AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING
AND ENTREPRENEURIAL DEVELOPMENT

GROWTH AND YIELD PERFORMANCE OF CUCUMBER AS INFLUENCED BY FERTILIZER AMENDMENTS AND PLANT SPACING

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DECLARATION

Candidate's Declaration

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

Candidate Name: Anita Dwomoh

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

Supervisors' Declaration

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

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DEDICATION

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

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LIST OF ACRONYMS/ABBREVIATIONS

CM	Chicken Manure
NPK	Nitrogen Phosphorus Potassium
POME	Palm Oil Mill Effluent
RCBD	Randomized Complete Block Design
SSA	Sub-Saharan Africa
DAP	Days After Planting

ABSTRACT

The world uses cucumber as both a food and a medicine; however, its producers are faced with challenges. These challenges include farmers inability to afford or purchase inputs like fertilizer among others. The study was conducted to determine the effects of different rates of soil amendments and plant spacing on growth and yield of cucumber. The experiment was conducted at the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Mampong Campus, Multipurpose Crop Nursery in two cropping seasons (major and minor) from March to July 2023 and August to December 2023. The experimental design was a 6 × 2 factorial experiment arranged in a Randomized Complete Block Design (RCBD) with three (3) replications. The factors were (A) fertilizer amendment which included; (i) 30 t/ha chicken manure (CM), (ii) 15 t/ha chicken manure (CM), (iii) 100 kg/ha NPK, (iv) 50 kg/ha NPK, (v) 15 t/ha chicken manure (CM) + 50 kg/ha NPK and (vi) Control (No fertilizer) and (B) plant spacing which also included (i) 40 cm × 20 cm and (ii) 40 cm × 25 cm. The results showed that 30 t/ha of chicken manure caused an increase in the vegetative growth of cucumber (plant height, number of vines, stem girth and leaf area). Fruit diameter was significantly higher in 30 t/ha chicken manure. The 15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm produced significantly greater number of marketable fruits per plot (33 and 37), fruit weight per plant (4.5 kg and 5.4 kg) and fruit yield (62.5 t/ha and 75.4 t/ha) than the other amendments and the control in the minor and major seasons respectively. The combination of 50 kg/ha NPK and 40 cm × 25 cm yielded the maximum benefit to cost ratio in both cropping seasons. In addition, all treatments, except the control (no fertilizer) had significant benefit to cost ratio. For optimal marketable yields and heaviest fruit weight in both seasons, it is recommended to cucumber farmers to apply chicken manure at 15 t/ha + 50 kg/ha NPK and plant spacing of 40 cm × 20 cm.

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

Cucumber (*Cucumis sativus* L.) is one of the most widely cultivated cucurbitaceous vegetables (Mallick, 2022). Cucumbers may be grown year-round, making them an off-season crop for the market and providing farmers with lucrative income. Cucumber belongs to the same family as other types of squash, watermelon, and melon (*Cucumis melo* L.). After tomato and watermelon, cucumber and melon are the most widely farmed vegetable species in the world (Maynard, 2007; Rural & Maria, 2002; Bie *et al*., 2017). Originating in India, East Asia, and Nigeria in Africa, cucumber is believed to be one of the oldest vegetable crops produced by humans, with historical records reaching back to 5,000 years ago (Chomicki *et al*., 2020; Wehner & Guner, 2004).

Cucumbers are one of the most extensively grown and consumed crops in the United States. In 2019, the country produced 19,944,700 cwt on the supply side. On the consumer side, per capita consumption increased by 25 percent since 2000, reaching 8 lb in 2019. In the majority of African households, such as those in Nigeria, vegetables are taken as a source of minerals and vitamins, and in some instances, as a substitute for the more expensive animal protein. Despite these economic opportunities, majority of vegetable farming households are small-scale farmers (Joshi & Piya, 2021).

Cucumber has been listed as one of the exportable vegetables growing in Ghana (Norman, 2003). According to Arankumar *et al*. (2011), cucumber fruits can be eaten either raw or cooked. Cucumber is consumed raw as a relish or used in the production of stew, and it is occasionally combined with other vegetables. Cucumbers are regarded as a valuable source of nourishment in most East and Southeast Asian civilizations due to the crop's numerous benefits to humans and nearly all other living species (Kelly, 2005). In China, trepang, the processed body wall of sea cucumbers, is regarded a perfect tonic diet. An extract of boiling skin is also widely used as a tonic in Malaysia (Choo, 2008), and the fermented cucumber viscera, known as 'konowata' in Japan, is considered a delicacy (Kinch *et al*. 2008). Traditional medical uses of this plant include treating hypertension, asthma, rheumatism, wounds, burns, impotence, and constipation (Bordbar *et al*., 2011; Rahman, 2014). Cucumbers contain significant amounts of bioactive compounds, including triterpene glycosides (saponins), glycosaminoglycan, cerebrosides, sulfated polysaccharides, chondroitin sulfates, sterols (glycosides and sulfates), phenolics, peptides, lectins, glycoproteins, glycosphingolipids, and essential fatty acids (Bordbar *et al*., 2011; Mamelona *et al*., 2007; Rahman, 2014).

1.2 Problem Statement and Justification

The world uses cucumber as both a food and a medicine; however, its producers are faced with challenges such as agronomic and socio-economic factors (Sabo & Zira, 2009), which include farmers unable to afford to purchase necessary farm inputs such as fertilizer, pesticides and improved seeds; human activities, soil fertility constraints and soil borne diseases (Ogbodo, 2012; Yeboah *et al*., 2014). These challenges may result in decreased Smallholder agriculture outputs which is the most prevalent kind of agricultural production in sub-Saharan Africa (SSA) and a crucial instrument for eradicating poverty in the region. Self-sufficiency in food production has been a key concern in Ghana, one of the SSA nations (Khan & Ali, 2013). Concerns have been raised about the viability of vegetable production in Ghana and other sub-Saharan nations in order to meet the needs of a growing population (Khan & Ali, 2013; Arsanti *et al*., 2007).

The vast majority of the vegetables available in Ghana are grown directly or indirectly in open-field soil. However, only some of the soil's components are required for plant growth and development. The primary functions of field soil are to act as a reservoir for nutrients and water and to provide physical support to the plant through its roots. As a result of farming over time, the majority of soils have experienced nutrient depletion to the point where high yields can only be achieved with the careful use of inorganic fertilizers. Numerous crop-specific studies (Mamia *et al.*, 2018; Haile & Ayalew, 2018; Kiran *et al.*, 2016; Manea & Abbas, 2018; Sachan & Krishna, 2021) have demonstrated the enormous benefits of utilizing inorganic fertilizers. Inappropriate plant spacing can results in overcrowding and can lead to competition for resources such as sunshine, water, and nutrients (Padhiyar *et al*., 2023). Spacing plants allows their roots to spread and have access to essential soil nutrients.

Excessive use of chemical fertilizers and pesticides leads to significant environmental issues, including degradation, soil erosion, a disrupted food chain, and increased insect resistance. The global challenges posed by the misuse of these substances are critical, necessitating a shift towards organic fertilizers and biological pest control. Small-scale farmers cultivating Cucumis sativus often cannot meet nutrient requirements, resulting in negative nutrient balances that threaten food security. Utilizing various organic substrates can improve nutrient absorption, growth, and development of plants, often yielding comparable or superior results to conventional soil, albeit at a higher cost. The addition of organic waste such as manure and compost enhances soil organic matter and quality, providing essential nutrients to plants. While inorganic fertilizers are expensive and can lead to water contamination through leaching, they offer rapid nutrient release which can benefit crop demand in the short term. Nonetheless, sustainable practices mandate careful nutrient application to improve long-term productivity, as studies indicate that inorganic fertilizers alone cannot maintain soil productivity in intensive cropping scenarios (Tahir et al., 2019; Zulfiqar et al., 2019; Timsina, 2018).

1.3 Objectives of the Study

1.3.1 Main Objective

The main objective of the study was to improved cucumber production using soil amendments and plant spacing.

1.3.2 Specific Objectives of the Study

The specific objectives of the study were to;

1. Assess the effect of fertilizer amendment and plant spacing on the growth of cucumber.
2. Evaluate the effect of fertilizer amendment and plant spacing on the yield and yield components.
3. Determine the profitability or economic benefits of cucumber production as affected by fertilizer amendment and plant spacing.

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin and Distribution

The cucumber (*Cucumis sativus* L.) is believed to have originated in India or Burma, where it has been cultivated for over three thousand years, and was possibly introduced to other regions of the world. The crop is a monoecious edible plant grown for its fruits, and it is one of the most well-known Cucurbitaceae family members (Adedayo *et al*., 2023; Chomicki *et al*., 2020).

2.2 Varieties

Originating in India, where numerous cultivars have been identified, is the cucumber plant (Ranjan *et al*., 2019). There are two essential cucumber types: those consumed fresh after peeling and slicing, also known as slicing market types (Hongu *et al*., 2017; Du *et al*., 2022), and those consumed processed, also known as pickling types. The most acceptable and popular form of cucumber is the dark-green, smooth-skinned, long variety typically used for salad preparation (Suma *et al*., 2021).

Regarding the sexual characteristics of cucumbers, there are monoecious cultivars that produce both male and female flowers on the same plant, gynoecious cultivars that produce only female flowers, and parthenocarpic cultivars whose female flowers do not require pollination or fertilization for fruit production. Generally, the most prolific cucumber kinds are gynoecious, generating only female flowers, and their fruits have smoother skins than monoecious varieties, which produce both male and female flowers. The majority of greenhouse-grown cucumbers are parthenocarpic, or seedless, because the fruits are developed without pollination (Sharma *et al.*, 2020; Grumet 2022).

2.3 Benefits of cucumber

2.3.1 Economic Benefits

Sharma *et al*. (2020) stated that cucumber is one of the crops grown for sale in the tropical region. Cucumbers are an essential vegetable in the culinary and pharmaceutical industries. Almost all edible components of the majority of cucurbitaceae vegetables are employed (Rolnik & Olas, 2020). Cucumbers can be eaten raw as a relish or used to make vegetable salad, stew, or sandwiches in Ghana. Due to their distinct texture and flavor, cucumbers are also eaten as an appetizer or combined with other vegetables (Harmayani *et al*., 2019; Montet *et al*., 2014). In terms of their economic significance in Asia, cucumbers rank after tomatoes, cabbage, and onions, whereas in Western Europe they are second behind tomatoes. The crop is one of the foreign vegetables cultivated in Ghana and has export potential (Osei *et al*., 2025). 100 grams of edible fruit contains 96 percent water, 0.5 grams of protein, 2.9 grams of carbohydrates, 0.1 grams of lipids, and 0.6 grams of fiber. This 100g also contains 13 kcal of calories, 14 mg of calcium, 17 mg and 2 mg of potassium and sodium, as well as 0.03 mg of thiamine, 0.02 mg of riboflavin, 0.30 mg of niacin, and 4.7 mg of ascorbic acid.

Cucumbers are an exceptional source of vitamins A, C, K, and B6 (Adewumi, 2021). Cucumber fruit is an excellent source of minerals, and it also contains phytonutrients like xanthein-B, lutein, and carotene-B. Cucumber juice is beneficial for healthy skin and complexion development and has anti-inflammatory effects (Sharma *et al*., 2020). The fruit is ingested in its fresh state and contains pantothenic acid and fewer calories. Phytochemical research has proven that cucurbits possess numerous therapeutic qualities. Several substances having therapeutic qualities, including momorcharins, momordenol, charantine, cucurbitins, cucurbitacins, cucurbitanes, urease, and polypeptide-P insulinin, are isolated from cucurbits and utilized for rats and people (Chakraborty & Rayalu, 2021). Cucumber extracts, such as cucurbitacin, inhibit the activity of cyclooxygenase enzymes, which would otherwise produce inflammation (Ninkuu *et al.*, 2021).

2.3.2 Medicinal Benefits

Since ancient times, the therapeutic benefits of cucumber have been documented. Different plant parts, including leaf, fruit, and seed, have been investigated for their medicinal properties. *C. sativus* fruits and seeds have significant therapeutic significance in Indian systems of medicine (Mukherjee *et al*., 2013), particularly in Ayurveda, where over 200 herbs, minerals, and numerous formulations are offered for the control of aging (Mukherjee *et al*., 2011). They are commonly used for a variety of skin conditions, including under-eye puffiness and sunburn. It is claimed that they provide inflamed skin with a refreshing, cooling, healing, relaxing, emollient, and anti-itching impact (Uthpala *et al*., 2020; Ergun & Susluoglu, 2019). In traditional Chinese medicine, the leaves, stems, and roots are typically employed as antidiarrheal, detoxicant, and antigonorrheal medicines. Several pharmacological properties, including as antioxidant, antiwrinkle, antibacterial, anti-diabetic, and hypolipidemic, have been attributed to this plant. Antihyaluronidase and anti-elastase properties have been demonstrated for cosmetic applications, including facial masks, body creams, lotions, and shampoo. Few bioactive substances belonging to diverse chemical classes have been isolated from this plant (Mukherjee *et al*., 2013).

The nutritional composition of cucumber per 100 g edible portion (ends trimmed, not peeled, 97 percent edible portion) is as follows: water 96.4 g, energy 42 kJ (10 kcal), protein 0.7 g, fat 0.1 g, carbohydrates 1.5 g, dietary fibre 0.6 g, calcium 18 mg, magnesium 8 mg, phosphorus 49 mg, iron 0.3 mg, zinc 0.1 mg, beta-carotene 60 g, thiamin 0. Crepsin, proteolytic enzyme, ascorbic acid, oxidase, succinic and malic dehydrogenase have likewise been identified in fruits. Likewise, Mozafari *et al*. (2025) reported Lycopene, which is present in cucumbers, is a potent antioxidant believed to prevent sickness, aid in the fight against some types of cancer, such as cervical and prostate malignancies, and combat cardiovascular disease by preventing the hardening of the arteries. One cup of cucumber has 9.09 mg of lycopene, while one cup of fresh tomatoes contains only 4 mg (NWPB, 2003). According to reports, cucumber fruits contain a significant concentration of ascorbic acid, while pulp and peel extracts include lactic acid (7-8% w/w), which shown antioxidant action. Fermented cucumber that was treated with common salt (2% NaCl) was found to have volatile chemicals (Zhang *et al*., 2022). As a fruit and vegetable, cucumber is a crucial crop for the culinary, medicinal, and cosmetic industries.

2.4 Production Estimate

In spite of the importance of the cucumber crop in Asia and Western Europe, it has not been graded in Africa due to insufficient demand. China is the world's leading cucumber producer. Egypt produced the most cucumbers in Africa and ranked ninth in the world among cucumber-producing nations. Cote d'Ivoire produced the most cucumbers in West Africa with 23,000 tons and ranked 67th in the globe, while Ghana produced the least with 132 tons and ranked 125th in the world (Zhao *et al*., 2019; Xu & Zhao, 2015).

