

**AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS
TRAINING AND ENTREPRENEURIAL DEVELOPMENT
MAMPONG - ASHANTI**



**GROWTH AND YIELD RESPONSE OF COWPEA (*Vigna
unguiculata* (L.) Walp) TO DIFFERENT SOIL
AMENDMENTS**

**ALFRED NII AYI ARYEETAY
MASTER OF EDUCATION (M. Ed) IN AGRICULTURE
(CROP SCIENCE)**

2023

**AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND
ENTREPRENEURIAL DEVELOPMENT
FACULTY OF AGRICULTURE EDUCATION
DEPARTMENT OF CROP AND SOIL SCIENCES EDUCATION
MAMPONG – ASHANTI**



**GROWTH AND YIELD RESPONSE OF COWPEA (*Vigna unguiculata* (L.) Walp)
TO DIFFERENT SOIL AMENDMENTS**

**ALFRED NII AYI ARYEETAY
(7201910021)**

**A DISSERTATION SUBMITTED TO THE DEPARTMENT OF CROP AND
SOIL SCIENCES EDUCATION, FACULTY OF AGRICULTURE EDUCATION,
AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND
ENTREPRENEURIAL DEVELOPMENT, MAMPONG -ASHANTI, IN PARTIAL
FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER
OF EDUCATION (M. Ed) IN AGRICULTURE**

JUNE, 2023

DECLARATION

STUDENT’S DECLARATION

I ALFRED NII AYI ARYEETAY declare that, except for references to authors who have been duly acknowledged, this dissertation is the outcome of my original research under supervision and that this dissertation has neither in whole nor in part been presented in this University or elsewhere.

ARYEETAY, ALFRED NII AYI

SIGNATURE.....

DATE.....

SUPERVISOR’S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of dissertation as laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development. Mampong – Ashanti.

MR. EMMANUEL K. ASIEDU

SIGNATURE.....

DATE.....

ACKNOWLEDGEMENT

Nothing could have been possible and completed without the Almighty God. I, therefore, thank God for protecting and guiding me through this project.

I am most indebted to my supervisor Mr E.K. Asiedu for his guidance, ideas, and suggestions which contributed in no small way to the success of this dissertation. His professional and academic suggestions were very useful. God richly bless him.

I wish to express my profound gratitude to Mr Alex Otabil, Mr E.K. Amponsah, and Mr Anthony Anaba for their assistance, support, and suggestion in terms of equipment and technical advice during the project.

Many thanks also go to Mrs Ivy Lariba Awuni my project partners, the Authors whose works served as sources of information, and all the loved ones who contributed in one way or the other to make this project a reality.

DEDICATION

This work is completely dedicated to God Almighty, my, wife Joyceline Osei Takyiwaa, and my mother, Margret Yaa Tanoh for the unconditional love they show me. Special dedication also goes to my late father and sister Mr James .C. Aryeetey and Naa Dedei Aryeetey and finally to my kids, Jeremy, Jesse, Alfred Junior, and, Bryan.

TABLE OF CONTENTS

DECLARATION	iii
ACKNOWLEDGEMENT	iv
DEDICATION	v
TABLE OF CONTENTS	vi
LIST OF TABLES	ix
LIST OF FIGURES	x
LIST OF ABBREVIATIONS/ACRONYMS	xi
ABSTRACT	xii
CHAPTER ONE	1
INTRODUCTION	1
1.1 Background of the study	1
1.2 Statement of the problem and justification	3
1.3 General Objectives of the Study	5
1.3.1 <i>Specific objectives</i>	5
1.4 Significance of the Study	5
CHAPTER TWO	7
LITERATURE REVIEW	7
2.1 Botanical Description of Cowpea	7
2.2 Origin, and production of Cowpea	8
2.3 Growth and Agronomic requirement	9
2.4 Importance and nutritional quality of cowpea	10
2.5 Biological nitrogen fixation process	13
2.6 Soil fertility conditions in Ghana.....	14
2.7 Fertilizer use trends in Ghana and on Cowpea	16
2.8 Composition and value of organic manure	16
2.9 Effects of organic fertilizer (Chicken manure) on the growth and yield of Cowpea	17
2.10 Effect of N P K fertiliser on the growth and yield of Cowpea	18
2.10.1 <i>Nitrogen</i>	18
2.10.2 <i>Phosphorus</i>	19

2.10.3 Potassium.....	21
2.11 Combination of organic and inorganic fertilizer on the growth, and yield of Cowpea.	22
CHAPTER THREE.....	23
MATERIALS AND METHODS.....	23
3.1 Location of experiment.....	23
3.2 Climatic condition of the area.....	23
3.3 Soil type and vegetation.....	23
3.4 Experimental Design	24
3.5 Treatments and their application	24
3.6 Land preparation and field layout.....	24
3.7 Chicken manure preparation, application and inorganic fertilizer application.....	26
3.8 Planting material and sowing.....	26
3.9 Agronomic Practices.....	26
3.9.1 Weed control.....	26
3.9.2 Watering	27
3.9.3 Pest and disease and their control.....	27
3.9.4 Harvesting.....	27
3.10 Sampling and Data Collection	27
3.10.1 Plant Height.....	28
3.10.2 Number of Leaves per plant.....	28
3.10.3 Stem diameter	28
3.10.4 Number of Branches per plant.....	28
3.10.5 Canopy Width	28
3.10.6 Days to 50% flowering	28
3.10.7 Number of pods per plant	29
3.10.8 Number of filled pods per plot.....	29
3.10.9 Number of unfilled pods per plot.....	29
3.10.10 Pod length.....	29
3.10.11 Number of Seed per pod	29
3.10.12 Pod weight per plant.....	30
3.10.13 100 - Seed weight.....	30
3.10.14 Grain yield.....	30

3.11 Data Statistical Analysis	30
CHAPTER FOUR	31
RESULTS	31
4.1 Treatment types and their effects on Plant height of Cowpea	31
4.2 Treatment types and their effects on the number of leaves in weeks after planting	32
4.3 Treatment types and their effect on stem diameter of cowpea	32
4.4 Treatment types and their effect on the number of branches per plant	34
4.5 Treatment types and their effects on the canopy width of cowpea.....	35
4.6 Treatment types and their effects on the number of Days to 50% flowering	36
4.7 Treatment types and their effect on the number of pods per plant and the number of filled and unfilled pods per plot	37
4.8 Treatment types and their effects on pod length, number of seeds per pod and, pod weight per plot	38
4.9 Treatment types and their effects on 100 - seed weight(g). Seed weight per plot(g) and yield(tons/ha)	40
CHAPTER FIVE	42
DISCUSSION.....	42
5.1 Effect of Soil Amendments on Vegetative Growth of Cowpea	42
5.2 Effects of Soil Amendments on Flowering of Cowpea	45
5.3 Effect of Soil Amendments on Yield and yield components of Cowpea	46
CHAPTER SIX	51
CONCLUSION AND RECOMMENDATIONS.....	51
6.1 Conclusion	51
6.2 Recommendations.....	51
REFERENCES	53
APPENDICES.....	71

LIST OF TABLES

Table 2.1 Nutritional value of cowpea seeds and leaves	12
Table 4.1 Treatment types and its effects on Plant height of Cowpea	31
Table 4.2: Treatments and their effect on the stem diameter of Cowpea	33
Table 4.3: Treatment types and Number of branches per plant of Cowpea	34
Table 4.4 Treatment types and canopy width of Cowpea	35
Table 4.5: Treatment types and their effect on yield and yield component of Cowpea	38
Table 4.6: Treatment types and their effects on yield and yield component of cowpea	39
Table 4.7: Treatment types and their effects on yield and yield components of Cowpea	41

LIST OF FIGURES

Figure 3.1: Field layout of the experimental plots.....	25
Figure 4.1 Treatment and its effect on the number of leaves of cowpea, 2-5 WAP.....	32
Figure 4.2: Treatments and Days to 50% Flowering of Cowpea	36

LIST OF ABBREVIATIONS/ACRONYMS

AAMUSTED	Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development
ANOVA	Analysis of variance
RCBD	Randomized Complete Block Design
ATP	Adenosine triphosphate
ADP	Adenosine diphosphate
BNF	Biological Nitrogen Fixation
CM	Centimetre
CSIR	Council for Scientific and Industrial Research
CV	Co-efficient of Variation
DAP	Days after planting
ECEC	Effective Cation Exchange Capacity
FSP	Fertilizer Subsidy Programme
ISFM	Integrated Soil Fertility Management
LSD	Least Significant Difference
MoFA	Ministry of Food and Agriculture
MKP	Mono Potassium Phosphate
N	Nitrogen
NH₃	Ammonia
NO₃	Nitrate
NPK	Nitrogen Phosphate Potassium
OECD	Organization for Economic Co-operation and Development
P	Phosphorus
pH	Power of Hydrogen
PCBs	Polychlorinated biphenyls
SSA	Sub-Saharan Africa
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
WAP	Weeks after planting

ABSTRACT

The field experiment was conducted from June to September 2022 at the Multipurpose Crop Nursery of the Akyem Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Mampong – Ashanti. The main objective of the study was to determine the response of Cowpea (*Vigna unguiculata* (L.) Walp) to different soil amendments. Randomized Complete Block Design (RCBD) was used with five treatments and replicated three times. The treatments were: 10 t/ha chicken manure, 225 kg/ha NPK (15-15-15), 225 kg/ha of NPK (15-15-15) + 60 kg/ha Mono Potassium Phosphate (KH_2PO_4), a combination of 5 t/ha chicken manure and 112.5 kg/ha NPK (15-15-15), 60 kg/ha Mono Potassium Phosphate (KH_2PO_4) and control (no fertilizer). The results revealed that although 10 t/ha Chicken manure, was the best in terms of both vegetative and yield parameters, the Combination of 5 t/ha chicken manure and 112.5 kg/ha NPK (15-15-15), 225 kg/ha NPK (15-15-15), 225 kg/ha of NPK (15 - 15 - 15) + 60 kg/ha Mono Potassium Phosphate (KH_2PO_4), and 60kg/ha Mono Potassium Phosphate (KH_2PO_4) were all significantly ($P \leq 0.05$) higher than the control. Specifically, 10 t/ha Chicken manure promoted the stem diameter growth of cowpea plants, canopy width, and timely flowering of the cowpea plant as compared to the others. It also contributed to the number of pods per cowpea plant, the number of filled pods per plot as well as pod length, and the number of seeds per pod. In conclusion, chicken manure was found to influence the vegetative growth and yield of cowpea, so policymakers and stakeholders in the Agricultural sectors should support farmers through education to enable them to use organic fertilizer rather than inorganic fertilizer which is costly and scarce.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Cowpea (*Vigna unguiculata* (L.) Walp) is an ancient crop that is widely cultivated throughout the world, particularly in Africa, because it produces seeds with a high protein content (20% to 25%) and is used as a nutritional supplement to cereals for human consumption. It is also more cost-effective than animal protein for smallholder farmers and rural dwellers (Singh *et al.*, 2003; Simion, 2018). The leaves and green pods of cowpeas are consumed as vegetables, and the dried grain is utilized in a variety of cuisines. Protein concentrations in dry grains range from 21 to 33 percent and between 27 and 43 percent in cowpea leaves (Ddamulira *et. al.*, 2015; Abudulai *et. al.*, 2016). It is a nourishing annual leguminous crop whose importance to the tropics in terms of soil fertility, livestock nutrition, and human nutrition cannot be overstated (Onwerenmadu *et. al.*, 2003).

By producing some viable forage, severe feed scarcity can be resolved. Legumes are crucial among forages for providing animals with high-quality and nutrient-demanding nutrients including protein, minerals, and vitamins. To increase the digestibility of the feed and the general effectiveness of the ruminants, legume forage can be used as a supplement to diets based on straw (Hasan *et. al.*, 2010). Cowpea (*Vigna unguiculata*), a multipurpose, short-lived leguminous plant, is cultivated in semiarid and wet tropical regions as a grain pulse, vegetable, and fodder (Snapp *et al.*, 2019) It is a valuable source of livestock fodder in the West African savannas, making the dual-purpose cultivars particularly appealing to farmers (Singh *et al.*, 2003; Kamara *et al.*, 2012).

Because it fixes atmospheric nitrogen and helps increase soil fertility, particularly in smallholder farming systems where little to no fertilizer is used, cowpea is an essential aspect of traditional cropping system, thus an important component of the predominantly cereal/legume production systems in the tropics (Ntare *et al.*, 2016). It is resilient to drought and suited to challenging settings where many crops struggle to thrive (Bisikwa *et al.*, 2014; Ddamulira *et al.*, 2015). From 1962 to 1969, the Food and Agriculture Organization performed intensive fertiliser use studies in Ghana in partnership with the Ministry of Food and Agriculture (MoFA) and the Council for Scientific and Industrial Research (CSIR) and recommended 20-40-20 NPK for cowpea (FAO/UN, 1974). However, soil conditions have changed over time, and these rates may no longer be acceptable; therefore, an updated and site-specific fertiliser recommendation for essential food crops is required (Nwokwu, 2020).

Cowpea production in Ghana is dominated by Smallholder farmers and large amounts of the cowpea are under rainfed conditions, particularly in the savanna and transitional Agroecological zones (Agyeman *et al.*, 2014). According to IITA (2003) estimated cowpea production in Africa, notably Ghana, is 45% of that in developed nations, of which the yields range from 310 to 450 kg/ha making it extremely poor (Ofosu-Budu *et al.*, 2008; Boddey *et al.*, 2017). As a result, attempts have been made to expand the production of cowpea in Ghana through a variety of methods including the use of improved cultivars, of which the cowpea variety Zamzam is one (Addo-Quaye *et al.*, 2011). However, without the right soil amendments, these improved varieties cannot independently produce the full output level of yields.

1.2 Statement of the problem and justification

It is an irrefutable fact that farmers must raise their output as the world population rises to meet the rising demand for food. According to Onwueme and Sinha (1991), all African nations can attain food self-sufficiency provided they make a significant effort to enhance agricultural production. The issue of poor soil fertility confronts farmers despite their efforts to increase production to meet consumer demand (Korem, 1982). According to Tajudeen and Babajide (2018), although cowpea occupies a less proportion of the crop area than cereals, it contributes significantly to household food security in West and Central Africa, and unlike other crops, it has received little attention from plant breeders and more efforts need to be made for higher yields to be achieved (Eyitayo and Okoye, 2010).

All agricultural systems include harvesting crops, which removes minerals from the soil, and if these nutrients are not replaced, crop yields will eventually decrease (Alan, 1993). There are several different ways that soil fertility is lost, including crop removal, erosion, leaching, burning, oxidation, and decrease of organic matter (Akinsanmi, 2000). Food crop production in Ghana is characterized by little to no fertilizer use, according to Ennin and Dapaah (2008). Continued use of chemical fertilizer, according to Ulysses (1982), has negative long-term repercussions on the soils, animals, and people who eat the agricultural products grown on those soils. Typically, inorganic fertilizers contaminate water bodies when they are carried into them by severe rains. While inorganic fertilizers do deliver nutrients, Leonard (1981) argued that they do not enhance the physical characteristics of the soil, such as texture, structure, or water-holding capacity, and that this has caused nutrient depletion through erosion and percolation.

Poor soil fertility, particularly the low level of accessible phosphorus (P), which causes extensive cowpea reactions to P fertilizer, is one barrier to the high production of cowpea (Sanginga *et al.*, 2000). Ghana, like other West African nations, has the lowest production of cowpeas in the world, averaging 360 kg ha⁻¹ (IITA, 1993). Declining soil fertility and invasion by pests and diseases are some of the main obstacles to cowpea production in the nation. The majority of farmers cultivate vegetables, fruits, cocoyam, yam, cocoa, plantains, and other food crops in their fertile fields. The majority of villages in Ghana, however, grow cowpea and cassava on impoverished soils. Farmers of cowpeas in Ghana rarely apply to their fields with both organic and inorganic fertilisers. This is due to the ability of cowpea, a leguminous crop, to fix atmospheric nitrogen into the soil for plant use (Wrigley, 1981; Palaniappan, 1985). Farmers are also discouraged from utilising fertilisers because of their high cost. According to Singh and Lamba (1971), adding triple superphosphate or other phosphorus-based fertilizer to the soil increased cowpea growth and production.

However, because this phosphorus source is costly, cowpea growers do not use it. The use of manures in farming is frequently recommended due to the rising cost of chemical fertilizers, the related depletion of soil micronutrients, environmental and health concerns of these chemicals, as well as the typical premium prices for crops grown with manure globally (Ramesh *et al.*, 2005). The substantial correlation between soil fertility and food security, according to Kipot (2008), has made improving soil fertility management a top priority on the development policy agenda. Thus, this research must be done to evaluate the effects of various fertilizers, including NPK(15-15-15), NPK(15-15-15) + Phosphorus, Chicken manure, and a combination of Chicken manure + NPK(15-15-15), on the growth and yield of cowpea.

