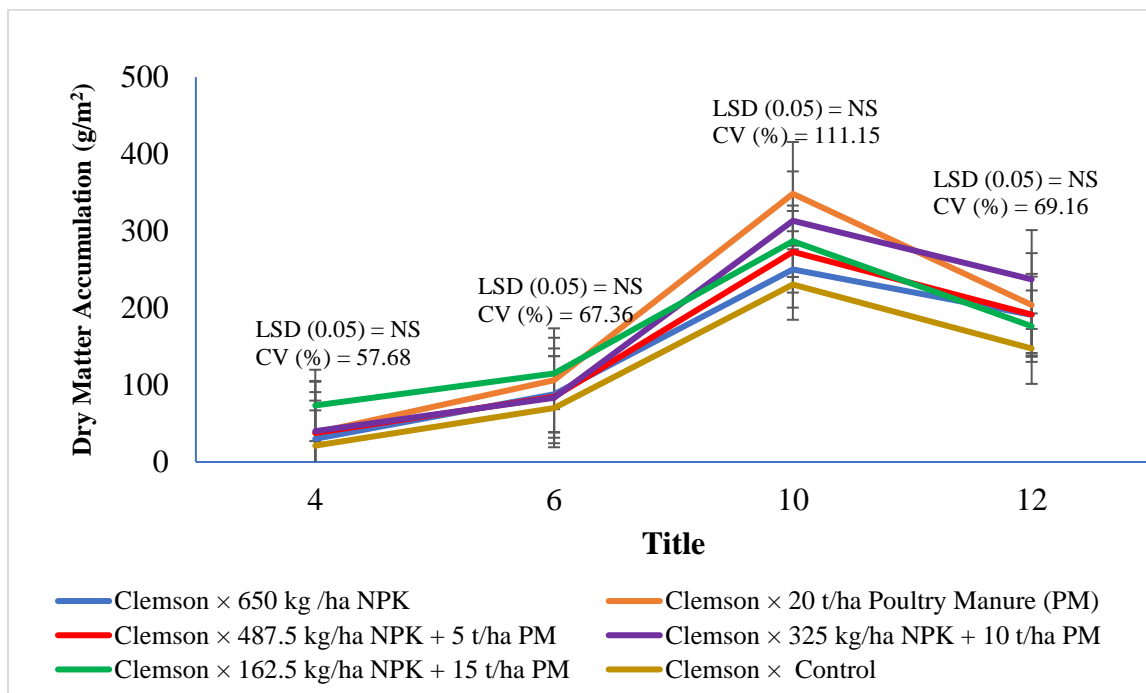
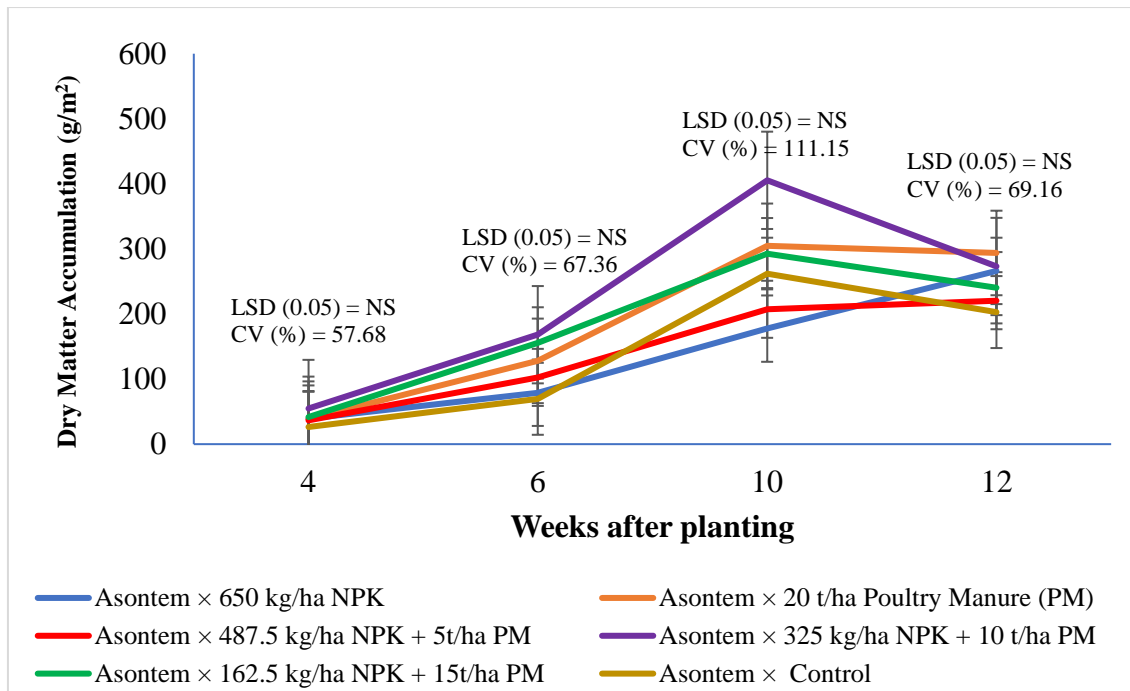


Figure 4. 13: Effect of integrated nutrient management on dry matter accumulation of okro 2021 and 2022

4.6 Yield and Yield Components

4.6.1 Number of fruits per plant

Table 4.8 shows the results of the number of fruits per plant as effected by the integrated nutrient management. There were significant differences in the number of fruits per plant between the varieties and among the fertilizer combinations for both seasons. On the average, Clemson spineless produced slightly higher number of fruits per plant (17-22) than Asontem (17-20) in both seasons (Table 4.8). Across the two seasons, the no fertilizer (control) treatment had the least number of fruits per plant (15-19) compared with the fertilizer treatments (17-22). Although, the number of fruits per plant were similar among the fertilizer treatments, the 325 kg/ha NPK +10 t/ha PM and 162.5 kg/ha NPK +15 t/ha PM produced slightly higher fruits per plant (20-22) compared with the other which ranged from 19-21 fruits per plant (Table 4.8).

Table 4. 8: Influence of integrated nutrient management on number of fruits per plant.

Fertilizer	Number of fruits per plant					
	2021 cropping season			2022 cropping season		
	Ason-tem	Clem-son	Mean	Ason-tem	Clem-son	Mean
650 kg /ha NPK	20	21	21	16	18	17
20 t/ha Poultry Manure	20	22	21	18	20	19
487.5 kg /ha NPK + 5 t/ ha PM	20	22	21	18	20	19
325 kg/ ha NPK + 10 t/ha PM	21	23	22	18	21	20
162.5 kg/ ha NPK + 15 t/ha PM	20	23	22	18	21	20
Control	18	20	19	14	16	15
Mean	20	22		17	19	
CV (%)		10.91			10.91	
Year (LSD=0.05)		NS			NS	
Variety (LSD=0.05)		0.86**			0.86**	
Fertilizer (LSD=0.05)		1.49*			1.49*	
Interaction						
Year x Variety (LSD=0.05)		NS			NS	
Year x Fertilizer (LSD=0.05)		NS			NS	
Variety x Fert. (LSD=0.05)		NS			NS	
Year x Var. x Fert. (LSD=0.05)		NS			NS	

NS= Not significant, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

4.6.2 Fruit length

Table 4.9 shows the fresh fruit length of Asontem and Clemson spineless okro varieties as affected by integrated nutrient management during the 2021 and 2022 cropping seasons. Generally, the fruit length differed significantly among the varieties in 2021 and the 2022 cropping seasons. The year x fertilizer interaction was also significant for the fruit length. However, there were no significant differences among the fertilizer treatments nor the year x variety, variety x fertilizer and year x variety x fertilizer interactions. In both 2021 and 2022 cropping seasons, the Clemson spineless variety had longer fruit length (9.22 cm and 12.99 cm, respectively) than Asontem variety (6.79 cm and 10.19 cm, respectively) (Table 4.9). For the year x fertilizer interaction, 325 kg/ha NPK + 10 t/ha PM and 162.5 kg/ha NPK +15 t/ha PM treatments had the longest mean fruit length in the 2021 cropping season (8.28 cm – 8.60 cm), while the 650 kg/ha NPK and 487.5 kg/ha +5 t/ha PM had the longest mean fruit length in the 2022 cropping season (12.05 cm – 13.20 cm). The 650 kg/ha NPK had the least mean fruit length in 2021 cropping season, while the control (no fertilizer) had the least fruit length in 2022 cropping season (Table 4.9).

Table 4. 9: Effect of integrated nutrient management on fruit length of okro varieties

Fertilizer	Fruit length (cm)					
	2021 cropping season			2022 cropping season		
	Ason-tem	Clem-son	Mean	Ason-tem	Clem-son	Mean
650 kg /ha NPK	8.20	7.18	7.69	11.57	14.83	13.20
20 t/ha Poultry Manure	6.15	10.10	8.13	10.87	12.35	11.61
487.5 kg /ha NPK + 5 t/ ha PM	5.53	9.10	7.32	9.45	14.65	12.05
325 kg/ ha NPK + 10 t/ha PM	6.93	10.27	8.60	9.88	13.5	11.69
162.5 kg/ ha NPK + 15 t/ha PM	7.28	9.28	8.28	10.49	13.28	11.89
Control	6.68	9.40	8.04	8.87	9.36	9.12
Mean	6.79	9.22		10.19	12.99	
CV (%)		21.07			21.07	
Year (LSD=0.05)		NS			NS	
Variety (LSD=0.05)		0.84**			0.84**	
Fertilizer (LSD=0.05)		NS			NS	
Interaction						
Year x Variety (LSD=0.05)		NS			NS	
Year x Fertilizer (LSD=0.05)		2.06*			2.06*	
Variety x Fert. (LSD=0.05)		NS			NS	
Year x Var. x Fert. (LSD=0.05)		NS			NS	

NS= Not significant, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

4.6.3 Fruit diameter

Table 4.10 show the effects of different fertilizer combinations on fruit diameter of two okro varieties (Ason-tem and Clem-son) during the 2021 and 2022 cropping seasons. Generally, the fruit diameter differed significantly between the varieties and among the fertilizer treatments in both cropping seasons. On the average in the 2021 and 2022 cropping seasons, Ason-tem had greater fruit diameter (2.30 cm and 2.69 cm, respectively) compared with the Clem-son spineless variety (2.01cm and 2.41cm, respectively) (Table 4.10). For the fertilizer treatments, the 650 kg/ha NPK (full NPK), 20 t/ha PM (full PM) and 325 kg/ha NPK + 10 t/ha PM ($\frac{1}{2}$ NPK + $\frac{1}{2}$ PM) had the highest fruit diameter in 2021 cropping season, while the control (no fertilizer) and 162.5 kg/ ha NPK + 15 t/ha PM treatments had the least fruit diameter. Similar results were obtained in the 2022 cropping season, where the 650 kg/ha NPK (full NPK), 20 t/ha PM (full PM) and 325 kg/ha NPK +

10 t/ha PM ((½ NPK + ½ PM) treatments had the highest fruit diameter, while the the control (no fertilizer) treatment had the least fruit diameter (Table 4.10).

The variety x fertilizer interaction was significant for both years. However, all the other interactions were not significant (Table 4.10). The least fruit diameter for Asontem and Clemson was obtained in the 162.5 kg/ha NPK + 15 t/ha PM and no fertilizer (control) respectively treatments in 2021 cropping seasons. The least average fruit diameter for both Asontem and Clemson spineless was obtained in the no fertilizer (control) in 2022 cropping season (Table 4.10).

Table 4. 10: Effect of integrated nutrient management on fruit diameter of okro varieties in 2021 and 2022 cropping season.

Fertilizer combination	Fruit diameter (cm)					
	2021 cropping season			2022 cropping season		
	Asontem	Clemson	Mean	Asontem	Clemson	Mean
650 kg /ha NPK	2.33	2.16	2.25	2.78	2.54	2.66
20 t/ha Poultry Manure	2.54	2.01	2.28	2.88	2.32	2.60
487.5 kg /ha NPK + 5t/ ha	2.27	1.93	2.10	2.70	2.29	2.49
325 kg/ ha NPK + 10 t/ha PM	2.27	2.08	2.18	2.81	2.42	2.62
162.5 kg/ ha NPK + 15t/ha PM	2.16	1.97	2.07	2.48	2.60	2.54
Control	2.25	1.89	2.07	2.53	2.29	2.41
Mean	2.30	2.01		2.69	2.41	
CV (%)	10.28			10.28		
Year (LSD=0.05)	NS			NS		
Variety (LSD=0.05)	0.10**			0.10**		
Fertilizer (LSD=0.05)	0.16*			0.16*		
Interaction						
Year x Variety (LSD=0.05)	NS			NS		
Year x Fertilizer (LSD=0.05)	NS			NS		
Variety x Fert. (LSD=0.05)	0.23*			0.23*		
Year x Var. x Fert. (LSD=0.05)	NS			NS		

NS= Not significant, * = p< 0.05, ** = p <0.01, *** = p < 0.001

4.6.4 Total fruit yield

Table 4.11 shows the effects of different fertilizer combinations on the total fruit yield of the two okro varieties (Asontem and Clemson) during the 2021 and 2022 cropping seasons. Generally, the total fruit yield differed significantly between the varieties and among the fertilizer over the 2021 and the 2022 cropping seasons. There were no significant interaction effects on fruit yield. In the 2021 cropping season, Asontem produced higher fruit yield (9.39 t/ha, about 19% higher) than that produced by Clemson spineless (7.90 t/ha). Similarly, in the 2022 cropping season, Asontem produced (4.17 t/ha) about 53.3% higher than the fruit yield produced by Clemson spineless (2.72 t/ha).

On the average, both Asontem and Clemson in 2021, the 162.5 kg/ha NPK + 15 t/ha PM treatment significantly produced the highest total fruit yield, while the 487.5 kg/ha NPK + 5 t/ha PM and 325 kg/ha NPK + 10 t/ha PM treatments produced intermediate fruit yields. The 650 kg/ha NPK (full NPK), 20 t/ha PM (full PM) and control (no fertilizer) treatments produced the least (Table 4. 11). Across the 2022 cropping season however, the 162.5 kg/ha NPK + 15 t/ha PM, 487.5 kg/ha NPK + 5 t/ha PM and 325 kg/ha NPK + 10 t/ha PM treatments produced similar but significantly higher fruit yields than the 650 kg/ha NPK (full NPK), 20 t/ha PM (full PM) and control (no fertilizer) treatments

Table 4. 11: Influence of integrated nutrient management on total fruit yield (t/ha) and number of fruits per plant.

Fertilizer combination	Total Fruit Yield (t/ha)					
	2021 cropping season			2022 cropping season		
	Asontem	Clemson	Mean	Asontem	Clemson	Mean
650 kg /ha NPK	8.99	7.89	8.44	3.83	2.39	3.11
20 t/ha Poultry Manure	8.94	7.96	8.45	3.79	2.95	3.37
487.5 kg /ha NPK + 5t/ ha	9.87	8.04	8.96	4.49	2.78	3.64
325 kg/ ha NPK + 10 t/ha PM	9.75	8.18	8.97	4.49	2.95	3.72
162.5 kg/ ha NPK + 15t/ha PM	10.03	7.84	9.94	4.73	2.98	3.86
Control	8.76	7.51	8.14	3.68	2.29	2.99
Mean	9.39	7.90		4.17	2.72	
CV (%)	9.72			9.72		
Year (LSD=0.05)	NS			NS		
Variety (LSD=0.05)	0.24**			0.24**		
Fertilizer (LSD=0.05)	0.41**			0.41**		
Interaction						
Year x Variety (LSD=0.05)	NS			NS		
Year x Fertilizer (LSD=0.05)	NS			NS		
Variety x Fert. (LSD=0.05)	NS			NS		
Year x Var. x Fert. (LSD=0.05)	NS			NS		

NS= Not significant, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

4.6.5 Partial Budget Analysis

4.6.5.1 Patial budget analysis for 2021

The partial budget analyses were done considering only fertilizer cost and its application as the total variable cost. All other production costs such as cost of land preparation, planting, weeding, etc, that did not vary among the treatments were not considered. The partial budget analysis for the 2021 cropping season is shown in Tables 4.12 and 4.13.

In general, all the treatments were economically attractive or profitable as they had positive net benefits. Furthermore, all the benefit cost ratio (BCR) for all the fertilizer treatments under the two varieties were greater than 5.0, ranging from 10.01-12.13 for Asontem and 7.45 – 8.44 for Clemson spineless (Tables 4.12 and 4.13). The results indicate that the Asontem variety with 162.5 kg/ha NPK + 15 t/ha PM application gave the highest net benefit and BCR among the treatments in 2021, while the Clemson spineless 650 kg/ha NPK gave the least net benefit and BCR. The 325 kg/ha NPK + 10 t/ha PM and 20 t/ha PM

treatments under both Asontem and Clemson spineless gave intermediate BCR (Table 4.12 and 4.13).

The dominance analysis (MRR) for the 2021 cropping season shows that Asontem no fertilizer (control) treatment has dominated both Clemson spineless and Asontem at 20 t/ha PM and then Clemson at 162.5 kg/ha NPK + 15 t/ha PM because these treatments had higher TVC and lower net benefit compared to the Asontem no fertilizer (control) treatment (Tables 4.12 a and 4.13). The MRR results gave an MRR of 66.21% for Asontem at 162.5 kg/ha NPK + 15 t/ha PM over Asontem control (no fertilizer treatment), indicating that adopting Asontem at 162.5 kg/ha NPK + 15 t/ha PM over Asontem control (no fertilizer treatment) would give an additional gain of 65.21 Ghana cedis for every extra cedi invested. Asontem at 162.5 kg/ha NPK + 15 t/ha PM has dominated all other treatments because it has a higher Net benefit, but a lower TVC than all the other treatments (Table 4.12 and 4.13).

Table 4. 12: Partial budget analysis of Asontem during 2021 cropping season

	Asontem Full NPK	Asontem Full PM	Asontem ¾ NPK + ¼ PM	Asontem ½ NPK + ½ PM	Asontem ¼ NPK + ¾ PM	Asontem Control
<u>Gross Benefits (GB)</u>						
Total fruit yield	8.99	8.94	9.87	9.75	10.03	8.76
Farm gate price (GH¢/ton)	8000	8000	8000	8000	8000	8000
Total Gross Benefits (GH¢)	71920	71520	78960	78000	80240	70080
<u>Variable Cost (VC)</u>						
Cost of NPK (GH¢)	5850	0	4387.5	2925	1462.5	0
Cost of PM (GH¢)	0	5000	1250	2500	3750	0
Transportation cost for NPK and PM	200	300	300	300	300	0
Labour cost of application	480	600	600	600	600	0
Total Variable Cost (TVC) (GH¢)	6530	5900	6537.5	6325	6112.5	0
Net Benefit (NB) (GH¢)	65390	65620	72422.5	71675	74127.5	70080
Benefit: Cost Ratio (BCR)	10.014	11.122	11.078	11.332	12.127	0.000
<u>Marginal Rate of Returns (MRR)</u>						
	Clemson Control	Asontem Control	Clemson Full PM	Asontem Full PM	Clemson ¼ NPK + ¾ PM	Asontem ¼ NPK + ¾ PM
TVC (GH¢)	0	0	5900	5900	6112.5	6112.5
NB (GH¢)	52570	70080	49820	65620	48767.5	74127.5
			D*	D*	D*	66.217
MRR=(ΔNB/ΔTVC) x 100				221.187		

TVC=Total Variable Cost (GH¢); NB=Net Benefit (GH¢); MRR= Marginal Rate of Returns; D*=Dominated

Table 4. 13: Partial budget analysis of Clemson Spineless during 2021 cropping season

	Clemson Full NPK	Clemson Full PM	Clemson ¾ NPK + ¼ PM	Clemson ½ NPK + ½ PM	Clemson ¼ NPK + ¾ PM	Clemson Control
<u>Gross Benefits</u>						
Total fruit yield	7.89	7.96	8.04	8.18	7.84	7.51
Farm gate price (GH¢/ton)	7000	7000	7000	7000	7000	7000
Total Gross Benefits (GH¢)	55230	55720	56280	57260	54880	52570
<u>Variable Cost</u>						
Cost of NPK (GH¢)	5850	0	4387.5	2925	1462.5	0
Cost of PM (GH¢)	0	5000	1250	2500	3750	0
Transportation cost for NPK and PM	200	300	300	300	300	0
Labour cost of application	480	600	600	600	600	0
Total Variable Cost (TVC) (GH¢)	6530	5900	6537.5	6325	6112.5	0
Net Benefit (NB) (GH¢)	48700	49820	49742.5	50935	48767.5	52570
Benefit: Cost Ratio (BCR)	7.458	8.444	7.609	8.053	7.978	0.000
<u>Marginal Rate of Returns (MRR)</u>						
	Clemson ½ NPK + ½ PM	Asontem ½ NPK + ½ PM	Clemson Full NPK	Asontem Full NPK	Clemson ¾ NPK + ¼ PM	Asontem ¾ NPK + ¼ PM
TVC (GH¢)	6325	6325	6530	6530	6537.5	6537.5
NB (GH¢)	50935	71675	48700	65390	49742.5	72422.5
	D*	D*	D*	D*	D*	D*
MRR=(ΔNB/ΔTVC) x 100			D*	D*	D*	351.765

TVC=Total Variable Cost (GH¢); NB=Net Benefit (GH¢); MRR= Marginal Rate of Returns; D*=Dominated

4.6.5.2 Partial budget analysis for 2022

Tables 4.14 and 4.15 show the partial budget analysis for the 2022 cropping season. Like the 2021 cropping season, all the treatments were economically attractive or profitable with positive net benefits. In addition, all the benefit: cost ratio (BCR) for all the fertilizer treatments under the two varieties were close to 2.0, ranging from 3.69 – 5.19 for Asontem and 1.56 – 2.50 for Clemson spineless (Tables 4.14 and 4.15). Similarly, in 2022, the Asontem variety with 162.5 kg/ha NPK + 15 t/ha PM fertilizer application gave the highest net benefit and BCR, while the Clemson spineless 650 kg/ha NPK gave the least net benefit and BCR (Tables 4.14 and 4.15). The 325 kg/ha NPK + 10 t/ha and 487.5 kg/ha NPK + 5 t/ha PM treatments under Asontem and 325 kg/ha NPK + 10 t/ha and 162.5 kg/ha NPK + 15 t/ha PM under Clemson spineless gave intermediate BCR (Tables 4.14 and 4.15).