From 2012 to 2022, the total output value in Africa increased by an average of 1.4% per year; the trend pattern demonstrated that there were notable changes throughout the examined period. The growth rate appeared to be the fastest in 2020, with a 35 percent increase. From 2014 to 2022, however, the level of output failed to regain momentum. In 2022, Egypt, Sudan, and Cameroon had the largest production volumes in Africa, accounting for 67 percent of the continent's entire output. From 2012 to 2022, Sudan's production increased the most, while the other leaders' production increased at more modest rates. In 2022, the average output of cucumbers and gherkins in Africa decreased slightly and leveled off at 2021 levels. In general, the trend pattern of yield was quite flat. In 2019, when the yield climbed by 12 percent, the most notable rate of expansion was observed. In 2014, the yield reached its highest point; however, from 2015 to 2022, the yield was significantly lower. Future yield numbers may still be affected by severe weather conditions despite the greater usage of contemporary agriculture techniques and practices. Comparing 2022 to 2021, the average amount of cucumbers and gherkins produced in Africa stayed pretty steady. From 2012 to 2022, the harvested area rose at an average yearly rate of +2.4%; the trend pattern was reasonably consistent with only small changes during the examined period. In 2014, an increase of 13 percent was the most notable growth rate reported. The level of harvested area reached its pinnacle in 2016, but from 2017 to 2022, it failed to regain speed. The production rate, production per person, production size and yield of the first 10 ranked producer of cucumber worldwide is shown in Table 2.1.

In terms of yield per hectare, cucumber production in Ghana was 12 tons, compared to 37.4 tons in Morocco and 666.7 tons on average in the Netherlands (FAOstat, 2013). Increasing human populations compete for arable lands for human activities such as the formation of human settlements, recreational centers, and the disposal of organic wastes, resulting in land scarcity and constraints that reduce the area for agricultural production and the yield (Mwaguni *et al*., 2016). The majority of Ghana's soils are deficient in organic matter, resulting in low crop yields. The irregular nature of rainfall in Ghana causes water stress, which in turn impacts hydration, biochemical and metabolic processes, nutrient absorption and translocation, photosynthesis, respiration, and yield and quality (Asabere *et al*., 2018; Bationo *et al*., 2018). Currently, the majority of cucumbers are grown in open fields that are exposed to abiotic elements such as high temperature, low temperature, and unpredictability of the weather. Biotic conditions, such as fruit fly and the occurrence of downy/powdery mildew, are also detrimental to cucumber growth in open fields. Therefore, it is not possible to produce cucumbers of the same size, shape, and color as those grown in a protected environment that are also free of illnesses and pests.

Table 2.1: Top 10 Worldwide Leading Producers of Cucumber

S/N	Country	Production (Tons)	Production Per Person (kg)	Acreage (Hectare)	Yield (kg/Hectare)
	China	56,293,530	40.387	1,046,237	53,805.7
	Iran	2,283,750	27.933	79,649	28,672.8
	Turkey	1,848,273	22.872	37,605	49,149.8
	Russian Federation	1,604,346	10.923	42,830	37,458.5
	Mexico	1,072,048	8.594	19,597	54,704.8
	Ukraine	985,120	23.309	49,500	19,901.4
	Uzbekistan	857,076	26.247	23,077	37,139.8
	United States of America	700,819	2.138	44,880	15,615.4
	Spain	643,661	13.795	7,507	85,741.4

Gelaye (2023)

2.5 Constraints of cucumber production in Ghana

2.5.1 Environmental Factors that Affect Cucumber Production

Cucumber crop thrives well in conditions or environments with the following characteristics: high temperature, low humidity, moderate light intensity, good textured and structured soils with a consistent supply of water and nutrients. However, cucumber producers in Ghana are experiencing low yields (Mariani, & Ferrante, 2017; Abdul-Rahman *et al*., 2021; Sayvas *et al.*, 2017).

The optimal temperature range for cucumber growth is between 20 ^{0}C and 25 ^{0}C, with growth slowing between 26 ^{0}C and 30 ^{0}C. (Mahssin *et al*., 2021). According to Chen *et al*. (2013), growth and development of cucumbers were adversely affected at temperatures below 40°C, but rose with increasing temperatures up to 50°C, and reduced drastically over 50°C.

Since humidity is reliant on precipitation, it is greater during the rainy season than during the dry season (Zemp *et al*., 2014). The increased danger of water condensing on plants and the development of major diseases such as Downy and Powdery mildew are disadvantages of cultivating in conditions of high relative humidity. Low transpiration rates are responsible for insufficient absorption and transfer of some nutrients, particularly calcium, to the leaf margins and fruits. At low relative humidity, irrigation becomes crucial because significant amounts of water must be given to the growth medium without constantly flooding the roots and depriving them of oxygen (Ferrante & Mariani, 2018). Powdery mildew and spider mites thrive in environments with low relative humidity. According to Launay *et al*. (2014) and Shamshiri *et al*. (2018), fungal disease incidence is directly proportional to atmospheric humidity.

Cucumber is described as a day-neutral crop; yet, research indicates that high light intensity tends to enhance the number of staminate (male) flowers, while low light levels tend to boost the development of pistillate (female) flowers (Pineda *et al*., 2020). Fruit production is boosted by short day lengths and short-day lengths in conjunction with relatively high night temperatures. High light intensity, such as a 100-watt light bulb, combined with high temperature, such as 400 degrees Celsius, is detrimental to fruit-set because it influences the internal temperature of the cucumber's reproductive organ (Cocetta *et al*., 2017; Heuvelink & Okello, 2018). The soil offers a medium in which air, water, and nutrients are in equilibrium. If this equilibrium is maintained, plant roots may quickly absorb water and nutrients, leading to rapid development. Although cucumbers can be produced on a wide range of soil types, those with the highest organic-matter concentration include loams, sandy loams, and some silty-loams (Zhou *et al*., 2017).

Water, a vital plant component for hydration, a medium for biochemical and metabolic activities, as well as nutrient absorption and translocation, is constantly in flux. Thus, water stress impacts photosynthesis, respiration, and all the aforementioned processes (Yadav *et al*., 2020; Chen *et al*., 2019). Continued water deprivation causes irreversible modifications in the plant that ultimately result in its demise. He added that under hot, dry conditions, plants that are not architecturally built to avoid water loss may experience rapid water loss (McDowell *et al*., 2022). In spite of the cucumber plant's large and somewhat deep root system, which enables it to acquire bigger quantities of water from the soil, its broad leaves tend to lose water rapidly under intense sunlight (Xu *et al*., 2017; Vitti *et al*., 2013). For optimal fruit growth, tomatoes, cucumbers, and peppers should be adequately hydrated between the flowering and fruiting periods, according to research and recommendation (Abdelkhalik *et al*., 2020). Water stress may induce a 50 percent decrease in the weight of cucumber fruit. Cucumber fruit is around 95 percent water, and water stress may cause a 50 percent decrease in cucumber fruit weight (Ashad, 2017).

2.5.2 Influence of Soil pH on Vegetable Crops

A soil's pH indicates its acidity or alkalinity. It influences the availability of soil nutrients to agricultural plants. It has been observed that a pH range of 6.0 to 6.5 is optimal for cucumber production (Msimbira & Smith, 2020). According to Wang *et al*. (2023), excessive salt caused cucumber roots to burn at pH levels greater than 7.2. Soils with a pH below 5.5 are regarded low (quite acidic) and may not have readily available calcium, molybdenum, magnesium, or phosphorus, whereas soils with a pH of 7.8 or above are considered high and may have low availability of phosphorus, iron, manganese, and zinc.

Magnesic lime fertilizer helped fix a soil low in calcium and magnesium for tomato growing, whereas liming some extremely acidic soils to a pH of 5.5 boosted phosphate availability (Holland *et al.*, 2018). In addition, 20-30% of the total phosphorus in the top 15 cm of most Ghanaian soils was organic phosphorus (Yeboah *et al.*, 2022; Emmanuel *et al.*, 2020). Again, rising precipitation may cause organic phosphates to travel down the profile and out of reach of plant roots, but this is unlikely to occur with inorganic phosphates, which are held in place by iron and aluminum. According to Rhodes (2013), sulphur and aluminum compounds are commonly applied to soil to lower its pH.

2.5.3 Effect of Heavy Use of Inorganic Fertilizer on Curcubits

Cucurbits are members of the Cucurbitaceae family and are home to some of the most popular garden crops in the world. The Cucurbitaceae is a family of frost-sensitive and predominantly tendril- bearing vining plants that are found in subtropical and tropical regions around which includes cucumber.

Inorganic fertilizers, often known as commercial or chemical fertilizers, have a far higher nutrient content than organic manures but lack their soil-improving qualities (Liu *et al.*, 2021). It has been shown that extensive use of inorganic fertilizer had a depressing effect on the yield of water melon, resulting in a reduction in the number of fruits, delayed and reduced fruit setting, and delayed ripening (Kacha *et al.*, 2017). Furthermore, it has been confirmed that inorganic fertilizer is a significant source of nitrogen, thereby causing heavy vegetative growth. However, the authors advised for an integrated use of organic manure and inorganic fertilizers for the provision of necessary quantities of plant nutrients required to maintain optimal crop productivity and profitability while reducing environmental effect from nutrient use. Cucumbers require magnesium to achieve a dark green fruit color (Maurya, 2020). Heavy doses of nitrogen fertilizers such as ammonium sulphate (20.5%

nitrogen, 23.4% sulphur) or ammonium nitrate (32.5% N) can cause toxicity in water melon (*Citrulus vulgaris*) and muskmelon (*Cucumis melo* var reticulatus), hence retarding plant growth. Kumar & Prasad (2020) highlighted that chemical fertilizers impair plant resilience to assault by pests and diseases, as well as taste quality and shelf-life of cucumbers.

2.6 Organic and Inorganic Manures as Nutrient Sources for Vegetable Production

The organic vegetable grower relies only on unfortified organic nutrient sources. Some of these organic sources consistently have fewer nutrients than inorganic fertilizers. Inevitably, significant amounts are required to provide all the macro- and micronutrients necessary for optimal crop development and output (Mensah, 2015; Adamu, 2016). Studies on the yield response of cabbage to Palm Oil Mill Effluent (POME) revealed that 60 t/ha of POME yielded 21t/ha-1, while 1.5 t/ha of inorganic fertilizer raised yield to 34 t/ha (Frimpong, 2011). The organic and inorganic fertilizers utilized in the study, together with their yields, were as follows: Control - 9.3 t/ha. Chicken manure - 22.90 t/ha. Kusocom - 21.20 t/ha. Worm-compost - 20.10 t/ha. NPK 15- 15-15 (600 kg/ha) - 15.7 t/ha. Paudel *et al*. (2004) studied the influence of three types of organic manures (cow dung, chicken manure, and duck manure) and inorganic manures on lettuce (NPK15-15-15 and Ammonium sulphate). The application rates for organic manures were 4.5, 4.7, and 5.8 t/ha, whereas the rates for NPK15-15-15 and ammonium sulphate were 156 kg/ha and 82 kg/ha, respectively.

The crop planted with 4.7 t/ha of chicken manure alone and its combination with inorganic manures (2.35 t/ha of chicken manure + 156 kg NPK15-15-15 and 82 kg/ha of ammonium sulphate) produced a significantly better yield over the course of the growing season. These results demonstrate that the availability of nutrients in various organic fertilizers varies and may not always be sufficient for good yields. Green manure alone, applied at 29-37 t/ha, resulted in low yields (13.53 t/ha) compared to green manure + inorganic fertilizer (52.24 t/ha) in a trial on the effect of green manure on cucumber output. Thus, green manure cannot be the only source of organic nutrients.

2.7 Poultry Manure as an Alternative Organic Fertilizer

Population growth necessitates a boost in food production (Crist *et al.*, 2017; Mancosu *et al.*, 2015). Restricting access to land for agricultural purposes in West Africa undermines traditional ways of preserving soil fertility, such as long fallow seasons and the clearing of new areas. As a result, the soil nutrient capital that historically supported such settlements is being steadily depleted by harvesting and leaching. The authors went on to note that the situation is exacerbated by the failure of most farmers to adequately compensate for these losses by returning nutrients to the soil through crop leftovers, animal and poultry manures, and chemical fertilizers (Assefa & Hans-Rudolf, 2015; Richards, 2023). As an alternative fertilizer, poultry manure could be utilized to boost vegetable yield. The application of poultry manure to provide nutrients for crops also aims to satisfy the five pillars of the International Framework for Evaluating Sustainable Land Management, as outlined in the 1998 paper by Dreschsel and Quansah (Ravindran *et al.*, 2017; Yang *et al.*, 2016; Sallam *et al.*, 2021), these are;

1. Maintaining or enhancing productivity
2. Reducing levels of production risks.
3. Protecting the environment.
4. Economically viable.
5. Socially acceptable.

Poultry manure is rich in nitrogen and aids in the preservation of soil moisture, enhances soil structure, gives quality and greater yields, is inexpensive, has a prolonged field action, and inhibits nematodes (Singh *et al.*, 2020; Das & Ghosh, 2022). Chemical fertilizer cannot provide the soil with the essential organic matter to rebuild its ever-decreasing humus content as does poultry manure (Rahman *et al.*, 2021). It has been reported that broiler dung contains around 4.4% total nitrogen, 2.1% total phosphorus, 2.6% total potassium, 2.3%

total calcium, 1.0% total magnesium, and 0.6% total sulphur (Ngosong *et al*., 2020). Iqbal *et al*. (2019) also reported that poultry manure is inexpensive and effective as a good supply of nitrogen for sustainable crop production, which is related with strong photosynthetic activity, vigorous vegetative development, and dark green leaf color.

2.8 Disease Control Ability of Poultry Manure

Amulu & Adekunle (2015) investigated the influence of chicken manure application on the severity of *Meloidogyne incognita* race 1 attack on tomato in the greenhouse, the field, and in-vitro in Nigeria using four levels of poultry manure at 0, 2, 4, and 8 t/ha. The results of the three trials demonstrated that poultry manure has significant potential for preventing root knot nematodes. The growth and output of tomato fruits rose dramatically when poultry manure was applied at rates of 4 t/ha or higher. The predatory fungus that destroys nematodes, according to Wairimu *et al*. (2022), thrives in soils rich in organic matter. Increased rates of poultry manure application led to a decrease in soil nematodes as well as an increase in crop output, as one of the various benefits organic soil amendments provide for crop development. Adding organic matter to the soil helps reduce crop damage from nematodes (Jaffuel *et al*., 2017). Organic amendments are more effective at increasing the water-holding capacity of sandy soils, where root knot nematodes tend to be more prevalent, than inorganic amendments (Ravindra *et al*., 2017).

2.9 Effect of Poultry manure on Growth and Yield of Cucurbits

Under typical conditions, 8 tons per hectare of poultry manure might be applied to cucumbers and watermelons (Dalorima *et al*., 2018). Due to nutrient losses and limited release, each ton of broiler dung must contain at least 9 kilogram of nitrogen, 4.5 kg of phosphorus, and 2.3 kg of potassium. Cucumber reacts well to soils with a relatively high organic matter level; nevertheless, for strong yields in the tropics, the crop requires a deep soil with a higher organic matter concentration (Kaiwen *et al.*, 20p15). Consequently, if possible, the soil should be amended with up to 8 t/ha of well-composted poultry manure during the initial stages of soil preparation. Zhen *et al.* (2020) advised an application rate of 2.5-4.5 t/ha of chicken manure for cucumber production. Mahmoud and Taha (2018) utilized poultry manure in addition to NPK fertilizer and microelements including zinc and manganese. The mixture including 88 percent poultry manure powder, 4 percent Urea, 40 percent potassium chloride, and 4 percent boric sulphate proved optimal for cucumber development.