1.3 General Objectives of the Study

The project is to determine the effects of organic (chicken manure) and inorganic fertilizers NPK (15-15-15), NPK (15-15-15) + Phosphorus, and a combination of both organic (chicken manure), and inorganic NPK (15-15-15) on the growth and yield of Cowpea.

1.3.1 Specific objectives

The specific objectives of the project are to ascertain the influence of five soil amendments: 10 t/ha Chicken manure, 225 kg/ha NPK 15-15-15, 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono Potassium Phosphate and a combination of both 5 t/ha Chicken manure and 112.5 kg/ha NPK 15-15-15) and finally 60 kg/ha Mono Potassium Phosphate (KH₂PO₄) on:

- ✓ Vegetative growth of Cowpea
- ✓ Reproductive/flowering of Cowpea, and
- ✓ Yield and yield components of Cowpea

1.4 Significance of the Study

The study will help to determine or bring out the most cost-effective and suitable soil amendment for increased yield and other growth characteristics of Cowpea and the results would be recommended to farmers through Agriculture Extension Agents in and around Mampong-Ashanti. Findings from the study may provide evidence-informed data to the Ministry of Food and Agriculture and local farmers on the soil amendment types suitable for the growth and yield of cowpea. The findings from the study may also serve as reference material to scholars and researchers who may have an interest in the soil

amendment types for future studies on Cowpea growth and yield in the Ashanti Mampong Municipality.

CHAPTER TWO

LITERATURE REVIEW

2.1 Botanical Description of Cowpea

Cowpea (*Vigna unguiculata* L. Walp.) is a tropical annual herbaceous legume that belongs to the family *Papilionaceae* (Fabaceae), order Leguminosae, and genus *Vigna* (Singh *et al.*, 1997). There are 169 species in the genus *Vigna*, 120 of which are native to Africa, 28 to Asia, 14 to America, and 7 to Australia. Cowpea Chromosome $2n=22$ belongs to the cowpea plant. There are numerous names for it, including black-eyed pea, southern pea, field pea, China bean, and crowder pea (Ng and Marechal, 1985). The genus *Vigna* contains a large number of species and is widely distributed in tropical and subtropical regions. It also has a significant diversity of morphology and ecology. For more than 200 million people living in the arid savanna of tropical Africa, it is a significant source of food grain legume (Ng and Marechal, 1985).

Cowpeas can grow either prostrately or indeterminately or erectly or determinately, which are the two primary varieties of growth habits. Size, shape, colour, and texture are all variable in seed pods. Pods typically have an upright, coiled, or crescent shape (Padulosi and Ng, 1997; OECD, 2016). The seeds might be kidney-shaped, ovoid, crowded, globose, or rhomboid with varying colours and have a smooth texture and different 'seed eye' colours and patterns (Adewale *et al.*, 2011). At the distal ends of 5 to 60-cm long peduncles, the blooms are prominent, self-pollinating, and carried on short pedicels, and the corollas can be white, dirty yellow, pink, pale blue, or purple (Kay, 1979). The pod starts green and typically turns yellow, light brown, pink, or purple as it ages with pod length ranging from 11 cm to more than 100 cm (Rawal, 1976; Singh and Rachie, 1985). The leaves are trifoliolate and alternating. The first leaf pair is

straightforward and opposing. The shape and size of the leaves can vary greatly, ranging from linear to lanceolate to oval, and they are typically dark green with a strong taproot that has several spreading lateral roots in the soil's top layer and numerous globular nodules (Singh *et al.*, 1997). The root nodules have a diameter of around 5 mm and are smooth and spherical (Singh *et al.*, 1997). According to Ahenkora *et al.*, (1998), the majority of the protein consumed by both rural and urban families comes from seeds. The crude protein content of cowpea seeds and leaves ranges from 23 to 32 per cent, respectively, according to Diouf (2011).

2.2 Origin, and Production of Cowpea

Numerous theories have been put up on the domestication of the cowpea in various regions of sub-Saharan Africa, as summarised in Ba *et al.* (2004). According to Padulosi and Ng (1997), cowpea was probably only domesticated once, most likely in West Africa around 2000 B.C. The wild cowpea *V. unguiculata* var. *spontanae* was the ancestor of all domesticated cowpea (Pasquet, 1999). Numerous weedy variants are intermediates between truly wild forms and very small-seeded farmed cowpeas in West Africa, where the majority of the world's cowpeas are grown (Rawal, 1975). The "asparagus bean" has undergone a severe genetic bottleneck during domestication in Asia from its African ancestors, according to recent genomic findings (Fang *et al.*, 2007; Xu *et al.*, 2010).

Southern Africa, which includes Namibia to the west, Botswana, Zambia, Zimbabwe, and Mozambique to the east, and South Africa, and Swaziland to the south, has the most genetic variety in wild relatives of cowpea (Padulosi and Ng, 1997). Many primitive features that were lost during domestication, such as perenniality, hairiness, the tiny size of seeds and pods, hard seeds, pod cracking, and outbreeding, are included in this genetic diversity. In this region, cowpeas are also grown for human use. Due to the occurrence of

the most basic subspecies there, the South African Transvaal may have served as the breeding ground for *Vigna unguiculata* (Padulosi and Ng, 1997). With an annual production of more than 9.3 million metric tonnes, West Africa is where it is most significant (Ortiz, 1998). Despite being an African native crop, it is widely farmed throughout the tropics and subtropics, especially in Africa, Asia, and South and Central America (Tan *et al.*, 2012). Sub-Saharan Africa, often known as the Sudano-Sahelian vegetation zone, is where the majority of the world's cowpea-producing nations are located (Boukar *et al.*, 2019). Nigeria, Niger, and Burkina Faso, in that order, have the largest production output. Nigeria is the world's top producer of cowpea grain in terms of metric tonnes produced (FAO, 2020). In Ghana, it is one of the most extensively grown grain legumes, particularly in the savanna and transitional zones (CRI, 1994). Peasant farmers with smallholdings grow it primarily (0.4-2.0 ha). Cowpea is a key component of traditional farming culture in northern Ghana's compound farming systems. However, only a small portion of the Volta, Northern, Upper, and Brong-Ahafo regions in Ghana are used for commercial cowpea farming (CRI, 1994).

2.3 Growth and Agronomic requirement

Cowpea can be cultivated under rainfed conditions as well as with irrigation or residual moisture along the river or lake flood plains during the dry season, as long as the minimum and maximum temperatures during the growing season are between 28 and 30°C (night and day). Cowpea grows well in agroecological zones with rainfall ranging from 500 to 1200 mm/year (Nkaa *et al.*, 2014). However, by developing extra-early and early-maturing cowpea types, the crop may grow in the Sahel, where rainfall is less than 500 mm per year. It is drought tolerant and adapts well to sandy soil and soils with low nutrients. It has minimal tolerance for salt but is moderately tolerant of aluminium-rich

soils. Like other legumes, cowpea cannot resist wet or flooded conditions. The best yields, however, are produced on well-drained sandy loam to clay loam soils with pH levels between 6 and 7. (Ecocrop, 2009). It is a warm-season crop that can thrive in semi-arid and subtropical environments. It is grown all across the Mediterranean Basin. In temperate regions, it is grown from spring until fall. Due to its resilience to acidity, dryness, and high temperatures, this legume is quite interesting from an agronomic perspective (Ehlers and Hall, 1997; Hall, 2011). Because it fixes its nitrogen from the air using the nodules in its roots, cowpea doesn't need a lot of nitrogen fertiliser. However, in regions with low soil nitrogen levels, a beginning dose of just around 15 kg/ha of nitrogen in the form of NPK 15-15-15 (2 bags or 100 kg) is required for a healthy harvest. The plant will grow luxuriantly but produce little grain if too much nitrogen fertiliser is utilised. To help the crop nodulate well and fix its nitrogen from the air, cowpea needs more phosphorus than nitrogen (FAO, 2005). In most cases, the addition of organic amendments is a recycling process that cannot compensate for nutrients exported through crop products (Tajudeen & Babajide, 2018). As a result, the use of external inputs such as inorganic plant nutrients or local sources of P such as phosphate rock are essential requirements for soil productivity and improve the yield of crops such as cowpea (Ntare *et al.*, 2016).

2.4 Importance and nutritional quality of cowpea

Cowpea is a native African legume and the most significant crop in terms of delivering necessary elements for human dietary needs as well as livestock fodder from economic, nutritional, and environmental standpoints. It also exhibits other multi-functional qualities, such as the ability to fix nitrogen and maintain the equilibrium of the soil's ecology by facilitating a symbiotic relationship with bacteria that produce nodules

(Ravelombola *et al.*, 2017). It is frequently utilized in mixed cropping systems to provide the multiple advantages of a nutrient-rich grain, as a fodder crop, and as a way to increase soil fertility (Agza *et al.*, 2012; Belay *et al.*, 2017). Another significant benefit of cowpea cultivation is that it encourages the establishment of advantageous soil microorganisms and decreases the usage of synthetic agrochemicals when grown as an intercrop with other crops (Bukovsky-Reyes *et al.*, 2019; Sun *et al.*, 2019). According to various studies by (Martins *et al.*, 2003; Olajide and Ilori, 2017; Ovalesha *et al.*, 2017; Cardona-Ayala *et al.*, 2020), cowpea cultivation is crucial to Africa's economic productivity and environmental sustainability and according to Agbogidi and Egho (2012) and Muranaka *et al.* (2016), that is why it is cherished as a source of nutritious food and a range of snacks that offer humans less expensive proteins, hence improving food security.

The high protein level of cowpeas, which is 20–25 percent and double that of most cereals, accounts for much of their nutritious value (Kay, 1979). The crop can easily be substituted for meat and fish, which are generally more expensive in West African nations. Therefore, in Ghana and other West African nations, cowpea is a crucial primary source of vegetable protein of which the dry grain can be processed into cowpea flour for the preparation of ‘agawu’ and ‘koose’(Ampah, 2020). With significant medicinal and nutritional security benefits, cowpea is an essential source of healthy micronutrients, proteins, amino acids, antioxidants, vitamins, and minerals. (Jayathilake *et al.*, 2018; Olabanji *et al.*, 2018; Gondwe *et al.*, 2019; Irondi *et al.*, 2019; Owade *et al.*, 2020).

Table 2.1 Nutritional value of cowpea seeds and leaves

Nutrients	Component (100g edible portion)	
	Dried seed	Dried leaves
Energy(kcal)	343	142
Protein (g)	23.52	13.4
Fat (g)	1.15	1.5
Carbohydrates (g)	60.03	22.9
Fibre (g)	10.6	12.2
Calcium(mg)	110	343.9
Iron (mg)	6.74	21.6
Magnesium (mg)	189	173.1
Phosphorous (mg)	366	209.1
Potassium (mg)	1392	1733.8
Sodium (mg)	24	50.9
Zinc (mg)	2.77	1.63
Vitamin C	4.3	220.1
Thiamine (mg)	0.6	0.05
Riboflavin	0.16	0.42
Niacin (mg)	1.77	1.1
Vitamin B6 (mg)	0.27	0.27
Sugar (g)	5.58	0.6
Folate (μ g)	622	763

Source: USDA National Nutrient Database (2021).

The haulms cannot be left out since they are a valuable source of protein for cattle, whilst the grain is a good supply of protein for humans (Fatokun, 2002). In addition, it provides a source of income for many smallholder farmers in sub-Saharan Africa and improves soil fertility in marginal lands by fixing nitrogen, reducing weeds, and providing ground cover and plant waste (Ajayi *et al.*, 2007).

2.5 Biological nitrogen fixation process

Biological nitrogen fixation is the conversion of nitrogen gas into ammonia, according to De Bruijn, & Hungria, (2022). Although nitrogen is present in the atmosphere as a diatomic molecule (N_2), the molecule's structure renders it inert. Then, as diazotrophs, prokaryotic bacteria fix atmospheric N_2 as ammonia (NH_3) (Galloway *et al.*, 2008; Riggs *et al.*, 2001). To break the bonds between the nitrogen atoms and enable the nitrogen to mix with hydrogen, the procedure calls for sixteen molecules of ATP. By killing and lysing free nitrogen-fixing bacteria or as a result of some nitrogen-fixing bacteria's symbiotic relationship with plants, fixed nitrogen is made available to plants (Chenn, 1999). Numerous different kinds of microorganisms, including bacteria, actinomycetes, fungi, and algae, are found in soil. When associated with legume plants, a particular type of soil bacterium known as rhizobia promote the growth of legumes by biologically fixing otherwise inaccessible atmospheric nitrogen into a form that plants may use for growth and development (Chenn, 1999).

Rhizobia can coexist with host legumes as nodules on the roots of the plants, or they can survive as saprophytic organisms in the soil. The legumes communicate with suitable rhizobia to initiate the nodule formation process by releasing substances from their roots known as flavonoids, which in turn cause the bacteria to produce knot factors (Hutton, 2010). Numerous biochemical and morphological changes occur as a result of the root's perception of the nod factor, causing the root cortex's cell division that results in the nodule. The root hair growth is then instructed to wind many times around the bacteria, encasing one or more of them completely. The bacteria that are enclosed divide repeatedly to create a microcolony. The bacteria move from this microcolony into the growing nodule via a structure known as an infection thread, which passes through the

root hair into the basal part of the epidermis cell and then into the root cortex. There, they are encircled by a membrane derived from plants and differentiate into nitrogen-fixing bacteroids (Watanabe, 2000). Different components of the nodulation process are controlled by sets of genes in the bacterium. A particular *Rhizobium* strain infects which legume is determined by specificity genes. Even if the strain can infect a legume, it's possible that the nodules that develop will not be able to fix nitrogen. Nitrogen-fixing nodules are only induced by efficient strains. The *knot* genes responsible for nodulation control its efficacy. Because it continuously supplies nitrogen for plant growth, the biological nitrogen fixation process significantly contributes to increasing the fertility and productivity of low-N soils (Lindemann and Glover, 2003). Because the fixed nitrogen is directly available to the host plant, it can flourish in low-nitrogen settings and experience fewer losses from denitrification, volatilization, and leaching. According to studies, grain legumes in Africa fix between 15 and 210 kgNha⁻¹ per season (Dakora and Keya, 1997).

2.6 Soil fertility conditions in Ghana

Ghana has a total land area of 23,853,900 ha, of which 13,628,179 ha (57.1%) are suitable for agriculture. However, the majority of these soils have low inherent fertility. According to Bationo *et al.* (2018), the physical characteristics of the soils are impacted by how coarse they are, and water stress is frequent during the growing season. Significant soil erosion and land degradation in many forms have affected large portions of the country's geographical area, especially the Interior savannah zone. In sub-Saharan Africa, Ghana has one of the greatest rates of soil nutrient depletion, with predicted annual losses of 35 kg N, 4 kg P, and 20 kg K ha⁻¹. All agroecological zones have significant nutrient depletion, with nitrogen and phosphorus being the most deficient

nutrients, (Bationo, 2015). The usage of equivalent amounts of plant nutrients in the form of organic and inorganic fertilizers has not compensated for the nutrients lost to crop harvest from the soils. With only 8 kg of inorganic fertilizer applied annually per hectare, Ghana has one of the highest rates of soil nutrient depletion in SSA. Therefore, sustained agricultural development in Ghana will necessitate a clear focus on soil nutrient replenishment, even when compared to most other African nations with vulnerable soils. There has been a lot of research and policy analysis on fertilizer use in Ghana, but there are still knowledge gaps regarding the fertility of Ghanaian soils, the yield response to fertilizer for major crops, the profitability of fertilizer use, and the likelihood that changing climatic conditions will have an impact on the profitability of fertilizer use. (Jayne *et al.*, 2015).

The majority of Ghana's soils are formed from severely weathered parent materials. They are old and have been leached for a long time (Jayne *et al.*, 2015). Nutrients extracted from the soil through crop harvesting, leaching, and water erosion typically outweigh those imported naturally through atmospheric deposition, biological nitrogen fixation, and artificially through organic manure and mineral fertilisers (Nwokwu, 2020). Their organic matter level is often poor, and their natural fertility is low. Nitrogen and phosphorus are the two most deficient nutrients, owing to the relatively low organic matter concentration. The regular burning of crop residue and/or competitive usage of these residues for fuel, animal feed, or building purposes further limit the accumulation of any quantity of organic matter (Bationo *et al.*, 2018).