The dominance analysis (MRR) for the 2022 cropping season showed that Asontem control (no fertilizer) treatment has dominated both Clemson spineless at 20 t/ha PM. However, Asontem at 20 t/ha PM had an MRR of 5.254% over Asontem no fertilizer control, indicating that adoption of Asontem at 20 t/ha PM over the Asontem no fertilizer (control) would give an additional 4.524 Ghana cedis for every extra one cedi invested. Asontem 20 t/ha PM also Clemson spineless at 162.5 kg/ha NPK + 15 t/ha PM because this treatment had a higher TVC and lower net benefit compared to the Asontem at 20 t/ha PM (Tables 4.14 and 4.15). The MRR results of 3438.82% for Asontem at 162.5 kg/ha NPK + 15 t/ha PM over Asontem at 20t/ha PM, indicating that adopting Asontem at 162.5 kg/ha NPK + 15 t/ha PM over Asontem at 20 t/ha PM would give an additional gain of 3437.82 Ghana cedis for every extra one cedi invested. Similar to 2021, Asontem at 162.5 kg/ha NPK + 15 t/ha PM has dominated all other treatments in 2022 cropping season, because it has a higher net benefit, but a lower TVC than all the other treatments (Tables 4.14 and 4.15).

Table 4. 14: Partial budget analysis of Asontem during 2022 cropping season

	Asontem Full NPK	Asontem Full PM	Asontem ¾ NPK + ¼ PM	Asontem ½ NPK + ½ PM	Asontem ¼ NPK + ¾ PM	Asontem Control
<u>Gross Benefits (GB)</u>						
Total fruit yield	3.83	3.79	4.49	4.49	4.73	3.68
Farm gate price (GH¢/ton)	8000	8000	8000	8000	8000	8000
Total Gross Benefits (GH¢)	30640	30320	35920	35920	37840	29440
<u>Variable Cost (VC)</u>						
Cost of NPK (GH¢)	5850	0	4387.5	2925	1462.5	0
Cost of PM (GH¢)	0	5000	1250	2500	3750	0
Transportation cost for NPK and PM	200	300	300	300	300	0
Labour cost of application	480	600	600	600	600	0
Total Variable Cost (TVC) (GH¢)	6530	5900	6537.5	6325	6112.5	0
Net Benefit (NB) (GH¢)	24110	24420	29382.5	29595	31727.5	29440
Benefit: Cost Ratio (BCR)	3.692	4.139	4.494	4.679	5.191	0.000
<u>Marginal Rate of Returns (MRR)</u>						
	Clemson Control	Asontem Control	Clemson Full PM	Asontem Full PM	Clemson ¼ NPK + ¾ PM	Asontem ¼ NPK + ¾ PM
TVC (GH¢)	0	0	5900	5900	6112.5	6112.5
NB (GH¢)	16030	24110	14750	24420	14747.5	31727.5
			D*	5.254	D*	3438.823
MRR=(ΔNB/ΔTVC) x 100				142.203		

TVC=Total Variable Cost (GH¢); NB=Net Benefit (GH¢); MRR= Marginal Rate of Returns; D*=Dominated

Table 4. 15: Partial budget analysis of Clemson Spineles during 2022 cropping season

	Clemson Full NPK	Clemson Full PM	Clemson ¾ NPK + ¼ PM	Clemson ½ NPK + ½ PM	Clemson ¼ NPK + ¾ PM	Clemson Control
<u>Gross Benefits (GB)</u>						
Total fruit yield	2.39	2.95	2.78	2.95	2.98	2.29
Farm gate price (GH¢/ton)	7000	7000	7000	7000	7000	7000
Total Gross Benefits (GH¢)	16730	20650	19460	20650	20860	16030
<u>Variable Cost (VC)</u>						
Cost of NPK (GH¢)	5850	0	4387.5	2925	1462.5	0
Cost of PM (GH¢)	0	5000	1250	2500	3750	0
Transportation cost for NPK and PM	200	300	300	300	300	0
Labour cost of application	480	600	600	600	600	0
Total Variable Cost (TVC) (GH¢)	6530	5900	6537.5	6325	6112.5	0
Net Benefit (NB) (GH¢)	10200	14750	12922.5	14325	14747.5	16030
Benefit: Cost Ratio (BCR)	1.562	2.500	1.977	2.265	2.413	0.000
<u>Marginal Rate of Returns (MRR)</u>						
	Clemson ½ NPK + ½ PM	Asontem ½ NPK + ½ PM	Clemson Full NPK	Asontem Full NPK	Clemson ¾ NPK + ¼ PM	Asontem ¾ NPK + ¼ PM
TVC (GH¢)	6325	6325	6530	6530	6537.5	6537.5
NB (GH¢)	14325	29595	10200	24110	12922.5	29382.5
	D*	D*	D*	D*	D*	D*
MRR=(ΔNB/ΔTVC) x 100			D*	D*	D*	D*

TVC=Total Variable Cost (GH¢); NB=Net Benefit (GH¢); MRR= Marginal Rate of Returns; D*=Dominated

4.7 Nutritional (Proximate) Analysis of Harvested Fresh Okro Fruits

4.7.1 Moisture content

The effect of integrated nutrient management on the storage nutritional status of fresh okro from the field showed that there was a significant difference in the mean percentage moisture content between the varieties and among the fertilizer treatments (Table 4.16). There was also a significant variety x fertilizer interaction on moisture content. The fresh fruit percentage moisture ranged from 26.30 % – 26.74 % and 25.69 % - 26.44 % for Asontem and Clemson spineless, respectively (Table 4.16). Under Asontem, the 650 kg/ha NPK had the highest percentage moisture, while 20 t/ha PM had the least percentage moisture content (Table 4.16). However, under Clemson spineless variety, 487.5 kg/ha NPK + 5 t/ha PM had the highest percentage moisture content with the 20 t/ha PM having the lowest moisture content (Table 4.16).

4.7.2 Ash content

The percentage ash content of fresh okro fruits also showed significant differences between the varieties and among the fertilizer treatments as well as the variety x fertilizer interaction (Table 4.16). The ash content of okro ranged from 7.80 % - 8.00 % for Asontem and 8.25 % - 8.60 % for Clemson spineless. The highest ash content of Asontem was achieved for 162.5 kg/ ha NPK + 15t/ha PM treatment, while the least was in 487.5 kg/ha NPK+5 t/ha PM and the control treatment. The highest percentage ash content in Clemson spineless was achieved under the control (no fertilizer) while the least percentage ash content was observed in 487.5 kg/ha NPK+5 t/ha PM treatment (Table 4.16).

Table 4. 16: Effect of integrated nutrient management on nutritional analysis of fresh okro fruit for combined 2021 and 2022 cropping seasons.

Treatment combinations		Moisture	Total Ash	Crude Protein	Crude Fat	Crude Fibre	Carbohydrate
		(%)	(%)	(%)	(%)	(%)	(%)
Asontem	650 kg /ha NPK	26.74	7.96	15.46	2.39	15.07	32.37
	20 t/ha Poultry Manure	26.30	7.81	15.19	2.25	14.52	33.93
	487.5 kg /ha NPK + 5t/ ha PM	26.47	7.80	15.49	2.31	14.40	33.54
	325 kg/ ha NPK + 10 t/ha PM	26.64	7.86	15.30	2.42	14.11	33.69
	162.5 kg/ ha NPK + 15t/ha PM	26.52	8.00	15.51	2.73	14.12	33.14
	Control	26.61	7.80	15.60	2.47	14.59	32.94
Clemson	650 kg /ha NPK	26.22	8.34	16.46	2.49	13.95	32.54
	20 t/ha Poultry Manure	26.00	8.52	15.62	2.20	14.61	33.05
	487.5 kg /ha NPK + 5t/ ha PM	26.44	8.25	16.26	2.56	14.57	31.93
	325 kg/ ha NPK + 10 t/ha PM	25.69	8.39	16.23	2.38	14.73	32.58
	162.5 kg/ ha NPK + 15t/ha PM	25.82	8.47	16.07	2.27	14.53	32.84
	Control	26.14	8.60	15.74	2.55	13.85	33.12
Mean		24.09	8.15	15.74	2.42	13.21	32.97
CV (%)		1.03	1.00	1.26	9.75	3.69	1.86
Variety (LSD=0.05)		0.08**	0.02**	0.06**	NS	NS	0.181**
Fertilizer (LSD=0.05)		0.139**	0.04**	0.102*	0.13**	NS	0.315**
Interactions							
Variety x Fertilizer (LSD=0.05)		0.025**	0.041**	0.36**	0.05**	0.12**	0.06**

NS= Not significant, * = p< 0.05, ** = p <0.01, *** = p < 0.001

4.7.3 Crude protein content

The results on percentage crude protein shown in Table 4.16 similarly indicated significant difference among varieties, fertilizer treatments and variety x fertilizer interaction. Asontem okro had the highest mean value of percentage crude protein recorded in the control (no fertilizer), while the least was obtained under the application of 20 t/ha PM. Under Clemson spineless, however, the highest mean crude protein percentage was recorded under 650 kg/ha NPK, with the least percentage crude protein content at 20 t/ha PM applied.

4.7.4 Crude fat content

Table 4.16 indicates results of crude fat content of okro varieties as influenced by Integrated Nutrient Management. Crude fibre content ranged from 2.25 % - 2.73 % for Asotem and 2.20 % - 2.56 % for Clemson spineless. The results showed that there were no significant differences between the varieties. However, there were significant differences among the fertilizer treatments as well as the variety x fertilizer interaction (Table 4.16). Under Asontem the highest percentage crude fat mean was recorded under 162.5 kg/ha NPK + 15 t/ha PM, while the lowest was under the 20 t/ha PM treatment. The rest of the treatments had for combined 2021 and 2022 cropping seasons crude fat content. Under Clemson spineless variety, the highest percentage crude fat content was obtained under 487.5 kg/ha NPK + 5 t/ha PM, while the lowest was achieved under 20 t/ha PM treatment (Table 4.16).

4.7.5 Crude fibre content

The results of crude fibre content presented in Table 4.16. showed that there were no significant differences between the varieties as well as the fertilizer treatments. However, the variety x fertilizer interaction was significant. The crude fibre content ranged from

14.11 % - 15.07 % for Asontem and 13.85 % - 14.73 % for Clemson spineless (Table 4.16). Under Asontem, the highest crude fibre content was recorded with the application of 650 kg/ha NPK, while the least was recorded with the application of 325 kg/ha NPK +10 t/ha PM fertilizer. With the Clemson spineless variety, the highest crude fibre content was obtained when 325 kg/ha NPK +10 t/ha PM was applied. Clemson recorded the least crude protein content value under the control (no fertilizer) treatment.

4.7.6 Carbohydrate content

Table 4.16 shows the carbohydrate content results differed significantly among the varieties, fertilizer treatments and the variety x fertilizer interaction. The carbohydrate contents ranged from 32.37 % - 33.93 % and 31.93 % - 33.12 % for Asontem and Clemson spineless, respectively (Table 4.16). Under the Asontem variety the highest percentage of carbohydrate content was recorded when 20 t/ha PM fertilizer was applied, while the lowest was observed 650 kg/ha NPK application. Clemson spineless had the highest carbohydrate content in the control treatment, while the least was obtained where 487.5 kg /ha NPK + 5t/ha PM was applied.

4.7.7 Total sugars content

The effect of integrated nutrient management on the nutritional status of fresh okro fruits showed that there was a significant difference in the mean total sugars content among the varieties, fertilizer treatments and variety x fertilizer interaction (Table 4.17). The total sugars content ranged from 32.09 % - 40.50 % for Asontem and 37.91% - 40.76 % for Clemson spineless. Under Asontem, total sugars content was higher with the control (no fertilizer) treatment, while the lowest total sugars were observed in the 162.5 kg/ha NPK + 15 t/ha PM (Table 4.17). Under Clemson, the highest content of total sugars was obtained

with the application of 650 Kg/ha NPK, while the least was observed with the application of 325 kg/ha NPK +10 t/ha PM treatment.

4.7.8 Total solids content

The total solids content of the fresh okro fruits ranged from 73.26 % - 73.70 % for Asontem and 73.56 % - 74.31 % for Clemson spineless (Table 4.17). The results indicated that the variety, fertilizer and variety x fertilizer interaction differed significant for total solids content in the fresh fruits. Asontem had the highest fresh okro mean total solids content when 20 t/ha PM was applied, while the lowest fresh total solids content was obtained where 650 kg/ha NPK was applied (Table 4.17). The highest mean total solids content of fresh fruits under Clemson was obtained with the application of 325 kg/ha NPK +10 t/ha PM, while the lowest was observed in treatments where 487.5 kg/ha NPK+5 t/ha PM was applied (Table 4.17).

4.7.9 Total energy content

The results in Table 4.17 shows that fertilizer and variety x fertilizer interaction significantly affected the total energy content of the fresh okro fruits. Total energy did not differ significantly between the varieties. The total energy ranged from 212.90 – 217.66 kcal/100mg for Asontem and 214.48 – 218.39 kcal/100 for Clemson spineless. With Asontem, the highest total energy content was obtained where 325 kg/ha NPK +10 t/ha PM was applied, while the least was obtained where 650 kg/ha NPK was applied (Table 4.17). Under Clemson spineless, the highest fresh okro total energy content was recorded with the control (no fertilizer) application and the lowest was observed in the application of 20 t/ha PM (Table 4.17). Generally, the total energy mean values recorded in Asontem were slightly lower than the values recorded in Clemson (Table 4.17).

Table 4. 17: Effect of integrated nutrient management on nutritional analysis of fresh okro fruits for combined 2021 and 2022 cropping seasons.

Treatment combinations		Total Sugars (%)	Total Solids (%)	Total Energy (kcal/100g)	Nitrogen (%)	Vitamin C (mg/100g)	Potassium (mg/100g)
Asontem	650 kg /ha NPK	34.89	73.26	212.90	2.47	20.63	302.97
	20 t/ha Poultry Manure	34.29	73.70	216.72	2.43	20.79	294.03
	487.5 kg /ha NPK + 5t/ ha PM	36.34	73.53	216.90	2.48	20.28	300.19
	325 kg/ ha NPK + 10 t/ha PM	34.00	73.36	217.66	2.45	20.21	298.87
	162.5 kg/ ha NPK + 15t/ha PM	32.09	73.48	216.12	2.48	20.74	294.57
	Control	40.50	73.39	216.33	2.50	19.91	293.77
Clemson	650 kg /ha NPK	40.76	73.77	218.37	2.63	22.64	286.55
	20 t/ha Poultry Manure	38.82	73.99	214.48	2.50	21.92	290.68
	487.5 kg /ha NPK + 5t/ ha PM	39.54	73.56	215.77	2.60	20.65	300.78
	325 kg/ ha NPK + 10 t/ha PM	37.91	74.31	216.66	2.60	22.44	299.01
	162.5 kg/ ha NPK + 15t/ha PM	39.65	74.18	216.05	2.57	20.30	291.96
	Control	40.09	73.86	218.39	2.52	20.40	288.84
Mean		37.41	73.69	216.36	2.52	20.91	295.19
CV (%)		1.65	0.37	1.23	1.28	6.36	1.05
Variety (LSD=0.05)		0.18**	0.08**	NS	0.1*	0.39**	0.92**
Fertilizer (LSD=0.05)		0.33**	0.14**	1.36**	0.3*	0.68**	1.59**
Interactions							
Variety x Fertilizer (LSD=0.05)		0.22**	0.15**	0.26**	0.13**	0.71**	0.65**

NS= Not significant, * = p< 0.05, ** = p <0.01, *** = p < 0.001

4.7.10 Nitrogen content

The effect of integrated nutrient management on the nitrogen content of fresh okro fruits showed that there were significant differences among the varieties, fertilizer treatments and the variety x fertilizer interaction (Table 4.17). The content of N in Asontem ranged from 2.43 % to 2.50 %, while that in Clemson spineless ranged from 2.50 % to 2.63 % (Table 4.17). Under Asontem, the highest nitrogen content was obtained with the control (no fertilizer) treatment, whereas the lowest was observed with the 20 t/ha PM treatment. With the Clemson spineless variety, the highest N content was obtained with the application of 650 kg/ha NPK, while the least N content was obtained with the application of 20 t/ha PM (Table 4.17).

4.7.11 Vitamin C content

The results on the vitamin C content of fresh fruit okro as shown in Table 4.17 indicates that there were significant differences in variety, fertilizer treatments and variety x fertilizer interaction. Vitamin C in the fresh fruits ranged from 19.91 – 20.79 mg/100g for Asontem and 20.30 – 22.44 mg/100g for Clemson spineless. The highest Vitamin C content under Asontem was obtained where 20 t/ha PM was applied, while the lowest was observed where no fertilizer (control) was applied. With the Clemson spineless variety, vitamin C content was highest with the application of 325 kg/ha NPK + 10 t/ha PM, while the least vitamin C content was obtained at 162.5 kg/ha NPK + 15 t/ha PM treatment.

4.7.12 Potassium content

The results in Table 4.17 show that the potassium (K) content of fresh okro from the field was significantly affected by variety, fertilizer and variety x fertilizer interaction. The K content ranged from 293.77 – 302.97 mg/100g for Asontem and 286.55 – 300.78 mg/100g

for Clemson spineless. Generally, the K content was slightly higher in Asontem than in Clemson spineless. The highest potassium content under Asontem was recorded where 650 kg/ha NPK was applied and the lowest K content where control (no fertilizer) was applied (Table 4.17). With Clemson spinelss, the highest K content was obtained with the application of 487.5 kg/ha NPK + 5 t/ha PM, whereas the least was recorded with the application of 650 kg/ha NPK (Tabl 4.17)

Experiment 2: Storage Experiment

4.8 Nutritional Analysis of Okro Fruits after Storage

4.8.1 Moisture content

The result from Table 4.18 indicates that there were significant differences in moisture content of okro after storage among the varieties, fertilizer treatments, the storage methods and their interactions. Generally, the average moisture content for the fresh okro fruits was 87.53 % compared with the other storage methods which had moisture contents ranging from 9.95 – 12.68 % (Table 4.18). Among the storage methods, Clemson spineless with 487.5 kg/ha NPK + 5 t/ha PM stored as whole/cut powdered had the highest moisture content, while Asontem with 20 t/ha PM had the least moisture content under whole/cut-powdered storage method (Table 4.18). When stored as cut dried okro, Asontem with 650 kg/ha NPK fertilizer application had the highest moisture content under that storage method, while the least moisture content was obtained with Clemson spineless applied with 162.5 kg/ha NPK + 15 t/ha PM (Table 4.18). Under whole dried method, Clemson spineless with 650 kg/ha NPK application had the highest moisture content, whereas Clemson spineless with 325 kg/ha NPK + 10 t/ha PM had the least moisture content. When stored as okro fresh fruits, Asontem with 487.5 kg/ha NPK + 5 t/ha PM application had the highest moisture content, while Clemson spineless with 325 kg/ha NPK + 10 t/ha PM recorded the lowest moisture content (Table 4.18).