2.10 Effect of Plant Spacing on Vegetables

Vegetable production is influenced by the plant population or plant density. Appropriate plant spacing can contribute to optimum seed yield, whereas excessive or insufficient plant spacing may result in relatively low yield and quality (Mao *et al.*, 2014; Testa *et al.*, 2016). The observed increase in plant height as population density increased may be the result of strong competition among plants for light (Kayani *et al.*, 2017). Kyeraa (2003), who studied the influence of spacing and weeding frequency on the growth and yield of ravaya, found that although spacing had no effect on plant height, closer spacing generated higher plants, a larger canopy, and the greatest quantity of fruits per plant and per hectare. Yield is significantly influenced by plant density. Up until a certain point, yield per unit area tends to increase as plant density rises, and thereafter it drops (Akintoye *et al.*, 2009). Wider spacing, on the other hand, led to an increase in tomato fruit yield per plant, as well as an increase in the proportion of cracked fruits (Law-Ogbomo & Egharevba, 2009). Significant impact was exerted by plant density on groundnut growth metrics (Tana & Urage, 2017).

Comparing 45 cm × 15 cm spacing to 30 cm × 10 cm spacing, the plant height and number of branches per plant increased under 45 cm × 15 cm spacing. It was explained that since the feeding zone per plant under wider spacing was greater compared to closer spacing, the plants developed laterally and produced a greater number of branches per plant. Morwal & Patel (2017) investigated the impact of sowing date and plant spacing on the development and yield of okra (*Abelmoschus esculentus*) and found that closer plant spacing led to taller okra plants. According to Jamuna and Gopalakrishnan's (2004) research on the influence of spacing on melon yields, the maximum yields were achieved with the closest spacing. The main vine length, diameter, number of leaves, and number of lateral branches were greatest at 1.5 m in-row spacing, according to an evaluation of the effect of cultivars and in-row spacing on melons' vegetative growth and yield components. With increased plant spacing, yield was drastically diminished. In general, yield was reduced by 25% when inter-row spacing was 1.5 m. As plant spacing increased, the yield per hectare decreased linearly, whereas yield per plant increased linearly (Elsevier, 2006). The inter-row spacing of 30 centimeters produced the highest yield (Tegen & Jembere, 2021).

Paththinige *et al*. (2008) conducted a field experiment to determine the influence of plant spacing on okra yield and fruit attributes. The four plant intervals (90 cm × 60 cm, 60 cm × 45 cm, 45 cm × 45 cm and 45 cm × 30 cm) were used. Weight of fruits and number of fruits per plant increased at widest spacing (90 cm × 60 cm). In comparison to wider spacing and fewer plants per hectare, the total quantity of fruits and fruit weight per hectare increased as plant population grew. Wang *et al*. (2015) investigated the influence of spacing on the growth and yield of egg plant. They found that the number of fruits per plant and fruit weight rose with wider spacing, however, the number of fruits per hectare and fruit weight per hectare increased with closer spacing. Working on tomato spacing, Roy *et al*. (2012) rerported increased yields with a higher plant population. They also observed that a reduction in spacing led to a fall in fruit weight and fruit yield per plant. The effect of spacing (40 cm × 45 cm and 50 cm × 60 cm) and stem pruning (one stem, two stems, three stems and no pruning) on the yield was evaluated on tomato (Thakur *et al*., 2018), wider spacing (50 cm × 60 cm) gave the greatest number and weight of marketable fruits/plant than closer spacing but in terms of per hectare, tighter spacing produced the greatest yield and weight of marketable (Amarre & Gebremedhin, 2020).

Additionally, it has been stated that the tallest okra plants were obtained with a distance of 30 cm × 30 cm but number of branches was highest at 45 cm × 45 cm. Spacing had no effect on the days to 50% flowering. The number of fruits/plants, fruit weight and yield/ha were highest at 45 cm×45 cm and 60 cm×30 cm compared to control (30 cm × 30 cm). The spacing of 60 cm × 20 cm and 45 cm × 30 cm gave similar yields. A field experiment on okra comprising four spacings (60 cm × 30 cm, 60 cm × 40 cm, 60 cm × 50 cm, and 60 cm × 60 cm) was conducted by Moniruzzaman *et al*. (2007) to find out the optimum plant spacing. Plant spacing of 60 cm × 30 cm produced the highest yield of okra (2.86 t/ha).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Description of Experimental Site

Two (2) field experiments were conducted at the Multipurpose Crop Nursery of the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development during the major and minor rainy seasons from March to July 2023 and August to December 2023. Mampong is located at 07°04'N, 01°24'W, and 457.5 meters above sea level, and within Ghana's forest-savannah transitional zone. It is between the southern rain forest and the northern Guinea Savannah belt. The rainfall pattern in Mampong is bimodal, the primary or major rainy season is from April to July, and the secondary or minor season is from September to December. The soil at the experimental site is classed as a savannah ochrosol type, which is part of the Bediesi soil series and derived from the voltaian sandstone and has been classified as Chronic luvisol according to FAO/UNESCO classification (FAO/UNESCO, 1990).

3.2 Experimental Design and Treatment

The experimental design used was a 6 × 2 factorial experiment arranged in Randomized Completely Block Design (RCBD) with twelve (12) treatments and each replicated three (3) times. The factors were (A) fertilizer amendment which included; (i) 30 t/ha chicken manure (CM), (ii) 15 t/ha chicken manure (CM), (iii) 100 kg/ha NPK, (iv) 50 kg/ha NPK, (v) 15 t/ha chicken manure (CM) + 50 kg/ha NPK and (vi) Control (No fertilizer) and (B) plant spacing which also included (i) 40 cm × 20 cm and (ii) 40 cm × 25 cm.

3.2.1 Treatment Combinations

The total number of treatment combinations is provided in Table 3.1.

Table 3. 1: Treatment Combination

Treatment	Description
T1	30 t/ha CM + 40 cm × 20 cm
T2	30 t/ha CM + 40 cm × 25 cm
T3	15 t/ha CM + 40 cm × 20 cm
T4	15 t/ha CM + 40 cm × 25 cm
T5	100 kg/ha NPK + 40 cm × 20 cm
T6	100 kg/ha NPK + 40 cm × 25 cm
T7	50 kg/ha NPK + 40 cm × 20 cm
T8	50 kg/ha NPK + 40 cm × 25 cm
T9	15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm
T10	15 t/ha CM + 50 kg/ha NPK + 40 cm × 25 cm
T11	No fertilizer (Control) + 40 cm × 20 cm
T12	No fertilizer (Control) + 40 cm × 25 cm

3.3 Cultural and Management Practices

3.3.1 Preparation of Chicken Manure and Application

Chicken droppings were collected from local poultry farmers in Mampong, heaped and covered with black polythene. Adequate moisture and aeration were maintained by frequent sprinkling of water and stirring with a hand rake. The setup was maintained for a period of three (3) months for further decomposition. The chicken manure was incorporated into the soil according to treatment and frequently watered and stirred two weeks before planting. The chicken manure was incorporated into the soil with a garden fork and a shovel to break down the manure and mix it with the soil at the rate of 16.6 kg for full CM and 8.3 for half CM for each plot.

3.3.2 Planting Material and Planting

Poinsett cucumber seeds were obtained from Kyeiwaa Agrochemicals, a certified agrochemical dealer in Asante Mampong. The Poinsett variety produces fruits with deep green colour, fully matures in 45 – 60 days, with an average weight of 250 g. It is tolerant to some diseases including powdery mildew (*Sphaerotheca Fuliginea*) and cucumber mosaic virus (CMV).

Planting of seeds was done on 22nd June 2023 and 20th September 2023 for major and minor seasons, respectively. There were 6 rows per plot, 10 plants per rows for 40 cm × 20 cm and 13 plants per rows for 40 cm × 25 cm. There were total plant population of sixty (60) plants for the closest plant spacing (40 cm × 20 cm) and seventy-eight (78) plants for the widest space (40 cm × 25 cm).

3.3.3 Land Preparation and Field Layout

The field was ploughed and harrowed. The field was demarcated, lined and pegged. The experimental area measured 34.8 m × 9 m (313.2 m^2). The area was divided into three blocks. Each block was further divided into twelve plots. A distance of 1 m was left between blocks and 0.5 m within plots.

3.3.4 NPK Fertilizer Application

After two (2) weeks of planting, soil near the bases of plants was top-dressed with NPK compound fertilizer (20-10-10) at a rate of 0.05 kg for half NPK and 0.10 kg for full NPK was applied.

3.3.5 Staking

All plants were staked at 4 weeks after planting. Individual staking was done using bamboo stems of about 1.2 m in height. A rope was used to tie the vines to some of the side shoots to the bamboo. Stakes were placed 10 cm away from the plant in order not to disturb the roots.

3.3.6 Weed Control

Weeds were controlled on the plots mainly by hoeing. Hand pulling of weeds close to plants and hoeing was done 3 times at 2, 4 and 6 weeks after planting during the growth period of the plants.

3.3.7 Irrigation

The experimental period experienced rainy, humid, and intermittent dry spells within the wet season, so supplementary watering was occasionally done using rubber hose and watering can. This was done in the morning and evening and it was ensured that plants received the same quantity of water.

3.3.8 Pest and Disease Control

Spraying was done every two (2) weeks during the experimental period to control pest and diseases. Cucumber beetles were controlled using Golan XL (AI acetamiprid 200g/L) at the rate of 30 ml per litre of water at each spraying. Downy mildew was controlled with Forum TMR fungicide (AI dimethomorph) at the rate of 37.3 g per litre of water. A CP16 Knapsack sprayer was used in spraying the pesticides.

3.4 Data Collected

3.4.1 Soil and Manure Sampling and Analysis

Soil samples were taken from five randomly selected locations on each experimental plot at a depth of 0-20 cm. Soil samples from each plot were combined and thoroughly mixed in a container, air-dried, and passed through a 2.0 mm sieve to achieve a fine texture, following which sub-samples were placed in labeled plastic bags. The labelled soil and chicken manure samples were subsequently taken to the KNUST Soil Science Laboratory in Kumasi to assess the chemical properties of the soil. This was done for each experimental site before planting.

- Soil pH

The pH of the soil was determined using a Suntex pH (mv) Sp meter (701) for soil: water ratio of 1:2.5 as was used by Apori & Byalebeka (2021). A 20 g soil sample was weighed into a 100 ml beaker. To this 50 ml distilled water was added and the suspension was stirred continuously for 20 minutes and allowed to stand for 15 minutes. After calibrating the pH meter with buffer solutions of pH 4.0 and 7.0, the pH was read by immersing the electrode into the upper part of the suspension.

- Total Nitrogen

The total nitrogen content of the soil was assessed utilizing the Kjeldahl digestion and distillation method as outlined by Silva (2016). Ten grams of soil and fifty milliliters of runoff were measured into a 500 mL Kjeldahl digestion flask, to which one spatula of a combination including copper sulfate, sodium sulfate, and selenium was added, followed by 30 mL of concentrated H_2SO_4. The mixture was heated vigorously to provide a permanent clear green hue in the soil. The digest was cooled and transferred to a 100 mL volumetric flask, then diluted to the mark with distilled water. A 10 mL aliquot of the digest was transferred to a Tecator distillation flask, and 20 mL of 40% NaOH solution was added. Steam from a Foss Tecator device was let to enter the flask. The distilled ammonium was collected in a 250 mL flask containing 10 mL of 4% boric acid with a mixed indicator of bromocresol green and methyl red. The distillate was titrated using 0.1 N HCl solutions. A blank digestion, distillation, and titration were performed without soil to verify the absence of nitrogen residues in the reagents and water utilized.

It was mathematically expressed as:

$$\% \text{ N} = \frac{(\text{a} - \text{b})\text{x } 1.4 \text{ xN x V}}{\text{s x t}}$$

Where; a = mL HCl used for sample titration b = mL HCl used for blank titration 1.4 = 14 x 10-3 x 100 % (14 = atomic weight of N) N = normality of HCl V = total volume of digest s = mass air-dried soil sample taken for digestion in grams (10.0 g) or volume of runoff sample taken for digestion in mL (50mL) t = volume of aliquot taken for distillation (10.0 mL).

- Available Phosphorus

A 2.0 g soil sample was weighed into a 50 ml shaking bottle and 20 mL of Bray-1 extracting solution was added. The sample was shaken for one minute and then filtered through No. 42 Whatman filter paper. Ten millilitres of the filtrate was pipetted into a 25 mL volumetric flask and 1 mL each of molybdate reagent and reducing agent were added for colour development. The percent transmission was measured at 650 nm wavelength on a spectrophotometer. The concentration of P in the extract was obtained by comparison of the results with a standard curve (Lumbanraja *et al*., 2017).

- Soil Exchangeable Potassium

Potassium in the soil extract was determined by flame photometry. Standard solutions of 0, 2, 4, 6, 8 and 10 ppm K+ and Na+ were prepared by diluting appropriate volumes of 100 ppm K+ and Na+ solution to 100 mL in volumetric flask using distilled water. Photometer readings for the standard solutions were determined and a standard curve constructed. Potassium concentrations were read from the standard curve.

- Organic Carbon

Organic carbon content was determined by the dichromateacid oxidation method (Rao *et al*., 2019). Ten milliliters (10 mL) each of concentrated sulphuric acid, 0.5 N potassium dichromate solution and concentrated orthophosphoric acid were added to 0.05 g of sample in Erlenmeyer flask. The solution was allowed to stand for 30 minutes after addition with distilled water. It was then back titrated with 0.5 N ferrous sulphate solutions with diphenylamine indicator. The organic carbon content was calculated from the equation:

$$\% Carbon = \frac{\mathrm{N} * (\mathrm{a} * \mathrm{b}) * 3 * (10)3 * 100 * 1.3}{\mathrm{w}}$$

where: N = normality of ferrous sulphate a = mL ferrous sulphate solution required for sample titration b = mL ferrous sulphate solution required for blank titration w = weight of ovendried sample in gram 0.003 = equivalent weight of carbon 1.3 = compensation factor allowing for incomplete combustion

3.4.2 Vegetative Growth Data

- Plant height

Plant height was measured from the soil surface to the apex of the main vine of 5 selected/tagged plants in the central rows at 21, 28 and 35 DAP and the mean estimated. The plant height was determined using the meter rule.

- Stem Girth

Stem girth was measured with a flexible tape measure from five (5) randomly selected central rows. The tape measure was wrapped around the stem at the base, ensuring it is flat against the stem, and recorded in centimeters. This was done at 21, 28 and 35 DAP.

- Number of Leaves Per Plant

The total number of leaves per plant was counted on the five selected plants from the middle rows at 28 and 35 DAP and the mean estimated.

- Number of Vines per plant

The total number of vines per plant was counted on the five sampled plants from middle rows at 21, 28 and 35 DAP and the mean estimated.