2.7 Fertilizer use trends in Ghana and on Cowpea

Since 2010, Ghana's fertilizer consumption has increased six to ten times more than it did in the early 2000s and this according to Fearon *et al.* (2015) was mostly due to the Fertilizer Subsidy Programme (FSP), which was established in 2008 and accounted for over 40% of all fertilizer usage from 2011 to 2013. Except for Ethiopia, Nigeria, and South Africa, Ghana imported more fertilizer in 2012 than any other nation in sub-Saharan Africa, (Bonilla *et al.*, 2020) Many African countries, including Ghana, employ fertiliser primarily on maize, sorghum/millet, and rice (Camara & Heinemann, 2006), with cowpea receiving minimal attention from farmers in terms of fertiliser application.

In the absence of additional technologies and practices that increase yield, inorganic fertilizer does not always increase agricultural output (Vanlauwe *et al.*, 2014). It is generally known that complementing investments in soil and water conservation is essential for effective and optimal nitrogen uptake, especially on degraded soils, to both increase the profitability of fertilizer use and create a sustainable agricultural system. Many African countries, including Ghana, employ fertiliser primarily on maize, sorghum/millet, and rice (Camara and Heinemann, 2006), with cowpea receiving minimal attention from farmers in terms of fertiliser application.

2.8 Composition and value of organic manure

Since the oldest civilizations, compost and animal manure have been employed to enhance the properties of the soil. These fertilizers used to be the only sources of nutrients for the growing of crops. The use of organic fertilizers as a source of nutrients on many farms has significantly increased even though they contain relatively low concentrations of nutrients and need labour-intensive handling (Kannan *et al.*, 2005). They have a significant advantage over inorganic fertilizers due to their favourable

impact on the physical characteristics of soil and the ease with which they decompose inside the soil (Kannan *et al.*, 2005). The organic portion of manure contributes significantly to the improvement of soil structure, soil infiltration capacity, and soil organic matter and tilth (Reyhan and Amiraslani, 2006). However, a large portion of the nutrients in the manure are bound to the organic component and must undergo decomposition to be transformed into inorganic forms that plants may absorb (Kannan and Saravanan, 2006).

2.9 Effects of organic fertilizer (Chicken manure) on the growth and yield of

Cowpea

A crucial component in the management of soils, particularly tropical soils, is organic matter (Obalum *et al.*, 2011). It influences many of the physical, chemical, and biological processes that characterize soil productivity, making it a good indicator of soil quality (Bot and Benites, 2005; Obalum *et al.*, 2017). Inadequate nutrient availability, which is largely governed by organic matter content, as well as the physical and chemical characteristics of the soil are some of the constraints on agricultural production (Warman, 1981; Chan *et al.*, 2003). Numerous studies conducted in various tropical regions have revealed, according to Wilson and Webster (1975), that the majority of annual crops benefit from the application of organic manure. Cowpea can fix atmospheric nitrogen, therefore they will thrive in soil with little organic manure (Sinnadurai, 1992). The usage of organic fertilisers has been resurrected globally due to the need to employ sustainable energy sources and minimise the cost of fertilising crops. The promotion of expanded usage of organic materials is motivated by the need to improve environmental conditions and the need of protecting public health (Seifritz, 1982; Ojeniyi, 2000; Maritus and Vlelc, 2001).

According to Petersen *et al.* (2007) and Sommer *et al.* (2013), applying chicken manures is a significant way to recycle nutrients in the soil. Furthermore, manures from livestock husbandry help crop production and vice versa, making them simpler to obtain than mineral fertilizers (Kolavalli and Adam, 2011). Savci (2012) asserts that while the toxic substances (lead, mercury, dioxins, and polychlorinated biphenyls (PCBs)) that accumulate within the crops could harm people and animals who consume them, the negative effects of chemical fertilizers on the soil are not immediately evident because soils have strong buffering capacity.

2.10 Effect of N P K fertiliser on the growth and yield of Cowpea

According to Tindall (1992), NPK fertiliser applied before planting, followed by a top dressing of potash or nitrate, stimulates early growth. Cooke (1982) observed that chemical fertilisers have distinct functions in that they provide additional nutrients to the soil for plant use. Farmers' income rises as a result of fertiliser use, and nutrients are readily available to plants (Akinsanmi, 2000).

2.10.1 Nitrogen

Tisdale *et al.* (1993) provide a comprehensive assessment of the N-requirement of crops. Nitrogen is a crucial plant nutrient whose availability can be managed by humans (Adediran and Banjoko, 1995; Shanti *et al.*, 1997). Although nitrogen can be fixed by leguminous forages, such as cowpea, at the beginning of the development cycle before nodules form in the root system, nitrogen fertilizer is still necessary. In light of this, starting doses of nitrogen fertilizer are occasionally utilized. Cowpea responds to additional nitrogen despite their ability to fix nitrogen using *Rhizobium* (Sultana, 2003). Investigations in the tropics have shown either little reaction or a considerable response

to nitrogen fertilizer treatment, even though there are various opinions on nitrogen application to legumes, notably cowpea (Akinola, 1978). Numerous substances, such as chlorophyll and enzymes necessary for the growth of plants, contain nitrogen as a key component. It is a crucial element in the production of related proteins and amino acids. In addition to stimulating root growth and development and nutrient uptake, nitrogen is crucial for plants to utilize carbohydrates. This substance enhances the deep green colour of the leaves and promotes above-ground vegetative growth (Brady, 1990). The height of the plants and the number of primary and secondary branches per plant of several legumes have been reported to be significantly and favourably changed by the administration of nitrogen fertilizer (Kaviraja, 2017). Because it affects the leaf area index and subsequently light absorption, nitrogen is crucial for plant growth (Grindlay, 1997). Lack of nitrogen typically results in stunted growth and chlorotic leaves due to poor assimilate generation, which shortens the growth cycle and causes early blooming. N that is present in excess encourages the growth of above-ground organs with a surplus of tissues that are soft and dark green (rich in chlorophyll) and comparatively poor root growth. As a result, there is a higher chance of lodging and a decreased ability of the plant to withstand adverse weather and foliar diseases (Lincoln and Edvardo, 2006).

2.10.2 Phosphorus

Poor soil fertility, particularly the low quantity of phosphorus (P) that is readily available, is one factor preventing the cowpea from being very productive. As a result, cowpea reactions to P fertilizer are common (Sanginga *et al.*, 2000). In most tropical soils, phosphorus deficiency is the main cause of low production of legume crops because it not only plays a crucial role in root formation but also promotes the growth of the rhizobium bacteria, which fix nitrogen. The primary macronutrient needed for

nitrogen fixation is phosphorus. The nutrient is crucial to the acquisition, storage, and usage of energy in a variety of molecular and biochemical plant activities. The supply of phosphorus has a significant impact on nodulation and nitrogen fixation (Nkaa *et al.*, 2014). For Rhizobium bacteria to transform atmospheric nitrogen (N_2) into ammonium (NH_4) from usable form for plants, phosphorus is a necessary component. Nitrogenase, an enzyme that catalyzes the transformation of nitrogen into two molecules of ammonia, can be produced by Rhizobium (NH_3). When 16 adenosine triphosphate (ATP) molecules are changed into adenosine diphosphate (ADP) as each nitrogen molecule is reduced to NH_3 , phosphorus is used as an energy source. When light energy is converted and stored as ATP for use by the plant, later on, the ATP is produced during the process of photosynthesis.

Plants that fix nitrogen, like legumes, have a higher need for phosphorus because it's essential for nodule growth and signal transmission. Legumes may experience nitrogen deficit if their phosphorus source is insufficient (Jakobsen, 1985). Although we have inorganic phosphorus, Manures, microbial tissues, and plant remnants all contain organic phosphorus. Only 3% of the phosphorus in soils with low levels of organic matter may be found in the form of phosphorus, whereas soils with high levels of organic matter may have 50% or more of their total phosphorus content in the form of phosphorus (Weisnay *et al.*, 2013). Apatite, which is the primary source of all phosphorus, complexes of iron and aluminium 14 phosphates, and phosphorus adsorbed onto clay particles are the three main inorganic forms of soil phosphorus. Only very little amounts of soil phosphorus are ever in solution at any given moment due to the extremely low solubility of these phosphorus compounds and organic phosphorus (Weisnay, *et al.*, 2013). Cowpea yield is

increased by adding phosphorus, which increases the number of pods per plant, the number of seeds per pod, and the mean seed weight (Ayodele and Oso, 2014).

2.10.3 Potassium

Numerous crops require significant amounts of potassium, as stated by Hue (1995). It is necessary for preserving plants' turgidity and the osmotic potential of cells. Potassium (K) plays a significant function in water relations in the plant because it controls the osmotic potential of cells and the conditions under which stomata close or open. Water intake from the soil, water retention in plant tissue, and long-distance movement of water in the xylem and of photosynthates in the phloem are all influenced by potassium (Marschner, 1995). Potassium has an impact on cell growth. A plant's resistance to lodging, pests, and diseases is increased when its cell walls are stronger due to appropriate K levels (Bergmann, 1992). The shelf life of fruits and vegetables appears to be extended when they are produced with enough K. Because of this, K-deficient plants have small, shrivelled seeds and fruits as well as inadequate disease resistance (Martin-Prevel, 1989; Perrenoud, 1993).

Although it plays no direct part in nodulation, potassium can enhance nodulation in soils that are lacking in it (Giller, 2000). According to Sangakkara *et al.* (2001), K fertilizer can be thought of as having a crucial role in helping Cowpea and Mungbean overcome soil moisture stress by encouraging vegetative development and maximizing physiological factors that affect subsequent pod yields, potassium was discovered to be crucial for cowpea in dry conditions (Oliveira *et al.*, 2009). Compared to phosphate, potassium is far more mobile in soils. Roots absorb it in the form of K^+ , which is how it is present in soil solution. Although K^+ can be partially maintained by negative charges

on a clay surface, when gypsum or dolomite is applied, Ca^{2+} or Mg^{2+} can displace it into the soil solution. K may thus be lost through leaching if it is not absorbed by plants (Bergmann, 1992; Perrenoud, 1993; Singh and Trehan, 1998). The addition of organic matter to the soil, such as compost, can help to prevent K leaching. Organic material often has a high cation exchange capacity, which effectively retains K.

2.11 Combination of organic and inorganic fertilizer on the growth, and yield of Cowpea.

In Ghana, vegetable productivity has grown due to integrated nutrient management, better varieties, and enhanced cultural practices. (Komolafe *et al.*, 1980). The combined benefits of mineral fertilisers and poultry manure are better than either of them utilised alone at varying rates of application, according to Yogodin (1984) and Asubonteng (1997). This is because while inorganic fertilisers give nutrients, they do not enhance the soil's physical characteristics (Leonard, 1981). Pichot *et al.* (1981), also shared a similar view that the addition of manure to minor fertiliser applications enhanced the soil more than applying crop residues alone or big fertiliser doses. When organic and mineral fertilisers were used together rather than either organic or mineral fertiliser alone, Palm (1995) and Quansah (2010) also noticed a noticeable improvement in crop yields.

Using balanced NPK fertilization like NPK (15:15:15) in conjunction with organic matter amendments, high and sustained crop yields can be achieved. (Ayoola and Makinde, 2007).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Location of experiment

The field experiment was carried out at the Multipurpose Crop Nursery of the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Mampong – Ashanti from June to August 2022. Mampong – Ashanti is in the Transitional Zone between the Forest and the Savanna Zones of Ghana. Mampong is located within longitudes $0^{\circ} 05''$ and $7^{\circ} 30''$ west and latitudes $0^{\circ} 05''$ and $1^{\circ} 30''$ north of the equator (Meteorological Service Department, 2010).

3.2 Climatic condition of the area

The area has a bimodal rainfall. The major rainy season begins in March and ends in July while the minor season begins in September and ends in November. The mean monthly rainfall of the area is about 91.2 mm and the average annual temperature is 27.0°C with variations in mean monthly temperature of 22°C and 30°C (Meteorological Service Department, 2010).

3.3 Soil type and vegetation

The soil of Mampong belongs to the Bediesi Series. It is red, permeable, friable, and well-drained. It contains a moderate amount of organic matter and has a moderate water-holding capacity. The soil was derived from the Voltaian sandstone and is classified as Chromic Luvisol in the FAO – UNESCO system (Asiamah, 2000; Adu and Asiamah, 2003). The pH ranges from 6.5-7.0 (Opoku, 1993). The soil is good for the cultivation of many vegetables such as sweet pepper, carrots, and arable crops like maize, cowpea, and cassava. The vegetation cover of the area is a semi-deciduous type with thick grass. But

due to some human activities such as bush burning, indiscriminate felling of trees, and charcoal preparation, the amount of rainfall has declined and this has subsequently affected the vegetation of the area (MoFA, 2005).

3.4 Experimental Design

The Randomized Complete Block Design (RCBD) was used for the experiment and the treatments were replicated three times.

3.5 Treatments and their Application

The treatments were as follows;

- ❖ T1 = 10 t/ha of chicken manure;
- ❖ T2 = 225 kg/ha of NPK (15 - 15 - 15)
- ❖ T3 = 225 kg/ha of NPK (15 - 15 - 15) + 60 kg/ha Mono Potassium Phosphate (KH₂PO₄)
- ❖ T4 = Combination of 5 t/ha chicken manure and 112.5 kg/ha NPK (15-15-15)
- ❖ T5 = 60 kg/ha Mono Potassium Phosphate, (KH₂PO₄)
- ❖ T6 = Control (no fertilizer).

The treatments were written on pieces of paper and randomly picked and assigned to the plots, block after block.

3.6 Land Preparation and field layout

An area measuring 19 m x13 m was demarcated, cleared with cutlass and the debris raked off on 2nd June 2022. Lining and pegging were done on 5th June 2022. eighteen plots each measuring 3 m x 2 m were marked out. Each plot was prepared into a bed with

a height of about 20 cm. The beds and blocks were separated by a 1 m wide path. There were six (6) plots in each block which were replicated three times.

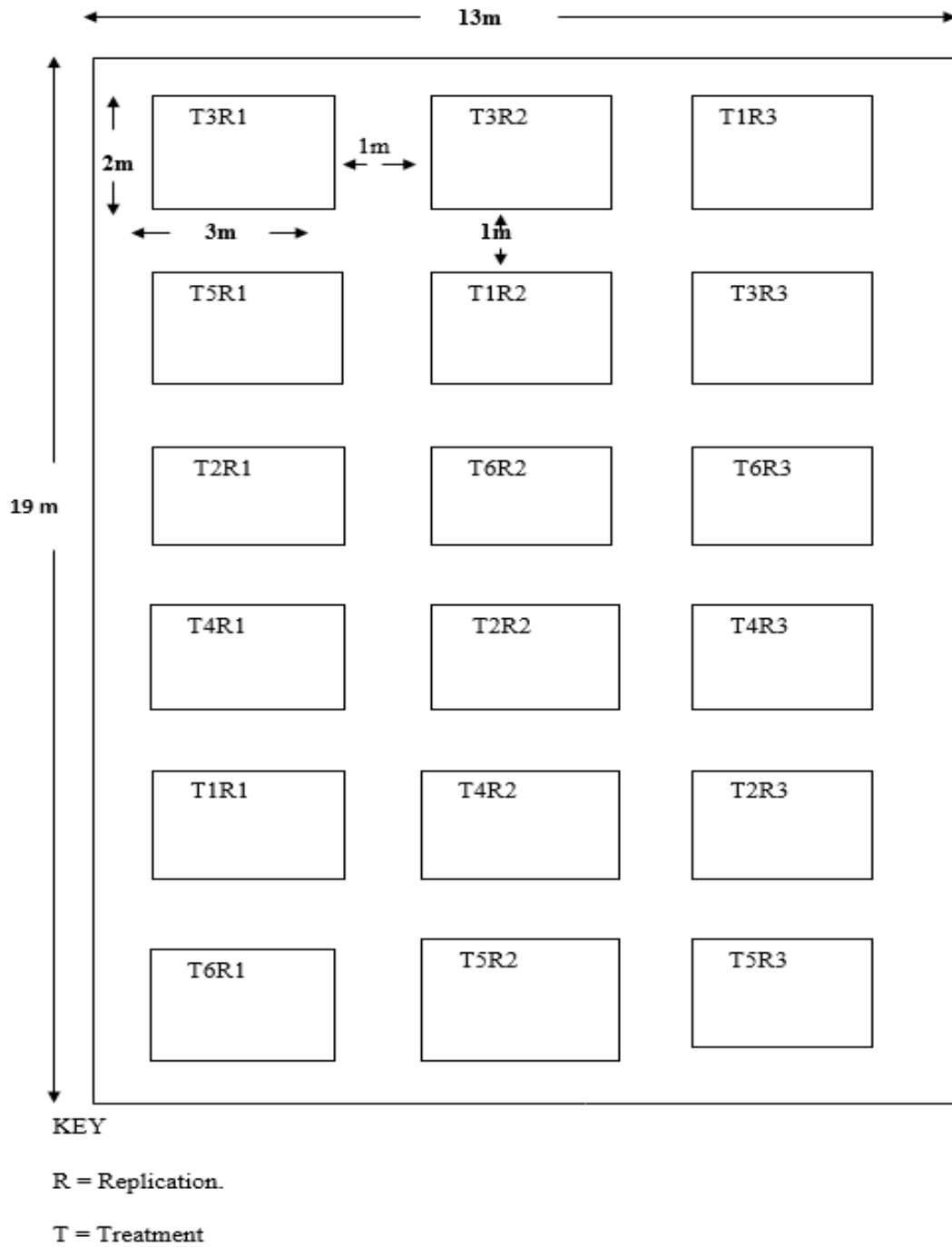


Figure 3.1: Field layout of the experimental plots

3.7 Chicken manure preparation, application and inorganic fertilizer application

The chicken manure was obtained from the livestock unit of the University farm while the NPK (15-15-15) and Mono Potassium Phosphate (KH₂PO₄) fertilizer were obtained from Demeter Ghana Limited. The chicken manure was evenly spread on the plots with chicken manure as treatment and was incorporated into the soil using a garden fork on June 24, 2022, and allowed for two weeks for further decomposition before planting. The NPK (15 - 15 - 15) and Mono Potassium Phosphate (KH₂PO₄) was applied one week after sowing by side placement.