4.8.2 Total ash content

The ash content of okro fruits stored under the various storage methods showed significant effects of variety, fertilizer, storage methods and their interactions (Table 4.18). Among the storage methods the ash content on the average ranged from 9.14 % - 9.79 % for the dried storage methods compared with 2.50 % for the fresh storage method. The variety x

fertilizer under the dried storage methods showed that Asontem with 162.5 kg/ha NPK + 15 t/ha PM stored as whole/cut powdered had the highest ash content, while Clemson with 487.5 kg/ha NPK + 5 t/ha PM applied fertilizer and cut dried had the least ash content. With the fresh fruits storage, Clemson under no fertilizer (control) treatment had the highest ash content, while Asontem with 487.5 kg/ha NPK + 5 t/ha PM had the lowest ash content (Table. 4.18).

With the Clemson spineless variety, 162.5 kg/ha NPK + 15 t/ha PM fertilizer application under the whole dried storage had the highest ash content. The lowest ash content was obtained by Clemson spineless with no fertilizer (control) treatment under cut dried and at 325 kg/ha NPK + 10 t/ha PM under whole/cut powdered. For Clemson fresh fruits, no fertilizer (control) treatment had the highest ash content, while Clemson with 650 kg/ha NPK had the least ash content in both cropping seasons (Table 4.18).

Table 4. 18: Effect of integrated nutrient management on moisture and ash of fresh and dried okro after storage combined for 2021 and 2022 cropping seasons

Treatment combination		Moisture (%)				Total Ash (%)			
		Whole/Cut Powdered	Cut Dried	Whole Dried	Fresh Okro	Whole/Cut Powdered	Cut Dried	Whole Dried	Fresh Okro
Asontem	650 kg /ha NPK	11.62	11.03	10.78	88.53	9.46	8.85	9.60	2.52
	20 t/ha Poultry Manure	11.15	9.69	10.66	88.49	9.72	8.73	9.06	2.56
	487.5 kg /ha NPK + 5t/ ha PM	11.82	9.39	10.68	88.75	9.31	8.08	9.47	2.44
	325 kg/ ha NPK + 10 t/ha PM	11.30	10.5	11.53	87.97	9.57	8.57	9.37	2.52
	162.5 kg/ ha NPK + 15t/ha PM	11.83	9.70	11.87	87.77	9.73	8.98	9.20	2.63
	Control	11.52	10.4	11.09	88.48	9.51	8.16	9.31	2.77
Clemson	650 kg /ha NPK	12.05	10.3	11.06	86.16	9.80	9.42	10.26	2.20
	20 t/ha Poultry Manure	11.97	9.49	10.49	86.52	9.61	10.6	10.02	2.40
	487.5 kg /ha NPK + 5t/ ha PM	12.24	10.5	10.48	87.43	9.92	10.0	9.38	2.26
	325 kg/ ha NPK + 10 t/ha PM	11.97	9.46	9.46	85.70	9.31	9.56	10.74	2.37
	162.5 kg/ ha NPK + 15t/ha PM	11.37	9.00	9.52	87.74	9.66	9.39	10.87	2.43
	Control	11.67	9.98	10.82	86.79	10.02	9.30	10.29	2.91
Mean		12.68	9.95	10.62	87.53	9.64	9.14	9.79	2.50
CV (%)				1.03				0.99	
Variety (LSD=0.05)				0.08**				0.024**	
Fertilizer (LSD=0.05)				0.14**				0.04**	
S. Method (LSD=0.05)				0.13**				0.04**	
Interactions									
Variety x S. Method (LSD=0.05)				0.042**				0.013**	
Fertilizer x S. Method (LSD=0.05)				0.13**				0.015**	
Var x Fert x S. Method (LSD=0.05)				0.25**				0.076**	

NS= Not significant, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

4.8.3 Crude protein content

The effect of integrated nutrient management on the crude protein content of fresh and dried okro is presented in Table 4.19. There were significant differences among the varieties, fertilizer treatments, storage methods and their interactions. Crude protein content for the dry methods averaged across variety and fertilizer treatments ranged from 18.10-20.51 % (Table 4.19). Under Asontem variety, crude protein content for the dry methods ranged from 16.75 % - 21.34 % compared with the fresh okro fruits which had crude protein content ranged from 2.88 % to 3.20 %. Over the dry methods, Asontem with 487.5 kg/ha NPK+ 5 t/ha PM applied and whole/cut powdered had the highest crude protein content, while cut dried Asontem with 487.5 kg/ha NPK+5 t/ha PM application had the least crude protein content (Table 4.19). With the fresh okro fruits, Asontem with 162.5 kg/ha NPK + 15 t/ha PM application had the highest crude protein, while Asontem with 20 t/ha PM (full PM) had the least fresh fruit crude protein content (Table 4.19).

Under the Clemson spineless variety, crude protein content ranged from 17.62 % to 21.13 % for the dry methods and 2.60 % to 2.95 % for the fresh okro fruits (Table 4.19). Whole/cut powdered Clemson spineless with control (no fertilizer) treatment had the highest crude protein among the dry methods, while cut dried Clemson spineless with full PM application had the lowest crude protein content (Table 4.19). With the fresh fruits, Clemson spineless with 325 kg/ha NPK + 10 t/ha PM application had the highest crude protein content, while full PM application had the lowest crude protein content (Table 4.19).

4.8.4 Crude fat content

Table 4.19 shows the effect of integrated nutrient management on the crude fat content of fresh and dried okro after storage. There were significant differences among the varieties, fertilizer, storage methods and their interaction. Averaged across variety and fertilizer treatments, the crude fat content for the dry methods ranged from 2.22 % – 3.07 %, and 1.22 % for the fresh fruits (Table 4.19).

With Asontem variety, crude fat content for the storage methods ranged from 1.92 % - 3.49 %, compared with 2.88 % to 3.20 % crude protein content for the fresh okro fruits. Over the dry methods, Asontem with 162.5 kg/ha NPK + 15 t/ha PM fertilizer application and whole/cut powdered had the highest crude fat content, while whole dried Asontem with 487.5 kg/ha NPK+5 t/ha PM application had the least crude fat content (Table 4.19). With the fresh okro fruits, Asontem with 325 kg/ha NPK+ 10 t/ha PM application had the highest crude fat, while Asontem with 487.5 kg/ha NPK+ 5 t/ha PM fertilizer application had the least fresh fruit crude fat content (Table 4.19).

Under the Clemson spineless variety, crude fat content ranged from 1.66 % to 3.61 % for the dry methods and 1.23 % to 1.39 % for the fresh okro fruits (Table 4.19). Whole/cut powdered Clemson spineless with 487.5 kg/ha NPK+ 5 t/ha PM application had the highest crude fat among the dry methods, whereas whole dried Clemson spineless with full PM application had the lowest crude fat content (Table 4.19). With the fresh fruits, Clemson spineless with 20 t/ha PM application had the highest crude fat content, while 162.5 kg/ha NPK + 15 t/ha PM fertilizer application had the lowest crude fat content (Table 4.19).

Table 4. 19: Effect of integrated nutrient management on crude protein and crude fat content of okro combined for 2021 and 2022

cropping seasons

Treatment combination		Crude protein (%)				Crude fat (%)			
		Whole/Cut Powdered	Cut Dried	Whole Dried	Fresh Okro	Whole/Cut Powdered	Cut Dried	Whole Dried	Fresh Okro
Asontem	650 kg /ha NPK	20.25	17.18	18.94	2.98	2.76	2.47	2.42	1.14
	20 t/ha Poultry Manure	20.69	17.34	17.29	2.88	2.63	2.42	2.57	1.14
	487.5 kg /ha NPK + 5t/ ha PM	21.34	16.75	18.85	3.11	2.88	2.65	1.92	1.03
	325 kg/ ha NPK + 10 t/ha PM	20.30	18.50	17.73	2.98	3.09	2.42	2.12	1.19
	162.5 kg/ ha NPK + 15t/ha PM	20.74	17.22	19.15	3.20	3.49	2.45	3.07	1.08
	Control	21.24	18.28	18.50	2.93	3.40	2.53	2.12	1.16
Clemson	650 kg /ha NPK	20.73	18.94	20.49	2.68	3.03	2.43	1.89	1.32
	20 t/ha Poultry Manure	19.59	17.62	19.59	2.60	2.55	2.62	1.66	1.39
	487.5 kg /ha NPK + 5t/ ha PM	20.67	19.38	19.09	2.78	3.61	2.59	2.05	1.32
	325 kg/ ha NPK + 10 t/ha PM	19.48	19.21	20.25	2.95	3.25	2.56	1.78	1.38
	162.5 kg/ ha NPK + 15t/ha PM	19.93	18.94	20.91	2.73	2.82	2.55	2.14	1.23
	Control	21.13	17.84	18.72	2.70	3.37	2.57	2.85	1.26
Mean		20.51	18.10	19.13	2.88	3.07	2.31	2.22	1.22
CV (%)			1.26				9.75		
Variety (LSD=0.05)			0.06**				0.07**		
Fertilizer (LSD=0.05)			0.10**				0.12**		
S. Method (LSD=0.05)			0.09**				0.11**		
Interactions									
Variety x S. Method (LSD=0.05)			0.031**				0.116*		
Fertilizer x S. Method (LSD=0.05)			0.038**				0.11**		
Var x Fert x S. Method (LSD=0.05)			0.186**				0.22**		

NS= Not significant, * = p< 0.05, ** = p <0.01, *** = p < 0.00

4.8.5 Crude fibre content

The effects of integrated nutrient management on the crude fibre content of fresh and dried okro fruits stored under different methods are presented in Table 4.20. There were no significant differences among the varieties and fertilizer treatments. However, there were significant differences among the storage methods and their interactions with variety and fertilizer (Table 4.20). Crude fibre content for the dry storage methods averaged across variety and fertilizer treatments ranged from 16.61 % – 17.73 %, and for the fresh fruits crude fibre averaged 2.47 % (Table 4.20).

Under Asontem variety, crude fibre content for the dry methods ranged from 14.41 % - 19.91 % compared with the fresh okro fruits which had crude fibre content ranged from 2.32 % to 2.81 % (Table 4.20). Over the dry storage methods, Asontem with 487.5 kg/ha NPK+ 5 t/ha PM applied and cut dried had the highest crude fibre content, while cut dried Asontem with 325 kg/ha NPK+ 10 t/ha PM application had the lowest crude fibre content (Table 4.20). With the fresh okro fruits, Asontem with control (no fertilizer) application had the highest fibre protein, whereas Asontem with full PM had the least fresh fruit crude fibre content (Table 4.20).

Under the Clemson spineless variety, crude fibre content ranged from 14.80 % to 19.50 % for the dry methods and 2.27 % to 2.56 % for the fresh okro fruits (Table 4.20). Cut dried Clemson spineless with 325 kg/ha NPK + 10 t/ha PM application had the highest crude fibre among the dry methods, while whole/cut powdered Clemson spineless with control (no fertilizer) application had the lowest crude fibre content (Table 4.20). With the fresh fruits, Clemson spineless with control (no fertilizer) application had the highest crude fibre

content, whereas application of 325 kg/ha NPK + 10 t/ha PM had the lowest crude fibre content (Table 4.20).

4.8.6 Carbohydrate content

Table 4.20 presents the results on the effects of integrated nutrient management on the carbohydrate content of fresh and dried okro fruits stored under different methods. There were significant differences among varieties, fertilizer treatments, storage methods and their interactions (Table 4.20). Carbohydrate content for the dry storage methods averaged across variety and fertilizer treatments ranged from 38.49 % – 43.41 %, and for the fresh fruits carbohydrate content averaged 3.41 % (Table 4.20).

The carbohydrate content for Asontem under the dry methods ranged from 36.52 % - 46.74 % compared with 1.84 % - 2.84% for the fresh okro fruits (Table 4.20). Over the dry storage methods, cut dried Asontem with 162.5 kg/ha NPK+ 15 t/ha PM application had the highest carbohydrate content, while whole/cut powdered Asontem with control (no fertilizer) application had the lowest carbohydrate content (Table 4.20). With the fresh okro fruits, Asontem with 325 kg/ha NPK + 10 t/ha PM application had the highest carbohydrate content, whereas Asontem with full PM had the least fresh fruit carbohydrate content (Table 4.20).

Under the Clemson spineless variety, carbohydrate content ranged from 36.94 % to 43.88 % for the dry methods and 3.52 % to 5.33 % for the fresh okro fruits (Table 4.20). Cut dried Clemson spineless with 650 kg /ha NPK application had the highest carbohydrate content among the dry methods, while whole/cut powdered Clemson spineless with 650 kg/ha NPK application had the lowest carbohydrate content (Table 4.20). With the fresh

fruits, Clemson spineless with 325 kg/ha NPK + 10 t/ha PM application had the highest carbohydrate content, whereas application of 162.5 kg/ha NPK + 15 t/ha PM had the lowest crude fibre content (Table 4.20).

Table 4. 20: Effect of integrated nutrient management on crude fibre and carbohydrate content of okro combined for 2021 and 2022

cropping seasons

Treatment combination		Crude fibre (%)				Carbohydrate (%)			
		Whole/Cut Powdered	Cut Dried	Whole Dried	Fresh Okro	Whole/Cut Powdered	Cut Dried	Whole Dried	Fresh Okro
Asontem	650 kg /ha NPK	18.28	15.26	19.64	2.55	37.65	45.22	38.64	2.27
	20 t/ha Poultry Manure	18.10	15.49	16.97	2.32	37.72	46.35	43.47	2.61
	487.5 kg /ha NPK + 5t/ ha PM	15.25	19.91	15.04	2.57	39.41	43.23	44.06	2.10
	325 kg/ ha NPK + 10 t/ha PM	16.79	14.41	17.89	2.51	38.44	45.64	41.38	2.84
	162.5 kg/ ha NPK + 15t/ha PM	16.19	14.92	17.56	2.62	38.34	46.74	39.29	2.69
	Control	18.10	15.78	16.70	2.81	36.52	44.90	42.30	1.84
Clemson	650 kg /ha NPK	17.49	14.85	19.16	2.39	36.94	44.11	37.16	5.25
	20 t/ha Poultry Manure	16.56	18.33	19.06	2.34	39.73	41.38	39.19	4.75
	487.5 kg /ha NPK + 5t/ ha PM	16.11	18.48	19.11	2.30	37.46	39.11	39.90	3.90
	325 kg/ ha NPK + 10 t/ha PM	16.53	19.50	17.58	2.27	39.48	39.56	40.20	5.33
	162.5 kg/ ha NPK + 15t/ha PM	15.12	18.39	18.43	2.36	41.12	41.75	38.15	3.52
	Control	14.80	17.44	15.66	2.56	39.03	42.88	41.68	3.78
Mean		16.61	16.89	17.73	2.47	38.49	43.41	40.45	3.41
CV (%)			3.69				1.86		
Variety (LSD=0.05)			NS				0.18**		
Fertilizer (LSD=0.05)			NS				0.31**		
Storage Method (LSD=0.05)			0.25**				0.29**		
Interactions									
Variety x S. Method (LSD=0.05)			0.083**				0.096**		
Fertilizer x S. Method (LSD=0.05)			0.248**				0.287**		
Var x Fert x S. Method (LSD=0.05)			0.497**				0.573**		

NS= Not significant, * = p< 0.05, ** = p <0.01, *** = p < 0.001

4.8.7 Total sugars

The effect of integrated nutrient management on the total sugars content of fresh and dried okro after storage are presented in Table 4.21. There were significant differences among the varieties, fertilizer, storage methods and their interaction. Averaged across variety and fertilizer treatments, the total sugars for the dry methods and the fresh fruits ranged from 36.87 % – 37.55 %, and 37.48 %, respectively (Table 4.21).

With Asontem variety, total sugars content for both the dry methods and fresh fruits ranged from 31.30 % - 42.84 %. With regards to all the storage methods, Asontem fresh fruits with control (no fertilizer) application had the highest total sugars content, while Asontem fresh fruits with 162.5 kg/ha NPK + 15 t/ha PM fertilizer application had the least total sugars content (Table 4.21).

With the Clemson spineless variety, total sugars content ranged from 37.11 % - 41.34 % for both the dry methods and fresh okro fruits storage methods (Table 4.21). Whole dried Clemson spineless with 650 kg/ha NPK application had the highest total sugars, whereas cut dried Clemson spineless with 325 kg/ha NPK + 10 t/ha PM fertilizer application had the lowest total sugars content (Table 4.21).

4.8.8 Total solids

The results on the effects of integrated nutrient management on the total solids content of fresh and dried okro fruits stored under different methods are shown in Table 4.21. There were significant differences among varieties, fertilizer treatments, storage methods and their interactions (Table 4.21). Total solids content for the dry storage methods averaged

across variety and fertilizer treatments ranged from 88.30 % – 90.05 %, and for the fresh fruits, carbohydrate content averaged 12.47 % (Table 4.21).

The total solids content for Asontem under the dry methods ranged from 88.17 % - 90.61 % compared with 11.25 % -12.23 % for the fresh okro fruits (Table 4.21). Over the dry storage methods, cut dried Asontem with 487.5 kg/ha NPK+ 5 t/ha PM application had the highest total solids content, while whole/cut powdered Asontem with 325 kg/ha NPK + 10 t/ha PM application had the lowest total solids content (Table 4.21). With the fresh okro fruits, Asontem with 162.5 kg/ha NPK + 15 t/ha PM application had the highest total solids content, whereas Asontem with 487.5 kg/ha NPK + 5 t/ha PM had the least fresh fruit total solids content (Table 4.21).

Under the Clemson spineless variety, total solids ranged from 87.76 % to 91.01 % for the dry methods and 12.26 % to 14.30 % for the fresh okro fruits (Table 4.21). Cut dried Clemson spineless with 162.5 kg/ha NPK + 15 t/ha PM application had the highest total solids content among the dry methods, while whole/cut powdered Clemson spineless with 487.5 kg/ha NPK+ 5 t/ha PM application had the lowest total solids (Table 4.21). With the fresh fruits, Clemson spineless with 325 kg/ha NPK + 10 t/ha PM application had the highest total solids, whereas application of 162.5 kg/ha NPK + 15 t/ha PM had the lowest total solids (Table 4.21).

Table 4. 21: Effect of integrated nutrient management on total sugars, total solids of fresh and dried okro after storage combined for 2021 and 2022 cropping seasons

Treatment combination		Total sugars (%)				Total solids (%)			
		Whole/Cut Powdered	Cut Dried	Whole Dried	Fresh Okro	Whole/Cut Powdered	Cut Dried	Whole Dried	Fresh Okro
Asontem	650 kg /ha NPK	35.01	34.05	34.84	35.44	88.39	88.98	89.23	11.47
	20 t/ha Poultry Manure	34.54	32.00	35.07	34.40	88.85	90.32	89.34	11.51
	487.5 kg /ha NPK + 5t/ ha PM	36.40	35.51	36.01	37.47	88.18	90.61	89.32	11.25
	325 kg/ ha NPK + 10 t/ha PM	34.47	33.81	34.40	33.08	88.17	89.53	88.48	12.03
	162.5 kg/ ha NPK + 15t/ha PM	32.35	32.08	32.45	31.30	88.49	90.31	88.25	12.23
	Control	38.38	41.11	39.09	42.84	88.76	89.65	88.91	11.52
Clemson	650 kg /ha NPK	41.02	39.10	41.34	40.83	87.98	89.74	88.95	13.84
	20 t/ha Poultry Manure	39.45	39.14	38.51	37.93	88.03	90.52	89.51	13.48
	487.5 kg /ha NPK + 5t/ ha PM	39.75	39.57	39.18	39.20	87.76	89.56	89.52	12.57
	325 kg/ ha NPK + 10 t/ha PM	38.10	37.11	38.63	37.66	88.03	90.37	90.55	14.30
	162.5 kg/ ha NPK + 15t/ha PM	40.51	39.13	40.18	39.44	88.63	91.01	90.49	12.26
	Control	40.55	39.83	39.71	40.21	88.33	90.03	89.18	13.21
Mean		37.55	36.87	37.45	37.48	88.30	90.05	89.31	12.47
CV (%)				1.65				0.37	
Variety (LSD=0.05)				0.18**				0.08**	
Fertilizer (LSD=0.05)				0.32**				0.14**	
Storage Method (LSD=0.05)				0.29**				0.13**	
Interactions									
Variety x S. Method (LSD=0.05)				0.096*				0.042**	
Fertilizer x S. Method (LSD=0.05)				0.288**				0.127**	
Var x Fert x S. Method (LSD=0.05)				0.576**				0.253**	

NS= Not significant, * = p< 0.05, ** = p <0.01, *** = p < 0.001

4.8.9 Total energy

The results presented in Table 4.22 show the effects of integrated nutrient management on the total energy content of fresh and dried okro fruits stored under different methods. There were no significant differences between the varieties, but significant differences were observed among fertilizer treatments, storage methods and their interactions (Table 4.22). Total energy content averaged across variety and fertilizer treatments for the dry storage methods ranged from 258.20 – 268.68 kcal/100mg, and for the fresh fruits total energy content averaged 36.13 kcal/100g (Table 4.22).