- Leaf Chlorophyll Content

The leaf chlorophyll content was measured on five (5) randomly selected tagged plants from the 3 m x 3 m area within the four (4) central rows per plot using the calibrated SPAD meter at three (3) weeks after planting and at one (1) weeks interval for three (3) times and the mean was computed.

- Plant Dry Matter Accumulation

Four (4) plants per treatment three (3) each at vegetative and reproductive stages was used for the plant dry matter determination. Fresh sub-sample each of shoot and root weighing 250 g was weighed using electronic weighing scale. Each subsample was placed in a paper bag and put in an oven at 78 degrees Celsius for 72 hours until a constant weight was attained. Each sub-sample was then immediately weighed using an electronic weighing scale and recorded as shoot and root dry weight. The mean dry weight was then estimated and recorded.

3.4.3 Yield and Yield Components

- Number of Fruits Per Plant and Per Plot

The number of fruits per plant was achieved by counting the total number of fruits on five randomly selected plants from the middle rows per plot at harvest and the mean recorded. The number of fruits per plot was also obtained by counting the total fruits on all plants in the middle rows per each plot.

- Number of Marketable Fruits Per Plot

Total number of marketable fruits (disease free, uniform in colour, undamaged by pests, not misshapen) was counted from the number of fruits harvested per plot and the mean was estimated.

- Number of Non-Marketable Fruits Per Plot

Total number of unmarketable fruits (those that were diseased, not uniform in colour, damaged by pests, bruised, overgrown and misshapen) were counted from the number of fruits harvested.

- Fruit Weight Per Plant

All fruits from the randomly selected plants in each treatment plot were collected, weighed with an electronic scale, and the mean weight was estimated in kg.

- Total Weight of Fruits Per Plot

An electronic weighing scale was used to weigh all harvested fruits per plot and the average calculated and recorded in kg.

- Fruit Diameter

Fruit diameter was measured from five (5) randomly selected fruits per plot after harvest. A pair of Vernier calipers was used to measure the diameter at the center of the fruit, and the mean was recorded.

- Fruit Yield

The fruit yield was estimated using the formular below: Fruit Yield (t/ha) = (Total fruit weight (kg)/ Area (m^2)) * (10,000 m^2/1,000 kg)

3.5 Statistical Analysis

Data collected were analyzed by Analysis of variance (ANOVA) using Genstat version 23 Statistical Package. The means that showed significant differences were separated at 5% probability rate by Tukey's honestly significant difference (HSD) test. Partial budget analysis was carried out among fertilizer amendments and plant spacing of cucumber.

CHAPTER FOUR: RESULTS

4.1 Initial Soil Chemical Properties

The chemical characteristics of soil components during both major and minor seasons at 0-15 cm and 15-30 cm depths are shown in Table 4.1. At a depth of 0-15 cm, organic carbon (OC) was 0.95 % and 1.15% for major and minor seasons, respectively which is considered low (Appendix 1). Organic matter (OM) was moderate, recording 1.65% and 1.75% respectively for major and minor season. Sodium (Na) content was moderate (1.15 cmol/kg and 1.50 cmol/kg respectively). The total nitrogen was recorded as 0.19% and 0.17% for the major and minor seasons, respectively which is considered low (Appendix 1), potassium (K) was 0.52 cmol/kg and 0.45 cmol/kg, Magnesium (Mg) was 1.65 cmol/kg and 1.50 cmol/kg and phosphorus (P) was 177.7 mg/kg and 160.24 mg/kg respectively which are all considered low (Appendix). The pH recorded was 5.1 for both seasons which is also considered acidic (Appendix 1).

At a depth of 15-30 cm, organic carbon (OC) was 0.70% and 0.69% for major and minor seasons respectively which is low (Appendix 1), organic matter (OM) was also moderate (recorded as 1.24% and 1.20% respectively for major and minor season) and then sodium (Na) was also obtained as 1.05 cmol/kg and 1.10 cmol/kg respectively which is considered moderate. The total nitrogen was recorded as 0.17% and 0.22% at the major and minor seasons respectively which is also moderate (Appendix1), potassium (K) was 0.41 cmol/kg and 0.40 cmol/kg which is considered high, Magnesium (Mg) was 2.56 cmol/kg and 1.95 cmol/kg which is considered moderate and phosphorus (P) was also high as it recorded 143.8 mg/kg and 142.8 mg/kg respectively (Appendix 1). The pH level also changed as it reduced in the 15-30 cm depth and recorded 4.7 which is very acidic (Appendix 1) (Table 4.1) . The general classification of the soil was then considered to be loam based on the data obtained for the various constituents (Appendix 1).

Table 4. 1: Initial Soil Chemical Properties in the Major and Minor Season of 2023

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

4.2 Chicken Manure Chemical Properties

Table 4.2 shows the chemical characteristics of the chicken manure used in the analysis. The results in table shows that organic carbon was recorded as 5.01% which is high, organic matter was 8.80% which is also high, total nitrogen was also high (3.40%), potassium (K) was high (3.11 cmol/kg), Sodium (Na) was high (3.44 cmol/kg), Magnesium (mg) was 7.88 cmol/kg, phosphorus was 24.73 mg/kg and pH was 6.8 were both high (Appendix 1).

Table 4. 2: Chemical Properties of Chicken

Nutrient	**Proportion**
Organic Carbon (%)	5.01
Organic Matter (%)	8.80
Total nitrogen (%)	3.40
K (cmol/kg)	3.11
Na (cmol/kg)	3.44
Mg (cmol/kg)	7.88
Available P (mg/kg or ppm)	24.73
pH	6.80

4.3 Climatic Conditions at the Experimental Sites

The climatic variables measured during the experimental periods at the major cropping season (March 2023 to July 2023) and at minor cropping season (August 2023 to December 2023) are shown in Table 4.3. During the major cropping season, 784 mm of rainfall was recorded from March 2023 to July 2023 with the highest peak in April, June and July. During the minor cropping season, a total rainfall of 786.9 mm was recorded from August 2023 to December 2023 with the peak in October and August. However, no amount of rainfall was recorded in December (Table 4.3).

The relative humidity ranged from 88-92% for 6hrs and 55-71% for during the major season, and 44-74% for 6 hrs and 15 hrs respectively for major and minor season. Temperature ranged from 25.1-28.5^{0}C for the major and minor seasons, respectively.

Table 4. 3: Climatic Conditions at the Experimental Sites for Major and Minor Cropping Seasons of 2023

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

4.4 Growth Performance

4.4.1 Number of Leaves Per Plant

The mean number of leaves per cucumber plants as affected by plant spacing, fertilizer amendment and their interaction at 21, 28 and 35 DAP for major and minor rainy seasons is indicated in Table 4.4.

Plant spacing had no significant effect on number of leaves on all days of sampling (Table 4.4).

Fertilizer amendments had significant ($P<0.05$) differences in the number of leaves at 28 and 35 DAP during the minor season. At 28 DAP, treatment effect of the 15 t/ha was significantly higher than both NKP only treatments as well as the control treatment. At 35 DAP, treatment effect 50 kg/ha NPK was greater, but this was significantly higher than that of 30 t/ha CM treatment only. In the major season, treatment effects were significant at 21 and 28 DAP only. At 21 DAP, the 30 t/ha CM treatment effect was significantly higher than that of the control and 100 kg/ha NPK treatment only. All other treatment differeces were not significant. At 28 DAP, the treatment effect of the 15 ton per hectare CM was The greatest, but this was greater than the NPK only treatment and the control. On all sample occasions, the spacing by fertilizer interactions was not significant.

(Table 4.4).

Table 4. 4: Effect of Fertilizer Amendment and Plant Spacing on Number of Leaves of Cucumber

	Number of Leaves Per Plant					
	Major Season			Minor Season		
Treatment	21 DAP	28 DAP	35 DAP	21 DAP	28 DAP	35 DAP
Fertilizer Amendment						
30 t/ha CM	11	18	44	10	18	24
15 t/ha CM	10	21	45	10	21	28
100 kg/ha NPK	8	13	33	8	14	28
50 kg/ha NPK	10	13	44	10	14	41
15 t/ha CM + 50 kg/ha NPK	10	18	40	10	18	34
Control	8	12	29	8	14	37
HSD (P<0.05)	2.08	6.49	16.21	2.44	5.87	16.03
Plant Spacing						
40 cm × 20 cm	10	16	38	32	32	32
40 cm × 25 cm	9	16	40	32	32	32
HSD (P<0.05)	NS	NS	NS	NS	NS	NS
Fertilizer Amend × Plant Spacing						
30 t/ha CM + 40 cm × 20 cm	11	19	41	10	19	22
30 t/ha CM + 40 cm × 25 cm	10	17	46	10	17	26
15 t/ha CM + 40 cm × 20 cm	10	22	49	10	22	34
15 t/ha CM + 40 cm × 25 cm	10	21	41	10	21	22
100 kg/ha NPK + 40 cm × 20 cm	8	13	32	8	13	29
100 kg/ha NPK + 40 cm × 25 cm	8	13	33	8	15	28
50 kg/ha NPK + 40 cm × 20 cm	11	14	32	10	15	32
50 kg/ha NPK + 40 cm × 25 cm	10	13	56	10	14	50
15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm	10	18	41	10	18	36
15 t/ha CM + 50 kg/ha NPK + 40 cm × 25 cm	9	19	39	10	19	32
Control + 40 cm × 20 cm	9	13	31	9	13	44
Control + 40 cm × 25 cm	8	11	26	8	14	31
HSD (P<0.05)	NS	NS	NS	NS	NS	NS
CV (%)	12.50	22.65	23.26	14.6	19.71	27.6

4.4.2 Plant Height

The mean plant height of cucumber as affected by plant spacing, fertilizer amendment and their interaction at 21, 28 and 35 DAP for major and minor rainy seasons are indicated in Table 4.5

Plant spacing did not significantly affect plant height on all sampling days. Also, spacing by fertilizer interactions was not significant on all these of sampling.

There were significant treatment differences in plant height on all sampling days in both major and minor rainy seasons (Table 4.5).

There were significant ($p<0.05$) differences in the height of cucumber plants among the fertilizer amendment at 21, 28 and 35 DAP at both the major and minor rainy seasons (Table 4.5). At 21 DAP, in the major rainy season, the tallest plants (22.5 cm) were recorded on 30 t/ha CM treatment which was highly significant ($P<0.05$) than Control (15.4 cm) and 100 kg/ha NPK (13.1 cm) treatment only. During the minor season, both 30 t/ha Chicken manure treatment recorded the tallest plants And this was significantly higher than those of the control and 100 kg/ha and NPK treatments only. At 28 DAP, the tallest plants recorded 99.3 cm and 66.7 cm for major and minor seasons were recorded on 50 kg/ha NPK and 30 t/ha Chicken respectively and these effects were significantly higher than those of the control and 100 kg/ha treatment in both seasons. Similar results occurred at 35 DAP , where in both seasons the 30 t/ha CM treatment effect was the greatest, and these were significantly higher than the control and 100 kg/ha PK treatment effects (Table 4.5).

Table 4. 5: Effect of Fertilizer Amendment and Plant Spacing on Plant Height of Cucumber

	Plant Height (cm)					
	Major Season			Minor Season		
Treatment	21 DAP	28 DAP	35 DAP	21 DAP	28 DAP	35 DAP
Fertilizer Amendment						
30 t/ha CM	22.5	92.8	159.2	23.9	66.7	108.2
15 t/ha CM	22.3	89.5	149.9	21.6	63.8	106.2
100 kg/ha NPK	13.1	60.8	118.1	11.8	52.0	94.8
50 kg/ha NPK	20.6	99.3	133.1	20.6	62.5	104.6
15 t/ha CM + 50 kg/ha NPK	21.6	81.4	148.2	23.4	64.6	106.2
Control	15.4	63.4	106.3	12.2	53.9	95.5
HSD (P<0.05)	5.97	27.78	27.85	3.18	4.8	5.7
Plant Spacing						
40 cm × 20 cm	20.0	84.8	136.1	19.4	61.1	102.3
40 cm × 25 cm	18.5	77.6	135.5	18.4	60.0	102.8
HSD (P<0.05)	NS	NS	NS	NS	NS	NS
Fertilizer Amend × Plant Spacing						
30 t/ha CM + 40 cm × 20 cm	21.9	89.3	159.6	24.6	67.4	108.4
30 t/ha CM + 40 cm × 25 cm	23.1	96.3	158.8	23.1	66.0	108.1
15 t/ha CM + 40 cm × 20 cm	23.4	93.3	156.6	20.5	62.1	105.1
15 t/ha CM + 40 cm × 25 cm	21.1	85.8	143.2	22.8	65.4	107.2
100 kg/ha NPK + 40 cm × 20 cm	13.4	66.6	126.8	13.4	53.1	94.4
100 kg/ha NPK + 40 cm × 25 cm	12.7	54.9	109.4	10.2	50.9	95.2
50 kg/ha NPK + 40 cm × 20 cm	22.0	102.4	119.9	21.7	64.1	105.3
50 kg/ha NPK + 40 cm × 25 cm	19.3	96.2	146.4	19.4	60.9	103.8
15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm	22.1	85.0	153.3	25.1	66.6	106.1
15 t/ha CM + 50 kg/ha NPK + 40 cm × 25 cm	21.0	77.9	143.1	21.6	62.6	106.2
Control + 40 cm × 20 cm	17.3	72.0	100.5	10.8	53.5	94.8
Control + 40 cm × 25 cm	13.6	54.7	112.2	13.6	54.3	96.2
HSD (P<0.05)	NS	NS	NS	5.24	NS	NS
CV (%)	17.39	19.17	11.49	9.34	4.40	3.10

4.4.3 Chlorophyll Content of Leaf

The mean chlorophyll content of cucumber leaf as affected by plant spacing, fertilizer amendment and their interaction at 21, 28 and 35 DAP for the major and minor rainy seasons are indicated in Table 4.6.

Plant spacing was significant only at 28 DAP in the minor season with the 40 by 20CM effects being greater than the 40 by 25 CM effect. Spacing differences in other sampling days were not significant. Spacing by fertilizer application was significant at 28 DAP In the minor season and 21 and 28 DAP in the major season. Fertilizer application had significant effects in chlorophyll content of Cucumber Leaf on all days of sampling (Table 4.6). The minor season results showed that at 21 and 28 DAP sampling occasions, the 15 t/ha CM treatment effect was the greatest, but this was significantly higher than the control treatment effect on both days. At 35 DAP, the 50 t/ha NPK treatment effect was significantly higher than all other treatment effects, except that of the 15 t/ha CM treatment. In the major season, at 21 DAP, the 15 t/ha CM treatment effect was greater than the control treatment only. All other treatment differences were not significant. At 28 DAP, the combined treatment effect was significantly higher than those of the control and 50 kg/ha NPK treatment only. All other treatments had similar treatment effects. At 35 days after planting, the 30 t/ha CM treatment effect was significantly higher than the control treatment only. All other differences were not significant (Table 4.6).