3.8 Planting material and sowing

The Cowpea seed was purchased from CSIR-Crops Research Institute Kumasi, Ghana and the variety for the experiment was Zamzam of which the growth habit is semi-erect. This variety was selected based on farmers' preference due to its early maturity, and yield and consumer preferences due to the taste. Seeds were sown on 8th July 2022, at a spacing of 50 cm x 30 cm. Three seeds were sown per hill and were later thinned to two seedlings per hill after it had taken 5 to 8 days to emerge. This gave a total of 72 seedlings on each plot.

3.9 Agronomic Practices

3.9.1 Weed control

Weeding was done twice before the canopy was formed by using a cutlass and hoe. The first weeding was done one week after sowing while the second weeding was done three weeks after sowing.

3.9.2 Watering

The first watering was done on July 8, 2022. Subsequent waterings were done at three days intervals. Watering was done usually in the evenings with watering cans to ensure the efficient use of water by the plants.

3.9.3 Pest and disease and their control

Although there were no diseases, some beetles and caterpillars attacked the plants at the vegetative stage. However, these insect pests were controlled by applying Lambda-cyhalothrin at the rate of 50ml/15L.

3.9.4 Harvesting

Harvesting was done at physiological maturity when about 85% of pods had turned brown and more than 75% of leaves had senescence. It was done three times manually at five days intervals from 58 days after sowing by picking the matured pods and parting tagged-plant harvest from untagged-plant harvest.

3.10 Sampling and Data Collection

Four plants out of the total seventy-two were chosen randomly and tagged from the middle row of each plot for data collection. Data on plant height, number of leaves, stem diameter, number of branches, and canopy length were taken at weekly intervals. Days to 50% flowering, as well as yield and yield components such as Number of pods per plant, Number of filled pods per plant, Number of unfilled pods per plant, Pod length, Seeds per pod, Pod weight per plot, 100-seed weight (g), Seed weight per plot (g) and Mean yield (tons/ha), were all taken at harvest.

3.10.1 Plant Height

Plant height was measured from the base of the stem to the tip of the highest apical bud using a meter rule. In the situation where the stem is not straight rope was used and later stretched on a meter rule. The mean height for each plot was determined and recorded.

3.10.2 Number of Leaves per plant

All matured and fully open leaves of the four tagged plants were counted, and its average is calculated and recorded for each treatment per plot.

3.10.3 Stem diameter

This was measured using Vernier Callipers 4cm above the soil level of the four tagged plants and averages were calculated and recorded for each plot.

3.10.4 Number of Branches per plant

The number of branches on the four tagged plants was counted. The average number of branches per plant on each plot was calculated and recorded.

3.10.5 Canopy Width

Measurement was done by taking the length of the longest opposite branches on the four (4) tagged plants and the averages of each plot were calculated and recorded.

3.10.6 Days to 50% flowering

Days to 50 % were determined by recording the number of days half the plants within the central rows had at least one open flower.

3.10.7 Number of pods per plant

Pods harvested from the tagged plants for each plot were counted and the average was recorded.

3.10.8 Number of filled pods per plot

After harvesting pods from four central rows for each plot, pods with complete seeds were separated and counted and the average for each plot was calculated and recorded.

3.10.9 Number of unfilled pods per plot

After harvesting pods from four central rows for each plot, pods with incomplete seeds were separated and counted and the average for each plot was calculated and recorded.

3.10.10 Pod length

This was determined by randomly picking eight pods from the tagged plants from each plot. Pods were measured from one end to the other using a meter rule and the average pod length was calculated and recorded.

3.10.11 Number of Seed per pod

This was determined by randomly picking eight pods from the tagged plants from each plot. Pods were shelled, seeds counted and the average number of seeds per pod for each plot was calculated and recorded.

3.10.12 Pod weight per plant

Weights of pods per plant were taken from the four (4) tagged plants on the various plots with an electronic balance, after which the average weight per plant for each plot was calculated and recorded.

3.10.13 100 - Seed weight

The average 100-seed weight was determined by randomly counting hundred (100) seeds from the threshed after sun-dried for four days from the central rows of each plot. Seeds were randomly selected, weighed and recorded in grams (g).

3.10.14 Grain yield

The mean grain yield was determined by weighing the harvested grain from each plot excluding the border plants. The weight of grains for each plot was extrapolated into tons per hectare.

3.11 Data Statistical Analysis

The data were analyzed statistically by using ANOVA and GenStat (version 18) and the treatment means were separated by the Least Significant Difference (LSD) at a 5% probability level.

CHAPTER FOUR

RESULTS

4.1 Treatment types and their effects on Plant height of Cowpea

Table 4.1 presents treatment types and their effects on the plant height of Cowpea from week 2 to week 5 after planting (WAP). In terms of individual treatments effect on plant height, the results showed 10 t/ha Chicken manure contributed 33.77 cm in 2WAP, and the highest but was not significantly ($P \geq 0.05$) different from 225kg/ha NPK(15-15-15) and 5 t/ha Chicken manure + 112.5 kg/ha NPK(15-15-15) but was significantly ($P \leq 0.05$) different from the rest of the treatments. 10 t/ha Chicken manure again recorded the tallest plants at 3WAP, 4WAP and 5WAP of which it was significantly ($P \leq 0.05$) higher than the rest at 5WAP. 5 t/ha Chicken manure + 112.5 kg/ha NPK(15-15-15), 225 kg/ha NPK(15-15-15) + 60 kg/ha Mono potassium phosphate, and 60 kg/ha Mono potassium phosphate were all significantly ($P \leq 0.05$) different from the Control (No fertilizer application) at all the weeks after planting.

Table 4.1 Treatment types and its effects on Plant height of Cowpea

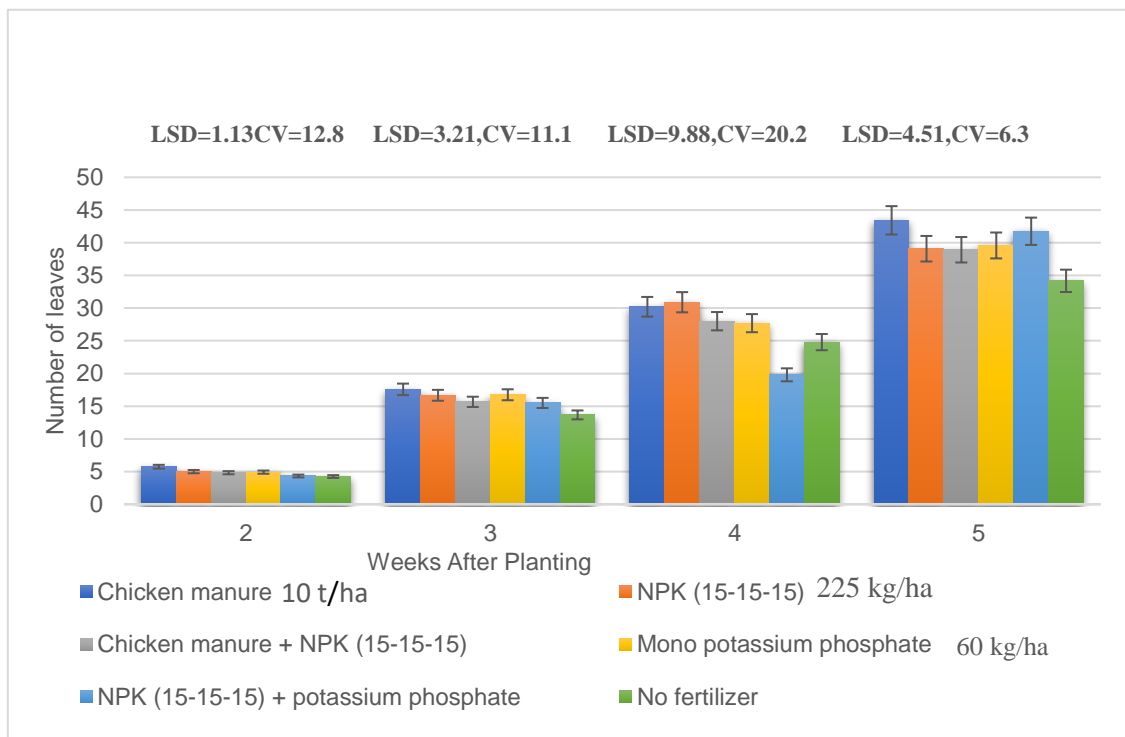
Treatment	Plant height (cm)			
	2WAP	3WAP	4WAP	5WAP
10 t/ha Chicken manure	33.77c	41.10d	53.5b	84.3c
225 kg/ha NPK (15-15-15)	31.89bc	40.61cd	51.2b	69.5b
5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15)	30.58bc	36.60bc	46.6ab	67.8b
60 kg/ha Mono potassium phosphate	28.89b	37.23bcd	39.7a	61.3ab
225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate	30.14b	34.64ab	52.6b	66.3b
No fertilizer	23.14a	31.94a	44ab	52.1a
LSD (0.05)	3.56	4.34	9.59	9.89
CV (%)	6.6	6.4	11.0	8.1

Source: Field Data, 2022

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; CV=coefficient of variation, LSD=least significant difference at 5%

4.2 Treatment types and their effects on the number of leaves in weeks after planting

Figure 4.1 presents the treatment types and their effects on the number of leaves from 2 to 5 weeks after planting cowpea. At 2 WAP, plants treated with 10 t/ha Chicken manure had the highest number of leaves, followed by 225 kg/ha NPK (15-15-15) with slight differences between 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15), 225 kg/ha NPK(15-15-15) + 60 kg/ha Mono potassium phosphate and 60 kg/ha Mono Potassium phosphate. The control (no fertilizer application) had the lowest values throughout the number of weeks after planting. The trend did not change, 10 t/ha Chicken manure continued to have a higher number of leaves at 4WAP and 5WAP and it was significantly ($P \leq 0.05$) higher than the other treatments.



Source: Field Data, 2022

Figure 4.1 Treatment and its effect on the number of leaves of cowpea, 2-5 WAP

4.3 Treatment types and their effect on stem diameter of cowpea

Table 4.2 presents the effects of treatment types on the stem diameter of the cowpea plant. At 2WAP, 10 t/ha Chicken manure contributed to the greater stem diameter of 0.49 cm, followed by the combined effects of 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15) of 0.46 cm, 225 kg/ha NPK (15-15-15) had 0.44 cm, 60 kg/ha Mono potassium phosphate was 0.41 cm, combined effects of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate was 0.43cm, and the control (no fertilizer application) was 0.39 cm. Overall, the least significant difference (LSD) for stem diameter at 5% was 0.04, and the coefficient of variation was 5.7. At 3WAP, 4WAP, and 5WAP, the stem diameter of the cowpea plant increased respectively for each treatment type, with chicken manure still being the highest contributing treatment.

Table 4.2: Treatments and their effect on stem diameter of Cowpea

Treatment	Stem diameter (cm)			
	2WAP	3WAP	4WAP	5WAP
10 t/ha Chicken manure	0.49d	0.69c	0.87c	0.97c
225 kg/ha NPK (15-15-15)	0.44bc	0.68c	0.84c	0.92bc
5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15)	0.46cd	0.66c	0.76b	0.91bc
60 kg/ha Mono potassium phosphate	0.41ab	0.57ab	0.69ab	0.78a
225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate	0.43bc	0.62bc	0.76b	0.89b
No fertilizer	0.39a	0.55a	0.66a	0.75a
LSD (0.05)	0.04	0.07	0.07	0.06
CV (%)	5.7	6.3	5.1	4.2

Source: Field Data, 2022

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; CV=coefficient of variation, LSD=least significant difference at 5%

4.4 Treatment types and their effect on the number of branches per plant

Table 4.3 indicates the treatment types and the number of branches of the cowpea plant. At 3WAP, 225 kg/ha NPK (15-15-15) treatment contributed the highest number of branches of the cowpea plant of 4.50, followed by the combined effects of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate of 4.33. However, 10 t/ha Chicken manure, combined effects of 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15), and 60 kg/ha Mono potassium phosphate all contributed the same effect of 4.25, and those cowpea plants without the application of any treatment had the lowest number of branches of 3.33. There was a corresponding increase in the number of branches of the cowpea plant on the 4WAP and 6WAP of the cowpea plants. However, there was no significantly different ($P \geq 0.05$) between the various types of treatment applications and the number of branches.

Table 4.3: Treatment types and Number of branches per plant of cowpea

Treatment	Number of branches per plant		
	3WAP	4WAP	6WAP
10 t/ha Chicken manure	4.25b	4.58a	5.00a
225 kg/ha NPK (15-15-15)	4.50b	5.00a	4.83a
5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15)	4.25b	4.58a	4.92a
60 kg/ha Mono potassium phosphate	4.25b	4.68a	4.75a
225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate	4.33b	4.92a	5.17a
No fertilizer	3.33a	4.25a	4.50a
LSD (0.05)	0.79	NS	NS
CV (%)	10.5	11.5	9.0

Source: Field Data, 2022

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; CV=coefficient of variation, LSD=least significant difference at 5%.

4.5 Treatment types and their effects on the canopy width of cowpea

Table 4.4 presents the treatment types and their effects on the canopy width of the cowpea plant. With the canopy width of the cowpea plant, 10 t/ha chicken manure contributed the highest which was 49.27 cm on 3WAP, followed by 225 kg/ha NPK (15-15-15) of 48.43 cm on the same 3WAP. The next highest contributor was the combined application of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate of 45.04 cm, for both 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15) was 44.44 cm, 60 kg/ha Mono potassium phosphate was 43.32 cm, and the control (no fertilizer application) was 39.25 cm. At 4 and 5 WAP, there was a corresponding increase in the canopy width of the cowpea plant, with 10 t/ha Chicken manure still the highest with a figure of 111.6 cm at 5WAP, a combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate followed with 106.0 cm, 225 kg/ha NPK (15-15-15) and 60 kg/ha Mono potassium phosphate on 5WAP had 98.0 cm and 98.0 cm respectively. Also, a combination of 10 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15) was 82.9 cm, and the control had 78.7 cm which was the lowest.