The total energy for Asontem under the dry methods ranged from 252.04 – 278.30 kcal/100mg compared with 29.56 – 33.96 kcal/100mg for the fresh okro fruits (Table 4.22). Over the dry storage methods, cut dried Asontem with 325 kg/ha NPK + 10 t/ha PM application had the highest total energy, while whole dried Asontem with 650 kg/ha NPK application had the lowest total energy (Table 4.22). With the fresh okro fruits, Asontem with 325 kg/ha NPK + 10 t/ha PM application had the highest total energy, whereas Asontem with control (no fertilizer) application had the least fresh fruit total energy (Table 4.22).

With the Clemson spineless variety, total energy ranged from 247.57 – 273.90 kcal/100mg for the dry methods and 36.03 – 45.56 kcal/100mg for the fresh okro fruits (Table 4.22). Cut dried Clemson spineless with 650 kg/ha NPK application had the highest total energy among the dry methods, while whole dried Clemson spineless with 650 kg/ha NPK application had the lowest total energy (Table 4.22). With the fresh fruits, Clemson spineless with 325 kg/ha NPK + 10 t/ha PM application had the highest total energy,

whereas application of 162.5 kg/ha NPK + 15 t/ha PM had the lowest total energy (Table 4.22).

4.8.10 Nitrogen content

The effects of integrated nutrient management on the nitrogen content of fresh and dried okro fruits stored under different storage methods are presented in Table 4.22. There were significant differences among the varieties, fertilizer treatments, storage methods and their interactions (Table 4.22). The nitrogen content averaged across variety and fertilizer treatments for the dry storage methods ranged from 2.90 % - 3.28 %, and for the fresh fruits nitrogen content averaged 0.46 % (Table 4.22).

For Asontem under the dry methods, the nitrogen content ranged from 2.68 % - 3.41 % compared with 0.46 % - 0.51% for the fresh okro fruits (Table 4.22). Over the dry storage methods, whole/cut powdered Asontem with 487.5 kg /ha NPK + 5t/ ha PM fertilizer application had the highest nitrogen content, while cut dired Asontem with 487.5 kg/ha NPK + 5 t/ha PM application had the lowest nitrogen content (Table 4.22). With the fresh okro fruits, Asontem with 162.5 kg/ha NPK + 15 t/ha PM application had the highest nitrogen content, whereas Asontem with 20 t/ha PM application had the least fresh fruit nitrogen content (Table 4.22).

For the Clemson spineless variety, the nitrogen content ranged from 2.82 % - 3.38 % for the dry methods and 0.41 % - 0.47 % for the fresh okro fruits (Table 4.22). Whole/cut powdered Clemson spineless with control (no fertilizer) application had the highest nitrogen content among the dry methods, while cut dried Clemson spineless with 20 t/ha PM application had the lowest nitrogen content (Table 4.22). With the fresh fruits, Clemson

spineless with 325 kg/ha NPK + 10 t/ha PM application had the highest percent nitrogen content, whereas application of 20 t/ha PM had the lowest percentage nitrogen content (Table 4.22).

Table 4. 22: Effect of integrated nutrient management on total energy and nitrogen of fresh and dried okro after storage combined for 2021 and 2022 cropping seasons

Treatment combination		Total energy (kcal/100g)				Nitrogen (%)			
		Whole/Cut Powdered	Cut Dried	Whole Dried	Fresh Okro	Whole/Cut Powdered	Cut Dried	Whole Dried	Fresh Okro
Asontem	650 kg /ha NPK	256.38	271.8	252.04	31.28	3.24	2.75	3.03	0.48
	20 t/ha Poultry Manure	257.29	276.5	266.11	32.20	3.31	2.77	2.77	0.46
	487.5 kg /ha NPK + 5t/ ha PM	268.90	263.8	268.84	30.13	3.41	2.68	3.02	0.50
	325 kg/ ha NPK + 10 t/ha PM	262.73	278.3	255.48	33.96	3.25	2.96	2.84	0.48
	162.5 kg/ ha NPK + 15t/ha PM	267.69	277.9	261.33	33.32	3.32	2.76	3.06	0.51
	Control	261.62	275.5	262.22	29.56	3.40	2.92	2.96	0.47
Clemson	650 kg /ha NPK	257.91	273.9	247.57	43.63	3.32	3.03	3.28	0.43
	20 t/ha Poultry Manure	260.19	259.6	250.02	41.93	3.13	2.82	3.13	0.41
	487.5 kg /ha NPK + 5t/ ha PM	264.97	257.2	254.39	38.66	3.31	3.10	3.05	0.45
	325 kg/ ha NPK + 10 t/ha PM	265.03	258.1	257.80	45.56	3.12	3.07	3.24	0.47
	162.5 kg/ ha NPK + 15t/ha PM	269.54	265.7	255.44	36.03	3.19	3.03	3.35	0.44
	Control	270.89	265.9	267.19	37.25	3.38	2.85	3.00	0.43
Mean		263.60	268.68	258.20	36.13	3.28	2.90	3.06	0.46
CV (%)			1.22				1.28		
Variety (LSD=0.05)			NS				0.01**		
Fertilizer (LSD=0.05)			1.36*				0.02**		
Storage Method (LSD=0.05)			1.24**				0.02**		
Interactions									
Variety x S. Method (LSD=0.05)			0.41**				0.01**		
Fertilizer x S. Method (LSD=0.05)			1.24**				0.02**		
Var x Fert x S. Method (LSD=0.05)			2.48**				0.03**		

NS= Not significant, * = p< 0.05, ** = p <0.01, *** = p < 0.001

4.8.11 Vitamin C content

The results presented in Table 4.23 show the effects of integrated nutrient management on the Vitamin C content of fresh and dried okro fruits stored under different methods. There were significant differences among the varieties, fertilizer treatments, storage methods and their interactions (Table 4.23). The Vitamin C content averaged across variety and fertilizer treatments for the dry storage methods ranged from 16.58 – 18.22 mg/100g, and for the fresh fruits total energy content averaged 34.72 mg/100g (Table 4.23).

The Vitamin C content for Asontem under the dry methods ranged from 16.04 – 18.38 mg/100g compared with 29.14 – 32.60 mg/100g for the fresh okro fruits (Table 4.23). Over the dry storage methods, whole/cut powdered Asontem with 487.5 kg/ha NPK + 5 t/ha PM and 162.5 kg/ha NPK + 15 t/ha PM fertilizer applications had the highest Vitamin C content, whereas cut dried Asontem with 487.5 kg/ha NPK + 5 t/ha PM application had the lowest Vitamin C content (Table 4.23). With the fresh okro fruits, Asontem with 162.5 kg/ha NPK + 15 t/ha PM application had the highest Vitamin C content, whereas Asontem with control (no fertilizer) application had the lowest fresh fruit Vitamin C content (Table 4.23).

With the Clemson spineless variety, Vitamin C content ranged from 15.10 – 18.92 mg/100g for the dry methods and 32.18 – 42.90 mg/100g for the fresh okro fruits (Table 4.23). Whole/cut powdered Clemson spineless with 162.5 kg/ha NPK + 15 t/ha PM application had the highest Vitamin C content among the dry methods, while cut dried Clemson spineless with 487.5 kg/ha NPK + 5 t/ha PM application had the lowest Vitamin C content (Table 4.23). With the fresh fruits, Clemson spineless with 650 kg/ha NPK application had

the highest Vitamin C content, whereas application of control (no fertilizer) application had the lowest Vitamin C content (Table 4.23).

4.8.12 Potassium content

The effects of integrated nutrient management on the potassium content of fresh and dried okro fruits stored under different methods are shown in Table 4.23. There were significant differences in potassium content among the varieties, fertilizer treatments, storage methods and their interactions (Table 4.23). Averaged across variety and fertilizer treatments for the dry storage methods, the potassium content ranged from 306.22 – 347.06 mg/100g, and for the fresh fruits total energy content averaged 170.18 mg/100g (Table 4.23).

With Asontem variety under the dry methods, the potassium content ranged from 302.84 – 355.57 mg/100g, compared with 166.87 – 177.63 mg/100g for the fresh okro fruits (Table 4.23). Over the dry storage methods, whole/cut powdered Asontem with 650 kg/ha NPK fertilizer applications had the highest potassium content, whereas cut dried Asontem with control (no fertilizer) application had the lowest potassium content (Table 4.23). With the fresh okro fruits, Asontem with 650 kg/ha NPK application had the highest potassium content, whereas Asontem with control (no fertilizer) application had the lowest fresh fruit potassium content (Table 4.23).

With the Clemson spineless variety, the potassium content ranged from 301.43 – 359.44 mg/100g for the dry methods and 165.46 – 172.13 mg/100g for the fresh okro fruits (Table 4.23). Whole/cut powdered Clemson spineless with 325 kg/ha NPK + 10 t/ha PM application had the highest potassium content among the dry methods, whereas cut dried Clemson spineless with 20 t/ha PM application had the lowest potassium content (Table

4.23). With the fresh fruits, Clemson spineless with 487.5 kg/ha NPK + 5 t/ha PM application had the highest potassium content, whereas application of 20 t/ha PM had the lowest potassium content (Table 4.23).

Table 4. 23: Effect of integrated nutrient management on vitamin C and potassium content of fresh and dried okro after storage combined for 2021 and 2022 cropping seasons

Treatment combination		Vitamin C (mg/100g)				Potassium (mg/100g)			
		Whole/Cut Powdered	Cut Dried	Whole Dried	Fresh Okro	Whole/Cut Powdered	Cut Dried	Whole Dried	Fresh Okro
Asontem	650 kg /ha NPK	18.37	16.63	18.28	32.42	355.57	313.6	327.98	177.63
	20 t/ha Poultry Manure	18.34	18.08	17.55	32.53	342.97	307.1	321.49	171.14
	487.5 kg /ha NPK + 5t/ ha PM	18.38	16.04	17.37	32.34	352.24	311.19	325.57	175.22
	325 kg/ ha NPK + 10 t/ha PM	18.08	17.12	16.61	32.42	350.93	309.87	324.25	173.90
	162.5 kg/ ha NPK + 15t/ha PM	18.38	17.01	18.22	32.60	346.25	305.82	320.20	169.85
	Control	18.35	17.33	17.56	29.14	348.70	302.84	317.22	166.87
Clemson	650 kg /ha NPK	17.82	17.06	16.71	42.90	329.07	303.91	318.29	167.94
	20 t/ha Poultry Manure	18.07	15.69	18.26	39.17	343.11	301.43	315.81	165.46
	487.5 kg /ha NPK + 5t/ ha PM	17.42	15.10	15.84	35.76	358.35	308.10	322.48	172.13
	325 kg/ ha NPK + 10 t/ha PM	18.08	15.74	16.43	42.67	359.44	304.41	318.79	168.44
	162.5 kg/ ha NPK + 15t/ha PM	18.92	16.46	15.91	32.56	345.45	302.01	316.39	166.04
	Control	18.41	16.66	17.37	32.18	334.58	304.41	317.89	167.54
Mean		18.22	16.58	17.18	34.72	347.06	306.22	320.53	170.18
CV (%)			6.36				1.05		
Variety (LSD=0.05)			0.39**				0.92**		
Fertilizer (LSD=0.05)			0.69**				1.58**		
Storage Method (LSD=0.05)			0.62**				1.45**		
Interactions									
Variety x S. Method (LSD=0.05)			0.21**				NS		
Fertilizer x S. Method (LSD=0.05)			0.62**				1.45**		
Var x Fert x S. Method (LSD=0.05)			1.24**				2.89**		

NS= Not significant, * = p< 0.05, ** = p <0.01, *** = p < 0.001

CHAPTER FIVE: DISCUSSION

5.1 Soil and Poultry Manure Analyses

5.1.1 Initial physical and chemical composition of soil and poultry manure

The initial chemical and physical properties of the soil across the two seasons indicated moderately acidic soil environment (Table 4.1), which is typical of many tropical cultivated soils and can influence nutrient availability, especially phosphorus (P). This is supported by the findings of Asiedu *et al.* (2021). The medium nitrogen (N) status obtained in both seasons suggests enhanced soil fertility due to some previously applied amendments on the sites. This trend aligns with findings by Opoku-Mensah *et al.* (2025), who reported that organic amendments such as poultry manure significantly improve soil N status over time.

Available P were generally low in both seasons, although slightly higher in 2022. The below-critical P levels confirm the well-known fixation effect in moderately acidic soils. However, the K levels slightly above the critical threshold suggest that the soil can support crop growth, but may still require supplementation to prevent depletion, consistent with the assertions of Das *et al.* (2022). The calcium (Ca) and magnesium (Mg) levels were moderate, with Ca slightly exceeding critical thresholds (Table 4.1), thus the initial soil was expected to supply substantial quantities of exchangeable bases for crop growth (Zhang *et al.*, 2021b).

The sandy-loam texture observed in both years indicated soils with good drainage, but moderate water-holding capacity. Such soils typically require organic inputs to improve structure and nutrient-holding potential (Aytenuw & Bore, 2020). The adequate CEC observed in both seasons supports the notion that even though the soil is sandy loam, the presence of organic inputs improves nutrient retention.

The poultry manure characteristics showed slightly alkaline pH values 7.22 in 2021 and 7.7 in 2022, which can help neutralize soil acidity, improve nutrient availability and suitable for the cultivation of okro as noted by Espeland & Kettenring (2018). The manure was rich in N, P, K, Ca, Mg, and micronutrients, confirming its value as a balanced organic amendment. In support of this, Abass *et al.* (2019) reported that poultry manure increases soil pH, macronutrients, phosphorus, and cation exchange capacity, which could improve okro production. Zhang *et al.* (2021b) also noted that these rich components in the poultry manure used enable the poultry manure to supply substantial quantities of exchangeable bases. The significantly higher P content in the poultry manure aligns with the observations of Yang (2024), who noted seasonal and management-driven variation in manure nutrient composition. High Na levels observed in both seasons warrant cautious use, as excessive Na can affect soil structure; however, organic carbon and moisture content indicate good decomposition dynamics and nutrient release patterns (Li *et al.*, 2023).

5.1.2 Post-harvest soil analysis in 2021 and 2022 cropping seasons

Generally, the post-harvest soil analysis showed the soils were moderately acidic in both cropping seasons, similar to observations made by Brandenber *et al.* (2019), who noted that okro is tolerant to a wide range of soil pH, although does very well at pH between 6.0 and 6.8; and at or below 5.8 okro can have poorly developed pods.

The soils were moderate in organic carbon and phosphorus and low in total nitrogen. Calcium and potassium were moderate in the experimental location, while magnesium and sodium were high. Cation exchange capacity was low. The organic matter content of the soil was moderate in both cropping seasons. These findings are similar to the research findings by Rizzo *et al.* (2020), who observed that nutrients seemed more available to okro plants in an

integrated form than the organic or inorganic materials alone. Abass *et al.* (2019) had reported similar findings that poultry manure increases soil pH, macronutrients, phosphorus and cation exchange capacity of the soil which improves okro production. The moderate organic matter content reflects the cumulative effect of manure application, consistent with findings by Lin *et al.* (2019), who were of the view that repeated organic inputs enhance soil OM and buffer capacity. The physical soil analysis still showed the soils in both seasons was sandy loam.

5.2 Plant Phenology

5.2.1 Days to 50% emergence

Generally, the treatments involving poultry manure (PM) either alone or in combination with NPK applied in the two varieties emerged earlier compared with the sole application of 650 kg/ha NPK, indicating that organic or integrated nutrient sources promoted quicker emergence. This might be due to the increased moisture content or retention from the poultry manure which was applied two weeks earlier before planting in the sole PM or integrated nutrient treatments. Recent studies in West Africa showed that poultry manure improves soil structure, moisture retention, and microbial activity, leading to enhanced germination and early seedling growth (Agbede *et al.*, 2025).

With regards to the two varieties, generally Clemson emerged faster than Asontem in both seasons, reflecting varietal difference which suggests inherent genetic advantages in Clemson, a finding supported by Mustapha *et al.* (2022), who reported that Clemson-based okro varieties typically exhibit stronger early vigor and quicker establishment.

The slight earlier in emergence time during the 2022 season may be attributed to seasonal environmental variability such as rainfall patterns and soil temperature, factors known to affect germination dynamics (Habte *et al.*, 2023).

5.2.2 Number of days to 50% flowering

Days to 50% flowering was significantly influenced by both the okro variety and the integrated nutrient management (INM) treatments. The Asontem variety exhibited delayed flowering (up to 77 days) under treatments involving 20 t/ha poultry manure (PM), 487.5 kg/ha NPK + 5 t/ha PM, 325 kg/ha NPK + 10 t/ha PM, and the control. In contrast, the Clemson Spineless variety, known for its early maturity, reached 50% flowering in fewer days (56 days), regardless of nutrient application treatment, demonstrating its genetic predisposition to early flowering. Similar findings have been reported by Shittu *et al.* (2025) and Yusuf *et al.* (2020), who noted that varietal differences and balanced nutrient supply significantly influenced phenological traits such as days to flowering. The delayed flowering in Asontem could be attributed to its late-maturing nature and the possible nitrogen-induced vegetative growth resulting from higher NPK and organic manure applications (Miaha *et al.*, 2020). Conversely, Clemson Spineless's shorter flowering period aligns with previous studies identifying it as an early-maturing cultivar. Clemson is an early maturing okro variety hence early flowering and fewer days to 50% flowering. This finding is in support of (Hayamanesh, 2018; Iwuala *et al.*, 2021).

5.2.3 Number of days to 50% podding

Consistent with the number of days to 50% flowering, the days to podding differed significantly between Asontem and Clemson spineless, with Clemson spineless podding earlier (57- 61 days) than Asontem (76 – 79 days). Shittu *et al.* (2025) and Yusuf *et al.* (2020) noted similar varietal differences which significantly influenced phenological traits such as days to podding. The delayed podding in Asontem could be attributed to its late-maturing nature (Miaha *et al.*, 2020) and Clemson Spineless's shorter flowering period resulting in earlier podding aligns with previous studies identifying it as an early-maturing cultivar (Abua *et al.*, 2026).

The results showed that although poultry manure and NPK combinations improved soil nutrient availability, these changes did not substantially alter the inherent phenology of the okro varieties evaluated. This observation aligns with Ali *et al.* (2024) and Verma *et al.* (2024), who noted that INM and organic manure applications mainly enhance soil fertility, nutrient uptake and biomass accumulation, but exert limited influence on genetically predetermined reproductive timing.

Some studies of vegetable and field crops report that genotype explains much of the variation in days to flowering/podding, while nutrient management more commonly affects vegetative vigour and final yield than the calendar date of reproductive onset. These studies have indicated that poultry manure and manure + NPK combinations often improve growth traits more than they modify phenological traits (Rostaei, 2024; Tandoh, 2024). Under such conditions, high organic inputs may delay reproductive development slightly due to greater early vegetative vigour and slower nutrient mineralization. Organic amendments typically

release nutrients gradually, which can promote vigorous vegetative growth and sometimes extend the vegetative phase before flowering or podding (Rostaei, 2024).

In contrast, some studies have reported earlier reproductive development where higher mineral N availability accelerates physiological processes, particularly under higher NPK rates (Chawla & Sadawarti, 2020). While some reports indicated earlier podding under high mineral N, others record delayed podding under heavy organic applications (Khan *et al.*, 2023; Tandoh, 2024). These contrasting reports reflect differences in manure mineralization rate, soil moisture, textural class, and varietal genetic responses; and such environmental and genetic interactions strongly mediate how crops respond to INM practices (Fosu *et al.*, 2021; Tandoh, 2024).

Given that varietal differences remained the most significant determinant of podding date in this experiment, the findings confirm that phenology in okro is largely genotype-controlled, with nutrient management exerting only minor modifications under typical field conditions in Ghana's forest–savannah transition zone.