Table 4. 6: Effect of Fertilizer Amendment and Plant Spacing on Chlorophyll Content of Leaf

	Chlorophyll Content of Leaf (µmol/m^2)					
	Major Season			Minor Season		
Treatment	21 DAP	28 DAP	35 DAP	21 DAP	28 DAP	35 DAP
Fertilizer Amendment						
30 t/ha CM	40.83	56.67	67.21	39.46	44.33	47.90
15 t/ha CM	40.91	55.95	66.55	40.55	47.58	50.15
100 kg/ha NPK	39.54	55.34	65.61	39.84	43.21	46.61
50 kg/ha NPK	40.30	52.35	67.21	40.42	42.27	58.68
15 t/ha CM + 50 kg/ha NPK	40.46	56.85	67.12	38.93	42.79	47.36
Control	34.27	50.89	61.39	34.24	37.11	42.01
HSD (P<0.05)	2.88	3.70	5.29	5.84	7.44	9.90
Plant Spacing						
40 cm × 20 cm	39.45	54.42	65.68	39.13	44.73	50.34
40 cm × 25 cm	39.32	54.93	66.01	38.68	41.03	47.23
HSD (P<0.05)	NS	NS	NS	NS	2.86	NS
Fertilizer Amend × Plant Spacing						
30 t/ha CM + 40 cm × 20 cm	40.02	55.98	65.71	38.65	44.52	48.92
30 t/ha CM + 40 cm × 25 cm	41.64	57.37	68.70	40.27	44.14	46.87
15 t/ha CM + 40 cm × 20 cm	40.68	55.47	65.80	41.65	47.51	49.25
15 t/ha CM + 40 cm × 25 cm	41.15	56.43	67.29	39.45	47.65	51.05
100 kg/ha NPK + 40 cm × 20 cm	42.38	57.89	67.75	41.68	47.21	51.28
100 kg/ha NPK + 40 cm × 25 cm	36.70	52.80	63.47	38.00	39.20	41.93
50 kg/ha NPK + 40 cm × 20 cm	40.50	51.40	67.88	40.40	47.33	62.30
50 kg/ha NPK + 40 cm × 25 cm	40.10	53.30	66.55	40.43	37.20	55.07
15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm	39.46	55.78	66.05	39.09	46.63	51.03
15 t/ha CM + 50 kg/ha NPK + 40 cm × 25 cm	41.46	57.93	68.19	38.76	38.96	43.69
Control + 40 cm × 20 cm	33.68	50.03	60.89	33.31	35.18	39.25
Control + 40 cm × 25 cm	34.87	51.75	61.89	35.17	39.03	44.77
HSD (P<0.05)	4.76	6.11	NS	NS	12.28	NS
CV (%)	4.11	3.80	4.50	8.35	9.64	11.28

4.4.4 Stem Girth

The stem girth as affected by different plant spacing, fertilizer amendments and their interaction at 21, 28 and 35 DAP is shown in Table 4.8.

The stem girth of cucumber plants was not significantly ($P>0.05$) influenced by spacing in both seasons. Spacing × fertilizer interactions were not significant during the major season, but were significant at each sampling date in the minor season (Table 4.8).

Fertilizer application showed significant differences in all sampling days. At 21 to 35 DAP during major seasons, Control treatment recorded the lowest stem girth (0.7 cm for 21 DAP and 0.8 for 28 DAP) except at 35 DAP where 100 kg/ha NPK recorded the smallest stem girth (0.9 cm), 50 kg/ha NPK recorded the highest stem girth from 21 to 35 DAP (1.0 cm, 1.2 cm and 2.0 cm for 21 cm for 21 DAP, 28 DAP and 35 DAP respectively). Dring the minor season, at 21 DAP, Control treatment again recorded the smallest stem girth (0.7 cm) which was significant from that of 50 kg/ha NPK (0.9 cm). But at 28 DAP and 35 DAP, 100 kg/ha NPK rather recorded the lowest stem girth (1.4 cm and 1.5 cm for 28 DAP and 35 DAP respectively).50 kg/ha NPK again recorded the highest stem girth (1.9 cm and 2.0 cm for 28 DAP and 35 DAP respectively) (Table 4.8).

There were no significant ($p<0.05$) interactions between plant spacing and fertilizer amendments in stem girth of cucumber at 21, 28 and 35 DAP during the major season but significant difference were observed at the minor season at 21, 28 and 35 DAP (Table 4.8). At 21 DAP at the minor season, 15 t/ha chicken manure + 40 cm × 20 cm and 15 t/ha chicken manure + 40 cm × 25 cm both recorded the widest stem (0.9 cm) and then both 100 kg/ha NPK + 40 cm × 25 cm and control + 15 t/ha chicken manure (0.6 cm) recorded the shortest stem girth. At 28 and 35 DAP, 50 kg/ha NPK + 40 cm × 25 cm recorded the highest as 2.0 cm and 2.1 cm respectively.

Season significantly affected stem girth at 28 DAP and 35 DAP. Major cropping season had the smallest stem girth at 28 DAP and 35 DAP (0.9 cm and 1.1 cm for 28 and 35 DAP respectively), the largest stem girth was recorded in the minor cropping season (1.7 cm and 1.8 cm for 28 DAP and 35 DAP respectively) (Table 4.8).

Table 4. 7: Effect of Fertilizer Amendment and Plant Spacing on Stem Girth of Cucumber in the 2023 major and minor seasons

	Stem Girth (cm)					
	Major Season			Minor Season		
Treatment	21 DAP	28 DAP	35 DAP	21 DAP	28 DAP	35 DAP
Fertilizer Amendment						
30 t/ha CM	0.8	1.0	1.1	0.8	1.7	1.9
15 t/ha CM	0.9	0.9	1.0	0.9	1.8	2.0
100 kg/ha NPK	0.6	0.7	0.9	0.6	1.4	1.5
50 kg/ha NPK	1.0	1.2	2.0	0.9	1.9	2.0
15 t/ha CM + 50 kg/ha NPK	0.8	0.8	1.0	0.8	1.7	1.9
Control	0.7	0.8	1.0	0.7	1.5	1.6
HSD (P<0.05)	0.18	0.35	0.25	0.15	0.32	0.29
Plant Spacing						
40 cm × 20 cm	0.8	1.0	1.1	0.8	1.7	1.9
40 cm × 25 cm	0.8	0.9	1.1	0.8	1.6	1.8
HSD (P<0.05)	NS	NS	NS	NS	NS	NS
Fertilizer Amend × Plant Spacing						
30 t/ha CM + 40 cm × 20 cm	0.8	1.0	1.1	0.8	1.7	1.9
30 t/ha CM + 40 cm × 25 cm	0.8	1.0	1.0	0.8	1.7	1.9
15 t/ha CM + 40 cm × 20 cm	0.9	0.9	1.0	0.9	1.9	2.0
15 t/ha CM + 40 cm × 25 cm	0.8	1.0	0.9	0.8	1.8	1.9
100 kg/ha NPK + 40 cm × 20 cm	0.7	0.9	0.8	0.7	1.4	1.6
100 kg/ha NPK + 40 cm × 25 cm	0.6	0.6	0.9	0.6	1.3	1.5
50 kg/ha NPK + 40 cm × 20 cm	1.0	1.2	1.9	0.8	1.8	2.0
50 kg/ha NPK + 40 cm × 25 cm	1.0	1.2	2.1	0.9	2.0	2.1
15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm	0.8	0.9	1.1	0.8	1.8	2.0
15 t/ha CM + 50 kg/ha NPK + 40 cm × 25 cm	0.8	0.7	1.0	0.8	1.7	1.9
Control + 40 cm × 20 cm	0.7	0.8	1.0	0.7	1.6	1.7
Control + 40 cm × 25 cm	0.7	0.7	0.9	0.6	1.4	1.5
HSD (P<0.05)	NS	NS	NS	0.25	0.53	0.47
CV (%)	13.15	22.01	12.53	10.8	10.8	8.7

DAP= Days after planting, HSD (P<0.05)=Tukey's honestly significant difference (5%), CV (%)=coefficient of variation

4.4.5 Number of Vines Per Plant

The mean number of vines per plant as affected by the different cucumber plant spacing, fertilizer amendments and their interaction at 28 and 35 DAP is indicated in Table 4.9.

Results indicate that the different plant spacing did not significantly ($p<0.05$) affect the number of vines per plant of cucumber during the major season, however, there were significant ($p<0.05$) differences during minor season at 28 and 35 DAP (Table 4.9). At 28 DAP, 40 cm × 25 cm recorded 8 vines and 23 vines at 28 DAP and 35 DAP.

Fertilizer Amendments significantly ($p<0.05$) affected number of vines per plant of cucumber at 28 and 35 DAP during both the major and minor growing seasons (Table 4.9). At 28 DAP, during both seasons, 50 kg/ha NPK produced the highest number of vines per plant (11 vines for both seasons) at 28 DAP, which were highly significantly ($p<0.05$) higher than those from the number of vines per plant produced by 100 kg/ha NPK and Control. During the major season at 35 DAP, the highest number of vines per plant was produced by 30 t/ha Chicken manure as 27, followed by 15 t/ha Chicken manure (25 vines), followed by 30 t/ha CM + 50 kg/ha NPK (24 vines), then by 50 kg/ha NPK (21 vines), also by 100 kg/ha NPK (18 vines) and then by Control (16 vines). During the minor season at 35 DAP, 15 t/ha CM + 50 kg/ha NPK rather produced more vines (27), followed by 100 kg/ha NPK (23 vines), followed by 50 kg/ha NPK (22 vines), also by 30 t/ha Chicken manure (17 vines), as 15 t/ha Chicken manure also recorded 15.0 and lastly by the Control treatment which recorded 12 vines.

Plant spacing and fertilizer amendments produced no significant ($p>0.05$) interactions with regard to the number of vines per plant during the major season at 35 DAP, but was significant during the minor season (Table 4.9). At 28 DAP, 50 kg/ha NPK recorded 11 vines and at 35 DAP, 15 t/ha chicken manure + 50 kg/ha NPK recorded 27 vines as the highest.

Season significantly affected number of vines per plant at 35 DAP. Major cropping season had the smallest number of leaves (19) and minor cropping season had the highest number of vines per plant (22) (Table 4.9).

Table 4. 8: Effect of Fertilizer Amendment and Plant Spacing on Number of Vines Per Plant of Cucumber in the 2023 major and minor seasons

	Number of Vines Per Plant			
	Major Season		Minor Season	
Treatment	28 DAP	35 DAP	28 DAP	35 DAP
Fertilizer Amendment				
30 t/ha CM	10	27	10	27
15 t/ha CM	9	25	9	25
100 kg/ha NPK	5	18	5	18
50 kg/ha NPK	11	21	11	21
15 t/ha CM + 50 kg/ha NPK	10	24	10	24
Control	5	16	5	16
HSD (P<0.05)	3.16	10.48	3.16	10.48
Plant Spacing				
40 cm × 20 cm	8	21	8	21
40 cm × 25 cm	8	23	8	23
HSD (P<0.05)	NS	NS	NS	NS
Fertilizer Amend × Plant Spacing				
30 t/ha CM + 40 cm × 20 cm	11	26	11	26
30 t/ha CM + 40 cm × 25 cm	9	28	9	28
15 t/ha CM + 40 cm × 20 cm	10	26	10	26
15 t/ha CM + 40 cm × 25 cm	9	23	9	23
100 kg/ha NPK + 40 cm × 20 cm	5	18	5	18
100 kg/ha NPK + 40 cm × 25 cm	5	18	5	18
50 kg/ha NPK + 40 cm × 20 cm	12	17	12	17
50 kg/ha NPK + 40 cm × 25 cm	10	26	10	26
15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm	9	23	9	23
15 t/ha CM + 50 kg/ha NPK + 40 cm × 25 cm	11	25	11	25
Control + 40 cm × 20 cm	4	15	4	15
Control + 40 cm × 25 cm	5	16	5	16
HSD (P<0.05)	NS	NS	NS	NS
CV (%)	21.77	26.79	21.77	26.79

DAP= Days after planting, HSD (P<0.05)=Tukey's honestly significant difference (5%), CV (%)=coefficient of variation

4.4.6 Dry Shoot Weight

The mean dry weight of cucumber shoots as affected by the different cucumber plant spacing, fertilizer amendments and their interaction are presented in Table 4.10.

Plant spacing was significant ($p>0.05$) with regard to the dry shoot weight during the major season and at minor season (Table 4.10). The heaviest dry shoot was recorded on 40 cm by 25 cm (189.4 g for major season and 166.8 g for minor season) which was significant from the lightest weight recorded on 40 cm by 20 cm as (150.4 g for major season and 129.2 g for minor season).

Fertilizer Amendments significantly ($p<0.05$) influenced dry shoot weight of cucumber during the major season, no significant ($p<0.05$) observation was made during the minor season. At the minor season, the highest value was from 50 kg/ha NPK (185.3 g), followed by 50 kg/ha NPK + 15 t/ha chicken manure which also had 165.4 g and then 15 t/ha chicken manure had the lightest weight (97.0 g).

Plant spacing and fertilizer amendments produced no significant ($p>0.05$) interactions with regard dry weight of cucumber shoots during both the major and minor seasons.

Season significantly affected dry shoot weight. Major cropping season had the heaviest weight of shoot (169.9 g for dry weight) and minor cropping season had the lightest weight (148.0 for dry weight).

Table 4. 9: Effect of Fertilizer Amendment and Plant Spacing on Dry Shoot Weight of Cucumber in 2023 major and minor seasons

	Dry Shoot Weight (g)	
Treatment	Major Season	Minor Season
Fertilizer Amendment		
30 t/ha CM	180.5	152.2
15 t/ha CM	111.5	97.0
100 kg/ha NPK	173.2	149.5
50 kg/ha NPK	194.1	185.3
15 t/ha CM + 50 kg/ha NPK	179.1	165.4
Control	161.1	138.7
HSD (P<0.05)	48.03	34.04
Plant Spacing		
40 cm × 20 cm	150.4	129.2
40 cm × 25 cm	189.4	166.8
HSD (P<0.05)	18.46	13.09
Fertilizer Amend + Plant Spacing		
30 t/ha CM + 40 cm × 20 cm	167.6	135.4
30 t/ha CM + 40 cm × 25 cm	193.5	169.1
15 t/ha CM + 40 cm × 20 cm	84.2	77.1
15 t/ha CM + 40 cm × 25 cm	138.8	116.8
100 kg/ha NPK + 40 cm × 20 cm	156.4	134.7
100 kg/ha NPK + 40 cm × 25 cm	190.0	164.4
50 kg/ha NPK + 40 cm × 20 cm	202.4	169.1
50 kg/ha NPK + 40 cm × 25 cm	225.9	201.5
15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm	152.5	140.5
15 t/ha CM + 50 kg/ha NPK + 40 cm × 25 cm	205.7	190.3
Control + 40 cm × 20 cm	139.4	118.6
Control + 40 cm × 25 cm	182.8	158.9
HSD (P<0.05)	NS	NS
CV (%)	15.84	12.88

DAP= Days after planting, HSD (P<0.05)=Tukey's honestly significant difference (5%), CV (%)=coefficient of variation

4.4.7 Dry Root Weight

The mean dry weights of cucumber root as affected by the different cucumber plant spacing, fertilizer amendments and their interaction are presented in Table 4.11.