Table 4.4 Treatment types and canopy width of cowpea

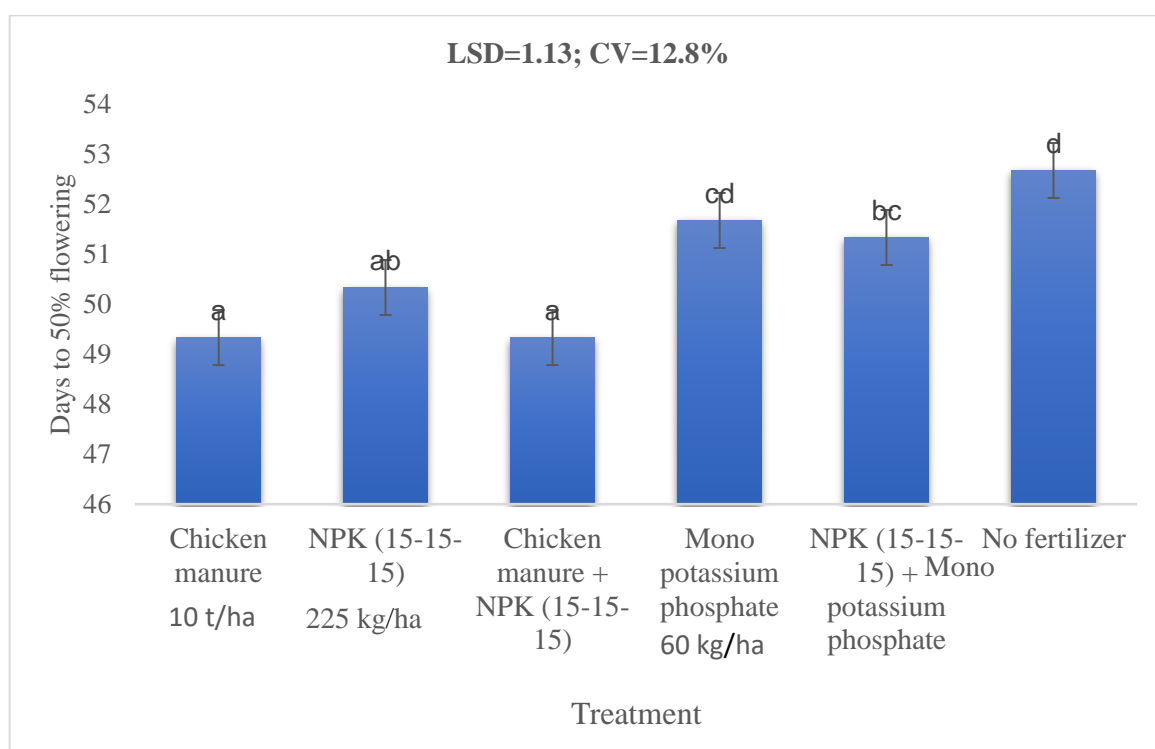
Treatment	Canopy width (cm)		
	3WAP	4WAP	5WAP
10 t/ha Chicken manure	49.27b	59.2a	111.6c
225 kg/ha NPK (15-15-15)	48.43b	61.9a	98.0bc
5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15)	44.44ab	60.8a	82.9ab
60 kg/ha Mono potassium phosphate	43.32ab	58.7a	98.0ab
225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate	45.04ab	65.2a	106.0c
No fertilizer	39.25a	55.8a	78.7a
LSD (0.05)	6.31	NS	18.41
CV (%)	7.7	13.7	10.8

Source: Field Data, 2022

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; CV=coefficient of variation, LSD=least significant difference at 5%

4.6 Treatment types and their effects on the number of Days to 50% flowering

Figure 4.2 indicates the treatment types and their effects on the number of days to 50% flowering of the cowpea plant. Cowpea plant with no fertilizer application has the highest number of days to 50% flowering, followed by the combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate, 60 kg/ha Mono potassium phosphate, 225 kg/ha NPK (15-15-15), a combination of 5 t/ha Chicken manure + 122.5 kg/ha NPK (15-15-15) and 10 t/ha Chicken manure in that order had the least days to obtain 50% flowering of the cowpea plant.



Source: *Field Data, 2022*

Figure 4.2: Treatments and Days to 50% flowering of Cowpea

4.7 Treatment types and their effect on the number of pods per plant and the number of filled and unfilled pods per plot

Table 4.5 presents the treatment types and their effects on yield parameters such as the number of pods per plant and, the number of filled and unfilled pods per plot of Cowpea. In terms of the number of pods per plot, 10 t/ha Chicken manure was 18.17, 225 kg/ha NPK (15-15-15) had 19.25, a combination of 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15) was 14.00, 60 kg/ha Mono potassium phosphate 12.58, a combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate was 16.58, and without fertilizer application was 8.67.

The number of filled pods per plot indicates 10 t/ha Chicken manure was 21.0, 225 kg/ha NPK (15-15-15) was 23.3, a combination of 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15) was 17.7, 60 kg/ha Mono potassium phosphate was 12.3, 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate was 20.7, and no fertilizer application was 19.3. Also, the number of unfilled pods per plot showed 10 t/ha Chicken manure was 38.3, 225 kg/ha NPK (15-15-15) was 52.0, a combination of 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15) was 35.3, 60 kg/ha Mono potassium phosphate was 23.3, a combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate was 36.0, and 22.7 for those with no fertilizer application to the cowpea plant. There was no significant difference at the 5% level of significance.

Table 4.5: Treatment types and their effect on yield and yield component of Cowpea

Treatment	Number of pods/plant	No. of filled pods/plot	No. unfilled pods/plot
10 t/ha Chicken manure	18.17c	21.0a	38.3bc
225 kg/ha NPK (15-15-15)	19.25c	23.3a	52.0c
5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15)	14.00b	17.7a	35.3ab
60 kg/ha Mono potassium phosphate	12.58ab	12.3a	23.3ab
225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate	16.58bc	20.7a	36.0ab
No fertilizer	8.67a	19.3a	22.7a
LSD (0.05)	4.10	NS	15.07
CV (%)	15.2	27.0	23.9

Source: Field Data, 2022

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; CV=coefficient of variation, LSD=least significant difference at 5%

4.8 Treatment types and their effects on pod length, number of seeds per pod and, pod weight per plot

Table 4.6 indicates the treatment types and yield components such as pod length, Number of seeds per pod and pod weight of cowpea. For pod length, 10 t/ha Chicken manure was 14.60 cm, 225 kg/ha NPK (15-15-15) 14.03 cm, a combination of 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15) was 14.66 cm, 60 kg/ha Mono potassium phosphate had 14.08 cm, a combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate was 14.08 cm, and with no fertilizer was 13.28 cm.

For the number of seeds per pod, 10 t/ha Chicken manure was 11.79, 225 kg/ha NPK (15-15-15) 10.59, 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15) had 11.55, 60

kg/ha Mono potassium phosphate was 10.09, a combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate was 9.7g, and without fertilizer application was 9.38. For pod weight per plot, 10 t/ha Chicken manure was 2077g, 225 kg/ha NPK (15-15-15) had 1792g, a combination of 5t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15) was 1657g, 60 kg/ha Mono potassium phosphate 1098g, a combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate was 1807g, and with no fertilizer application pod weight was 748g.

Table 4.6: Treatment types and their effects on yield and yield component of cowpea

Treatment	Pod length (cm)	Number of Seeds per pod	Pod weight per plot (g)
10 t/ha Chicken manure	14.60a	11.79c	2077c
225 kg/ha NPK (15-15-15)	14.30a	10.59abc	1792c
5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15)	14.66a	11.55bc	1657bc
60 kg/ha Mono potassium phosphate	14.08a	10.09abc	1098ab
225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate	14.08a	9.75ab	1807c
No fertilizer	13.28a	9.38a	748a
LSD (0.05)	NS	2.03	608
CV (%)	5.4	10.6	21.8

Source: Field Data, 2022

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; CV=coefficient of variation, LSD=least significant difference at 5%

4.9 Treatment types and their effects on 100 - seed weight(g). Seed weight per plot(g) and yield(tons/ha)

Table 4.7 presents the treatment types and their effects on Cowpea yield and its yield parameters. In terms of 100 - seed weight of cowpea, 10 t/ha Chicken manure had 93.98g, 225 kg/ha NPK (15-15-15) was 91.42g, a combination of 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15) was 90.33g, 60 kg/ha Mono potassium phosphate was 91.05g, a combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate was 89.75g and with no fertilizer was 88.18g. For seed weight per plot, 10 t/ha Chicken manure was 1427g, 225 kg/ha NPK (15-15-15) was 1189g, a combination of 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15) was 1129g, 60 kg/ha Mono potassium phosphate was 692g, a combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate was 1297g, and no fertilizer was 553g.

For cowpea seeds yield in tons per hectare showed 10 t/ha Chicken manure was 14.27 t/ha, 225 kg/ha NPK (15-15-15) was 11.89 t/ha, a combination of 5 t/ha Chicken manure + 112.5 kg NPK (15-15-15) was 11.29 t/ha, 60 kg/ha Mono potassium phosphate was 6.38 t/ha, a combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate was 12.97 t/ha, and without fertilizer application, cowpea yield in tons per hectare was 6.08 t/ha which was considered to be the lowest.

Table 4.7: Treatment types and their effects on yield and yield components of Cowpea

Treatment	100-seed weight (g)	Seed weight per plot (g)	Yield (tons/ha)
10 t/ha Chicken manure.	93.98a	1427b	14.27b
225 kg/ha NPK (15-15-15).	91.42a	1189b	11.89b
5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15).	90.33a	1129b	11.29b
60 kg/ha Mono potassium phosphate.	91.05a	692a	6.38a
225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate.	89.75a	1297b	12.97b
No fertilizer.	88.18a	553a	6.08a
LSD (0.05)	NS	398.8	4.09
CV (%)	3.7	20.9	21.5

Source: Field Data, 2022

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; CV=coefficient of variation, LSD=least significant difference at 5%

CHAPTER FIVE

DISCUSSION

5.1 Effect of Soil Amendments on Vegetative Growth of Cowpea

The results indicated that soils amended with 10 t/ha chicken manure, 225 kg/ha NPK (15-15-15), 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate, 60 kg/ha Mono potassium phosphate and a combination of 5 t/ha chicken manure and 112.5 kg/ha NPK (15-15-15) all help improved the soil nutrients and composition which influenced the vegetative growth of the cowpea than the Control (No Fertilizer application). From the study, the results showed that 10 t/ha Chicken manure amendment produced the tallest plants and highest number of leaves per plant at all the weeks after planting (WAP) and was found to be contributing significantly different ($P \leq 0.05$) from some treatments to the growth in height and the number of leaves of the cowpea plant. This was found to share similarities with studies of Alan (1993) whose findings equally reported that all agricultural systems include harvesting crops, which removes minerals from the soil, and if these nutrients are not replaced, crop growth and yields will eventually decrease.

Grindlay (1997) and Kaviraja (2017) also talked about how plant height and the number of primary and secondary branches per plant of several legumes have been reported to be significantly and favourably changed by the administration of nitrogen fertilizer because of its effects on the leaf area index and subsequently light absorption, playing a crucial role in plant growth. Again, findings from the study revealed soil amendments influenced the number of leaves weeks after planting. Results showed the number of leaves of cowpea plant increment depends on the type of treatment application. The treatment that contributed to the highest number of leaves was 10 t/ha Chicken manure

followed by 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate which was noted to have contributed to the increased number of leaves at 5WAP, and the treatment that contributed the least number of leaves was the control (no fertilizer application) which was the lowest throughout the weeks. This goes to confirm the fact that, soil amendments or treatments contribute to improving soil quality and fertility and hence helped in crop growth. Subsequently, from the study, soil amendments were found to influence the stem diameter of the cowpea plant. For example, 10 t/ha Chicken manure contributed to a greater stem diameter of 0.49 cm, at 2WAP and on 3WAP increased the stem diameter to 0.69 cm, 4WAP to 0.87 cm, and at 5WAP, it was further increased to 0.97 cm which gives a clear indication of the contributions of soil amendments to the vegetative growth of the cowpea plant. But when this was compared to the cowpea plant without fertilizer application a greater variation in the stem diameter of which a significant difference ($P \leq 0.05$) was obtained.

Because there was about a point variation in stem diameter on 2WAP and this almost doubled the stem diameter of the cowpea plant in 3WAP which clearly showed the vast influence of soil amendments on the vegetative growth of the cowpea. This gain was found to relate to the studies of Kaviraja (2017) about how plant height and the number of primary and secondary branches per plant of several legumes have been reported to be significantly and favourably changed by the administration of nitrogen fertilizer. Findings from the study further revealed that soil amendments and treatment types influenced the number of branches of the cowpea. At 3WAP, 225 kg/ha NPK (15-15-15) treatment contributed the highest number of branches 4.50, followed by the combined effects of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate of 4.33. However, other treatment types such as 10 t/ha Chicken manure, combined effects of 5

t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15), and 60 kg/ha Mono potassium phosphate all contributed the same effect of 4.25, and those cowpea plants without the application of any treatment had 3.33, which was found to be the least. There was a corresponding increase in the number of branches of the cowpea plant from 4WAP to 6WAP of the cowpea plants. This could equally be related to the studies of Alan (1993); Grindlay (1997) and Kaviraja (2017). Additionally, the study further revealed that soil amendment types influenced the canopy width of the cowpea plant. Findings indicate that although 10 t/ha Chicken manure contributed the highest canopy width at 3WAP, but was not significantly different ($P \geq 0.05$) from the rest except the Control (no fertilizer application). At 3WAP 225 kg/ha NPK (15-15-15) and 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate, were second and third respectively. 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15), and 60 kg/ha Mono potassium phosphate followed but there was no significant difference ($P \geq 0.05$) between them.

However, the cowpea plant without fertilizer application was the least, and this equally goes to confirm the previous argument of the influence of soil amendments and treatments on the vegetative growth of the cowpea plant. On the subsequent application at 4WAP and 5WAP, there was a corresponding increase in the canopy width of the cowpea plant, with 10 t/ha chicken manure still being the highest followed by the combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate, 225 kg/ha NPK (15-15-15) and 60 kg/ha Mono potassium phosphate as well as a combination of 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15). But cowpea plants with no fertilizer application had the least influence on the canopy width throughout the weeks. This was found to share similarities with studies of Akinsanmi (2000) whose findings equally reported that, there are several different ways that soil fertility is lost, including

crop removal, erosion, leaching, burning, oxidation, and decrease of organic matter and if these nutrients are not replaced, crop growth and yields will eventually decrease. Grindlay (1997) and Kaviraja (2017) also talked about how several primary and secondary branches per plant of several legumes have been significantly and favourably increased by the administration of nitrogen fertilizer because of its effects on the leaf area index and subsequently light absorption, playing a crucial role in plant growth.

5.2 Effects of Soil Amendments on Flowering of Cowpea

Good yield of cowpea depends heavily on soil fertility, and soil amendments and treatments such as 10 t/ha chicken manure, 225 kg/ha NPK (15-15-15), 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate, 60 kg/ha Mono potassium phosphate and a combination of 5 t/ha Chicken manure and 112.5 kg/ha NPK (15-15-15) all contributed significantly to improving the soil fertility and hence good yields than the control (no fertilizer application). From the study, the treatment types and days to 50% flowering of the cowpea plant showed cowpea plants with no fertilizer application had the highest number of days to 50% flowering. This means that cowpea plants that lacked soil amendments and treatments take a long period before they start flowering, and this could be attributed to the depletion of soil nutrients to support the growth and flowering of the cowpea plant. However, other soil amendments such as the combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate, 60 kg/ha Mono potassium phosphate, and 225 kg/ha NPK (15-15-15) have a medium number of days to flowering. Comparing these soil amendments to those without any soil amendments showed clearly that cowpea plants with soil amendments start flowering earlier than those without any form of soil amendments. Notwithstanding, soil amendments such as 10 t/ha Chicken manure, as well as a combination of 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-

15), have the least number of days to 50% flowering. This indicates that soil amendments such as 10 t/ha Chicken manure contributed more significantly to the flowering of the cowpea plant than other amendments as they had an early flowering period for cowpea plants than other soil amendments. This was found to relate to the studies of Bot and Benites (2005); Reyhan and Amiraslani (2006); Obalum *et al.* (2011); and Obalum *et al.* (2017), whose findings indicate that the crucial component in the management of soils, particularly tropical soils, is an organic matter of which chicken manure is one of the best sources and, influences many of the physical, chemical, and biological processes that characterize soil productivity, making it a good indicator of soil quality for the cowpea plant.

5.3 Effect of Soil Amendments on Yield and yield components of Cowpea

Findings further revealed that soil amendments influenced the yield parameters of the cowpea. Results showed the number of pods per cowpea plant with 225 kg/ha NPK (15-15-15) being the highest, followed by 10 t/ha Chicken manure, and 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate. Although the differences were not significant ($P \geq 0.05$) to each other, it was significantly higher ($P \leq 0.05$) than the rest, especially the control (no fertilizer application). This confirms the study of Reyhan and Amiraslani, (2006); Obalum *et al.*, (2011); Bot and Benites, (2005); Obalum *et al.* (2017) which talks about chicken manure not only supplying cowpea with nutrients but also improving the physical, chemical and biological processes which help in nutrients absorption by the plant for higher yield. A study by Ayodele and Oso (2014) also confirms that Cowpea yield is increased by adding phosphorus, which increases the number of pods per plant, the number of seeds per pod, and the mean seed weight.