5.3 Vegetative Growth of Okro

5.3.1 Plant height

Generally, plant height of both Asontem and Clemson spineless varieties increased with soil amendments application over the control (no fertilizer). These differences could be attributed to the integrated nutrient management strategy, suggesting that integrated use of poultry manure and NPK fertilizer enhances nutrient availability and promotes vegetative growth more effectively than single applications. These results agree with the observations made by Muhammad *et al.* (2020) that the combined application of poultry manure and

NPK fertilizer proved to be the most influential in producing good growth performance in okro. Generally, the maximum plant height of okro is influenced by the presence and availability of adequate plant nutrients. Abbas *et al.*, (2019) reported that poultry manure increases soil pH, macronutrients, phosphorus, and cation exchange capacity, improving okro production. According to Assi *et al.* (2017), potassium and phosphorus are also important for maintaining proper plant growth and development.

5.3.2 Number of leaves per plant and stem diameter

There were significant effects on the number of leaves and stem diameter of okro due to different nutrient sources, with generally the greatest number of leaves per plant and stem diameter observed in poultry manure and combination of poultry manure and NPK application, very similar results reported by Adhikari and Piya (2020). Poultry manure provides a gradual release of nutrients, improves soil structure, and enhances microbial activity, which together promote sustained vegetative growth, increased leaf formation and overall plant vigor in okro (Eifediyi & Remison, 2019; Ibrahim *et al.*, 2021).

Treatments combining moderate levels of NPK and poultry manure produced greater leaf numbers and stem diameter, indicating that a balanced nutrient supply enhances vegetative growth, leaf and stem development. These findings are also consistent with earlier studies that reported that combining organic and inorganic fertilizers promotes leaf formation and plant growth by improving soil fertility, nutrient uptake, and chlorophyll synthesis (Eifediyi & Remison, 2019). The lower leaf numbers per plant and stem diameter in control (no fertilizer) and low-nutrient treatments suggest nutrient deficiencies, particularly nitrogen, which is essential for leaf growth and photosynthetic activity (Singh & Ramesh, 2018). In contrast, the lower leaf number and stem diameter observed in the control

treatment could be due to nutrient imbalances or deficiencies, particularly nitrogen, which limits leaf expansion and photosynthetic efficiency as reported by Musa *et al.* (2017); and low organic carbon limiting plant growth and stem expansion (Singh & Ramesh, 2018).

The varietal differences observed with Clemson Spineless producing fewer leaves than Asontem, can be attributed to genetic variation, as early maturing varieties typically invest more in reproductive growth than in vegetative expansion, and its genetic potential for greater biomass accumulation and stem robustness (Olowe *et al.*, 2020).

5.3.3 Number of branches per plant

The Clemson variety recorded a greater number of branches compared with Asontem indicating genetic variability in branching potential. Varietal differences in branching have been widely reported in crops such as okro, where genotype influences vegetative growth and response to nutrient availability (Singh *et al.*, 2015; Verma *et al.*, 2023).

Generally, poultry manure or its combinations with NPK had higher number of branches compared to control (no fertilizer) and sole NPK application. Naim and Abker (2016b) reported that the production of okro with poultry manure could increase plant height and number of branches, thus indicating the importance of poultry manure on the vegetative growth of okro. This is also in conformity with the findings of Ibeh *et al.* (2019) who reported that poultry manure contains essential nutrients which are associated with high photosynthetic activities that promote root and vegetative growth. Similar results were reported by Dilshad *et al.* (2010), who found that nutrient applications significantly enhanced vegetative growth attributes due to improved nutrient uptake and photosynthetic activity.

The significant year \times variety interaction suggests that environmental conditions across seasons also influenced varietal expression, aligning with the findings of Acharya *et al.* (2025), who noted that genotype \times environment interactions significantly affect plant morphological traits under integrated nutrient management (INM). Similarly, the environmental conditions modulated the fertilizer response an outcome consistent with studies emphasizing the influence of seasonal variability on INM performance (Saud *et al.*, 2024).

5.3.4 Plant canopy spread

The results indicate that poultry manure (PM) significantly enhanced plant canopy spread, with Asontem plants treated with 20 t/ha PM showing larger canopy sizes than those receiving 650 kg/ha NPK or control treatments. This aligns with previous studies reporting that organic amendments, such as poultry manure, improve vegetative growth in okro by enhancing nutrient availability and soil structure (Musa *et al.*, 2020; Onyemaobi *et al.*, 2017). Integrated nutrient management (INM), combining NPK and PM fertilizers, (for instance 325 kg/ha NPK + 10 t/ha PM), resulted in the most pronounced canopy development than both single-fertilizer treatments. This confirms findings that INM synergistically enhances growth and yield in okro by balancing macro- and micro-nutrients while improving soil fertility (Olaniyan *et al.*, 2021).

Control plots without fertilizer consistently exhibited the smallest canopy sizes, reinforcing the critical role of fertilization in promoting okro canopy development.

5.3.5 Leaf chlorophyll content

In both cropping seasons, the Asontem variety consistently showed higher chlorophyll content than the Clemson variety under all fertilizer treatments. This indicates that Asontem has a greater physiological efficiency and better response to fertilizer application, possibly due to genetic differences in nutrient use efficiency or leaf pigment concentration. These results are also consistent with the findings of Olowe *et al.* (2020), who reported that okro varieties differ in their ability to assimilate and utilize nutrients, influencing leaf greenness and chlorophyll concentration.

The results on leaf chlorophyll content revealed significant variation among treatments due to differences in integrated nutrient management (INM) and okro variety. This indicates that the integration of organic and inorganic nutrients improved chlorophyll synthesis by ensuring a steady and balanced supply of essential nutrients, particularly nitrogen, which is a key component of chlorophyll molecules (Singh & Ramesh, 2018).

Moreover, the combined application of NPK and poultry manure has been shown to enhance soil fertility, microbial activity, and nutrient availability, leading to higher chlorophyll content and improved plant vigor (Eifediyi & Remison, 2019; Ibrahim *et al.*, 2021).

5.3.6 Dry matter accumulation

Generally, the results on dry matter accumulation indicated differences among the integrated nutrient management (INM) treatments (Figure 4.13), compared with the control plots that recorded the lowest dry matter values throughout the growth period (Figure 4.13). These results indicate that combining organic and inorganic nutrient sources enhance biomass accumulation through improved nutrient availability and soil fertility; and

supplying both immediate and slow-release nutrients (Ibrahim *et al.*, 2021). The superior performance of treatments that integrated poultry manure with NPK fertilizer could also be attributed to the synergistic effects of the organic and inorganic nutrient sources. While poultry manure improves soil organic matter, microbial activity, and nutrient retention, the NPK provides readily available nutrients essential for rapid vegetative growth (Eifediya & Remison, 2019). Furthermore, Abbas *et al.* (2019) reported that poultry manure combined with NPK fertilizer increases soil pH, macronutrients, phosphorus and cation exchange capacity of the soil which improves dry matter yield of okro. Similar findings were reported by Ibrahim *et al.* (2021) and Yusuf *et al.* (2020), who observed that integrated nutrient management significantly increased dry matter production in okro and other vegetable crops by enhancing photosynthetic efficiency and nutrient uptake. The consistently low dry matter in the control treatment suggests nutrient limitations that restricted plant growth and biomass accumulation (Olowe *et al.*, 2020).

Differences between varieties can be attributed to genetic variations in nutrient use efficiency and growth potential (Olowe *et al.*, 2020). The relatively lower DMA in Clemson Spineless compared to Asontem reflects its early-maturing nature, which typically results in less vegetative biomass production (Yusuf *et al.*, 2020).

5.4 Yield and Yield Components

5.4.1 Number of fruits per plant

Combined application of NPK fertilizer and poultry manure (PM) only significantly increased the number of fruits per plant for both Asontem and Clemson varieties (Table 4.8). These findings suggest that integrated nutrient management (i.e. combining inorganic and organic fertilizers) enhances fruit production (Adekiya & Agbele 2020) through its

capacity to improve soil structure, water retention, and nutrient availability due to a lower C/N ratio, which facilitates faster mineralization (Lal, 2015). Several researchers have reported that the combinations of organic and inorganic fertilizers perform better on crop yield than when each of them is solely used Mishra *et al.*, (2019). The control group has the least number of fruits per plant in both years. This confirms the research by Phares *et al.* (2020), who investigated the effects of organic and inorganic fertilizers on okro yield and quality, and found that combining organic and inorganic fertilizers significantly increased fruit yield, suggesting a synergistic effect.

5.4.2 Fruit length and fruit diameter

The results demonstrated that integrated nutrient management (INM) significantly influenced fruit length and fruit diameter in both Asontem and Clemson okro varieties (Table 4.9 and 4.10). This trend suggests that a balanced integration of organic and inorganic fertilizers enhances vegetative and reproductive growth of okro, possibly due to improved nutrient availability and soil structure thereby promoting better fruit formation (Egnime *et al.*, 2023). These results corroborate earlier findings by Phares *et al.* (2020), who reported that moderate to high NPK and poultry manure combinations improved okro growth parameters and yield and yield components such as fruit girth/diameter, length, and total fruit yield in okro.

The synergistic effect of organic and inorganic fertilizers supports sustainable nutrient supply, ensuring steady plant growth and optimal fruit development (Imran *et al.*, 2024).

5.4.3 Total fruit yield

Generally, the average total fruit yields of both Asontem and Clemson spineless varieties were influenced by integrated nutrient management, which support previous findings by Mishra *et al.* (2019), Imthiyas and Seran (2017), Prradhiepan *et al.* (2018) and Seran (2018), who reported that the combinations of organic and inorganic fertilizers performed better on crop yield than when each of them is used solely. These findings also align with previous research showing that the combined application of organic and inorganic fertilizers improves soil fertility, nutrient availability, and ultimately crop yield (Adekiya *et al.*, 2017; Ojeniyi *et al.*, 2014).

Nutrient use efficiency of crops tends to be better with a mixture of organic manure and inorganic fertilizer. Also, nutrients were more available to okro plants with the combination compared to only one type of manure (Chanchal *et al.* (2018). The control treatments recorded the lowest total fruit yields of in both years. Overall, Asontem performed better than Clemson in terms of fresh yield of okro in both 2021 and 2022 cropping seasons.

5.5 Partial Budget Analysis

The superior net benefit and benefit cost ratio (BCR) observed for the Asontem variety under 162.5 kg/ha NPK + 15 t/ha poultry manure (PM) suggests that integrated nutrient management optimizes input efficiency and profitability by combining immediate nutrient availability from mineral fertilizer with the soil-conditioning effects of organic amendments. This synergy enhances nutrient use efficiency, improves soil structure, and sustains crop productivity (Oluwaseun *et al.*, 2019). In contrast, the low net benefit and BCR recorded for Clemson spineless under 650 kg/ha NPK likely reflect diminishing economic returns due to high input costs and possible nutrient imbalances or leaching

losses associated with excessive inorganic fertilizer use (Chivenge *et al.*, 2021). The intermediate BCR values under 325 kg/ha NPK combined with 10 t/ha and 20 t/ha PM across both varieties further confirm that moderate integration of organic and inorganic inputs provides a balance between cost and yield benefits, aligning with findings that partial substitution of mineral fertilizers with organic sources improves profitability and sustainability in vegetable production systems (Agegnehu *et al.*, 2021).

The high net benefits and BCR observed under integrated nutrient management treatments agree with recent studies that showed that combining organic and inorganic fertilizers improves nutrient availability, enhances soil biological activity, and increases crop productivity more effectively than either source alone, especially the sole NPK; Saurabh *et al.*, 2022).

The dominance analysis also showed that Asontem at 162.5 kg/ha NPK + 15 t/ha PM had an MRR of 66.21 % over Asontem control (no fertilizer) treatment and also dominated all other treatments. Asontem variety in combination with 162.5 kg/ha NPK + 15 t/ha PM treatment achieved the highest yield, net benefit, and benefit–cost ratio, demonstrating superior profitability and resource use efficiency. These results align with economic evaluations in recent fertilizer integration studies, which report that combining organic and inorganic sources consistently yields MRR values well above the 100% threshold used in smallholder decision-making (Fening *et al.*, 2022). The trend generally showed strong crop responsiveness to balanced nutrient supply, consistent with findings that okro varieties with high nutrient demand perform exceptionally well under integrated nutrient management and produces higher productivity and profitability (Maruthi, 2020).

In contrast, Clemson Spineless, though responsive, generally produced lower yields and net benefits, suggesting lower varietal nutrient-use efficiency under the same management regime. The Clemson Spineless treatments performances might indicate less efficient use of inputs and lower economic performance a trend reported in comparative variety studies where certain okro varieties fail to translate nutrient supply into proportionate yield gains (Aminu *et al.*, 2016). Similar varietal differences in profitability and nutrient-use response have been reported in okro research across West Africa (Afe *et al.*, 2017). Given the consistent higher performance of Asontem over Clemson spineless, varietal choice alongside balanced fertilizer integration should be prioritized for sustainable and profitable okro production. These findings also support previous reports that indicated that varietal characteristics significantly influence economic performance under fertilizer regimes (Imran *et al.*, 2020).

5.6 Nutritional Quality of Fresh Harvested Okro Fruits

5.6.1 Moisture content and ash content of fresh okro

Generally, the moisture content of fresh okro fruits varied slightly across varieties and fertilizer treatments, ranging from 25.44% to 26.74%. Asontem recorded its highest moisture content (26.74%) with the application of 650 kg/ha NPK, while Clemson attained 26.44% under 487.5 kg/ha NPK + 5 t/ha poultry manure (PM). The lowest moisture contents (26.3% for Asontem and 26.0% for Clemson) were observed with the sole application of 20 t/ha PM. The relatively higher moisture levels under NPK and NPK + PM treatments suggest improved water uptake and retention due to better nutrient availability and soil structure (Khandaker *et al.*, 2024). These results are consistent with the findings of Uwiringiyimana *et al.* (2024), who observed that okro fruits possess naturally high moisture content compared to leaves, contributing to their tenderness and perishability. Moisture content is a key indicator of okro freshness and postharvest quality,

with higher levels promoting microbial activity and faster spoilage, while drying substantially reduces this risk (Chukwuma *et al.*, 2018; Arjun *et al.*, 2018).

The ash content of fresh okro fruits also showed significant varietal differences, with Clemson spineless showing higher mean ash content than Asontem. The highest ash contents were observed under 162.5 kg/ha NPK + 15 t/ha PM and control treatments for Asontem and Clemson spineless, respectively. However, the lowest ash contents were obtained for 487.5 kg/ha NPK + 5 t/ha PM treatment in both varieties. These variations may be attributed to differences in nutrient uptake efficiency and the mineralization rate of the applied organic materials (Cassity-Duffey *et al.*, 2020). The relatively higher ash content in Clemson spineless indicates a greater concentration of essential minerals such as calcium, potassium, and magnesium, which are influenced by soil nutrient dynamics and fertilizer composition. This aligns with findings from Arjun *et al.* (2018), who reported that integrated nutrient management systems enhance the mineral quality of vegetables, while maintaining desirable moisture levels.

5.6.2 Crude protein, crude fat and crude fibre content of fresh okro

The crude protein content varied significantly between varieties and among the fertilizer treatments. Asontem recorded the highest mean crude protein under the control treatment and the lowest with 20 t/ha PM. Similarly, Clemson spineless showed higher protein levels with 650 kg/ha NPK and the lowest under 20 t/ha PM Table 4.16. These findings indicate that moderate inorganic fertilization enhances nitrogen assimilation and protein synthesis in okro, while excessive organic inputs may slow nutrient mineralization (Khandaker *et al.*, 2024). This agrees with the report by Idris *et al.* (2022), who found that the combined

application of NPK and poultry manure improves soil nitrogen status, promoting higher protein accumulation in vegetables.

The crude fat content also differed significantly ($P < 0.05$) between treatments Table 16. Asontem produced the highest fat content (2.73%) under 162.5 kg/ha NPK + 15 t/ha PM, while the lowest (2.25%) was recorded with 20 t/ha PM alone. Clemson spineless exhibited similar trends, with 2.56% and 2.20% under 487.5 kg/ha NPK + 5 t/ha PM and 20 t/ha PM, respectively. The relatively higher fat content under integrated fertilizer treatments suggests improved energy metabolism due to balanced nutrient availability (Arjun *et al.*, 2018). This supports the assertion of Khandaker *et al.* (2024) that combining organic and inorganic fertilizers optimizes nutrient release, enhancing lipid accumulation in okro fruits.

Similar to crude protein and crude fat, the crude fibre content also differed significantly among treatments in both years. Asontem recorded the highest crude fibre content under 650 kg/ha NPK and 325 kg/ha NPK + 10 t/ha PM, while Clemson spineless had the highest crude fibre under 325 kg/ha NPK + 10 t/ha PM. The lowest fibre contents for both Asontem and Clemson spineless were recorded in the control treatments. Higher fibre levels under NPK and integrated treatments may be attributed to enhanced vegetative growth and structural carbohydrate accumulation (Tetteh *et al.*, 2022).

5.6.3 Carbohydrate, total sugar and total solids of fresh okro

The results showed that integrated nutrient management (INM) significantly influenced the carbohydrate, total sugar, and total solids content of fresh okro across both varieties. The highest carbohydrate levels were observed under 20 t/ha poultry manure (PM) in Asontem and the control in Clemson spineless, suggesting that organic matter and nutrient reserves

in the soil can influence carbohydrate accumulation in fruits. These findings are consistent with those of Adomako *et al.* (2021) and Idris *et al.* (2022), who reported that moderate organic fertilizer applications enhance carbohydrate formation by improving photosynthetic efficiency and soil organic carbon.

Clemson recorded slightly lower carbohydrate values compared to Asontem, indicating varietal variation in carbohydrate metabolism and nutrient use efficiency, which agrees with observations by Amponsah and Frimpong (2024). The significant interactive effects among variety, fertilizer, and year also emphasize the combined influence of genotype and environmental factors on nutrient accumulation in okro fruits.

The highest mean total sugar content was recorded under 487.5 kg/ha NPK + 5 t/ha PM and 650 kg/ha NPK in both Clemson spineless and Asontem, respectively (Table 4.17). The lowest sugar contents were observed under 325 kg/ha NPK + 10 t/ha PM and 162.5 kg/ha NPK + 15 t/ha PM. These results suggest that moderate combinations of inorganic and organic fertilizers enhance carbohydrate translocation and sugar synthesis (Tetteh *et al.*, 2022). Woumbo *et al.* (2022) similarly reported that nutrient-enriched soils promote higher sugar and mineral accumulation in okro, contributing to better fruit flavor and quality.

The fresh okro fruits recorded the low total solids due to their high moisture content. Asontem showed the highest total solids under 487.5 kg/ha NPK + 5 t/ha PM, while Clemson spineless recorded the highest under 325 kg/ha NPK + 10 t/ha PM. These results demonstrate that integrated fertilization enhances dry matter content and solid accumulation, improving the textural quality of okro fruits (Khandaker *et al.*, 2024). The

significant differences observed between varieties and treatments may be due to genetic differences in water retention and metabolic activity (Asante *et al.*, 2024).

5.6.4 Total energy of fresh okro

The total energy content of fresh fruits of Asontem was similar to Clemson spineless. The highest total energy in Asontem was observed under the combined application of 325 kg/ha NPK + 10 t/ha poultry manure (PM), while the lowest occurred at 650 kg/ha NPK. In Clemson, the highest total energy was recorded under 650 kg/ha NPK, whereas 20 t/ha PM produced the lowest total energy.

These variations suggest that the balance of organic and inorganic fertilizers plays a critical role in optimizing nutrient availability and energy accumulation in okro fruits. According to Mokgalabone *et al.* (2023), integrated nutrient application enhances the synthesis of carbohydrates, fats, and proteins, which contribute to higher caloric values. Similarly, Lumaya (2020) found that combining NPK and organic manure improves soil nutrient dynamics, leading to better nutrient uptake and higher biochemical energy reserves in okro pods. The significantly higher total energy content in Clemson compared to Asontem reflects varietal differences in metabolic activity and nutrient utilization efficiency, corroborating the findings of Khandaker *et al.* (2024). Additionally, Asante *et al.* (2020) noted that INM enhances both yield and nutritional quality by improving soil fertility and plant physiological responses.

5.6.5 Nitrogen, vitamin C, and potassium content of fresh okro

The study showed that integrated nutrient management (INM) significantly influenced the nitrogen, vitamin C, and potassium content of fresh okro across both Asontem and Clemson

spineless varieties. The nitrogen content was highest in treatments combining NPK and poultry manure (PM). Specifically, Asontem had the highest nitrogen content under 162.5 kg/ha NPK + 15 t/ha PM, while Clemson spineless had the highest N content under 650 kg/ha NPK. These findings support the results of Agyeman *et al.* (2022), who reported that INM enhances soil nitrogen availability and uptake efficiency in okro, leading to improved protein synthesis and overall plant growth.

Vitamin C content was slightly higher in Clemson spineless than Asontem, suggesting varietal differences in ascorbic acid biosynthesis. This aligns with Adu-Gyamfi *et al.* (2021), who reported that organic amendments improve vitamin content due to the slow release of essential micronutrients.