Plant spacing was significant ($p>0.05$) with regard to the root weights during both the major and minor seasons. Plant spacing was significantly ($p>0.05$) affected dry root weight during both experiments (Table 4.11). The heaviest dry root was recorded on 40 cm by 25 cm for major and minor season respectively, which was significant from the least weight recorded on 40 cm by 20 cm for major and minor season respectively.

As usual, fertilizer Amendments significantly ($p<0.05$) influenced dry root weights of cucumber during both the major and minor seasons (Table 4.11). For dry shoot weight, the highest was again recorded on 100 kg/ha NPK (85.8 g and 72.9 g for major and minor seasons respectively), followed by 50 kg/ha NPK (82.8 g and 67.6 g for major and minor seasons respectively) while the lightest weight was obtained on the control (36.9 g during the major season and 17.2 g during the minor season) treatment.

Plant spacing and fertilizer amendments produced no significant ($p>0.05$) interactions with regard to dry weights of cucumber root during both the major and minor seasons.

Season significantly affected dry root weight. Major cropping season had the heaviest dry weight of roots (62.3 g for dry weight) and minor cropping season had the lightest weight (46.4 g for dry weight) (Table 4.11).

Table 4. 10: Effect of Fertilizer Amendment and Plant Spacing on Dry Root Weight of Cucumber in 2023 major and minor seasons

	Root Weight (g)	
	Major Season	Minor Season
Treatment	Dry	Dry
Fertilizer Amendment		
30 t/ha CM	64.1	44.5
15 t/ha CM	28.9	19.6
100 kg/ha NPK	85.8	72.9
50 kg/ha NPK	82.8	67.6
15 t/ha CM + 50 kg/ha NPK	75.1	56.8
Control	36.9	17.2
HSD (P<0.05)	23.17	16.09
Plant Spacing		
40 cm × 20 cm	58.3	42.7
40 cm × 25 cm	66.3	50.1
HSD (P<0.05)	8.90	6.19
Fertilizer Amend × Plant Spacing		
30 t/ha CM + 40 cm × 20 cm	61.3	41.2
30 t/ha CM + 40 cm × 25 cm	66.9	47.8
15 t/ha CM + 40 cm × 20 cm	24.1	16.1
15 t/ha CM + 40 cm × 25 cm	33.7	23.1
100 kg/ha NPK + 40 cm × 20 cm	79.0	69.0
100 kg/ha NPK + 40 cm × 25 cm	92.7	76.7
50 kg/ha NPK + 40 cm × 20 cm	79.2	63.5
50 kg/ha NPK + 40 cm × 25 cm	86.5	71.7
15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm	70.3	53.5
15 t/ha CM + 50 kg/ha NPK + 40 cm × 25 cm	79.8	60.1
Control + 40 cm × 20 cm	35.8	13.1
Control + 40 cm × 25 cm	38.0	21.3
HSD (P<0.05)	NS	NS
CV (%)	20.84	19.42

DAP= Days after planting, HSD (P<0.05)=Tukey's honestly significant difference (5%), CV=coefficient of variation

4.5 Yield and Yield Components

4.5.1 Fruit Weight Per Plant

The mean fruit weight per plant of cucumber as affected by the different plant spacing, fertilizer amendments and their interaction are presented in Table 4.12.

There were no significant (p>0.05) differences in fruit weight per plant as affected by plant spacing during both experiments in the two seasons (Table 4.12).

As recorded in previous parameters, fertilizer amendments significantly ($p<0.05$) influenced the weight of fruit per plant of cucumber during both the major and minor seasons (Table 4.12). During the major season, 50 kg/ha NPK + 15 t/ha CM recorded the highest (4.6 kg) which was highly significant from the lowest weight of fruit per plant (2.4 kg) recorded on the control treatment. During the minor season, the same trend as observed in the major season repeated as 50 kg/ha NPK + 15 t/ha CM recorded 3.6 kg as the highest weight of fruit per plant and 15 t/ha Chicken manure recorded 3.3 kg as the next highest while the lowest was recorded on the control (1.4 kg) treatment.

There were significant ($p>0.05$) interactions produced by plant spacing and fertilizer amendments in both fruit weight per plant and fruit diameter during the major and minor During the minor season, 15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm had the highest fruit weight per plant (4.5 kg) in the minor season it recorded 5.4 kg (Table 4.12).

Table 4. 11: Effect of Fertilizer Amendment and Plant Spacing on Fruit Weight Per Plant of Cucumber in 2023 major and minor seasons

Fertilizer Amendment	Fruit Weight Per Plant (kg)					
	Major season			Minor season		
	40 cm × 20 cm	40 cm × 25 cm	**Mean**	40 cm × 20 cm	40 cm × 25 cm	**Mean**
30 t/ha CM	2.5	2.8	**2.7**	1.6	1.8	**1.7**
15 t/ha CM	3.0	2.6	**2.8**	2.0	1.9	**2.0**
100 kg/ha NPK	4.1	4.8	**4.5**	3.0	3.6	**3.3**
50 kg/ha NPK	2.7	3.7	**3.2**	1.9	2.6	**2.3**
15 t/ha CM + 50 kg/ha NPK	5.4	3.9	**4.7**	4.5	2.8	**3.7**
Control	1.5	3.3	**2.4**	0.8	2.1	**1.5**
Mean	**3.2**	**3.5**		**2.3**	**2.5**	
CV (%)	20.09			22.91		
Fertilizer Amendment (FA)	HSD (0.05) = 0.20			HSD (0.05) = 0.97		
Plant Spacing (PS)	HSD (0.05) = NS			HSD (0.05) = NS		
FA x PS	HSD (0.05) =1.98			HSD (0.05) = 1.61		
Season	HSD (0.05) = 0.14			HSD (0.05) = 0.14		

DAP= Days after planting, HSD=Tukey's honestly significant difference (5%), CV (%)=coefficient of variation

4.5.2 Fruit Diameter

The mean fruit weight per plant and fruit diameter of cucumber as affected by the different cucumber plant spacing, fertilizer amendments and their interaction are presented in Table 4.13.

There were no significant ($p>0.05$) differences in fruit diameter as affected by plant spacing during both experiments in the two seasons (Table 4.13).

As recorded in previous parameters, fertilizer amendments significantly ($p<0.05$) affected the fruit diameter of cucumber during both the major and minor seasons (Table 4.13). The widest diameter (8.8 cm) was recorded on fruits produced by 50 kg/ha NPK during the major growing season whereas 30 t/ha Chicken manure recorded 4.7 cm as the closest diameter. In the minor growing season, 15 t/ha Chicken manure had the widest fruit diameter (3.7 cm), followed by 15 t/ha CM + 50 kg/ha NPK (3.2 cm), followed by 100 kg/ha NPK (3.2 cm), followed by 30 t/ha Chicken manure (2.9 cm) and 50 kg/ha NPK recorded the closest diameter (2.5 cm).

There were significant ($p>0.05$) interactions produced by plant spacing and fertilizer amendments in fruit diameter during the major and minor seasons (Table 4.13). During the minor season, both 15 t/ha CM + 40 cm × 25 cm and 100 kg/ha NPK + 40 cm × 20 cm had the widest fruit diameter (3.8 cm), followed by 100 kg/ha NPK + 40 cm × 20 cm (3.6 cm) and the closest fruit was recorded by 30 t/ha CM + 40 cm × 25 cm (2.1 cm). During the major season, 50 kg/ha NPK + 40 cm by 25 cm recorded the widest fruit diameter (9.0 cm), followed by 50 kg/ha NPK + 40 cm × 20 cm (8.6 cm) and 30 t/ha CM + 40 cm × 20 cm recorded the closest diameter (4.3 cm).

Season significantly affected both fruit weight and fruit diameter per plant. Major cropping season had the heaviest fruits per plants and fruit diameter (3.4 kg for fruit weight and 5.6

cm g for fruit diameter) and minor cropping season had the lightest fruit weight and closest diameter (2.4 kg for fruit weight and 3.1 cm for fruit diameter).

Table 4. 12: Effect of Fertilizer Amendment and Plant Spacing on Fruits Diameter of Cucumber in 2023 major and minor seasons

Fertilizer Amendment	Fruits Diameter (cm)					
	Major season			Minor season		
	40 cm × 20 cm	40 cm × 25 cm	**Mean**	40 cm × 20 cm	40 cm × 25 cm	**Mean**
30 t/ha CM	4.3	5.0	4.7	3.6	2.1	**2.9**
15 t/ha CM	4.9	4.8	4.9	3.6	3.8	**3.7**
100 kg/ha NPK	5.0	4.9	5.0	3.8	2.7	**3.3**
50 kg/ha NPK	8.6	9.0	8.8	2.2	2.9	**2.6**
15 t/ha CM + 50 kg/ha NPK	5.3	5.2	5.3	3.5	3.2	**3.4**
Control	4.8	4.8	4.8	2.6	2.8	**2.7**
Mean	**5.5**	**5.6**		**3.2**	**2.9**	
CV (%)	8.32			18.12		
Fertilizer Amendment (FA)	HSD (0.05) = 0.82			HSD (0.05) = 0.99		
Plant Spacing (PS)	HSD (0.05) = NS			HSD (0.05) = NS		
FA x PS	HSD (0.05) =1.32			HSD (0.05) = 1.63		
Season	HSD (0.05) = 0.24			HSD (0.05) = 0.24		

DAP= Days after planting, HSD=Tukey's honestly significant difference (5%), CV (%)=coefficient of variation

4.5.3 Number of Fruits Per Plant

The mean number of fruits per plot of cucumber as affected by the different cucumber plant spacing, fertilizer amendments and their interaction are presented in Table 4.14.

There were no significant (p>0.05) differences in number of fruits per plot as influenced by plant spacing during both experiments in the two seasons (Table 4.14).

Fertilizer amendments significantly (p>0.05) influenced number of fruits per plot during both experiments in the two seasons (Table 4.13). During the minor season, the highest number of fruits per plot was recorded on 15 t/ha CM + 50 kg/ha NPK as 31 fruits and 38 fruits for major season, followed by 50 kg/ha NPK which recorded 28 fruits and 35 fruits in the major season, and the least was by the control, 13 fruits and 18 fruits for the minor and major seasons respectively (Table 14).

There were significant (p>0.05) interactions produced by plant spacing and fertilizer amendments in number of fruits per plot during both seasons (Table 4.14). The highest number of fruits recorded on 15 t/ha CM + 50 kg/ha NPK (38 fruits for minor season and 45 fruits for major season) and the fewest was also recorded on Control + 40 cm by 20 cm (7 fruits for minor season and 13 fruits major season).

Season significantly affected number of fruits per plot. Major cropping season had the highest number of fruits per plot (26 for number of fruits per plot) and minor cropping season had the fewest number of fruits per plot (20 for number of fruits per plot).

Table 4. 13: Effect of Fertilizer Amendment and Plant Spacing on Number of Fruits Per Plant of Cucumber in 2023 major and minor seasons

Fertilizer Amendment	Number of Fruits Per Plant					
	Major season			Minor season		
	40 cm × 20 cm	40 cm × 25 cm	**Mean**	40 cm × 20 cm	40 cm × 25 cm	**Mean**
30 t/ha CM	20	21	**21**	13	15	**14**
15 t/ha CM	23	19	**21**	17	16	**17**
100 kg/ha NPK	31	38	**35**	26	31	**29**
50 kg/ha NPK	20	29	**25**	16	22	**19**
15 t/ha CM + 50 kg/ha NPK	45	30	**38**	38	24	**31**
Control	13	22	**18**	7	18	**13**
Mean	**25**	**27**		**20**	**21**	
CV (%)	17.95			22.40		
Fertilizer Amendment (FA)	HSD (0.05) = 8.33			HSD (0.05) = 8.11		
Plant Spacing (PS)	HSD (0.05) = NS			HSD (0.05) = NS		
FA x PS	HSD (0.05) =13.73			HSD (0.05) = 13.37		
Season	HSD (0.05) = 2.18			HSD (0.05) = 2.18		

DAP= Days after planting, HSD (P<0.05) = Tukey’s honestly significant difference (5%), CV (%) = coefficient of variation

4.5.4 Fruit Yield

The mean fruit yield of cucumber as affected by the different cucumber plant spacing, fertilizer amendments and their interaction are presented in Table 4.15.

There were no significant (p>0.05) differences in fruit yield as influenced by plant spacing during both experiments in the two seasons (Table 4.15).

Fertilizer amendments significantly (p>0.05) influenced fruit yield during both experiments in the two seasons (Table 4.15). During the minor season, 15 t/ha CM + 50 kg/ha NPK recorded the highest fruit yield (51.0 t/ha), which was significantly (p>0.05) higher than 50 kg/ha NPK which recorded 31.5 t/ha and the least was recorded on control as 20.3 t/ha. In the Major season, the highest yield was recorded on 15 t/ha CM + 50 kg/ha NPK (65.1 t/ha), 15 t/ha CM also recorded 39.0 t/ha which was significantly higher than the Control treatment which recording 33.9 t/ha as the least.

There were significant (p>0.05) interactions produced by plant spacing and fertilizer amendments in fruit yield during both seasons (Table 4.15). During the minor season, the highest fruit yield was 62.5 t/ha which was recorded on 15 t/ha CM + 50 kg/ha NPK + 40 cm by 20 cm and the lowest on control + 40 cm by 20 cm which was recorded as 11.0 t/ha. During the major cropping season, 15 t/ha CM + 50 kg/ha NPK + 40 cm by 20 cm again had highest yield (75.4 t/ha), which was highly significant from 30 t/ha CM + 40 cm by 20 cm (34.7 t/ha), 30 t/ha CM + 40 cm by 25 cm (39.4), 50 t/ha NPK + 40 cm by 20 cm (37.3) and the least was recorded in the Control + 40 cm by 20 cm (21.6 t/ha).

Season significantly affected fruit yield. Major cropping season had the highest fruit yield (4.4 t/ha for fruit yield) and minor cropping season had the smallest fruit yield (3.4 t/ha for fruit yield).

Table 4. 14: Effect of Fertilizer Amendment and Plant Spacing on Fruit Yield of Cucumber in 2023 major and minor seasons

Fertilizer Amendment	Fruit Yield (t/ha)					
	Major season			Minor season		
	40 cm × 20 cm	40 cm × 25 cm	**Mean**	40 cm × 20 cm	40 cm × 25 cm	**Mean**
30 t/ha CM	34.7	39.4	**37.1**	21.9	24.7	**23.3**
15 t/ha CM	41.8	36.2	**39.0**	28.5	26.3	**27.4**
100 kg/ha NPK	57.7	66.6	**62.2**	42.2	51.0	**46.6**
50 kg/ha NPK	37.3	51.7	**44.5**	26.3	36.7	**31.5**
15 t/ha CM + 50 kg/ha NPK	75.4	54.7	**65.1**	62.5	39.5	**51.0**
Control	21.6	46.3	**34.0**	11.0	29.6	**20.3**
Mean	**44.8**	**49.2**		**32.1**	**34.6**	
CV (%)	18.34			20.99		
Fertilizer Amendment (FA)	HSD (0.05) = 15.49			HSD (0.05) = 12.59		
Plant Spacing (PS)	HSD (0.05) = NS			HSD (0.05) = NS		
FA x PS	HSD (0.05) =25.57			HSD (0.05) = 20.79		
Season	HSD (0.05) = 0.36			HSD (0.05) = 0.36		

DAP= Days after planting, HSD (P<0.05)=Tukey’s honestly significant difference (5%), CV (%)=coefficient of variation

4.5.5 Number of Marketable Fruits Per Plot

The mean numbers of marketable cucumber fruits as affected by the different cucumber plant spacing, fertilizer amendments and their interaction are presented in Table 4.16.