Other soil amendments such as 60 kg/ha Mono potassium phosphate and a combination of 112.5 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate were equally found to have a significant difference ($P \leq 0.05$) over the Control (no fertilizer application) on the number of pods per cowpea plant though it did not have the same effects as that of 225 kg/ha NPK (15-15-15), 10 t/ha Chicken manure, and 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate. This goes to confirm Sanginga *et al.* (2000) about Phosphorus deficiency in tropical soils and the crucial role phosphorus plays in root formation and the growth of the rhizobium bacteria when applied, which fixes nitrogen to improve the yield of cowpea. Also, findings further revealed that the number of filled pods per plot indicates 225 kg/ha NPK (15-15-15) had the highest number of filled pods compared to other soil amendments but was not significantly different ($P \geq 0.05$) from the other soil amendment and the control (no fertilizer application). This confirms Akinsanmi's (2000), study that the use of fertilizer brings about an increase in crop yield.

Mono Potassium phosphate had the least number of filled pods per plant. This still affirmed the previous assertion by Sanginga *et al.* (2000) whose findings indicate that phosphorus does not necessarily increase the number of filled pods or yield but plays a vital role in root formation and the growth of the rhizobium bacteria when applied, which fix nitrogen in the soil for plant growth. Regarding the treatment types and their effect on pod length, there was no significant difference ($P \geq 0.05$) in all the soil amendments including the control (no fertilizer application). 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15), was the highest followed by 10 t/ha Chicken manure, 225 kg/ha NPK (15-15-15), and others such as the 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate, 60 kg/ha Mono potassium phosphate and Control (no fertilizer

application). This affirmed the previous assertion by Ayoola, and Makinde (2007), which state that by using balanced NPK fertilization like NPK (15:15:15) in conjunction with chicken manure amendments, high and sustained crop yields can be achieved which Yogodin (1984) and Asubonteng (1997) made a similar assertion that combined benefits of mineral fertilisers and poultry manure are better than either of them utilised alone at varying rates of application. Again, in terms of the number of seeds per pod, 10 t/ha Chicken manure was the highest, followed by 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15), 225 kg/ha NPK (15-15-15), which were not significantly ($P \geq 0.05$) different from each other but significantly ($P \leq 0.05$) different from 60 kg/ha Mono potassium phosphate, and a combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate in that order with cowpea plant without fertilizer application recording the lowest number of seeds per pod. With regard to pod weight, 10 t/ha Chicken manure was still the highest followed by 225 kg/ha NPK (15-15-15), a combination of 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15), 60 kg/ha Mono potassium phosphate, and a combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate.

Additionally, findings from the study further revealed that the treatment types and cowpea yield parameters showed that in terms of 100-seed weight of cowpea, 10 t/ha Chicken manure contributed the highest of about 93.98g, followed by 225 kg/ha NPK (15-15-15), 60 kg/ha Mono potassium phosphate, a combination of 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15), and combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate. The cowpea plant with the poorest quantity of seeds, pod weight and 100-seed weight was the one with no fertilizer application. This could be attributed to the fact that soil fertility depletion generally affects plant seed quantity and quality and therefore could be the reason for cowpea without fertilizer

application to have lower seed per pod, lower pod weight and lower 100-seed weight as compared to those with the application of organic and inorganic fertilizers. This was however found to share similarities with studies of Bot and Benites (2005); Obalum *et al.* (2011); Obalum *et al.* (2017); Petersen *et al.* (2007); Kannan and Saravanan (2006) and Sommer *et al.* (2013) which findings indicate that the crucial component in the management of soils, particularly tropical soils, is organic matter content and applying chicken manure is a significant way to recycle nutrients in the soil which influences many of the physical, chemical, and biological processes that characterize soil productivity, making it a good indicator of soil quality. However, a large portion of the nutrients in the manure are bound to the organic component and must undergo decomposition to be transformed into inorganic forms that plants may absorb for growth and yield.

Findings further revealed that seed weight per plot indicates 10 t/ha Chicken manure contributed the highest seed weight per plot which was not significantly different ($P \geq 0.05$) from 225 kg/ha NPK (15-15-15), a combination of 5 t/ha Chicken manure + 112.5 kg/ha NPK(15-15-15) and 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate, but was significantly ($P \leq 0.05$) higher than 60 kg/ha Mono potassium phosphate and the control (no fertilizer application). In terms of overall yield in tons per hectare, results showed 10 t/ha Chicken manure contributed the highest yield of cowpea but was not significantly different from 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate, 225 kg/ha NPK (15-15-15), a combination of 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15), in that order. All the amendments were significantly ($P \leq 0.05$) higher than 60 kg/ha Mono potassium phosphate and the control (no fertilizer application). However, cowpea plants without fertilizer application

contributed the lowest cowpea yield in tons per hectare. This could equally be attributed to the same reasons for soil nutrient depletion, and poor soil nutrient quality and quantity which could have contributed to the poor yield of the cowpea. But soil amendments such as 10 t/ha Chicken manure, 225 kg/ha NPK (15-15-15), a combination of 5 t/ha Chicken manure + 112.5 kg/ha NPK (15-15-15), 60 kg/ha Mono potassium phosphate, and a combination of 225 kg/ha NPK (15-15-15) + 60 kg/ha Mono potassium phosphate contributed the higher yield because they complemented the soil constituents and improved on the nutrients of the soil, and thus contributed to the increased yield of cowpea.

This was found related to the study of Petersen *et al.* (2007); Obalum *et al.* (2011); Sommer *et al.* (2013) and Tajudeen & Babajide (2018) who indicate that the crucial component in the management of soils, particularly tropical soils, is organic matter content and stated that, applying chicken manures is a significant way to recycle nutrients in the soil and addition of organic amendments corresponds in most cases to a recycling process, which cannot compensate for nutrients exported through crop products as well. Ntare *et al.* (2016) and Nwokwu (2020) studies which reported that the use of external inputs such as inorganic plant nutrients or local sources of P such as phosphate rock are essential requirements for soil productivity and improve the yield of crops such as cowpea.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In conclusion, the study demonstrated the positive impact of soil amendments on the growth and yield of cowpea. Chicken manure at a rate of 10 t/ha, in particular, showed significant benefits in terms of plant development and productivity. These findings suggest that policymakers and agricultural stakeholders should encourage farmers to use organic fertilizers like chicken manure instead of costly and scarce inorganic fertilizers. This can be achieved through education and awareness programs to promote sustainable and environmentally friendly agricultural practices.

6.2 Recommendations

Based on the study results, the following recommendations were made:

1. Farmers should consider using chicken manure, either alone or in combination with NPK fertilizer, as an effective soil amendment for cowpea cultivation. This can lead to improved vegetative growth and higher yields.
2. Agricultural extension services should promote and educate farmers about the benefits of utilizing organic and inorganic soil amendments, emphasizing the use of chicken manure in particular.
3. Further research is recommended to investigate the long-term effects of different soil amendment combinations on cowpea cultivation, including their impact on soil fertility, crop rotation, and overall sustainability.
4. The Ministry of Food and Agriculture through the central government should take steps to establish a production plant of organic fertilizers and also include more

organic fertilizers (chicken manure) in Fertilizer Subsidy Programme to support cowpea farmers to help increase the production of cowpea in the country.

5. Policymakers and stakeholders in the agricultural sector should develop supportive policies and initiatives to encourage the adoption of organic fertilizers like chicken manure, aiming to reduce reliance on costly and limited supplies of inorganic fertilizers.

By implementing these recommendations, farmers can enhance their cowpea production, improve soil health, and contribute to more sustainable agricultural practices.

REFERENCES

- Abudulai, M., Seini, S. S., Haruna, M., Mohammed, A. M., and Asante, S. K. (2016). Farmer participatory pest management evaluations and variety selection in diagnostic farmer field Fora in cowpea in Ghana. *Afr. J. Agric. Res.* 11, 1765–1771. doi: 10.5897/AJAR2016.10887.
- Addo-Quaye A, Darkwa A, Ampiah M (2011) Performance of three cowpea (*Vigna unguiculata* (L) Walp) varieties in two agro-ecological zones of the Central Region of Ghana I: *Dry matter production and growth analysis J agric biol sci* 6:1-9.
- Adediran, J. A. and Banjoko, V. A. (1995). Response of maize to N, P, and K fertilizers in the savanna zone of Nigeria. *Commun. Soil Sci. Plant Anal.* 26: 593 - 606.
- Adewale, B. D., Adeigbe, O. O., & Aremu, C. O. (2011). Genetic distance and diversity among some cowpea (*Vigna unguiculata* L. Walp) genotypes. *International Journal of Research in Plant Science*, 1(2), 9-14.
- Adu, S.V and Asiamah, R.D. (2003). Soils of the Lawra-Wa region, Upper West region, Ghana. Soil Research Institute, CSIR, Kwadaso, Kumasi. Memoir No. 18.
- Agbogidi, O. M., and Egho, E. (2012). Evaluation of eight varieties of cowpea (*Vigna unguiculata* (L.) Walp) in Asaba agroecological environment, Delta state, Nigeria. *Eur. J. Sustain. Dev.* 1:303. doi: 10.14207/ejsd.2012. v1n2p303.
- Agyeman K, Berchie a, Bonsu I, Nartey T, Fordjour J (2014) Growth and yield performance of improved cowpea (*Vigna unguiculata* L.) varieties in Ghana. *Agric Sci* 2:44-52.

- Agza, B., Kasa, B., Zewdu, S., Aklilu, E., and Alemu, F. (2012). Animal feed potential and adaptability of some cowpea (*Vigna unguiculata*) varieties in northwest lowlands of Ethiopia. *J. Agric. Res.* 11, 478–483.
- Ahenkora K, Adu-Dapaah HK, Agyemang A (1998) Selected nutritional components and sensory attributes of cowpea (*Vigna unguiculata* [L.] Walp.) leaves. *Plant Foods Hum Nutr.* 52, 221–229. doi: 10.1023/A:1008019113245
- Ajayi, O. C., Akinnifesi, F. K., Sileshi, G., & Chakeredza, S. (2007). Adoption of renewable soil fertility replenishment technologies in the southern African region: Lessons learnt and the way forward. In *Natural resources forum* (Vol. 31, No. 4, pp. 306-317). Oxford, UK: Blackwell Publishing Ltd.
- Akinola, A. A.(1978). Influence of soil organic matter on cowpea: Response to N fertilizer. *American J. Agron.*, 70(1): 25.
- Akinsanmi, O. (2000). *Senior Secondary Agricultural Science*. Pearson Education Limited. Edinburgh Gate, Harlow Essex CM20 2JE, England. Pp. 181-188.
- Alan, W. (1993). *Soil and the environment*. Cambridge University Press. Pp 63.
- Ampah, J. K. (2020). *Assessment of nutritional level, functional properties and mineral contents of newly developed genotypes of cowpea [Vigna Unguiculata (L.) Walp.] in Ghana* (Doctoral dissertation, University of Cape Coast).
- Asiamah, R.D. (2000). *Soil and fertilizers*. Network for Africa, SOFERNET PAPER. № 9. Pp. 68.
- Asubonteng, K.O. (1997). *Effect of N..P.K Fertilization and combination on yields and qualities of vegetables*. National Agricultural Research Project. SRI. Kwadaso-Kumasi.

- Ayodele, O. J. and Oso, A. A. (2014), (a) Cowpea responses to phosphorus fertilizer application at Ado-Ekiti, South-West Nigeria. *J. Appl. Sci. & Agric.*, 9 (2) : 485-489.
- Ayodele, O. J. and Oso, A. A. (2014), (b) Effects of phosphorus fertilizer sources and application time on grain yield and nutrient composition of cowpea (*Vigna unguiculata* L.). *American J. Exp. Agri.*, 4 (12): 1517-1525.
- Ayoola, O. T., & Makinde, E. A. (2007). Complementary organic and inorganic fertilizer application: influence on growth and yield of cassava/maize/melon intercrop with a relayed cowpea. *Australian Journal of Basic and Applied Sciences*, 1(3), 187-192.
- Ba, F.S., R.S. Pasquet and P. Gepts. (2004), “Genetic diversity in cowpea [*Vigna unguiculata* (L.) Walp] as revealed by RAPD markers”, *Gen. Res. and Crop Evol.* Vol. 51 No. 5, pp. 539-550.
- Bationo, A., Fening, J. O., & Kwaw, A. (2018). Assessment of soil fertility status and integrated soil fertility management in Ghana. In *Improving the profitability, sustainability and efficiency of nutrients through site-specific fertilizer recommendations in West Africa agroecosystems* (pp. 93-138). Springer, Cham.
- Belay, F., Gebreslasie, A., and Meresa, H. (2017). Agronomic performance evaluation of cowpea (*Vigna unguiculata* (L.) Walp] varieties in Abergelle District, northern Ethiopia. *J. Plant Breed. Crop Sci.* 9, 139–143.
- Bergmann, W. (1992). *Nutritional disorders of plants*. 2nd ed. Gustav Fischer Verlag, Jena, Germany.
- Bisikwa, J., Kawooya, R., Ssebuliba, J. M., Ddungu, S. P., Biruma, M., and Okello, D. K. (2014). Effects of plant density on the performance of local and elite

- cowpea varieties in Eastern Uganda. *Afr. J. Appl. Agric. Sci. Technol.* 1, 28–41.
- Boddey, R. M., Fosu M, Atakora, W. K., Miranda, C. H., Boddey, L. H., Guimaraes, A. P., Ahiabor, B. D. (2017). Cowpea (*Vigna unguiculata*) crops in Africa can respond to inoculation with rhizobium. *Exp Agric* 53:578-587.
- Bonilla Cedrez, C., Chamberlin, J., Guo, Z., & Hijmans, R. J. (2020). Spatial variation in fertilizer prices in Sub-Saharan Africa. *PloS one*, 15(1), e0227764.
- Bot A. and Benites J. (2005). The importance of soil organic matter: *Key to drought-resistant soil and sustained food production*. Food and Agriculture Organization (FAO) of the United Nations, p.78.
- Boukar, O., Belko, N., Chamarthi, S., Togola, A., Batiemo, J., Owusu, E., et al. (2019). Cowpea (*Vigna unguiculata*): genetics, genomics, and breeding. *Plant Breed.* 138, 415–424. doi 10.1111/pbr.12589.
- Brady, N. C. (1990). *The Nature and Properties of Soils* (Tenth Edn.). Macmillan Publishing Company, New York. 315 pp.
- Bukovsky-Reyes, S., Isaac, M. E., and Blesh, J. (2019). Effects of intercropping and soil properties on root functional traits of cover crops. *Agric. Ecosyst. Environ.* 285:106614. doi: 10.1016/j.agee.2019.106614.
- Camara, O., & Heinemann, E. D. (2006). Overview of the fertilizer situation in Africa. *Background paper for the Africa fertilizer summit, Abuja*, 9, 13.
- Cardona-Ayala, C., Cardona-Villadiego, C., Peñate-Pacheco, C., Araméndiz-Tatis, H., and Espitia-Camacho, M. M. (2020). Growth, biomass distribution, gas exchange and chlorophyll fluorescence in cowpea (*Vigna unguiculata* (L.) Walp.) under drought conditions. *Aust. J. Crop. Sci.* 14, 371–381. doi: 10.21475/ajcs.20.14.02.p2557.

- Chan K.Y., Heenan D.P. and So H.B. (2003). Sequestration of carbon and changes in soil quality under conservation tillage on light-textured soils in Australia: A review. *Austr. J. Exp. Agric.*, 43 (4), 325-334. <https://doi.org/10.1071/EA02077>.
- Chenn, P. (1999). Micro-organisms in Agriculture. *Biological Sciences Review* 11: 2-4.
- Cooke, G.W. (1982). Fertilizing for maximum yield. Granada publishing limited.
- Crops Research Institute (1994) Maize and legume production guide. Ghana Grains Development Project, Crops Research Institute, Kumasi, Ghana. 45 pp.
- Dakora, F.D. and Keya, S.O. (1997). Contribution of legume nitrogen fixation to sustainable agriculture in Sub-Saharan Africa. *Soil Biology & Biochemistry* 29: 809-817.
- Ddamulira, G., Santos, C.A.F., Obuo, P., Alanyo, M. and Lwanga, C. K. (2015). Grain yield and protein content of Brazilian cowpea genotypes under diverse Ugandan environments. *American Journal of Plant Sciences* 6: 2074-2084. <http://dx.doi.org/10.4236/ajps.2015.613208>.
- De Bruijn, F. J., & Hungria, M. (2022). Biological nitrogen fixation. *Good Microbes in Medicine, Food Production, Biotechnology, Bioremediation, and Agriculture*, 466-475.
- Diouf, D. (2011). Recent advances in cowpea [*Vigna unguiculata* (L.) Walp.]“Omics” research for genetic improvement. *Afr. J. Biotechnol.* 10(15): 2803-2810.
- Ecocrop, (2009). Ecocrop database, FAO. <http://ecocrop.fao.org/ecocrop/srv/en/home>
- Ehlers, J.D., Hall, A.E. (1997). Cowpea (*Vigna unguiculata* L. Walp). *Field. Crop. Res.* 53, 187-204.