Potassium content was also influenced by both manure and NPK application, as supported by Khandaker *et al.* (2024), who observed that balanced nutrient application enhances potassium uptake, which contributes to improved fruit firmness, nutrient transport, and metabolic balance in okro.

5.7 Proximate Analysis of Fresh and Dried Okro after Storage

5.7.1 Moisture content, ash content, crude fat, and crude protein

As expected, the stored fresh okro fruits had higher moisture content compared with the moisture content in the dried methods used in the study, as a result of dehydration in the sun-dried methods. In addition, the study also showed that integrated nutrient management (INM) and processing methods significantly influenced the proximate composition of okro, particularly the moisture, ash, crude fat and crude protein contents. Sun-drying resulted in a marked reduction in moisture content, which in turn resulted in concentrated nutrients compared with the fresh fruits. Similar observations were reported by Combo *et al.* (2020),

who noted that moisture reduction during drying enhances nutrient density in okro by minimizing water activity and microbial susceptibility. Clemson spineless exhibited slightly higher moisture levels than Asontem, consistent with findings by Regmi *et al.* (2022), who attributed varietal differences in moisture content to genetic factors and the influence of nutrient balance on water uptake efficiency.

The generally, slightly high crude fat content across fertilizer treatments, reflect the influence of nutrient supply on lipid synthesis. Higher crude fat was generally observed under integrated NPK and poultry manure treatments agrees with Mustapha *et al.* (2024), who found that combined fertilizer applications increase oil precursors in vegetables due to improved nitrogen and phosphorus availability. The increased crude protein content under the integrated nutrient management systems shows enhanced protein accumulation, which aligns with the findings of Khandaker *et al.* (2024), who demonstrated that INM improves nitrogen assimilation and amino acid synthesis, leading to higher protein content in okro fruits.

5.7.2 Crude fibre content, carbohydrate, and total sugars

Integrated nutrient management (INM) and storage methods significantly influenced the crude fibre, carbohydrate, and total sugar content of okro (Table 4.20). The crude fibre content of both varieties was higher in the dried storage methods compared with the fresh fruits. The increase in fibre content after drying may be attributed to the reduction in moisture content, leading to the concentration of fibrous materials. Similar observations were reported by Regmi *et al.* (2022), who found that drying and nutrient management increase fibre concentration due to reduced water content and enhanced cell wall lignification. Crude fibre plays an essential role in improving digestion and preventing

metabolic disorders. Treatments that received integrated NPK and poultry manure combinations recorded higher fibre content, consistent with the findings of Rafee *et al.* (2024), who reported that organic-inorganic fertilizer integration enhances structural carbohydrate synthesis and fibre accumulation in okro.

The results indicated that carbohydrate content varied significantly among the storage methods and fertilizer treatments (Table 4.20). Dried samples recorded higher carbohydrate levels than fresh okro fruits, reflecting the effect of moisture loss and starch concentration during dehydration. Regmi *et al.* (2022), also observed similarly that drying increased carbohydrate content due to reduced water content. Clemson spineless recorded higher carbohydrate content than Asontem, indicating varietal influence on carbohydrate biosynthesis. These findings align with Magar *et al.* (2023), who noted that varietal differences and fertilizer interactions significantly affect carbohydrate partitioning and storage in vegetables under integrated nutrient management systems.

The total sugar content of both varieties showed slight variations across treatments, with the highest total sugar content recorded where the 650 kg/ha NPK treatment was applied. These results suggest that higher NPK levels enhanced sugar synthesis, possibly through increased photosynthetic efficiency and carbohydrate metabolism. Balanced fertilization promotes sugar accumulation and sweetness in okro fruits. The lack of significant differences between varieties indicates that environmental and postharvest factors may play a more substantial role than genotype in determining sugar concentration (Khandaker *et al.*, 2024).

5.7.3 Total solids and total energy

The results showed that the storage methods and integrated nutrient management (INM) had significant effects on the total solids and total energy content of okro. The total solids on the average were higher in the dried samples, with fresh okro fruits having the lowest total solids due to its high moisture content. Dried samples of both Asontem and Clemson varieties showed substantially higher total solids, which can be attributed to moisture loss and concentration of dry matter. Similar trends were reported by Cheng *et al.* (2018), who observed that drying and nutrient application increase total solids in vegetables by reducing water activity and concentrating biochemical constituents.

In Asontem, the highest total solids were recorded under the 325 kg/ha NPK + 10 t/ha poultry manure treatment, while Clemson spineless recorded the highest total solids under the control treatment. This highlights the differences in varietal responses to nutrient availability, with Clemson spineless maintaining higher total solids in unfertilized conditions.

Fresh okro fruits from Clemson spineless also exhibited higher total solids than Asontem, suggesting that genetic differences in fruit texture and mucilage composition affect water retention. According to Adu (2020), varietal variation plays a key role in determining moisture–solids balance, with higher solids content enhancing shelf stability and processing quality.

The total energy content of okro under the different storage methods ranged from 250.66 to 278.28 kcal/100 g, with the dried okro storage methods having higher energy values than fresh ones (Table 4.22). This increase in total energy in the dried storage methods

corresponds with the higher concentrations of carbohydrates, fats, and proteins in dried samples. Similar findings were reported by Idris *et al.* (2022), who noted that drying and integrated nutrient management improve the caloric density of leafy and fruit vegetables. Clemson generally exhibited higher energy values than Asontem, reflecting varietal differences in nutrient assimilation efficiency.

5.7.4 Nitrogen, vitamin C and potassium

The storage methods and integrated nutrient management (INM) significantly influenced the nitrogen (N) content of stored okro fruits across treatments. Storage and processing (drying and/or powdering) significantly reduced nitrogen content perhaps as a result of the drying and prolonged drying compared with fresh okro fruits. These results align with studies that showed that drying and prolonged storage generally decrease biochemical constituents, including nitrogenous compounds, due to oxidative and thermal degradation (Prity *et al.*, 2023). Varietal differences were evident, with Clemson spineless showing higher N accumulation than Asontem under similar fertilizer regimes. This reflects genotype-dependent responses and varietal differences in nutrient accumulation patterns to fertilizer inputs, a trend also observed in recent okro nutrient uptake studies (Lokesh *et al.*, 2024; Prity *et al.*, 2023). The effects of INM were evident among the varieties in storage, with high N content under 650 kg/ha NPK, which was statistically similar to combined treatments such as 487.5 kg/ha NPK + 5 t/ha PM and 325 kg/ha NPK + 10 t/ha PM. This is consistent with recent findings that integrating organic and inorganic fertilizers improves nutrient accumulation and overall crop quality (Gaddisa, 2024). Other studies have also shown that poultry manure enhances soil N mineralization and maintains a stable supply of plant-available N, which enhances nutrient uptake (Yasmin *et al.*, 2024).

The results also demonstrated that integrated nutrient management (INM) significantly influenced the Vitamin C (ascorbic acid) content of okro across the storage methods and varieties. A marked decline in Vitamin C content was observed in all dried storage methods samples compared to the stored fresh okro fruits. This reduction is expected because Vitamin C is highly sensitive to oxidation and thermal degradation. Similar reductions have been documented in recent studies where drying, especially at high temperatures, significantly decreased Vitamin C in okro and other vegetables (Obasi *et al.*, 2025). *Prity et al.* (2023) also observed substantial losses of heat-labile nutrients in processed okro, supporting the present findings. The consistent decline in Vitamin C in dried okro fruits in comparison with fresh okro fruits underscores the need for improved low-temperature or controlled-environment drying systems to minimize nutritional losses during storage.

Varietal differences were also evident, where Clemson spineless generally showed higher Vitamin C levels in the cut-powdered form compared to Asontem, confirming that genotypic variation plays a major role in vitamin accumulation. This observation aligns with Esiosa *et al.* (2024), who reported that different okro varieties respond differently to fertilizer regimes in terms of both growth and nutrient composition.

The significantly higher Vitamin C levels observed in certain INM treatments confirm the positive role of integrated nutrient application in enhancing the nutritional quality of okro. For instance, the highest Vitamin C content in whole-powdered Asontem under the application of 162.5 kg/ha NPK + 15 t/ha PM and Clemson spineless under 325 kg/ha NPK + 10 t/ha PM, supports earlier work indicating that combining organic and inorganic fertilizers enhances the accumulation of vitamins and antioxidants in vegetables (Mishra *et*

al., 2025; Sakr *et al.*, 2021) and improves vitamin C synthesis by increasing soil biological activity and micronutrient availability (Springer, 2023).

The results also showed that the potassium (K) content of okro varied significantly across varieties, fertilizer regimes, and storage methods. Storage and processing influenced potassium retention, as the whole/cut powdered method had higher K content than the cut-dried and whole-dried methods in both varieties. This suggests that drying may promote K loss, likely due to leaching and disruption of cellular structures, a mechanism described in postharvest nutritional studies of vegetable crops (Akinmutimi *et al.*, 2023). The higher K retention in powdered storage samples relative to the other dried methods might indicate that nutrient mobility during processing can vary with tissue structure and moisture content (Gideon & Adeoye, 2021).

Differences between varieties were also evident in all forms of stored/processed okro, with Clemson spineless having higher K accumulation than Asontem under INM, supporting evidence that varietal genotype interacts strongly with nutrient supply to influence K uptake efficiency (Assogba *et al.*, 2023). The significant variety \times fertilizer interaction observed in the present study therefore agrees with recent findings that okro cultivars respond differently to organic–mineral nutrient combinations.

The observed variation in potassium (K) content among treatments can be explained by differences in nutrient release patterns and plant availability between inorganic fertilizers and organic amendments. The higher K content recorded in whole/cut powdered Asontem under sole application of 650 kg/ha NPK is consistent with the rapid solubility and immediate availability of mineral fertilizers, which enhances nutrient uptake and

accumulation in plant tissues. Potassium exists in readily exchangeable forms in the soil solution and is quickly absorbed by crops when supplied through inorganic fertilizers (Gaddisa, 2024).

In contrast, the lower K content observed under 20 t/ha poultry manure may be attributed to the slow and gradual mineralization of organic materials. Although poultry manure contains appreciable nutrients, their release depends on microbial decomposition, which may not synchronize with peak crop nutrient demand, thereby limiting immediate K uptake (Adekiya *et al.*, 2020).

Similarly, the higher K content observed in Clemson Spineless under the combined application of 325 kg/ha NPK + 10 t/ha poultry manure supports the principle of integrated nutrient management. The combined use of organic and inorganic nutrient sources improves nutrient use efficiency by supplying both readily available nutrients and sustained nutrient release, while also enhancing soil properties such as cation exchange capacity and microbial activity. This synergistic effect leads to improved uptake of nutrients, including potassium (Essilfie *et al.*, 2024; Gaddisa, 2024)

These trends under Asontem indicate that mineral fertilizer supplied K more readily than organic manure alone, consistent with reports that higher mineral NPK rates enhance K availability and uptake in okro (Gideon & Adeoye, 2021; Akinmutimi *et al.*, 2023), while the trends under Clemson spineless demonstrate the effectiveness of integrated nutrient management (INM) in improving K accumulation, a trend also highlighted in recent INM trials on okro in West Africa (Islam *et al.*, 2021; Assogba *et al.*, 2023).

Fresh okro samples also exhibited significant differences, with the highest K contents in Asontem and Clemson spineless recorded under fertilizer applications that included mineral nutrient sources. These results support existing literature that fertilizer type and

rate significantly influence mineral content in fresh vegetables (Islam *et al.*, 2021; Gideon & Adeoye, 2021).

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The combination of poultry manure and NPK (15:15:15) used in the study improved the low fertility status of the soil. It also enhanced the growth, yield and nutritional quality of okro when used as soil amendment.

- The combination of $\frac{3}{4}$ NPK + $\frac{1}{4}$ PM and $\frac{1}{4}$ NPK + $\frac{3}{4}$ PM proved most effective, producing vigorous plants and optimal crop yield.
- The study established that integrating poultry manure with NPK fertilizer significantly enhances okro growth, with Asontem performing better than Clemson Spineless.
- The dried storage methods retained higher and concentrated nutrient constituents than the stored fresh fruits, except moisture content. Among the dried storage methods, the whole/cut powdered and the cut dried fruits had the highest crude protein, crude fibre and carbohydrate.
- Integrated NPK + PM treatments significantly improved yield, profitability, and viability with Asontem $\frac{1}{4}$ NPK + $\frac{3}{4}$ PM emerging as the most profitable and sustainable option.
- The integrated combination of NPK (15:15:15) and poultry manure at 325 kg/ha NPK +10 t/ha PM, 162.5 kg/ha NPK + 15 t/ha PM and 487.5 kg/ha NPK+5 t/ha PM also showed increased number of fruits per plant, fruit length and diameter as well as total fresh fruit yield. Asontem variety also had higher total fruit yields than Clemson spineless.
- The integrated combination of 325 kg/ha NPK +10 t/ha PM, 162.5 kg/ha NPK + 15 t/ha PM, 487.5 kg/ha NPK+5 t/ha PM and the sole application of 650 kg/ha NPK on the average produced the highest nutrient quality of harvested fresh fruits in

terms moisture, ash, crude protein, crude fibre, crude fat, carbohydrates, total sugars, solids and energy as well as nitrogen, vitamin C and potassium contents.

- The partial budget analysis indicated that 162.5 kg/ha NPK + 15 t/ha PM had the highest net benefit and BCR under both varieties. The 325 kg/ha NPK +10 t/ha PM and 20 t/ha PM had intermediate net benefits and BCR. With the dominant analysis (MRR), the 162.5 kg/ha NPK + 15 t/ha PM had an average of 66.21 % over the control treatments and dominated all other treatments under both varieties.
- The integrated nutrient management treatments 325 kg/ha NPK +10 t/ha PM, 162.5 kg/ha NPK + 15 t/ha PM and 487.5 kg/ha NPK+ 5 t/ha PM had the highest nutrient constituents in storage than the sole application of NPK and PM.

6.2 Recommendations for Adoption

- Integrated nutrient management should be adopted by okro farmers—specifically, a combination of NPK and poultry manure (at ratios between $\frac{3}{4}$ NPK + $\frac{1}{4}$ PM and $\frac{1}{4}$ NPK + $\frac{3}{4}$ PM)—to achieve optimal vegetative growth and yield.
- Okro farmers in the study area are advised to adopt the ($\frac{1}{4}$ NPK + $\frac{3}{4}$ PM) and ($\frac{1}{2}$ NPK + $\frac{1}{2}$ PM) integrated nutrient management strategy for both Asontem and Clemson okro production, with priority given to Asontem for higher profitability.
- Drying methods or dehydration could be useful in preserving okro (*Abelmoschus esculentus* L. Moench) more hygienically and retain higher and concentrated nutrient constituents (crude protein, crude fibre and carbohydrate) than the stored fresh fruits.
- It is recommended for consideration for adoption by okro farmers for okro production in the transitional zone, the application of 325 kg/ha NPK + 10 t/ha PM, ($\frac{1}{2}$ NPK + $\frac{1}{2}$ PM), 162.5 kg/ha NPK + 15 t/ha PM ($\frac{1}{4}$ NPK + $\frac{3}{4}$ PM), and 487.5 kg/ha NPK + 5 t/ha PM ($\frac{3}{4}$ NPK + $\frac{1}{4}$ PM) for improved okro growth and development and higher total fruit yield for both varieties, with priority given to Asontem for higher profitability.

6.3 Recommendations for Further/Future Studies

- It is recommended that a series of experiments on the same experimental fields could be carried out to study further the residual effect of the nutrient combination used on subsequent crops.
- Future studies could also target the biochemical characterization of any organic manure that would be used in research to determine lignin, polyphenols and other secondary metabolites present. This would enable researchers to recommend to farmers the appropriate organic.
- Carry out further investigations on the responses to Asontem and Clemson spineless varieties to pests and diseases under the integrated nutrient management regimes.

REFERENCES

- Abbas, Z., Mubashir, M., Riaz, U., Javid, Z., Ashraf, M., Rehman, S. ur, Qamar, M. J., Zulqadar, S. A., & Mehdi, S. M. (2019). Combined impacts of compost, poultry manure and NPK fertilizers on yield of okro plant (*Abelmoschus esculentus* L. Moench). *Pakistan Journal of Agricultural Research*, 32(3): 456-465.
- Abd El-Hack, M. E., Ashour, E. A., AlMalki, F., Khafaga, A. F., Moustafa, M., Alshaharni, M. O., Youssef, I. M., Elolimy, A. A., & Świątkiewicz, S. (2024). Harmful impacts of microplastic pollution on poultry and biodegradation techniques using microorganisms for consumer health protection: A review. *Poultry Science*. (2024).
- Abdelhamid, M., & Soliman, A. (2022). Advances in calorimetric techniques for food energy determination. *Journal of Food Composition and Analysis*, 108, 105–118.
- Abdulraheem, M.I., Ihtisham, M. MMoshood, A.Y, Khan, N. Shahid, M.O. Hussain, S. Abbas, K. and Zaman. F. (2022). Disease-free and organic okro (*Abelmoschus esculentus* L. Moench) production through treatments combination of mulching types and weeding regimes. *Sarhad Journal of Agriculture*, 38(1): 81-91.
- Abua, Mary & Obok, Ekemini & Edugbo, Richmond & Effa, Emmanuel. (2026). Study on phenology, agronomic performance and correlation of yield-related traits in some okra genotypes. *Global Journal of Pure and Applied Sciences*. 31. 913-923. 10.4314/gjpas.v31i5.12.
- Abubakar, M. A., Musa, A., & Yahaya, S. M. (2022). *Influence of weed management practices on growth and yield of okra (Abelmoschus esculentus) in northern Nigeria*. *Journal of Agricultural Science and Practice*, 7(2), 45–52.

- Acharya, N., Ghimire, H. P., Sapkota, R., Acharya, S., Dahal, S., & Gnyawali, P. (2025). Effect of integrated nutrient management on growth and yield of tomato. *International Journal of Horticulture*, 15(3), 99–104.
- Adekiya, A.O. and Agbede, T.M. (2020). Growth and yield of tomato (*Lycopersicon esculentus* L.) is influenced by poultry manure and NPK fertilizer. *Journal of Food and Agriculture*.21 (1): 10-20.
- Adekpe, D. I., Edeh, J. A., & Garba, A. M. (2020). *Effect of different weed control methods on the performance of okra in the southern Guinea savanna zone of Nigeria*. Nigerian Journal of Agriculture and Food.
- Aderemi, A. Y. & Sangodoyin, A. M. (2019). Comparative effects of poultry waste, biochar and blended biochar on the yield of okro (*Abelmoschus esculentus*). *International Journal of Research and Scientific Innovation*, 6, 200–206.
- Aderemi, T. A., Alejo, A., Omoyele, O. S., Olaoye, O. P., & Azuh, D. E. (2022). *An econometric analysis of clean energy supply and industrial development in Nigeria: Implications for sustainable development*. *International Journal of Energy Economics and Policy*, 12(3), 209–215.
- Adhikari, A. and Piya, A., (2020). Effect of different sources of nutrient on growth and yield of okro (*Abelmoschus esculentus* L. Monech). *International Journal of Environmental & Agriculture Research*, 6(1), pp.45-50.
- Adhikari, S. P., & Gyawali, C. (2024). Comparative analysis of manures and fertilizer on okra growth, yield and its economics in Baitadi, Nepal. *Archives of Agriculture and Environmental Science*, 9(3), 422-430.
- Adu, D. J. (2020). Proximate composition and consumers acceptability of okro seed flour cake (Doctoral dissertation, University of Education, Winneba).