There was no significant (p>0.05) difference in number of marketable fruits during the major cropping season, but significant difference was observed during the minor season. During the minor season, 40 cm by 25 cm (20) had the highest marketable fruits and the lowest was recorded on 40 cm by 20 cm (16) (Table 4.16).

Fertilizer amendments significantly (p>0.05) influence marketable fruits in the minor cropping season (Table 4.16). During the minor season 15 t/ha CM + 50 kg/ha NPK recorded the highest number of marketable fruits (28) and the control had the least marketable fruits (11 fruits). During the major season, 15 t/ha CM + 50 kg/ha NPK recorded the highest number of marketable fruits as 30 and both control treatment and 15 t/ha CM recorded 14 fruits as the lowest.

There were significant (p>0.05) interactions produced by plant spacing and fertilizer amendments in marketable during the major and minor seasons (Table 4.16). Thirty-three fruits (33 fruits) were counted on plots applied with 15 t/ha CM and 50 kg/ha NPK as the highest number of marketable fruits during the minor season, 15 t/ha CM + 50 kg/ha NPK + 40 cm by 20 cm had the highest (5 fruits) during the minor season and 8 fruits during the major season.

Season significantly affected marketable fruits. Major cropping season had the highest marketable (21 fruits) and minor cropping season had the fewest marketable fruits (18 fruits).

Table 4. 15: Effect of Fertilizer Amendment and Plant Spacing on Number of Marketable Fruits Per Plot of Cucumber in 2023 major and minor seasons

Fertilizer Amendment	Number of Marketable Fruits Per Plot					
	Major season			Minor season		
	40 cm × 20 cm	40 cm × 25 cm	**Mean**	40 cm × 20 cm	40 cm × 25 cm	**Mean**
30 t/ha CM	17	15	**16**	11	14	**13**
15 t/ha CM	16	12	**14**	16	15	**16**
100 kg/ha NPK	27	32	**30**	22	30	**26**
50 kg/ha NPK	17	23	**20**	12	21	**17**
15 t/ha CM + 50 kg/ha NPK	37	23	**30**	33	23	**28**
Control	9	18	**14**	4	17	**11**
Mean	**21**	**21**		**16**	**20**	
CV (%)	23.43			24.64		
Fertilizer Amendment (FA)	HSD (0.05) = 8.59			HSD (0.05) = 8.07		
Plant Spacing (PS)	HSD (0.05) = NS			HSD (0.05) = 3.10		
FA x PS	HSD (0.05) = 14.17			HSD (0.05) = 13.31		
Season	HSD (0.05) = 21.21			HSD (0.05) = 21.21		

DAP= Days after planting, HSD (P<0.05)=Tukey’s honestly significant difference (5%), CV (%)=coefficient of variation

4.5.6 Number of Non-Marketable Fruits Per Plot

The mean numbers of non marketable cucumber fruits per plot as affected by the different cucumber plant spacing, fertilizer amendments and their interaction are presented in Table 4.17.

There were significant ($p>0.05$) differences in non-marketable fruits per plot as influenced by plant spacing during the minor season (Table 4.17). During the minor season, 40 cm by 25 cm recorded the lowest non-marketable fruits per plot (1) and 40 cm by 20 cm rather recorded the highest non-marketable fruits per plot (3 fruits).

Fertilizer amendments significantly ($p>0.05$) influence non-marketable fruits per plot in the minor cropping season (Table 4.17). During the minor season, both 50 kg/ha NPK and 15 t/ha CM + 50 kg/ha NPK recorded the highest number of non-marketable fruits (3).

There were significant ($p>0.05$) interactions produced by plant spacing and fertilizer amendments in non-marketable fruits per plot during the major and minor seasons (Table 4.17). 15 t/ha CM + 50 kg/ha NPK + 40 cm by 20 cm had the highest (5 fruits) non-marketable fruits during the minor season and 8 fruits during the major season.

Season significantly affected non-marketable fruits. Major cropping season had the highest non-marketable fruits per plot (5 fruits) and minor cropping season had the fewest non-marketable fruits (2 fruits) (Table 4.17).

Table 4. 16: Effect of Fertilizer Amendment and Plant Spacing on Number of Non-Marketable Fruits Per Plot of Cucumber in 2023 major and minor seasons

Fertilizer Amendment	Number of Non-Marketable Fruits Per Plot					
	Major season			Minor season		
	40 cm × 20 cm	40 cm × 25 cm	**Mean**	40 cm × 20 cm	40 cm × 25 cm	**Mean**
30 t/ha CM	3	6	**5**	2	1	**2**
15 t/ha CM	7	7	**7**	2	1	**2**
100 kg/ha NPK	4	6	**5**	4	1	**3**
50 kg/ha NPK	3	7	**5**	4	2	**3**
15 t/ha CM + 50 kg/ha NPK	8	7	**8**	5	1	**3**
Control	4	4	**4**	2	1	**2**
Mean	**5**	**6**		**3**	**1**	
CV (%)	32.58			28.84		
Fertilizer Amendment (FA)	HSD (0.05) = NS			HSD (0.05) = 1.07		
Plant Spacing (PS)	HSD (0.05) = NS			HSD (0.05) = 0.41		
FA x PS	HSD (0.05) = NS			HSD (0.05) = 1.76		
Season	HSD (0.05) = 0.62			HSD (0.05) = 0.62		

DAP= Days after planting, HSD (P<0.05)=Tukey’s honestly significant difference (5%), CV (%)=coefficient of variation

4.6 Partial Budget Analysis

The partial budget analysis was done for both major and minor cropping seasons and the results is shown are Table 4.18 and 4.19. The adjusted fruit yield was obtained by deducting 10% of the fruit yield from the total fruit yield and then used to calculate the gross farm gate benefits.

The benefit to cost ratio showed that Yara Activa at 50 kg/ha NPK + 40 cm × 25 cm recorded the highest ratio of 34.8 and 49.4 for minor and major seasons respectively, followed by 50 kg/ha NPK + 40 cm × 20 cm which recorded 24.7 in the minor season and 35.4 in the major season, followed by 100 kg/ha NPK + 40 cm × 25 cm which also recorded 9.2 and 12.3 for minor and major seasons respectively. The least benefit to cost ratio was obtained on 30 t/ha CM + 40 cm × 20 cm which recorded 0.3 and 1.1 for minor and major seasons respectively, aside the two control treatments (no fertilizer) which had 0 benefit to cost ratio.

The marginal rate of returns (MRR) indicated that N Control + 40 cm × 20 cm, Control + 40 cm × 25 cm and 50 kg/ha NPK + 40 cm × 20 cm recorded 0, 100 kg/ha NPK + 40 cm × 20 cm dominated the 100 kg/ha NPK + 40 cm × 25 cm and 100 kg/ha NPK + 40 cm × 25 cm also dominated 15 t/ha CM + 40 cm × 20 cm. Again, 15 t/ha CM + 40 cm × 25 cm dominated 15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm and 15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm dominated 15 t/ha CM + 50 kg/ha NPK + 40 cm × 25 cm. 50 kg/ha NPK + 40 cm × 25 cm had MRR of 0.38 over 50 kg/ha NPK + 40 cm × 25 cm in the minor season but 0 in the major season. 15 t/ha CM + 40 cm × 25 cm also had 917.1 MRR over 15 t/ha CM + 40 cm × 20 cm in minor seasons but 15 t/ha CM + 40 cm × 20 cm dominated 15 t/ha CM + 40 cm × 25 in the major season.

T**able 4. 17:** Partial Budget Analysis for Major Cropping Season

	Treatment											
	30 t/ha CM + 40 cm × 20 cm	**30 t/ha CM + 40 cm × 25 cm**	**15 t/ha CM + 40 cm × 20 cm**	**15 t/ha CM + 40 cm × 25 cm**	**100 kg/ha NPK + 40 cm × 20 cm**	**100 kg/ha NPK + 40 cm × 25 cm**	**50 kg/ha NPK + 40 cm × 20 cm**	**50 kg/ha NPK + 40 cm × 25 cm**	**15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm**	**15 t/ha CM + 50 kg/ha NPK + 40 cm × 25 cm**	**Control + 40 cm × 20 cm**	**Control + 40 cm × 2 cm**
Fruit Yield (t/ha)	34.7	39.4	41.8	36.2	57.7	66.6	37.3	51.7	75.4	54.7	21.6	46.3
Adjusted yield (10%)	31.23	35.46	37.62	32.58	51.93	59.94	33.57	46.53	67.86	49.23	19.44	41.67
Farm Gate Price (GHS/t)	11230	11230	11230	11230	11230	11230	11230	11230	11230	11230	11230	11230
Total Gross Benefit (GHS)	350712.9	398215.8	422472.6	365873.4	583173.9	673126.2	376991.1	522531.9	762067.8	552852.9	218311.2	467954.1
Cost of NPK applied	-	-	-	-	0.44	0.44	0.22	0.22	0.22	0.22	0	0
Cost of Chicken manure (CM) applied	86.12	86.12	43.06	43.06	22	22	-	-	43.06	43.06	0	0
Cost of CM/NPK application/ha	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	0	0
Total Variable Cost per plot	91.6	91.6	48.6	48.6	27.9	27.9	5.7	5.7	48.8	48.8	0.0	0.0
Total Variable Cost per ha	165942	165942	87951.8	87951.8	50604.9	50604.9	10360.1	10360.1	88350.3	88350.3	0	0
Net Benefit (GHS)	184770.9	232273.8	334520.8	277921.6	532569.0	622521.3	366631.0	512171.8	673717.5	464502.6	218311.2	467954.1
Benefit to Cost ratio	**1.1**	**1.4**	**3.8**	**3.2**	**10.5**	**12.3**	**35.4**	**49.4**	**7.6**	**5.3**	**0.0**	**0.0**

MARGINAL RATE OF RETURN (MRR)	**Control + 40 cm × 20 cm**	**Control + 40 cm × 25 cm**	**50 kg/ha NPK + 40 cm × 20 cm**	**50 kg/ha NPK + 40 cm × 25 cm**	**100 kg/ha NPK + 40 cm × 20 cm**	**100 kg/ha NPK + 40 cm × 25 cm**	**15 t/ha CM + 40 cm × 20 cm**	**15 t/ha CM + 40 cm × 25 cm**	**15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm**	**15 t/ha CM + 50 kg/ha NPK + 40 cm × 25 cm**	**30 t/ha CM + 40 cm × 20 cm**	**30 t/ha CM + 40 cm × 25 cm**
Total Variable Cost (GHS)/ha	0.0	0.0	10360.1	10360.1	50604.9	50604.9	87951.8	87951.8	88350.3	88350.3	165942.0	165942.0
Net Benefit (GHS)	218311.2	467954.1	366631	512171.8	532569	622521.3	334520.8	277921.6	673717.5	464502.6	184770.9	232273.8
MRR ([ΔNB/ΔTVC]×100)	**0**	**0**	**D***	**-**	**50.68**	**-**	**D***	**D***	**135.64**	**D***	**D***	**D***

D*=dominated

Table 4. 18: Partial Budget Analysis for Minor Cropping Season

	Treatment											
	30 t/ha CM + 40 cm × 20 cm	**30 t/ha CM + 40 cm × 25 cm**	**15 t/ha CM + 40 cm × 20 cm**	**15 t/ha CM + 40 cm × 25 cm**	**100 kg/ha NPK + 40 cm × 20 cm**	**100 kg/ha NPK + 40 cm × 25 cm**	**50 kg/ha NPK + 40 cm × 20 cm**	**50 kg/ha NPK + 40 cm × 25 cm**	**15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm**	**15 t/ha CM + 50 kg/ha NPK + 40 cm × 25 cm**	**Control + 40 cm × 20 cm**	**Control + 40 cm × 25 cm**
Fruit Yield (t/ha)	21.9	24.7	28.5	26.3	42.2	51	26.3	36.7	62.5	39.5	11	29.6
Adjusted yield (10%)	19.71	22.23	25.65	23.67	37.98	45.9	23.67	33.03	56.25	35.55	9.9	26.64
Farm Gate Price (GHS/t)	11230	11230	11230	11230	11230	11230	11230	11230	11230	11230	11230	11230
Total Gross Benefit (GHS)	221343.3	249642.9	288049.5	265814.1	426515.4	515457	265814.1	370926.9	631687.5	399226.5	111177	299167.2
Cost of NPK applied	-	-	-	-	0.44	0.44	0.22	0.22	0.22	0.22	0	0
Cost of Chicken manure (CM) applied	86.12	86.12	43.06	43.06	22	22	-	-	43.06	43.06	0	0
Cost of CM/NPK application/ha	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	0	0
Total Variable Cost per plot	91.6	91.6	48.6	48.6	27.9	27.9	5.7	5.7	48.8	48.8	0.0	0.0
Total Variable Cost per ha (GHS)	165942.0	165942.0	87951.8	87951.8	50604.9	50604.9	10360.1	10360.1	88350.3	88350.3	0.0	0.0
Net Benefit (GHS)	55401.3	83700.9	200097.7	177862.3	375910.5	464852.1	255454.0	360566.8	543337.2	310876.2	111177.0	299167.2
Benefit to Cost ratio	**0.3**	**0.5**	**2.3**	**2.0**	**7.4**	**9.2**	**24.7**	**34.8**	**6.1**	**3.5**	**0.0**	**0.0**

MARGINAL RATE OF RETURN (MRR)	**Control + 40 cm × 20 cm**	**Control + 40 cm × 25 cm**	**50 kg/ha NPK + 40 cm × 20 cm**	**50 kg/ha NPK + 40 cm × 25 cm**	**100 kg/ha NPK + 40 cm × 20 cm**	**100 kg/ha NPK + 40 cm × 25 cm**	**15 t/ha CM + 40 cm × 20 cm**	**15 t/ha CM + 40 cm × 25 cm**	**15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm**	**15 t/ha CM + 50 kg/ha NPK + 40 cm × 25 cm**	**30 t/ha CM + 40 cm × 20 cm**	**30 t/ha CM + 40 cm × 25 cm**
Total Variable Cost (GHS)/ha	0	0	10360.1	10360.1	50604.9	50604.9	87951.8	87951.8	88350.3	88350.3	165942.0	165942.0
Net Benefit (GHS)	111177	299167.2	255454	360566.8	375910.5	464852.1	200097.7	177862.3	543337.2	310876.2	55401.3	83700.9
MRR ([ΔNB/ΔTVC]×100)	**0**		**D***	**-**	**38.12**	**-**	**D***	**D***	**207.93**	**D***	**D***	**0**

D*=dominated

CHAPTER FIVE: DISCUSSION

5.1 Effect of Plant Spacing and Fertilizer Amendment on Growth Performance of Cucumber

Statistical analyses revealed that there were no significant differences in the number of leaves and plant height of cucumber plants grown with two different plants spacing (40 cm by 20 cm and 40 cm × 25 cm), as well as the interaction between plant spacing and fertilizer amendments. However, there were significant differences in the number of leaves and plant height among the different fertilizer amendments. These differences were observed at 21, 28, and 35 days after planting in both major and minor rainy seasons. According to Adkhamovich *et al*. (2019), fast-growing vegetables such as cucumber experience a period of intense growth from emergence to the end of the vegetative growth stage, typically lasting 2-3 weeks. Nevertheless, the soil in the study region identified as sandy loam (Kumi, 2011) yielded cucumber plants with fewer leaves and shorter height. This can be attributed to the low nutrient levels in the soil, which therefore caused a delay in the plants' growth. There were significant changes in the number of leaves and plant height between the control treatment and the CM and NPK amendment treatments for both seasons. Chicken dung consistently resulted in a higher leaf count and longer plants in both seasons. The observed trend in the number of leaves and plant height of cucumber may be attributed to the various types of fertilizers employed as soil additives.