- Ennin, S.A. , and Dapaah, H.K. (2008). Legumes in sustainable maize and cassava cropping systems in Ghana. *Agricultural and food science Journal of Ghana*. Vol. 7. Crop Research Institute, Kumasi-Ghana. Pp. 520.
- Eyitayo, S., Oke, O., & Damilola, L. (2010). Growth and yield response of cowpea (*Vigna unguiculata* L . Walp) to soils from different fallow physiognomies in the rainforest zone of Nigeria. *ACTA BOT. CROAT*, 69(2), 291–297.
- Fang, J.G. et al. (2007), “Genetic diversity of cowpea [*Vigna unguiculata* (L.) Walp.] in four West African and USA breeding programs as determined by AFLP analysis”, *Genetic Resources and Crop Evolution*, Vol. 54, No. 6, pp. 1 197-1 209, <http://dx.doi.org/10.1007/s10722-006-9101-9>.
- FAO (2020). World Food and Agriculture - Statistical Yearbook 2020. Rome.
- FAO, (2005). Cowpea production database for Nigeria, 1990-2004. Food and Agricultural Organisation. <http://www.faostat.fao.org/>.
- FAO/UN. (1974). Fertilizer Legislation. Soils Bul. 20. Rome, Italy.
- Fatokun, C. (2002). Identify quantitative trait loci (QTL) for desirable traits in cowpea: mapping desirable traits in cowpea. IITA Project A: preserving enhancing germplasm agrobiodiversity.
- Fearon, J., Adraki, K. P., & Boateng, V. F. (2015). Fertilizer subsidy programme in Ghana: Evidence of performance after six years of implementation.
- Galloway, J.N., Townsend, A.R., Erisman, J.W., Bekunda, M., Cai, Z., Freney, J.R., Martinelli, L.A., Seitzinger, S.P., Sutton, M.A., (2008). Transformation of the nitrogen cycle: recent trends, questions, and potential solutions. *Science*. 320 (5878), 889- 892.
- Giller, K. E., (2000) *Nitrogen fixation in tropical cropping systems*. *Agric. Sci.* 2 (1): 1-8.

- Gondwe, T. M., Alamu, E. O., Mdziniso, P., and Maziya-Dixon, B. (2019). Cowpea (*Vigna unguiculata* (L.) Walp) for food security: an evaluation of end-user traits of improved varieties in Swaziland. *Sci. Rep.* 9:15991. doi: 10.1038/s41598-019-52360-w.
- Grindlay, D. J. C. (1997), Review towards an explanation of crop nitrogen demand based on the optimization of leaf nitrogen per unit leaf area. *J. Agri. Sci.*, 128: 377-396.
- Hall, A.E. (2011). “Breeding Cowpea for Future Climates” in *Crop Adaptation to Climate Change*, ed. Yadav, S.S., Redden, R.J., Hatfield, J.L., Lotze-Campen, H., Hall, A.E. (United States: Wiley-Blackwell), 340–355.
- Hasan, M. R., Akbar, M. A., Khandaker, Z. H., & Rahman, M. M. (2010). Effect of nitrogen fertilizer on yield contributing character, biomass yield and nutritive value of cowpea forage. *Bangladesh Journal of Animal Science*, 39(1-2), 83-88.
- Houndmills Basingstoke, London and Basingstoke. Pp. 283-284.
- Hue N. V. (1995). Sewage Sludge. In: J. E. Rechcigl (ed) *Soil amendment and environmental quality*. Lewis Publ., Boca Raton. FL. P. 193 – 239.
- Hutton Institute, (2010). *Biological Nitrogen Fixation by Legumes*. Available at: <http://www.livingfield.hutton.ac.uk/science/bnf>. [Accessed on 3-08-22].
- IITA (International Institute of Tropical Agriculture) (1993) *Annual Report of the IITA*. Ibadan, Nigeria. pp. 56-80.
- IITA (International Institute of Tropical Agriculture) (2003), *Crop and Farming Systems*. <http://www.iita.org/crop/cowpea.htm>. Accessed July. 2022.
- Irondi, E. A., Ogunsanmi, A. O., Ahmad, R. S., Ajani, E. O., Adegoke, B. M., and Boligon, A. A. (2019). Effect of roasting on phenolics composition,

- enzymes inhibitory and antioxidant properties of cowpea pulses. *J. Food Meas. Charact.* 13, 1489–1496. doi: 10.1007/s11694-019-00064-0.
- Jakobsen, I. (1985). The role of phosphorus in nitrogen fixation by young pea plants (*Pisum sativum*). *Plant physiology* 64: 190–196.
- Jayathilake, C., Visvanathan, R., Deen, A., Bangamuwage, R., Jayawardana, B. C., Nammi, S., et al. (2018). Cowpea: an overview on its nutritional facts and health benefits. *J. Sci. Food Agric.* 98, 4793–4806. doi: 10.1002/jsfa.9074.
- Jayne, T., Kolavalli, S., Debrah, K., Ariga, J., Brunache, P., Kabaghe, C., & Andam, K. (2015). *Towards a sustainable soil fertility strategy in Ghana* (No. 1879-2017-1467).
- Kamara, A. Y., Ewansiha, S. U., Ajeigbe, H. A., Okechukwu, R., Tefera, H., Boukar, O., et al. (2012). “Improvement in grain and fodder yield of cowpea (*Vigna unguiculata*) varieties in the Sudan savannas of Nigeria over the past four decades,” in *Innovative Research Along the Cowpea Value Chain*, eds O. Boukar, O. Coulibaly, C. A. Fatokun, K. Lopez, and M. Tamo [Ibadan: International Institute of Tropical Agriculture (IITA)], 179–188.
- Kannan, P. and A Saravanan, (2006). Crops growth benefits and soil quality impacts of using animal manure as fertilizer. *Trans. ASAE*, 5: 339-348.
- Kannan, P., A. Sarvanan, S. Krishnakumar and S.K. Natrajan, (2005). Biological properties of soil as influenced by different organic manure. *Res. J. Agric. Biol. Sci.*, 1: 181-183.

- Kaviraja, H. (2017). *Nutritional requirement of vegetable cowpea (Vigna unguiculata L.) in northern dryzone of Karnataka* (Doctoral dissertation, University of Horticultural Sciences (Bagalkot)).
- Kay, D. E. (1979) *Food legumes, crop and product digest*, No. 3. Natural Resources Institute, Chatham, UK. 214 pp.
- Kipot, E. (2008). *Experimental Agriculture. Cambridge University Press*. Vol. 44. Pp. 473.
- Kolavalli S. and Adam S. (2011). Manure Use in Northern Ghana: *Observations from a field trip*. <http://gssp.ifpri.info/files/2011/06/manure-use-in-northern-ghana3.docx>.
- Komolafe, M.F., Are, L.A., Adegbola, A.A. and Asheye, T.I. (1980). *Agricultural science for West African schools and colleges*. Oxford University Press, London. (2nd Edition). Pp. 52 – 57.
- Korem, A. (1982). Farming, Minimum Dependency on Imported Agric. Inputs: *Organic Fertilizers and Inorganic Fertilizers*. Agriculture bulletin 30. Pp. 26-29.
- Leonard, D. (1981). *Soils, Crops, and Fertilizer Use*. (3rd Edition). Peace Corps. Information Collection and Exchange.
- Lincoln, T. and Edvardo, Z. (2006) Assimilation of mineral nutrition. Inc. Pub., 705p.
- Lindemann, W.C. and Glover, C.R. (2003). Nitrogen fixation by legumes. College of Agriculture, Consumer and Environmental Sciences Guide A-129. Available at: <http://www.aces.nmsu.edu/pubs/a-/A129>. [Accessed on 24-11-13].
- London. Pp. 189.

- Maritus CHT, PLG, and Vlelc (2001). The management of organic matter in tropical soils: what are the priorities? *Nutrient cycling in Agroecosystems* 61: 1-16.
- Marschner, H. (1995). *Mineral nutrition of higher plants*. 2nd ed. Academic Press, San Diego, CA.
- Martin-Prevel, P. J. (1989). Physiological processes related to handling and storage quality of crops. In: *Proceedings of the 21st IPI Colloquium on Methods of K Research in Plants, Held at Louvain-la-Neuve, Belgium, 19 – 21 June 1989*. International Potash Institute, Bern, Switzerland. pp. 219 – 248.
- Martins LMV, Xavier GR, Rangel FW, Ribeiro JRA, Neves MCP, Morgado LB, Rumjanek NG.(2003). Contribution of biological nitrogen fixation to cowpea: a strategy for improving grain yield in the semi-arid region of Brazil. *Biol. Fertil. Soils*, 38(9), 333–339. DOI: <http://dx.doi.org/10.1007/s00374-003-0668-4>.
- Meteorological Service Department (2010). *Annual report*. Astanti-Mampong, Mampong Municipal of Ashanti Region.
- MOFA (Ministry of Food and Agriculture). (2005). *Annual report*. Sekyere West District, Mampong-Ashanti.
- Muranaka, S., Shono, M., Myoda, T., Takeuchi, J., Franco, J., Nakazawa, Y., et al. (2016). Genetic diversity of physical, nutritional, and functional properties of cowpea grain and relationships among the traits. *Plant Genet. Resour.* 14, 67–76. doi: 10.1017/S147926211500009X.

- Ng, N.Q. and Maréchal, R. (1985). Cowpea taxonomy, origin and germplasm. In: Singh, S.R. and Rachie, K.O. (Eds.). Cowpea Research, Production and Utilization., New York: John Wiley and Sons. 11–21.
- Nkaa, F.A., O.W. Nwokeocha and O. Ihuoma, (2014). Effect of phosphorus fertilizer on growth and yield of cowpea (*Vigna unguiculata*). IOSR J. Pharm. Biol. Sci., 9: 74-82.
- Ntare, B. R., Tarawali, S. A., & Tabo, R. (2016). Soil fertility management and cowpea production in the semiarid tropics. *Journal of Agriculture*, 2(2016), 301–318.
- Nwokwu, G.N. (2020). Effects of NPK (12:12:17) Fertilizer Rates on the Growth and Yield of Cowpea (*Vigna unguiculata*) Varieties. *Journal of Biology, Agriculture and Healthcare*, 3208(2020), 15-19.
- Obalum S.E., Chibuikwe G.U., Peth S. and Ouyang Y. (2017). Soil organic matter as sole indicator of soil degradation. *Environ. Monitoring Assessment*, 189 (4), Article 176. DOI: 10.1007/s10661-017-5881-y
- Obalum S.E., Okpara I.M., Obi M.E. and Wakatsuki T. (2011). Short-term effects of tillage-mulch practices under sorghum and soybean on organic carbon and eutrophic status of a degraded Ultisol in southeastern Nigeria. *Trop. Subtrop. Agroecosys.*, 14 (2), 393-403
- OECD (Organization for Economic Co-operation and Development). (2016). Safety assessment of transgenic organisms in the environment, Volume 6: OECD consensus documents, harmonization of regulatory oversight in biotechnology. OECD Publishing.
<https://doi.org/10.1787/9789264253421-en>.

- Ofosu-Budu K, Obeng-Ofori D, Afreh-Nuamah K, Annobill R (2008) Effect of phospho-compost on growth and yield of cowpea (*Vigna unguiculata*) Ghana J Agric Sci 40:169-176.
- Ojeniyi S. O. (2000). Effect of goat manure on soil nutrients and okra yield in a rain forest area of Nigeria. *Applied Tropical Agriculture*. Pp.5: 20 - 23.
- Olabanji, I., Ajayi, O., Oluyemi, E., Olawuni, I., Adeniji, A., Olasupo, O., et al. (2018). Nutraceuticals in different varieties of cowpeas. *Am. J. Food Sci. Tech.* 6, 68–75. doi: 10.12691/ajfst-6-2-2.
- Olajide, A. A., and Ilori, C. O. (2017). Genetic variability, performance and yield potentials of ten varieties of cowpea (*Vigna unguiculata* (L) Walp) under drought stress. *Legume Genomics Genet.* 8, 17–25. doi: 10.5376/lgg.2017.08.0003.
- Oliveira, A. P., Silva, J. A., Lopes, E. B., Silva, E. E., Araújo, L. E. A. and Ribeiro, V. V., (2009). Productive and economic yield of cowpea as affected by rates of potassium. *Agrotec Sci.*, 33: 629-634.
- Onwerenmadu, E. I., Opara, C. C., Duruigbo, C. I. and Ihejirika, C. O. (2003). Effect of different rates of dolomite limestone on the grain yield of white brown. *African Journal of Environmental Studies.* 4, (1)(2), pp. 123-125.
- Onwueme, I.C. and Sinha, T.D. (1991). *Field Crop Production in Tropical Africa, Principles and Practice*. Technical Center for Agricultural and Rural Co-operation. Pp. 13.
- Opoku Asiamah, Y. (1993). Horticulture for Senior Secondary Schools. Gangaram, H and Sons, Bombay 4000002, pp.33-36
- Ortiz, R.. (1998). Cowpea from Nigeria: A silent food revolution. *Outlook Agric.*, 27: 125-128.

- Ovalesha, M., Yadav, B., and Rai, P. K. (2017). Effects of polymer seed coating and seed treatment on plant growth, seed yield and quality of cowpea (*Vigna unguiculata*). *J. Pharmacogn. Phytochem. Res.* 6, 106–109.
- Owade, J. O., Abong, G., Okoth, M., and Mwangombe, A. W. (2020). A review of the contribution of cowpea leaves to food and nutrition security in East Africa. *Food Sci. Nutr.* 8, 36–47. doi: 10.1002/fsn3.1337.
- Padulosi, S. and N.J.A.i.c.r. Ng. (1997). Origin, taxonomy, and morphology of *Vigna unguiculata* (L.) Walp. In: Singh BB, Mohan Raj DR, Dashiell KE, Jackai LEN (eds) *Advances in Cowpea Research*. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). Sayce, Devon, UK, pp 1–12.
- Palaniappan, S. P. (1985) *Cropping systems in the tropics: Principles and management*. Wiley Eastern Ltd, New Delhi, India. 215 pp.
- Palm, C. A. (1995). Contribution of agroforestry trees to nutrient requirements of intercropped plants. In *Agroforestry: science, policy and practice: selected papers from the agroforestry sessions of the IUFRO 20th World Congress, Tampere, Finland, 6–12 August 1995* (pp. 105-124). Springer Netherlands.
- Pasquet, R.S. (1999). “Genetic relationships among subspecies of *Vigna unguiculata* (L.) Walp. based on allozyme variation”, *Theoretical and Applied Genetics* Vol. 98 No. 6, pp. 1104-1119.
- Perrenoud, S. (1993). *Fertilizing for high Yield Potato*. IPI Bulletin 8. 2nd Edition. International Potash Institute, Basel, Switzerland.

- Petersen S.O., Sommer S.G., Béline F., et al. (2007). Recycling of livestock manure in a whole-farm perspective. *Livestock Sci.*, 112 (3), 180-191. <https://doi.org/doi.org/10.1016/j.livsci.2007.09.001>.
- Pichot, J., Sedogo, P. M., Poulains, J. F. and Arrivets, J. (1981). “Evolution de la fertilité d’un sol ferrugineux tropical sous l’influence de fumures minérales et organiques”, *Agron. Trop.* 36:122-133.
- Quansah, G. W. (2010). *Effect of organic and inorganic fertilizers and their combinations on the growth and yield of maize in the semi-deciduous forest zone of Ghana* (Doctoral dissertation, KNUST).
- Ramesh P., Singh M. and Rao A.S. (2005). Organic farming: Its relevance to the Indian context. *Current Sci.*, 88 (4), 561-568. <https://doi.org/10.2307/24110255>.
- Ravelombola, W., Qin, J., Shi, A., Weng, Y., Bhattarai, G., Dong, L., et al. (2017). A SNP-based association analysis for plant growth habit in worldwide cowpea (*Vigna unguiculata* (L.) Walp) Germplasm. *Euphytica* 213:284. doi: 10.1007/s10681-017-2077-z.
- Rawal, K.M. (1975), “Natural hybridization among weedy and cultivated *Vigna unguiculata* (L.) Walp.”, *Euphytica*, Vol. 24, pp. 699-707.
- Reyhan, M.K. and F. Amiraslani. (2006). Studying the relationship between vegetation and physico- chemical properties of soil, case study: Tabas region, Iran. *Pak. J. Nutr.*, 5: 169-171.
- Riggs, P.J., Chelius, M.K., Iniguez, A.L., Kaeppler, S.M., Triplett, E.W. (2001). Enhanced maize productivity by inoculation with diazotrophic bacteria. *Funct. Plant. Biol.* 28 (9), 829-836.
- Sangakkara, U. R., Frehner, M. and Nosberger, J. (2001). Influence of soil moisture and fertilizer potassium on the vegetative growth of Mungbean (*Vigna radiata*

L.) and Cowpea (*Vigna unguiculata* L.). *J. Agronomy and Crop Sci.*, 186: 73–81.