- Adu-Dapaah, H., Asare, E., & Safo-Kantanka, O. (2018). Assessment of okro (*Abelmoschus esculentus* L. Moench) for resistance to major insect pests in Ghana. *Journal of Applied Sciences and Environmental Management*, 22(2): 184-190.
- Adu-Dapaah, H., Asare, E., & Safo-Kantanka, O. (2019). Genetic variation and heritability estimates of some okro (*Abelmoschus esculentus* L. Moench) genotypes using morphological and molecular markers. *Scientific African*, 5 (1) 12-22.
- Adzawla, W., Camara, O., Bindraban, P. S., Martey, E., Gouzaye, A., Eshun, E., & Zida, Aetiba, J.P.N. and E.A. Osekre, (2016). Management of insect pests of okro (*Abelmoschus esculentus* L. Moench) Using Oxymatrine-based Insecticide. *Advances in Research*, 6(1): 1-7.
- Afe, A. I., & Oluleye, F. (2017). Response of okra (*Abelmoschus esculentus* L. Moench) to combined organic and inorganic foliar fertilizers. *International Journal of Recycling of Organic Waste in Agriculture*, 6(3), 189-193.
- Afrane, O. K. (2018). A comprehensive step by step guide to okro production in Ghana okro production (mofa.gov.gh).
- Agbede, T. M. (2025). Poultry manure improves soil properties and grain mineral composition, maize productivity and economic profitability. *Scientific Reports*, 15(1), 16501.
- Agbenorhevi, J. K., Kpodo, F. M., Banful, B. K. B., Oduro, I. N., Abe-Inge, V., Datsomor, D. N., Atongo, J., & Obeng, B. (2020). Survey and evaluation of okra pectin extracted at different maturity stages. *Cogent Food & Agriculture*, 6(1),1760476.
- Agegnehu, G., Srivastava, A. K., & Bird, M. I. (2021). The role of biochar and organic

- Agyin-Birikorang, S., Tindjina, I., Fugice Jr, J., Dauda, H. W., Issahaku, A. R., Iddrissu, M., & Singh, U. (2022). Optimizing sulfur fertilizer application rate for profitable maize production in the savanna agroecological zones of Northern Ghana. *Journal of Plant Nutrition*, 45(15), 2315-2331.
- Ahiakpa, J. K., H. M. Amoatey, G. Amenorpe, J Apatay, E. A. Ayeh, E. K. Quartey and W. S. K Agbemavor, (2014). Mucilage content of 21 accessions of okro (*Abelmoschus spp* L.). *Sci. Agri.*, 2(2): 96-101.
- Akinmutimi, A. L., Ndimele, C. N., & Agu, J. C. (2023). Evaluation of soil chemical properties, growth and yield of okra. *International Journal of Agriculture and Environmental Research*, 9(3).
- Ali, A. (2024). Integrated nutrient management of fruits, vegetables, and crops: Concepts and recent advances. *Agriculture*, 14(8), 1330.
- amendments in improving soil fertility and crop productivity: A review. *Applied Soil Ecology*, 119, 156–170.
- Aminu, D., Bello, O. B., Gambo, B. A., Azeez, A. H., Agbolade, O. J., Iliyasu, A., & Abdulhamid, U. A. (2016). Varietal performance and correlation of okra pod yield and yield components. *Acta Universitatis Sapientiae, Agriculture and Environment*, 8(1), 112-125.
- Anwar, F., Qadir, R., & Ahmad, N. (2020). Cold pressed okro (*Abelmoschus esculentus*) seed oil. In *goldpPressed oils* (pp. 309–314). Elsevier.
- Aprilliz, E. (2017). Research and developmental final project okro syrup (Utilization of okro as a Healthy Beverage).
- Arjun, M. A., Singh, T., Shukla, M., & Namdeo, K. (2018). Integrated Nutrient Management on growth, yield and quality of okra (*Abelmoschus esculentus* L. Moench). *Annals of Plant and Soil Research*, 20(4), 344-348.

- Asante, J., Opoku, V. A., Hygienus, G., Andersen, M. N., Asare, P. A., & Adu, M. O. (2024). Photosynthetic efficiency and water retention in okra (*Abelmoschus esculentus*) contribute to tolerance to single and combined effects of drought and heat stress. *Scientific Reports*, 14(1), 28090.
- Aseffa, S., Degu, A., & Abebe, T. (2020). Effects of nitrogen and phosphorus fertilizer rates on growth, yield and yield components of okra (*Abelmoschus Esculentus* (L.) Monech) under rain fed condition in Metekel Zone, Northwestern Ethiopia. *Journal of Biology, Agriculture and Healthcare*, 10(11), 41-48.
- Asiedu, E. K., Tuffour, H. O., & Asare, E. (2021). Soil acidity and nutrient availability under smallholder farming systems in Ghana. *West African Journal of Applied Ecology*, 29(1), 45–56.
- Assi, O., Sidibe, D., Konan, Y., Coulibaly, A., Mahan, R., & Biege, H. (2017). Viscosity Study of Mucilages Extracted from *Abelmoschus esculentus*, *Beilschmiedia mannii*, *Corchorus olitorius* and *Irvingia gabonensis* from Côte d'Ivoire. *Journal of Applied Life Sciences International*, 11(1), 1–14.
- Association of Official Analytical Collaboration (AOAC) International. (2021). *Official methods of analysis of AOAC International* (21st ed.). AOAC International.
- Association of Official Analytical Collaboration (AOAC). (2005). *Official Methods of Analysis of AOAC International* (18th ed.). AOAC International.
- Association of Official Analytical Collaboration (AOAC). (2019). *Official Methods of Analysis of the Association of Official Analytical Chemists* (21st ed.). AOAC International, Washington, D.C.
- Assogba, D., Kouman, K. K., N'Dri, J. K., Amadji, G. L., & Kouamé, C. (2023). Response of okra to organic and mineral fertilization under different management systems. *Environmental Science and Pollution Research*, 30, 15020–15030.

- Atlas, Big. World okro production by country. Accessed online April 18, (2021).
- Awoonor, J. K., Amoakwah, E., Buri, M. M., Dogbey, B. F., & Gyamfi, J. K. (2025). Impact of Land use on soil quality: Insights from the forest-savannah transition zone of Ghana. *Heliyon*, 11(1).
- Axe, J. (2021). Okro nutrition: improve heart health, eyesight & cholesterol Levels. <https://draxe.com/nutrition/okra-nutrition/>.
- Ayanlade, A., Radeny, M., Morton, J. F., & Muchaba, T. (2018). Rainfall variability and drought characteristics in two agro-climatic zones: an assessment of climate change challenges in Africa. *Science of the Total Environment*, 630, 728-737.
- Aytenew, M., & Bore, G. (2020). Effects of organic amendments on soil fertility and environmental quality: A review. *Plant Sci*, 8(5), 112-119.
- Badrie, N., (2016). Nutrient profile, bioactive components, and functional properties of okro (*Abelmoschus esculentus* L. Moench). in fruits, vegetables, and herbs, Pp. 365-409.
- Banson, K. E., Quartey, E. K., Otoo¹, E. A., Baidoo¹, I., Aniabo, K. A. K. E. J., Cobbinah, J. F., ... & Nettey, S. N. A. (2024). The economic value of an Okra plant. *Mod Concepts Dev Agron*.
- Bationo, A., Kihara, J., & Vanlauwe, B. (2020). Soil fertility and management strategies for sub-Saharan Africa. *Advances in Agronomy*, 162, 1–31.
- Bawa, S. H., & Badrie, N. (2016). Nutrient profile, bioactive components, and functional properties of okro (*Abelmoschus esculentus* (L.) Moench). In *Fruits, Vegetables, and Herbs* (pp. 365–409). Elsevier.
- Boateng, O., Tuffour, H. O., & Adjei, I. O. (2020). Influence of phosphorus and potassium on growth, yield, and nutrient uptake of okro (*Abelmoschus esculentus* L.

- Moench) in the forest zone of Ghana. *Archives of Agronomy and Soil Science*, 66(3), 371–384.
- Brandenber, L., Shrefler, J., Damicone, J., Rebek, E. (2019). Oklahoma cooperative extension fact sheets Id: HLA-6025. are also available at: facts.okstate.edu.
- Bremner, J. M. (1996). *Nitrogen-Total*. In D. L. Sparks (Ed.), *Methods of Soil Analysis: Part 3—Chemical Methods* (pp. 1085–1121). Soil Science Society of America.
- Cassity-Duffey, K., Cabrera, M., Gaskin, J., Franklin, D., Kissel, D., & Saha, U. (2020). Nitrogen mineralization from organic materials and fertilizers: Predicting N release. *Soil Science Society of America Journal*, 84(2), 522-533.
- Chanchal, D. K., Alok, S., Kumar, M. (2018). A brief review of *Abelmoschus esculentus* (okra). *Int. J. Pharm. Sci. Res.* 58-66.
- Chawla, R., & Sadawarti, R. K. (2020). Effect of integrated nutrient management on vegetative and reproductive parameters of vegetable crops. *International Journal of Current Microbiology and Applied Sciences*, 9 (10), 2222–2235.
- Cheng, Z., Gong, X., Jing, W., Peng, Z., & Li, J. (2018). Quality change of postharvest okra at different storage temperatures. *Journal of Food Engineering and Technology*, 7(1), 43-43.
- Chivenge, P., Saito, K., Bunquin, M. A., Sharma, S., & Dobermann, A. (2021). Co-benefits of nutrient management tailored to smallholder agriculture. *Global Food Security*, 30, 100570.
- Chukwuma, C. I., Islam, M. S., & Amonsou, E. O. (2018). A comparative study on the physicochemical, anti-oxidative, anti-hyperglycemic and anti-lipidemic properties of amadumbe (*Colocasia esculenta*) and okro (*Abelmoschus esculentus* L. Beverage). *Journal of Food Biochemistry*, 42(5), e12601.

- Combo, A. M.-M., Dakia, P. A., Niaba, K. P. V., TraorÃ, N., & BeugrÃ G. A. M. (2020). Assessment of Chemical Composition and Nutritional Value of Some Varieties of okro available in the market of Daloa (Côte d'Ivoire). *Asian Journal of agriculture and food sciences*, 8(3).
- Dantas, T. L., Alonso Buriti, F. C., & Florentino, E. R. (2021). Okra (*Abelmoschus esculentus* L Moench.) as a potential functional food source of mucilage and bioactive compounds with technological applications and health benefits. *Plants*, 10(8), 1683.
- Das, D., Sahoo, J., Raza, M. B., Barman, M., & Das, R. (2022). Ongoing soil potassium depletion under intensive cropping in India and probable mitigation strategies. A review. *Agronomy for Sustainable Development*, 42(1), 4.
- Dash, S.K., Tripathy, P., Sahu, G., Pathak, M., Padhan, B., & Nayak H., (2020). Effect of integrated weed management practices on growth, yield attributes and yield of okro (*Abelmoschus esculentus* L. Moench) cv. Utkal Gaurav. *Journal of Crop and Weed*, 16(3): 253-255.
- Davis T. W. (2022b). Grower's guide: a review for sustainable production of okro (*Abelmoschus Esculentus* L. Moench) in West Africa and other Regions.
- Dilshad, M. D., Lone, M. I., Jilani, G., Malik, M. A., Yousaf, M., Khalid, R., & Shamim, F. (2010). *Integrated plant nutrient management (IPNM) on maize under rain-fed condition. Pakistan Journal of Nutrition*, 9(9), 896–901.
- Dubey, P., and Mishra, S. (2017). A review on: Diabetes and okro (*Abelmoschus Esculentus* L. Moench). *J. Med. Plants Stud.* 5, 23–26.
- Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. A., & Smith, F. (1956). *Colorimetric method for determination of sugars and related substances. Analytical Chemistry*, 28(3), 350–356.

- E. W. R. (2025). Fertilizer price hikes, farmers' willingness to pay and crop switching decision in Ghana. *Nutrient Cycling in Agroecosystems*.
- Eagri. (2023). Origin, area, production, varieties, package of practices for bhendi (syn: lady's finger, bhindi) (*abelmoschus esculentus* L. Moench) (2n = 130). (hindi: bhendi).
- Egnime, K. K., Outéndé, T., Atalaèso, B., & Koffi, T. (2023). Influence of reasoned organic and inorganic fertilization on okra (*Abelmoschus esculentus*) growth, productivity, and profitability on degraded sandy soil in South Togo. *Discover Agriculture*, 1(1), 9.
- Eifediyi, E. K., & Remison, S. U. (2019). Growth and yield response of okra (*Abelmoschus esculentus* L. Moench) to different levels of poultry manure and NPK fertilizer. *African Journal of Agricultural Research*, 14(3), 112–120.
- Enhancing sustainable crop production through integrated nutrient management: A systematic review. *Frontiers in Agronomy*, 6, 1422876.
- Esiosa, F. A., Efisue, A. A., & Adewale, C. I. (2024). Investigating the influence of inorganic and organic fertilizers on the growth and yield of three varieties of okro (*Abelmoschus esculentus*). *Vietnam Journal of Agricultural Sciences*, 7(3), 2195–2207.
- Espeland, E. K., & Kettenring, K. M. (2018). Strategic plant choices can alleviate climate change impacts: A review. *Journal of Environmental Management*, 222, 316–324.
- Essilfie, M. E., Darkwa, K., & Asamoah, V. (2024). Growth and yield response of maize
- Etaware, P, M. and Etaware, E.U. (2019b). Conservation of the functional properties of okro powder by local storage techniques. *Journal of Nanotechnology Research*. 1(2): 136-143.

- Etaware, P. M. and Etaware, E.U. (2019a). The effects of food processing techniques on Nutrient composition of okro (*Abelmoschus esculentus* L. Moench). *International journal of innovative research and advance studies*. 6(10): 90-94
- FAO (2021) Special Report - 2020 FAO/WFP Crop and food security assessment Mission (CFSAM) to the Republic of South Sudan.
- FAO/UNESCO/ISRIC (1988). *FAO/UNESCO soil map of the world: revised legend*. World Soil Resources Report No. 60, FAO, Rome.
- FAOSTAT (2022). *Food and Agricultural Organization Statistics*. <https://www.fao.org/faostat/en/#data/QCL> (assessed August 2022).
- Fening, J. O., Abubakari, A., & Banson, K. E. (2022). Profitability analysis of integrated soil fertility management among vegetable farmers in northern Ghana. *African Journal of Agricultural Economics*, 9(1), 14–27.
- Food and Agriculture Organization of the United Nations, FAO (2022). *The State of Food Security and Nutrition in the World 2022: Repurposing food and agricultural policies to make healthy diets more affordable*. Rome: FAO.
- Food and Agriculture Organization of the United Nations. (2021). *FAOSTAT statistical database*.
- for okro production: Effects on growth, yield, and nutrient uptake. *Journal of Plant Nutrition*, 42(9), 1021–1030.
- Fosu, M., Agyare, W. A., & Tetteh, F. M. (2021). Soil fertility amendments and crop response under Ghana's savannah agro-ecologies. *Ghana Journal of Agricultural Science*, 56(1), 45–58.
- Fufa, N. (2019). Propagation methods of okro (*Abelmoschus esculentus* L. Moench) and its application used in vitro plant regeneration. *Acta Scientific Agriculture* ISSN:2581-365X.

- Gaddisa, M. M. (2024). *Review on integrated nutrient management on yield and yield components of okra in Ethiopia. International Journal of Food Engineering and Technology*, 8(2), 34–41.
- Ghislain, W. T., Ndiaye-Faye, A., & Diouf, M. (2015). Assessing the effect of integrated crop management on okro production in Senegal. *African Crop Science Journal*, 23(4), 323-334.
- Gideon, C. O. K., & Adeoye, G. O. (2021). Dry matter yield of okra and nutrient dynamics with cocoa pod husk compost and NPK. *Eurasian Journal of Soil Science*, 10(1), 77–86.
- Gržinić, G., Piotrowicz-Cieślak, A. I., Klimkowicz-Pawlas, A., & Górny, R. L. (2022). Intensive poultry farming: A review of the impact on the environment and human health. *Journal of Occupational Health*, 64(1), e12411.
- Gyasi, F., Opoku, A., & Danquah, E. (2025). Sustainable nutrient management strategies for improved okra production under tropical conditions. *Ghanaian Journal of Agronomy and Environment*, 4(1), 10–20.
- Habte, A., Worku, W., Mamo, G., Ayalew, D., & Gayler, S. (2023). Rainfall variability and its seasonal events with associated risks for rainfed crop production in Southwest Ethiopia. *Cogent Food & Agriculture*, 9(1), 2231693.
- Haokip, S. W., Shankar, K., & Lalringheta, J. (2020). Climate change and its impact on fruit crops. *Journal of Pharmacognosy and Phytochemistry*, 9(1), 435-438.
- Hayamanesh, S. (2018). *The effect of high temperature on physiological and metabolic parameters and reproductive tissues of okro (Abelmoschus esculentus (L.) Moench)*.
- Hinsley, S. R. (2022). *Abelmoschus Notes*. <http://www.malvaceae.info/Genera/Abelmoschus/Abelmoschus.php>.

- Ibeh, C. U., Nsoanya, L., & Nweke, I. A. (2019a). Effect of Poultry Manure on Growth and Yield of Local Varieties of Okro (*Abelmoschus esculentus* L.)
- Ibeh, C. U., Nsoanya, L., & Nweke, I. A. (2019b). Effect of poultry manure on Growth and Yield of Local Varieties of Okra (*Abelmoschus esculentus*). *SSRN Electronic Journal*.
- Ibrahim, M., Bello, L., & Umar, S. (2021). Influence of integrated nutrient management on chlorophyll content and yield of okro (*Abelmoschus esculentus* L.). *Journal of Plant Nutrition and Soil Science*, 24(2), 78–85.
- Idris, M., Abdullahi, M., Ahmad, H., Garga, M. A., Ibrahim, N., Agyo-Likita, R., ... & Yusuf, I. M. (2022). The Comparative Study of the Proximate and Mineral Composition of Bush Okro (*Corchorus olitorius* L.) under the Influence of Jatropha Seed Cake, Chicken droppings and NPK fertilizer. *UMYU Journal of Microbiology Research (UJMR)*, 7(2), 30-35.
- Ilodibia, C.V., Achebe, U.A. and Chiafor, C. (2017). Nutrient characteristics assessment of two variants of okro (*Abelmoschus esculentus* L. Moench.) found in Anambra State, Nigeria. *Archives of Agriculture and Environmental Science*, 2(4): 298-300, DOI: 10.26832/24566632.2017.020408.
- Imran. (2024). Integration of organic, inorganic and bio fertilizer, improve maize-wheat system productivity and soil nutrients. *Journal of Plant Nutrition*, 47(15), 2494-2510.
- Imthiyas, M. S. M. and Seran, T. H. (2017), Marketable tuber yield of radish (*Raphanus sativus* L.) as influenced by compost and NPK fertilizers, *Res J Agric for Sci*. 5(11): 1-4.

- Islam, B., Akter, M., Khanam, M., Alam, A., Kabir, P., & Kamal, M. Z. U. (2021). Effect of integrated nutrient management on okra production in acid soil. *European Journal of Agriculture and Food Sciences*, 3(6), 406.
- Iwuala, E., Ajewole, T., Osundinakin, M., Popoola, M., Abiodun, I., & Agbolade, J. (2021). Impact of controlled microwave radiation in enhancing the productivity of *Abelmoschus esculentus* L. Moench. *Journal of Plant Interactions*, 16(1), 179–186. <https://doi.org/10.1080/17429145.2021.1912422>.
- Kaledhonkar, M. J., Meena, B. L., & Sharma, P. C. (2019). Reclamation and nutrients management for salt-affected soils. *Indian Journal of Fertilisers*, 15(5), 566–575.
- Kartini, N. L., Saifulloh, M., Trigunasih, N. M., Sukmawati, N. M. S., & Mega, I. (2024). Impact of long-term continuous cropping on soil nutrient depletion. *Ecological Engineering & Environmental Technology*, 25.
- Kaur, E., Sharma, R., & Singh, N. D. (2018). Efficacy of pre-emergence and post-emergence herbicides on weed control and yield in wheat. *International Journal of Current Microbiology and Applied Sciences*, 7(2), 883-887.
- Khan, S., Khan, A., Nadeem, T., Akbar, H., Hussain, Z. (2023). Phenology, crop stand, and dry matter production of wheat in response to beneficial microbes and organic matter sources. *SABRAO J. Breed. Genet.* 55(2): 463-475.
- Khandaker, M. M., Jusoh, N., Hafiza, N.A.A.R., Ismail, S. Z., (2017). The effect of different types of organic fertilizers on the growth and yield of *Abelmoschus esculentus*. Moench (okro). *Bulgarian journal of Agriculture science*, 23(1), Pp. 119-125.
- Khandaker, M. M., Nor M, F., Dalorima, T., Sajili, M. H., & Mat, N. (2017). Effect of different rates of inorganic fertilizer on physiology, growth and yield of okra

- (*Abelmoschus esculentus*) cultivated on Bris soil of Terengganu, Malaysia. *Australian Journal of Crop Science*, 11(7), 880-887.
- Kopittke, P. M., Harper, S. M., Asio, L. G., Asio, V. B., Batalon, J. T., Batuigas, A. M. T., ... & Sanchez, P. B. (2025). Soil degradation: An integrated model of the causes and drivers. *International Soil and Water Conservation Research*.
- Kpodo, F., Agbenorhevi, J.K., Alba, K., Oduro, I., Morris, G., & Kontotogiorgos, V. (2018). Structure-function relationships in pectin emulsification. *Foods Biophysics*, 13(1),71-79.
- Kugbe, X. J.; Salifu, A. & Ebenezer, S. K. (2019). Growth and yield of okro (*Abelmoschus esculentus* L. Moench) as affected by planting date and weeding regime in northern Ghana. *Journal of agriculture and crops*.5(4), 43-47.
- Kumar, R. (2019b). The impact of chemical fertilizers on our environment and ecosystem. *research trends in environmental sciences*, pp. 69-86.
- Kumar, R., Singh, A., Bhardwaj, A. K., Kumar, A., Yadav, R. K., & Sharma, P. C. (2022b). Reclamation of salt-affected soils in India: progress, emerging challenges, and future strategies. *Land degradation & development*, 33(13), 2169–2180.
- Kumar, V., Saikia, J., Nath, D.J., (2017). Effect of integrated nutrient management on growth, yield, and quality of okro (*Abelmoschus esculentus* L. Moench) cv. Arka Anamika. *IJCS*, 5 (5), Pp. 2001-2003.
- Lal, R. (2015). Restoring soil quality to mitigate soil degradation. *Sustainability*, 7(5), 5875–5895.
- Li, L., Wang, L., Zhang, X., & Shao, Q., (2019). Effects of controlled atmosphere storage on quality of okro fruit. *Journal of food process engineering*, 42(9), e13181.