These factors could have impacted the measured figures for the number of leaves and plant height of the cucumber. The analysis of their nutrient status revealed that the poultry manure had a higher nitrogen level of 3.5% and the NPK had a nitrogen level of 15%, whereas the control only had a nitrogen level of 0.19%. Hepperly (2018) classified soil with 3% nitrogen content as high, and Al-Tameemi & Al-Juboori (2020) stated that nitrogen promotes the growth of plants. Despite the higher nitrogen content (15%) in NPK (15-15-

15) compared to poultry manure (3.4%), it did not result in increased leaf production or longer plants. At 28 days after planting (DAP) throughout both the major and minor rainy seasons, plants treated with chicken manure had an average of 18 leaves. In contrast, plants treated with NPK (15-15-15) had an average of 13 leaves during the major season and 14 leaves during the minor season. It is possible that the number of leaves and plant height are influenced not only by nitrogen, but also by trace elements such as Fe^{2+} and Mn^{2+} found in chicken manure. These trace elements are necessary for the production of chlorophyll, which is employed in photosynthesis (Aboyeji *et al*., 2018; Ermis *et al*., 2020). Additionally, this phenomenon might be ascribed to the fact that the application of chicken manure enhanced soil fertility, hence creating a more conducive environment for plant development. Chicken dung is rich in nitrogen, which enhances plant growth. According to the findings of Sallam *et al*. (2021) and Orluchukwu & Confidence (2022), poultry dung, which is a high-quality type of animal manure, contains a greater amount of nutrients. This nutrient-rich manure also enhances the physical condition of the soil, leading to increased plant growth and development. Agbede & Oyewumi (2022) and Adekiya *et al*. (2019) also discovered similar findings, stating that the abundant nitrogen content in manure is readily accessible to plants, resulting in increased output.

Statistically significant difference among cucumber plants under fertilizer amendments on stem girth was observed. Also, comparing the results for the two seasons, stem girth was higher in the minor season than the major rainy seasons. This might be due to water availability. The average monthly rainfall during the growing period for the major season (March to July) was 156.96 mm while that of the minor rainy season was 157.22 mm. Availability of water in the soil during the minor rainy season might have increased the rate of decomposition of chicken manure and thus facilitated the release of nutrients from chicken manure and the subsequent uptake of nutrients in general. On the contrary in the major rainy season, though the same quantity of nutrients was given to treatment plants they could not get full access to them because water as a transporting medium for nutrients was inadequate in the soil (Russo *et al*., 2017; Thomas *et al*., 2020).

The consequence of this was reduction in manufactured food. Less water and nutrients absorption might have caused stomates to be partially or completely closed leading to decreased rate of diffusion of carbon dioxide into chlorophyll-containing cells which could have resulted in the production of less photosynthates. Less water in plants in the major rainy season might have also impeded translocation of manufactured food and other metabolic activities. Bhatla & Lal (2023) and Etesami & Adl (2020) stated that water is an essential plant constituent needed for metabolic reactions, nutrient absorption and translocation and is also in a continual state of flux. Water stress thus affects photosynthesis, biosynthesis and respiration in plants leading to the reduction in vegetative growth. The results of this study seem consistent with what was found by Oke *et al*. (2020) who found that increasing the rates of fertilizers leads to increased stem girth in the cucumber plant. At 35 DAP, 15 t/ha CM + 50 kg/ha NPK improved stem girth more than any other fertilizer amendment. This can be attributed to the fact that the chicken manure together with the NPK might have improved the soil physical and chemical properties and leading to the adequate supply of nutrients to the plants which might have improved stem girth.

The chlorophyll content in cucumber plants varied significantly due to different fertilizer amendments. However, there were no significant differences in chlorophyll content in leaves caused by plant spacing or the combination of plant spacing and fertilizer amendments, except at 28 days after planting (DAP) during the minor rainy season. The chlorophyll levels in leaves were continuously higher during the major rainy season compared to the minor rainy season which may be attributed to increased sunlight and warmth, which are crucial for chlorophyll synthesis (Ivanov *et al.,* 2020). The control treatment, which did not receive any fertilizer, consistently had the lowest chlorophyll levels. Chlorophyll is a crucial component of the energy conversion process in all green plant systems. Consequently, any significant changes in its levels can have notable impacts on the overall metabolism of plants (Wang & Grimm, 2021). In this study, the total chlorophyll content of chicken dung plants was more significantly impacted compared to other fertilizer additives. The current study is backed by the findings of Virginie *et al*. (2022), who proposed that the chlorophyll levels in bananas rose in proportion to the application of poultry manure. According to Maboko *et al*. (2017) and Merghany *et al*. (2019), the application of fertilizer resulted in an increase in the chlorophyll content of *Cucumis sativus* L. Behdarnejad *et al*. (2023) found and documented a notable influence of organic manure (specifically chicken manure) on the chlorophyll content of cucumber.

The fresh and shoot weight of the plants were not significantly affected by the spacing between them in both the major and minor seasons. However, the dry shoot weight was strongly influenced by the plant spacing during the major rainy season. Among the several plant spacing configurations, the 40 by 20 cm spacing recorded the highest dry shoot weight. The study found that as the spacing between plants increased, there was an increase in the dry weight of the plants. This could be due to reduced competition for resources like sunlight, water, nutrients among the plants during their growth stages, and allowing individual plants to thrive and allocate more resources to growth (Ding *et al.,* 2022). Once again, notable disparities were noted across the fertilizer amendments, with the 50 kg/ha NPK treatment yielding the highest dry weight of shoots. This outcome can likely be attributed to enhanced soil fertility and greater nutrient availability resulting from the application of this treatment. The study conducted by Amanullah *et al*. (2015) supports the findings the current investigation, as they observed that the use of NPK fertilizer resulted in an increase in the dry weight of both the shoots and roots of wheat and barley. Olowoboko *et al* (2017) also found that all phosphorus-based fertilizers resulted in an increase in both shoot and root weight of maize.

5.2 Effect of Plant Spacing and Fertilizer Amendment on Yield and Yield Components of Cucumber

The weight of fruit per plant and fruit diameter were not significantly affected by plant spacing. However, they were significantly influenced by the fertilizer amendment and the interaction of plant spacing and fertilizer amendment. Specifically, 15 t/ha CM + 50 kg/ha NPK had the heaviest fruit weight per plant and 50 kg/ha NPK recorded the largest fruit diameter in fertilizer amendment and in the interaction of fertilizer amendment and plant spacing, 50 kg/ha NPK + 40 cm by 25 cm recorded the highest fruit diameter. Plant spacing and fertilizers amendment did not have a significant impact on the amount of fruit produced and the number of fruits per plot. The minor season had lower values for both the quantity of fruits per plant and fruit diameter compared to the major season. This phenomenon may be attributed to favourable weather conditions, increased sunlight, and adequate water availability, all of which contribute to optimal plant growth and fruit development in the major season (Olubode, 2019).

This finding suggests that chicken manure resulted in the highest shoot weight and fruit yield during the main seasons, while NPK fertilizer resulted in lower yields, although the difference was not statistically significant. The Control treatment had a deficiency of nutrients, which hindered the proper preparation of plants during the vegetative stage for subsequent growth and development (Zhao *et al.*, 2021). Bisbis *et al.* (2018) claimed that the nutritional status of vegetables in the initial 2-3 weeks after they sprout significantly influences their ultimate yields. However, the limited supply of well-balanced nutrients from the 50 kg NPK, as mentioned, may have been beneficial during the fruit formation stage, resulting in a higher yield of fruits and greater fruit weight in the plants.

The addition of fertilizer had a notable impact on the quantity of fruits per plot. Specifically, the plot treated with 100 kg of NPK fertilizer yielded the highest number of fruits, while the control plot (without any fertilizer) had the lowest fruit count. The plant spacing and fertilizer amendment, as well as their interactions, did not have a significant impact on the quantity of non-marketable fruits in the major season. However, it was observed that a plant spacing of 40 by 25 cm resulted in a higher yield of both marketable and non-marketable fruits. Additionally, the application of 100 kg of NPK fertilizer led to an increase in the number of marketable fruits, while the application of 50 NPK fertilizer resulted in a higher yield of non-marketable fruits. This could be that, chicken manure with its humus content as reported by Aboyeji *et al.* (2021) effectively prevented soil water loss during the minor season compared to the 50 kg NPK plants. This is because the organic matter in poultry manure has the capacity to retain water, which in turn facilitates the release of more nutrients to support fruit development (Kusvuran *et al*., 2021).

The plants that were fertilized with chicken manure exhibited significantly higher number of marketable fruits and greater weight compared to the control plants in both seasons. However, the plants that received NPK fertilizer only had a significant influence in both seasons. The results were influenced by the seasonal fluctuations and the specific functions of different types of fertilizers.

During both seasons, the sorting of unmarketable fruits revealed that the control group experienced the most negative effects, followed by the plants that received NPK. The large quantity of unmarketable fruits and low fruit weight in the control treatments may be owing to inadequate soil nutrients. As a result, the cultivation of fruits that were smaller than the criteria set for both local and international markets became prevalent. Additionally, there were few deformed fruits. Insufficient potassium can lead to deformities in fruit, as stated by Elavarasan & Premalatha (2019) and Agbor *et al.* (2022). In order to be suitable for export, cucumber fruits should possess a straight shape and be of medium size (Sah & Johar, 2022).

5.3 Partial Budget Analysis

The scaling down of the fruit yield by 10% before the determination of partial budget was necessary to account for potential risks and uncertainties related to the project's actual performance or to prevent overestimation of the returns that farmers are likely to get, since experimental yields are usually higher than farmers yield because of higher management levels, small plot size, better harvesting methods and precision in harvesting (Azumah *et al*., 2020; Heagy *et al*., 2023).

The benefit to cost ratio varied significantly among the different treatments in both cropping seasons. The combination of 50 kg/ha NPK + 40 cm × 25 cm yielded the maximum benefit to cost ratio in both cropping seasons. In addition, all treatment except the control (no fertilizer) had significant benefit to cost ratio (more than 1). The study by Yadav *et al.* (2023) has found variations in benefit to cost ratio attributable to different fertilizer types including organic and inorganic. The increased benefit to cost ratio or net benefit from the plants that received fertilizer may be attributed to the increased fruit production, improved soil structure, water retention, and microbial activity, which all contribute to a more favorable environment for plant growth. which resulted in augmented benefit generation in respect to low production cost.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

- The interaction of fertilizer amendment and plant spacing (100 kg/ha NPK + 40 cm × 20 cm) produced more chlorophyll content in leaves than the other interactions. More number of vines per plant were produced by 15 t/ha CM + 50 kg/ha NPK + 40 cm × 25 cm. The plant spacing 40 cm × 25 cm significantly produced higher vines than 40 cm × 20 cm. 40 cm × 20 cm spacing had maximum dry shoot weight Fertilizer types significantly influenced dry shoot weight and dry root weight in the major season.

- The application of 30 tonnes ha^{-1} of chicken manure proved to increase the vegetative growth of cucumber better than application of 100 kg ha^{-1} of NPK for both major and minor rainy seasons. Fruit diameter in both seasons and weight of fruits per plant in minor season were significantly higher in 30 t/ha chicken manure, fruit yield was higher in 15 t/ha CM + 50 kg/ha NPK during the minor season but both 15 t/ha CM + 50 kg/ha NPK and 100 kg/ha NPK had more fruit yield during the major season. Weight of fruits per plant was higher in 15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm and 50 kg/ha NPK + 40 cm × 25 cm produced wider (75.4 t/ha) fruit diameter. Also, 15 t/ha CM + 50 kg/ha NPK + 40 cm × 20 cm had the highest fruit yield and number of fruits per plot in the major rainy season

- The combination of 50 kg/ha NPK + 40 cm × 25 cm yielded the maximum benefit to cost ratio in both cropping seasons. In addition, all treatment except the control (no fertilizer) had significant benefit to cost ratio (more than 1).

6.2 Recommendations

Based on the results of the study, it is recommended that:

- For optimal marketable yields in both seasons, it is recommended to farmers to apply chicken manure at 15 t/ + 50 kg/ha NPK and plant spacing of 40 cm × 25 cm.
- The experiment is replicated at several geographical places in Ghana in order to confirm the findings of this study.
- The experiment should be repeated using the same two factors (fertilizer amendments and plant spacing) but rather include more different rates of the fertilizer to find their effect on growth and yield of cucumber.

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LIST OF APPENDICES

Appendix 1: Guide to interpretation of soil analytical data in Ghana

Nutrient	Rank/Grade
Phosphorus, P (ppm), (Bray 1)	
< 10	Low
10 – 20	Moderate
> 20	High
Potassium, K (pmm)	
< 50	Low
50 – 100	Moderate
> 100	High
Calcium, Ca (ppm)/Meg = 0.25 Ca	
< 5.0	Low
5.0 – 10.0	Moderate
> 10.0	High
ECEC (cmol (+)/kg)	
< 10	Low
10 - 20	Moderate
> 20	High
Soil pH (Distilled Water Method)	
< 5.0	Very Acidic
5.1 – 5.5	Acidic
5.6 – 6.0	Moderately Acidic
6.0 – 6.5	Slightly Acidic
6.5 – 7.0	Neutral
7.0 – 7.5	Slightly Alkaline
7.6 – 8.5	Alkaline
> 8.5	Very Alkaline

% Organic Carbon	**% Organic Carbon**	**Interpretation**
< 1.0	< 1.5	Low
1.0– 2.0	1.6 – 3.0	Moderate
2.0-4.0	3.0	Adequate
> 4.0	>3.0	High

Nitrogen (%)	
< 0.1	Low
0.1 – 0.2	Moderate
> 0.2	High

Exchangeable cations (cmol (+)/kg)	**Units**	**low**	**moderate**	**High**
Sodium (Na)	(cmol (+)/kg)	-	0-2	> 2.0
Potassium (K)	(cmol (+)/kg)	<0.2	0.2 – 0.4	> 0.4
Calcium (Ca)	(cmol (+)/kg)	< 2.0	2.0-10	> 10
Magnesium (Mg)	(cmol (+)/kg)	< 1.0	1.0-3.0	> 3.0

Source: (SRI, 2007)