- Sanginga N, Lyasse O, Singh BB. (2000). Phosphorus use efficiency and nitrogen balance of cowpea breeding lines in a low P soil of the derived savanna zone in West Africa. *Plant Soil*, 220: 119–128. DOI: <http://dx.doi.org/10.1023/a:1004785720047>.
- Savci S. (2012). An agricultural pollutant: chemical fertilizer. *Int. J. Environ. Sci. Dev.*, 3 (1), 77-80. <https://doi.org/10.7763/IJESD.2012.V3.191>.
- Seifritz W, (1982). Alternative and Renewable Sources of Energy in Optimizing Yields- The Role of Fertilizers. In: *Proceedings of 12th IPI Congress*. Pp 153-163.
- Shanti, K. V. P., Rao, M. R., Reddy, M. S. and Sarma, R. S. (1997). Response of maize (*Zea mays*) hybrid and composite to different levels of nitrogen. *Indian J. Agric. Sci.* 67: 424 - 425.
- Simion, T. (2018). Breeding cowpea *Vigna unguiculata* L. Walp for quality traits. *Annals of Reviews and Research*, 3(2), 555609.
- Singh B, Ajeigbe HA, Tarawali SA, Fernandez-Rivera S, Abubakar M. (2003). Improving the production and utilization of cowpea as food and fodder. *Field Crops Res.*, 84: 169–150. DOI:10.1016/S0378-4290(03)00148-5.
- Singh, B.B. & Tarawali, S.A. (1997). Cowpea and its improvement: key to sustainable mixed crop/livestock farming systems in West Africa. In: Renard, C. (Ed.). *Crop residues in sustainable mixed crop/livestock farming systems*. Wallingford, ICRISAT/ILRI and CABI, Wallingford, United Kingdom, pp. 79-100, www.ilri.org/InfoServ/Webpub/fulldocs/X5454E/x5454e09.htm.

- Singh, J. P. & Trehan, S. P. (1998). Balanced fertilization to increase the yield of potato. In: Proceedings of the IPI-PRII-PAU Workshop on: Balanced Fertilization in Punjab Agriculture, held at Punjab Agricultural University, Ludhiana, India, 15 – 16 December 1997. pp 129 – 139.
- Singh, S. R. & Lamba, P. S. (1971) Agronomic studies on cowpea FS-68: Effect of soil moisture regimes, seed rates and levels of phosphorus on growth and yield. *Haryana Agric. Univ. J. Res.* 1 (3), 1-7.
- Singh, S. R., & Rachie, K. O. (1985). *Cowpea research, production, and utilization*. Wiley.
- Sinnadurai, S. (1992). *Vegetable Cultivation*. Asempa Publishers, Accra. Pp. 104-108 and 152-154.
- Snapp, S. S., Cox, C. M., & Peter, B. G. (2019). Multipurpose legumes for smallholders in sub-Saharan Africa: Identification of promising ‘scale out’ options. *Global Food Security*, 23, 22-32.
- Sommer S.G., Christensen M.L., Schmidt T. & Jensen L.S. (2013). *Animal Manure Recycling: Treatment and Management*. John Wiley and Sons Ltd. <https://doi.org/10.1002/9781118676677>.
- Sultana, M.N. (2003). Effects of Rhizobium inoculum and nitrogen fertilizer on yield and nutrient quality of cowpea (*Vigna unguiculata*) forage at different stages of maturity. M. Sc. (A.H). Thesis, Dept. of Animal Nutrition, Bangladesh Agricultural University, Mymensingh.
- Sun, F., Pan, K., Olatunji, O. A., Li, Z., Chen, W., Zhang, A., et al. (2019). Specific legumes allay drought effects on soil microbial food web activities of the focal species in agroecosystem. *Plant Soil* 437, 455–471. doi: 10.1007/s11104-019-03990-6.

- Tajudeen, A., & Babajide, A. P. (2018). Varietal response of cowpea (*Vigna unguiculata* L. Walp) as affected by soil amendments and mycorrhiza. *The Nigerian Journal of Agriculture and Forestry {NJAF}*, 6(September 2020), 1
- Tan, H., M. Tie, Q. Luo, Y. Zhu, J. Lai & H. Li. (2012). A review of molecular markers applied in cowpea (*Vigna unguiculata* L. Walp.) breeding. *J. Life Sci.* 6(11): 1190.
- Tindall, H.D. (1992). *Vegetables in the Tropics*. The Macmillan Press Limited.
- Tisdale, S. L., Nelson, W. J. & Beaton, J. D. (1993). *Soil Fertility and Fertilizers*. Macmillan Publishing Company. 4th Edition. New York.
- Ulysses, S.J. (1982). *Fertilizer and Soil Fertility*. Practice Hall, India Private Ltd. pp. 305 – 306.
- USDA National Nutrient Database. (2021). Cowpeas, common (blackeyes, crowder, southern), mature seeds, raw. <https://fdc.nal.usda.gov/fdc-app.html#/food-details/169159/nutrients>
- Vanlauwe, B., Wendt, J., Giller, K. E., Corbeels, M., Gerard, B., & Nolte, C. (2014). A fourth principle is required to define conservation agriculture in sub-Saharan Africa: the appropriate use of fertilizer to enhance crop productivity. *Field Crops Research*, 155, 10-13.
- Warman P. (1981). The basics of green manuring. *MacDonald Journals*, 40, 3-6
- Watanabe, I. (2000). *Biological Nitrogen Fixation and its use in Agriculture*. Cantho University, Vietnam. Available at: <http://www.asahi-net.or.jp/wtnb/BNF.html>. [Accessed on 10-08-22].
- Weisany, W., Raei, Y. & Allahverdipoor, K.H. (2013). Role of some mineral nutrients in biological nitrogen fixation. *Bulletin of Environment, Pharmacology and*

life sciences 2 (4): 77-84. Available at:

<http://www.pebls.com/march2013/14 .pdf>. [Accessed on 05-08-22].

Wilson, P.N. and Webster, C.C. (1975). *Agriculture in the tropics*. The England Book Society, England. Pp. 15 – 16.

Wrigley, G. (1981) Legume intercropping. *In Tropical agriculture*, 4th edn. Longman, London. 496 pp.

Xu, P. et al. (2010), “Development and polymorphism of *Vigna unguiculata* ssp. unguiculata microsatellite markers used for phylogenetic analysis in asparagus bean (*Vigna unguiculata* ssp. sesquipedialis (L.) Verdc.)”, *Molecular Breeding*, Vol. 25, No. 4, April, pp. 675-684, <http://dx.doi.org/10.1007/s11032-009-9364-x>.

Yogodin B. A. (1984). *Manure in Agricultural Chemistry 2*. English Translation, Mir. Publ, Moscow.

APPENDICES

APPENDIX 1: ANALYSIS OF VARIANCE TABLE FOR PLANT HEIGHT

AT WEEK TWO

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	18.357	9.178	2.39	
Treatment	5	197.851	39.570	10.30	0.001
Residual	10	38.401	3.840		
Total	17	24.955			

Coefficient of variation: 6.6%

APPENDIX 2: ANALYSIS OF VARIANCE TABLE FOR PLANT HEIGHT

AT WEEK THREE

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	12.821	6.411	1.12	
Treatment	5	183.611	36.722	6.44	0.006
Residual	10	56.989	5.699		
Total	17	253.422			

Coefficient of variation: 6.4%

APPENDIX 3: ANALYSIS OF VARIANCE TABLE FOR PLANT HEIGHT

AT WEEK FOUR

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	209.90	104.95	3.78	
Treatment	5	447.44	89.49	3.22	0.054
Residual	10	277.84	27.78		
Total	17	935.18			

Coefficient of variation: 11%

APPENDIX 4: ANALYSIS OF VARIANCE TABLE FOR PLANT HEIGHT

AT WEEK FIVE

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	110.57	55.28	1.87	
Treatment	5	1687.32	337.46	11.43	<.001
Residual	10	295.27	29.53		
Total	17	2093.16			

Coefficient of variation: 8.1 %

APPENDIX 5: ANALYSIS OF VARIANCE TABLE FOR STEM DIAMETER

AT WEEK TWO

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	0.0010111	0.0005056	0.82	
Treatment	5	0.0199778	0.0039956	646	0.006
Residual	10	0.0061889	0.0006189		
Total	17	0.0271778			

Coefficient of variation: 5.7%

APPENDIX 6: ANALYSIS OF VARIANCE TABLE FOR STEM DIAMETER

AT WEEK THREE

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	0.002011	0.001006	0.63	
Treatment	5	0.050428	0.010086	6.33	0.007
Residual	10	0.015922	0.001592		
Total	17	0.068361			

Coefficient of variation: 6.3%

APPENDIX 7: ANALYSIS OF VARIANCE TABLE FOR STEM DIAMETER

AT WEEK FOUR

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	0.000633	0.000317	0.21	
Treatment	5	0.104317	0.020863	13.64	<.001
Residual	10	0.015300	0.001530		
Total	17	0.12250			

Coefficient of variation: 5.1%

APPENDIX 8: ANALYSIS OF VARIANCE TABLE FOR STEM DIAMETER

AT WEEK FIVE

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	0.001878	0.000939	0.69	
Treatment	5	0.113161	0.022632	16	<.001
Residual	10	0.013589	0.001359		
Total	17	0.128628			

Coefficient of variation: 4.2%

APPENDIX 9: ANALYSIS OF VARIANCE TABLE FOR THE NUMBER OF BRANCHES AT WEEK THREE

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	0.0486	0.0243	0.13	
Treatment	5	2.5590	0.5118	2.68	0.087
Residual	10	1.9097	0.1910		
Total	17	4.5174			

Coefficient of variation: 10.5%

APPENDIX 10: ANALYSIS OF VARIANCE TABLE FOR NUMBER OF BRANCHES AT WEEK FOUR

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	1.3878	0.6939	2.40	
Treatment	5	1.0840	0.2168	0.75	0.604
Residual	10	2.8889	0.2889		
Total	17	5.3607			

Coefficient of variation: 11.5%

APPENDIX 11: ANALYSIS OF VARIANCE TABLE FOR NUMBER OF BRANCHES AT WEEK FIVE

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	0.9653	0.4826	2.53	
Treatment	5	0.7778	0.1556	0.81	0.566
Residual	10	1.9097	0.1910		
Total	17	3.6527			

Coefficient of variation: 9.0%

APPENDIX 12: ANALYSIS OF VARIANCE TABLE FOR CANOPY WIDTH AT WEEK THREE

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	11.54	5.77	0.48	
Treatment	5	198.40	39.68	3.29	0.052
Residual	10	120.65	12.06		
Total	17	330.59			

Coefficient of variation: 7.7%

**APPENDIX 13: ANALYSIS OF VARIANCE TABLE FOR CANOPY WIDTH AT
WEEK FOUR**

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	37.00	18.50	0.27	
Treatment	5	152.18	30.40	0.45	0.807
Residual	10	681.26	68.13		
Total	17	870.44			

Coefficient of variation: 13.7%

**APPENDIX 14: ANALYSIS OF VARIANCE TABLE FOR CANOPY WIDTH AT
WEEK FIVE**

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	521.6	260.8	2.55	
Treatment	5	2774.2	554.8	5.42	0.011
Residual	10	1023.6	102.4		
Total	17	4319.5			

Coefficient of variation: 10.8%

APPENDIX 15: ANALYSIS OF VARIANCE TABLE FOR NUMBER OF LEAVES AT WEEK TWO

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	0.02569	0.1285	0.33	
Treatment	5	4.3924	0.8785	2.27	0.126
Residual	10	3.8681	0.38 68		
Total	17	8.5174			

Coefficient of variation: %

APPENDIX 16: ANALYSIS OF VARIANCE TABLE FOR NUMBER OF LEAVES AT WEEK THREE

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	22.799	11.399	3.65	
Treatment	5	27.944	5.589	1.79	0.203
Residual	10	31.243	3.124		
Total	17	81.986			

Coefficient of variation: 12.8%

APPENDIX 17: ANALYSIS OF VARIANCE TABLE FOR NUMBER OF LEAVES AT WEEK FOUR

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	257.02	128.51	4.36	
Treatment	5	250.08	50.02	1.70	0.223
Residual	10	295.02	29.50		
Total	17	802.13			

Coefficient of variation: 11.1%

APPENDIX 18: ANALYSIS OF VARIANCE TABLE FOR NUMBER OF LEAVES AT WEEK FIVE

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	115.965	57.983	9.41	
Treatment	5	148.101	29.620	4.81	0.017
Residual	10	61.618	6.162		
Total	17	325.684			

Coefficient of variation: 6.3%

APPENDIX 19: ANALYSIS OF VARIANCE TABLE FOR NUMBER OF DAYS TO 50% FLOWERING

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	2.7778	1.3889	4.31	
Treatment	5	27.1111	5.4222	16.83	<.001
Residual	10	3.2222	0.3222		
Total	17	33.1111			

Coefficient of variation: 12.8%

APPENDIX 20: ANALYSIS OF VARIANCE TABLE FOR THE NUMBER OF FILLED PODS PER PLOT

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	318.11	159.06	2.43	
Treatment	5	215.61	43.12	0.66	0.662
Residual	10	653.22	65.32		
Total	17	1186.94			

Coefficient of variation: 27.0%

APPENDIX 21: ANALYSIS OF VARIANCE TABLE FOR THE NUMBER OF UNFILLED PODS PER PLOT

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	192.44	96.22	1.40	
Treatment	5	1765.61	353.12	5.15	0.014
Residual	10	686.22	68.62		
Total	17	2644.28			

Coefficient of variation: 23.9%

APPENDIX 22: ANALYSIS OF VARIANCE TABLE FOR THE NUMBER OF PODS PER PLANT

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	159.812	79.906	15.67	
Treatment	5	232.365	46.473	9.12	0.002
Residual	10	50.979	5.098		
Total	17	443.156			

Coefficient of variation: 15.2%

APPENDIX 23: ANALYSIS OF VARIANCE TABLE FOR POD LENGTH

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	0.3897	0.1949	0.33	
Treatment	5	3.7514	0.7503	1.28	0.345
Residual	10	5.8641	0.5864		
Total	17	10.0052			

Coefficient of variation: 5.4%

APPENDIX 24: ANALYSIS OF VARIANCE TABLE FOR POD WEIGHT

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	2000505.	1000252.	8.95	
Treatment	5	3774791.	754958.	6.76	0.005
Residual	10	1117093.	111709.		
Total	17	6892389			

Coefficient of variation: 21.8%

APPENDIX 25: ANALYSIS OF VARIANCE TABLE FOR THE NUMBER OF SEEDS PER POD

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	0.537	0.268	0.22	
Treatment	5	14.265	2.853	2.29	0.124
Residual	10	12.450	1.245		
Total	17	27.251			

Coefficient of variation: 10.6%

APPENDIX 26: ANALYSIS OF VARIANCE TABLE FOR 100-SEED WEIGHT

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	65.85	32.93	2.94	
Treatment	5	56.23	11.25	1.00	0.464
Residual	10	112.10	11.21		
Total	17	234.18			

Coefficient of variation: 3.7%

APPENDIX 27: ANALYSIS OF VARIANCE TABLE FOR SEED WEIGHT PER PLOT (GRAMS)

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	656482.	328241.	6.83	
Treatment	5	1812731.	362546.	7.55	0.004
Residual	10	480440.	48044.		
Total	17	2949653.			

Coefficient of variation: 20.9%

APPENDIX 28: ANALYSIS OF VARIANCE TABLE FOR SEED WEIGHT IN TONS PER HECTARE

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	V Value	F Prob.
Replication	2	65.567	32.784	6.46	
Treatment	5	178.400	35.689	7.03	0.005
Residual	10	50.748	5.075		
Total	17	294.715			

Coefficient of variation: 21.5%