- Li, Z., Zhou, J., & Wang, Q. (2023). Nutrient release patterns of poultry manure under varying environmental conditions. *Journal of Soil Science and Plant Nutrition*, 23(1), 112–124.
- Lin, Y., Ye, G., Kuzyakov, Y., Liu, D., Fan, J., & Ding, W. (2019). Long-term manure application increases soil organic matter and aggregation, and alters microbial community structure and keystone taxa. *Soil Biology and Biochemistry*, 134, 187-196.
- Liu, J., Zhao, Y., Wu, Q., John, A., Jiang, Y., Yang, J, Liu, H., Yang, B., (2019) Structure characterization of polysaccharides in vegetable “okro” and evaluation of hypoglycemic activity. *food chem* 242:211–216.
- Lumaya, L. (2020). Assessing the effect of organic and inorganic fertilizers on the severity of selected pests on the growth and yield of okra (doctoral dissertation, uganda martyrs university).
- Magar, S. K., Poudel, B., Dhungana, R., Rawal, S., Thapa, S., Bhusal, K. K., & Malla, S. (2023). Effect of integrated nutrient management on growth, yield, and soil nutrient status in okra (*Abelmoschus esculentus* cv. Arka Anamika). *Archives of agriculture and environmental science*, 8(1), 49-54,
- Mahajan, B. V. C., Bhagwat, P. K., & Kalyanshetti, A. (2018). Effect of post-harvest treatments on quality parameters of okro (*Abelmoschus esculentus* L. Moench). *International journal of current microbiology and applied sciences*, 7(11), 2062-2067.
- Maruthi, B. (2020). Effect of integrated nutrient management on growth, yield and quality of okra [*Abelmoschus esculentus* L. moench] cv. arka anamika.
- Mattila, T. J., & Rajala, J. (2022). Do different agronomic soil tests identify similar nutrient deficiencies?. *Soil Use and Management*, 38(1), 635-648.

- McLean, E. O. (1982). *Soil pH and lime requirement*. In A. L. Page (Ed.), *Methods of Soil Analysis: Part 2-Chemical and Microbiological Properties* (pp. 199–224). American Society of Agronomy.
- Mesfin, Y. M. (2024). Veterinary drug residues in food products of animal origin and their public-health consequences: A review. *Veterinary Medicine and Science* (review).
- Miah, R., Methela, N. J., & Ruhi, R.A. (2020). Effect of integrated nutrients management growth and yield of okro. *Tropical agrobiodiversity*, 1(2), 72-76.
- Mishra, B., Sahu, G. S., Tripathy, P., Mohanty, S., & Pradhan, S. (2019). Effect of organic and inorganic fertilizers on growth, yield and quality of okro under integrated nutrient management. *Int.J.Curr.Microbiol.App.Sci*, 8(8), 66–73.
- Mishra, V. K., Jain, A., Dhakar, R., Kumar, A., & Singh, A. (2025). Impact of integrated nutrient management on fruit yield and quality of okra. *International Journal of Research in Agronomy*, 8(4-B), 123–127. Moench). *SSRN Electronic Journal*, 9(3).
- Morris, A. L. and Mohiuddin, S. S. (2021). Biochemistry, Nutrients. In: StatPearls internet. treasure island (FL): *StatPearls Publishing*; 2022 Jan-. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK554545>.
- Muhammad, J., Khan, S., Lei, M., Khan, M. A., Nawab, J., & Rashid, A. (2020). Application of poultry manure in agriculture fields leads to food plant contamination with potentially toxic elements and causes health risk. *Environmental Technology & Innovation*, 19, 100909.
- Muhammad, M., Kutawa, A. B., Tadda, S. A., Muhammad, A., & Adamu, M. (2020). Productivity of okro (*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), 75–82.
- Musa, M., Bashir K. A. and Musa A. (2020). Influence of NPK fertilizer and poultry manure on growth, yield and quality of okro. *Int.J.Curr.Microbiol.App.Sci*, 8(8), 67-72.
- Musa, S., Amans, E. B., Babaji, B. A., & Ogunlela, V. B. (2017). Growth and yield response of okra and cowpea.
- Mustapha, R., Oluwole, B. I., & Daniya, E. (2024). Germination and seedling growth of okra: A comparative study with competitive weeds under salinity stress.
- Naim, A. H., & Abker, N. M. (2016). Effects of chicken manure and nitrogenous Fertilizer on growth,yield and yieldcComponents of okro (*Abelmoschus esculentus (L.) Monech*) under rainfed conditions. 7(6), 594-601.
- Nan, S. (2019). Thirteen the best okro varieties for your vegetable Patch/gadden.
- Ngogang, M. P., Ernest, T., Kariuki, J., Mouliom Mouiche, M. M., Ngogang, J., Wade, A., & van der Sande, M. A. B. (2021). Microbial contamination of chicken litter manure and antimicrobial.
- nutrient availability, crop productivity, and management options. *Agriculture, Forestry and Fisheries*, 13(2), 31–45.
- Nzweundji, J. G., Konan, K., Nyochembeng, L. M., Tchinda, N. D., & Niemenak, N. (2020). Improved germination of threatened medicinal *Prunus africana* for better domestication: Effects of temperature, growth regulators and salts. *Journal of Forestry Research*, 31(6), 2403–2411.
- Obasi, E., Nwankwo, C., & Chinedu, F. (2025). Effect of drying methods on the nutritional composition of selected vegetables (okra and tomato). *G-Journals of Agricultural Science*, 7(1), 45–53.

- Ogunkunle, C. O., Gambari, H., Agbaje, F., Okoro, H.K., Asogwa, N. T., Vishwakarma, V., Fatoba, P. O., (2020). Effect of low-dose nano titanium dioxide intervention on Cd uptake and stress enzymes activity in Cd-stressed cowpea [*Vigna unguiculata* (L.) Walp] plants. *Bulletin of Environmental Contamination and Toxicology*. 104, 619-626.
- Ojeniyi, S. O., Agbede, T. M., & Adekiya, A. O. (2014). Integrated use of organic and inorganic fertilizers for crop production in Nigeria. *Agriculture*, 4(2), 79–87.
- Okee, J. (2021). Evaluation of the effect of organic manure and inorganic fertilizer on the growth and yeild of okro (*Abelmoschus esculentus* L, moench) in lokoja, kogi state, Nigeria. *International Journal Of Agricultural Economics, Management And Development (IJAEMD)*, 8(2).
- Olaniyan, A. B., Adewale, O. M., & Adediran, J. A. (2021). Integrated nutrient management enhances growth and yield of okra under tropical conditions. *African Journal of Agricultural Research*, 16(7), 1123–1130.
- Olasantan, F. O., & Bello, N. J. (2021). *Weed interference and control in okra production under tropical conditions*. *African Journal of Plant Science*, 15(4), 123–131.2020 (November), 158–171.
- Olowe, O. M., Ajayi, O. J., & Ojo, A. A. (2020). Varietal differences in chlorophyll accumulation and nutrient uptake of okra under varying fertilizer regimes. *International Journal of Agricultural Science and Technology*, 8(1), 31-39.
- Oluwaseun, O. A., Olaniyi, J. O., & Akanbi, W. B. (2019). Integrated nutrient management
- Onyemaobi, O. F., Ogunkunle, A. O., & Adekunle, K. A. (2017). Effect of organic and inorganic fertilizers on vegetative growth of okra (*Abelmoschus esculentus*). *Journal of Horticultural Science*, 12(4), 221–228.

- Opoku-Mensah, S., Jacobs, B., & Cunningham, R. (2025). The role of intersectionality in shaping adaptive capacity of smallholder farmers in the Talensi district of Ghana. *Climate and Development*, 17(8), 759-774.
- Oppong-Sekyere, D., Akromah, R., Nyamah, E. Y., Brenya, E., & 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), 367-378.
- Ogunbor, G. (2020). Okro: origin, classification, uses, Pest, Disease.
- Osei, J. G., Danso, A., Agyenim Boateng, M. and Sarkodie-Addo, J. (2018). Effect of split application of nitrogen and phosphorus fertilizers on okro (*Abelmoschus esculentus* L. Moench) growth, yield and fruit quality in the forest-savannah transition zone of Ghana. *African Journal of Agricultural Research*, 13(8), 378-385.
- Otoo, J. A., and Agyeman. A. D., (2020). Evaluating the effect of water conservation practices on okro (*Abelmoschus esculentus* L. Moench) growth and yield. *Agricultural Water Management*, 232, 106066.
- Patil, P., Sutar, S., Joseph, J. K., Malik, S., Rao, S., Yadav, S., (2015). Systematic review of the genus *Abelmoschus* (Malvaceae). *Rheedea* 1, 14–30.
- Paulus, D., Ferreira, S. B., & Becker, D. (2021). Preservation and post-harvest quality of
- Phares, C. A., Atiah, K., Frimpong, K. A., Danquah, A., Asare, A. T., & Aggor-Woananu, S. (2020). Application of biochar and inorganic phosphorus fertilizer influenced rhizosphere soil characteristics, nodule formation and phytoconstituents of cowpea grown on tropical soil. *Heliyon*, 6(10).
- Prity, N., Syed, M., & Rahman, M. K. (2023). Performance and nutrient content of okro (*Abelmoschus esculentus* L. Moench) fruits as influenced by vermicompost,

- nitrogen and zinc. *Journal of Biodiversity Conservation and Bioresource Management*, 9(1), 101–108.
- Prradhiepan, T., Seran, T. H. and Hariharan, G. (2018). Effect of integrated nutrient management on green pod yield of chilli (*capsicum annum L.*) cv MIPC-01, *Sabaragamuwa Univ J.* 16(1): 28-33.
- Pua, K., Aung, T. N., & Hakim, M. (2017). Influence of harvesting time on the shelf life and quality of okro (*Abelmoschus esculentus L Moench.*). *Journal of Agriculture and Environment*, 18, 73-80.
- Quansah, C., & Darkwa, K. (2016). Effect of drip irrigation on the growth and yield of okro (*Abelmoschus esculentus L. Moench.*). *International Journal of Agriculture and Biology*, 18(4), 687-693.
- Quansah, G. W., Oppong, S. K., Sarkodie-Addo, J., & Abdulai, A. Y. (2017). Effects of nitrogen fertilizer application on the growth and yield of okro (*Abelmoschus esculentus L. Moench*) in the Guinea Savanna Zone of Ghana. *African Journal of Agricultural Research*, 12(20), 1768-1773.
- Rafee, M., Jaffar, M. S., Kalsoom, U., Khan, M. B., Haq, Z. U., & Ali, S. (2024). Effect of Manure Addition on the Growth, Yield, and Disease (Leaf Spot) Resistance of Different Varieties of Okra. *Phytopathogenomics and Disease Control*, 3, 221-232.
- Regmi, B., Bhattarai, K., Bhusal, N. R., Poudel, S. R., & Kunwar, S. (2022). Effects of various fertilizer combinations on Okra (*Abelmoschus esculentus L.*) varieties for dietary fiber content and vegetative characteristic. *Himalayan Journal of Science and Technology*, 6(1), 75-86.

- Rhoades, J. D. (1982). *Cation exchange capacity*. In A. L. Page (Ed.), *Methods of Soil Analysis: Part 2-Chemical and Microbiological Properties* (pp. 149–157). *American Society of Agronomy*.
- Rizzo, L., Gernjak, W., Krzeminski, P., Malato, S., McArdell, C.S., Sanchez Perez, J. A., Schaar, H., Fatta-Kassinos, D., (2020). Best available technologies and treatment trains to address current challenges in urban wastewater reuse for irrigation of crops in EU countries. *Sci. total. environ.*710, 136312.
- Rostaei, M. (2024). Organic manures enhance biomass and improve nutrient content: A review. *Journal of Organic Agriculture Research*.
- Sachan, S., Singh, D., Kasera, S., Mishra, S. K., Tripathi, Y., Mishra, V., & Singh, R. K. (2017). Integrated nutrient management (INM) in okro (*Abelmoschus esculentus* L.) Moench) for better growth and higher yield. *Pharmacognosy and phytochemistry*, 6(5), 1854–1856.
- Sakr, A. A., Ahmed, S., & Hassan, E. (2021). Soil-applied amendments and micronutrients improving vitamin and mineral composition of okro. *Journal of Plant Nutrition*, 44(10), 1501–1512.
- Sande, T. J., Tindwa, H. J., Alovisi, A. M. T., Shitindi, M. J., & Semoka, J. M. (2024).
- SAS Institute (2013). *Statistical analysis software (SAS) Release 9.3*. Cary, NC: SAS institute. USA. 1848 pp.
- Saud, G., Bhattarai, B. R., & Mahara, B. (2024). Effect of integrated nutrient management on growth and yield of potato (*Solanum tuberosum* L.). *Journal of Agriculture and Resource Management*, 1(1), 39–57.
- Saurabh, P. S., Tayde, A., & Niwariya, J. (2022). Influence of integrated nutrient management on growth, yield and economics of okra. *Annals of Horticulture*, 15(2), 157-161.

- Shittu, E. A., Alobo, A. I., & Buhari, F. Z. (2025). Growth and yield response of okra (*Abelmoschus esculentus* L.) as affected by varying rates of npk fertilizer and cowdung manure in a semi arid ecology. *Journal of Agripreneurship and Sustainable Development*, 8(2), 36-46.
- Singh, D., & Ramesh, P. (2018). Effect of organic and inorganic nutrient sources on chlorophyll content and productivity of okra. *Journal of Crop and Weed Science*, 14(2), 45–52.
- Singh, R., Kumar, A., & Shivakumar, B. G. (2015). Integrated plant nutrient management. *Indian Farming*, 60(1), 12–15. <https://epubs.icar.org.in/index.php/IndFarm/article/view/48371>.
- Springer, S. (2023). Improvement of nutritional quality of food crops with fertilizer: A global meta-analysis. *Agronomy for Sustainable Development*, 43(55), 1–15.
- Suleman, A., Yakubu, A., & Mohammed, S. (2023). Productivity and profitability of okro under organic and inorganic fertilizer regimes. *International Journal of Agronomy and Agricultural Research*, 17(4), 10–20.
- Sultana, C., M., Hossain, M. E., Rahman, M. M., Hasan, M. R., & Hasan, M. M. (2019). Antiulcerogenic and gastroprotective activities of *Abelmoschus esculentus*: A review. *Journal of Ethnopharmacology*, 236, 158–170.
- Sun, M., Yang, X.-L., Zhu, Z.-P., Xu, Q.-Y., Wu, K.-X., Kang, Y.-J., Wang, H., & Xiong, A.-S. (2021). Comparative transcriptome analysis provides insight into nitric oxide suppressing lignin accumulation of postharvest okro (*Abelmoschus esculentus* L. Moench) during cold storage. *plant physiology and Biochemistry*, 167, 49–67.
- Swamy, B. P. M., Samia, M., Boncodin, R., Marundan, S., Rebong, D. B., Ordonio, R. L., Miranda, R. T., Rebong, A. T. O., Alibuyog, A. Y., Adeva, C. C., Reinke, R.,

- & MacKenzie, D. J. (2023). Compositional analysis of genetically engineered gr2e “golden rice” in comparison to that of conventional rice. *Journal of Agricultural and Food Chemistry*, 67(28), 7986–7994.
- Tandoh, P. K. (2024). Growth and seed yield responses of okro to different organic amendments in a tropical environment. *ScienceWorld Journal*, 2024.
- Thomas, W. D, (2022). Grower’s guide: a review for sustainable production of okro (*Abelmoschus esculentus*) in West Africa and other Regions. *International Journal of research applied sciences & engineering technology*. 10(10), 128-138.
- Tiamiyu, R. A., Ahmed, H. G. and Muhammad, A. S. (2017). Effect of sources of organic manure on growth and yields of okro (*Abelmoschus esculentus* L.) in Sokoto, Nigeria. *Nigerian journal of basic and applied science*, 20(3), 213–216.
- to integrated nutrient management of chicken manure and inorganic fertilizer in different agroecological zones. *Heliyon*, 10(14), e34830.
- Uwiringiyimana, T., Habimana¹, S., Umuhozariho, M.G., Bigirimana, V. P, Uwamahoro, F. Ndereyimana, A., and Naramabuye, F. X. (2024). Review of okro (*Abelmoschus esculentus* L. Moench) Production, nutrition and health benefits. *Rwanda journal of agricultural sciences*, Vol 3, No. 1
- Verma, N. K., Manisha, Dhurve, R., Neha, Porte, D. P., & Ramnath. (2023). Assessment of integrated nutrient management on growth and yield of horsegram (*Macrotyloma uniflorum* (Lam.) Verdc.) in Chhattisgarh plains. *International Journal of Plant & Soil Science*, 35(22), 447–454.
- Vidhi, J. (2023). Okro: origin, inheritance and varieties | India. [https://www.biologydiscussion.com/vegetable-breeding/okro origin-](https://www.biologydiscussion.com/vegetable-breeding/okro-origin-)

- inheritance-and-varieties-india/68468 VIKAS. 2023. Bhendi – Vikaspedia.
<https://vikaspedia.in ›vegetables-1 ›bhindi-okro>.
- Vikash, K., Ramjan, Md. & Twarita, D. (2019). Cultivation practices of Okro. *Biomolecule Reports- An international eNewsletter*, Popular article, ISSN:2456-8759.
- Walkley, A., & Black, I. A. (1934). *An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method*. *Soil Science*, 37(1), 29–38.
- Warke, A. T., & Wakgari, T. (2024). A review on the impact of soil acidification on plant
- Wenli, S., Shahrajabian, M. H., and Qi, C. (2021). Health benefits of wolfberry (*Gou qi zi*, *fructus barbarum* l.) on the basis of ancient Chinese herbalism and Western modern medicine. *Avicenna Journal of Phytomedicine*, 11(2), 109–119.
- Wills, R., Barry M. G. Doug G. and Daryl, J. (2016), Post-harvest; An introduction to the handling of fruits, vegetables and ornamentals, 4th Edition Ap. 2.
- Woumbo, C. Y., Kuate, D., Tamo, D. G. M. and Womeni, H. M. (2022). Antioxidant and antidiabetic activities of a polyphenol rich extract obtained from *Abelmoschus esculentus* (okro) seeds using optimized conditions in microwave-assisted extraction (MAE). *Nutrition and Food Science Technology*. 9-2022.
- Xu, X., Zhang, L., Yagoub, A. E. A., Yu, X., Ma, H., & Zhou, C. (2021). Effects of ultrasound, freeze-thaw pre-treatments and drying methods on structure and functional properties of pectin during the processing of okro. *food hydrocolloids*, 120, 106965.
- Yang, L. (2024). Seasonal variation in nutrient composition of poultry manure and its implications for soil fertility management. *Nutrient Cycling in Agroecosystems*, 130(1), 77–89.

- Yasmin, Chauhan, M., Kumar, S., Kumar, R., & Sharma, H. (2024). Dynamics of nutrient availability in okra production with organic and inorganic fertilizers. *International Journal of Advanced Biochemistry Research*, SP-8(5), 415–420.
- Yusuf, A. M., Ibrahim, A., & Gana, A. S. (2020). Influence of fertilizer combinations on phenological and yield traits of okra varieties in the Sudan savanna. *Journal of Plant Nutrition and Soil Science*, 23(4), 112–120.
- Zhang, Y., Li, C., & Huang, X. (2021a). Poultry manure as a source of exchangeable bases for acidic soils. *Soil Systems*, 5(4), 62.
- Zhao, N. (2024). Effect of organic manure on crop yield, soil properties, and nutrient dynamics: A review. *Frontiers in Agricultural Science*.